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Performance, Profitability and Efficiency of Regional Air Transport

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Abstract

Commercial air transport has always been focused on performance, profitability and efficiency. However, the way these terms have been conceived has changed through commercial air transport history.
Profitability has always been pivotal to the success of any commercial activity. Through its history, commercial aviation has gone through several crises. However, COVID-19 outbreak has posed new challenges. Lower traffic volumes and passenger demand have forced air transport operators to reorganize themselves and their activities. The full impact of the pandemic on commercial air transport is yet to be thoroughly assessed.
Performance and efficiency have been pursued and implemented in different ways. The last years have seen environmental concerns come up in many countries, with public opinion more concerned about environmental impact of human activities. Aviation has been responding to the call for lower environmental footprint in different ways. Succeeding in reducing environmental footprint will be pivotal for the air transport industry in the upcoming decades.

The effects of COVID-19 pandemic and the rising environmental concerns call for a strong, joint effort to assess both issues. All players involved must focus on finding new ways and solutions to cope with the profound changes and the unprecedented challenges commercial aviation has been facing.

Bearing these premises in mind, this analysis aims at developing a model to assess performance, profitability and efficiency of regional aircraft in the Italian domestic market. This analysis focuses on propeller-driven regional aircraft, since they offer lower fuel consumption than turbofan aircraft and may operate in environments characterized by low passenger volumes.
The model has been developed with a modular pattern. This gives the opportunity to integrate sub-models to better analyze overall results. The model will be used to assess performance, profitability and efficiency of different aircraft types in their operating environment. Profitability is assessed with a break-even point analysis considering fixed and variable operating costs and passengers revenues. Fixed and variable operating costs will be estimated with a bottom-up cost model taking into account single cost items.
This analysis will focus on regional routes connecting islands to the Italian mainland. Insularity poses some issues, in that the need for reliable and fast connections to the mainland may clash with low passenger volumes.

The outcomes will then be analyzed and commented to identify and assess advantages and drawbacks of different aircraft types in their operating scenarios.

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Finally, I would like to thank my family and my friends. They know why.

Aeronautics was neither an industry nor even a science [...] it was a miracle.

I. I. Sikorsky

Le vent se lève !... Il faut tenter de vivre !

P. Valéry

Performance, Profitability and Efficiency of Regional Air Transport

Introduction

This work is aimed at assessing and analyzing the operating characteristics of regional aircraft in their operating environment. These characteristics may be assessed in terms of performance, that is the behavior of the aircraft in its operating environment, profitability, that is the aircraft ability to maximize revenues generated by performing its mission while minimizing operating costs, and efficiency, that is the ability to effectively and profitably operate with minimal drawback. Let aside safety, which is the *sine qua non* for all air operations, these aspects are essential to successfully perform commercial air operations. Hence, assessing their influence and effects and understanding how to assure and improve them is pivotal for all players involved in commercial air transport, in that poor assessing may result in improving some aspects at the expenses of others. To successfully perform commercial air operations all these aspects must combine and harmoniously coexist.

This analysis focuses on regional propeller-driven passenger aircraft. Each aircraft type is evaluated in different scenarios defined for the case study. The analysis is made using a modular model comprising several sub-models and tools. Each sub-model or tool is specifically built to carry out one or more tasks. The outcomes of these tasks are used as inputs for other sub-models or tools or taken as results.

Results are assessed in terms of costs and revenues evaluated for each route under conditions, hypotheses, and assumptions given by the scenario and the case study under analysis.

This work is divided into two main parts. Part I analyzes the air transport industry, with a focus on regional and short-haul air services in Italy and Europe. Part I has three chapters.

Chapter 1, *The operating environment*, offers an overview of air transport and gives a brief outline of the history of Italian and European air transport industry in the recent past. The chapter also discusses the impact of COVID-19 pandemic on the industry and what may come next in the near term.

Chapter 2, *The regional air transport*, provides a definition of regional air transport and of the different types of commercial air services. The chapter offers a brief synopsis of the EASA regulatory framework concerning commercial air operations. Lastly, the chapter discusses network planning, with a strong focus on the markets of interest.

Chapter 3, *The regional fleet*, focuses on the aircraft types operating short-haul air services. The chapter also discusses the influence of efficiency in today's air transport industry and its importance in the aircraft selection process. It then illustrates the main characteristics and performance of the types considered for this analysis.

Part II describes the performance, profitability and efficiency model and discusses the analysis and the outcomes. Part II has three chapters.

Chapter 4, *Performance, profitability and efficiency model*, provides a definition of the case studies and a description of the model used. Starting with the definition of the case studies, the chapter describes the purpose and scope of the model and the hypotheses and assumptions made. After that, the chapter provides an overview of the model structure with the sub-models and tools used for the analysis.

Chapter 5, *Case studies*, illustrates the results given by the model for different aircraft types in different scenarios. The results are presented in both tabular and graphic format. Charts are a powerful way to clearly assess results at a glance, while tables offer a thorough description of numerical figures.

Chapter 6, *Outcomes and conclusions*, discusses the outcomes reported in Chapter 5. The outcomes given by the model for the different aircraft types are analyzed and evaluated. The chapter also provides a brief overview of the measures taken in case of off-nominal scenarios.

Part I

The air transport industry

1. The operating environment

Air transport is today one of the most used and reliable, fastest and safest ways to travel. A relatively new way to move people and goods, air transport has been one of the fastest-growing transport industries. ICAO state that 4.5 billions people traveled on scheduled[1] air services in 2019[2] . By comparison, the number has doubled since 2005[3] .
The concept of air transport encompasses many different ways of traveling by air, from short hops flown with light aircraft to intercontinental flights operated by large wide-body jets. The two main categories of air transport are commercial and non-commercial air transport, the former being "any operation of an aircraft, in return for remuneration or other valuable consideration, which is available for the public or, when not made available to the public, which is performed under a contract between an operator and a customer, where the latter has no control over the operator"[4] . Consequently, non-commercial air transport is any other type of air transport. Commercial air carriers are companies offering commercial air transport services of people (passengers) or goods (freight). Commercial air services offered by air carriers are countless and may be classified using different metrics. One of the most widely used is flight length. Flights are usually classified as short-, medium-, or long-haul, depending on distance covered without stopping, either for technical or commercial reasons. There is not a universal way to define whether a flight is short-, medium-, or long-haul, since many airlines apply their own definition. Anyway, a good rule of thumb could be:

- Short-haul flights: flights with flight time of less than three hours.
- Medium-haul flights: flights with flight time between three and six hours.
- Long-haul flights: flights with flight time of more than six hours.

with flight time being "the time [elapsed] from the moment the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the next point of landing"[5] .
Other subcategories may apply to specific types of service, e.g. very-short-haul flights (less than one hour) and ultra-long-haul flights (more than twelve hours).
This analysis will focus on short-haul air services. However, to better understand and analyze commercial air transport, a brief overview of the world of air transport is required.

[1] According to ICAO, "a scheduled air service is typically an air service open to use by the general public and operated according to a published timetable or with such a regular frequency that it constitutes an easily recognizable systematic series of flights". A thorough definition of scheduled air services will be offered later on.
[2] ICAO. *Presentation of 2019 Air Transport Statistical Results*. ICAO website
[3] ICAO. *Appendix 1. Tables relating to the world of air transport in 2014*. ICAO website
[4] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). Annex I*
[5] FAA. *Glossary terms*. FAA website

1.1 Recent past

The last two decades have seen substantial changes in global air transport. With the exception of 9/11 events and global financial crisis, global air traffic has been constantly growing in terms of Revenue Passenger Kilometers (RPKs)[6] .

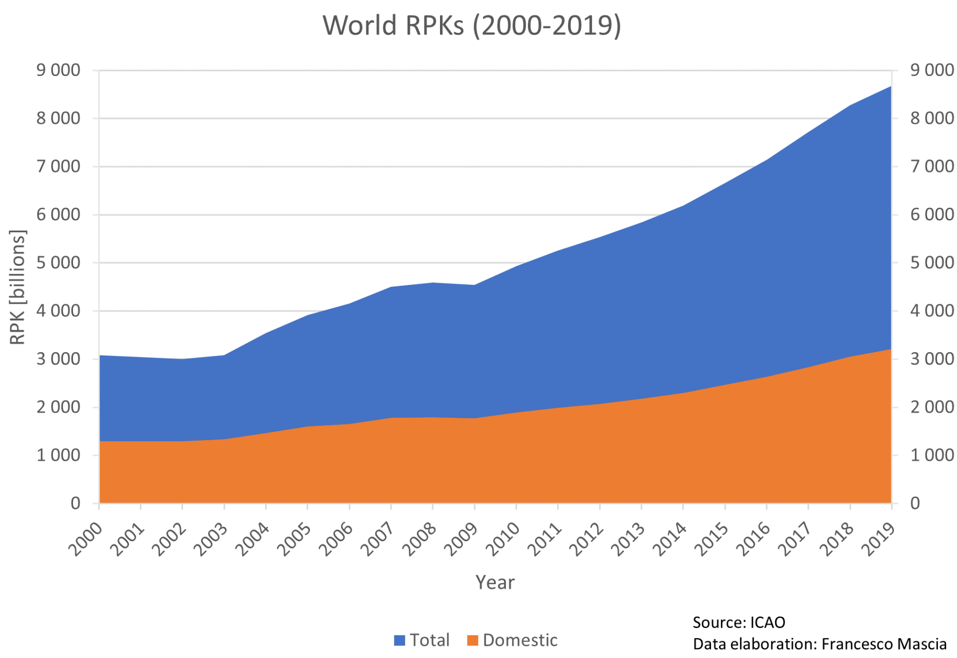

Figure 1.1: World Revenue Passenger Kilometers (2000-2019)

Commercial air transport, in what may be considered its modern form, was established by ICAO Convention on International Civil Aviation, signed at Chicago on December 7th, 1944 and entered into force on April 4th, 1947. The Convention set the principles of air navigation and air transport, establishing a system of agreements to facilitate and promote civil aviation. The air transport pattern established by the Convention was heavily dependent on contracting States. Contracting States had exclusive power in defining routes and services to be operated within their sovereignty. This gave stability to air transport, but gave airlines little-to-no freedom to control their network. The situation lasted for about three decades. In 1978 the Congress of the United States of America enacted the Airline Deregulation Act, progressively loosing State control on air transport and giving airlines more freedom to plan their strategies and networks. Europe followed years later with the Single European Act of 1986. Air transport deregulation was then gradually introduced in Europe during the 1980s and the 1990s[7] . The "third package" of the Single European Act introduced a single European market among EU-members and other European States, thus integrating national markets and setting common standards.

Liberalization changed the air transport pattern. With few exceptions, routes could be operated by airlines wishing to enter the market. This caused a differentiation in services offered by airlines. The main effect of air transport deregulation has been making a rather static market

[6] Revenue Passenger Kilometer is a metric frequently used in the air transport industry. RPKs are calculated by multiplying the number of passengers by the distance traveled.

[7] European Parliament. *Air transport: market rules*. European Parliament website

more dynamic. In the wake of deregulation, new levels of competition led to fare wars among carriers. This high level of competition heavily influenced the services offered. Before deregulation, especially in the early days of the Jet Age and on long-haul flights, large airlines focused on high quality of service, in that the oligopolistic market hindered or mitigated fares competition. Liberalization brought competition to new standards. Higher competition on fares, services offered, and schedules led to profound changes in the air transport market.

The years following the introduction of deregulated market saw air carriers dealing with a new environment. In coping with the effects of a liberalized market, airlines had to strengthen their position not to be cannibalized by competitors. Since deregulation, a trend towards consolidation has emerged. The first market to consolidate has been the North American market. In the years following the entry into force of Airline Deregulation Act, the number of air carriers in the USA plummeted. Consolidation in the US eventually led, by the early years of the new century, to just three legacy carriers, American Airlines, Delta Air Lines, and United Airlines. Consolidation in Europe has moved at a slower pace. The entry into effect of a single European market has not prevented countries from retaining their national carriers. Consolidation happened at national level first (e.g. Air France-Air Inter merger), but eventually led to airlines merging to form international groups. Unlike many US carriers, many European airlines have maintained their brand after merging. Thus, rather than forming new airlines, they formed airline groups, the three largest in Europe being IAG, parent company of British Airways and Iberia, among others, Lufthansa Group, parent company of Lufthansa and SWISS, among others, and Air France-KLM, parent company of Air France and KLM, among others.
Airlines have also created new forms of cooperation. During the last years of the century, some of the largest airlines formed alliances. The first alliance, Star Alliance, was founded in 1997 by Air Canada, Lufthansa, SAS, Thai Airways International and United Airlines. oneworld, founded by American Airlines, British Airways, Canadian Airlines, Cathay Pacific and Qantas, and SkyTeam, founded by Aeroméxico, Air France, Delta Air Lines and Korean Air, soon followed in 1999 and 2000, respectively. Alliances have proven to be a powerful and effective way for airlines to bolster their position as part of a worldwide network by entering agreements with "allied" airlines or code-sharing[8] with them. While not limited to "allied" airlines, code-share agreements may be facilitated among members of the same alliance.

Consolidation had, and still has, a heavy impact on short-haul and domestic market. After liberalization, smaller airlines faced new forms of competition. For many of them, competition was just too much to bear. The number of short-haul airlines in the USA almost halved from 1981 to 1993, plunging from 246 to 130[9] . Some merged with larger airlines, eventually becoming feeders. It is worth noting that consolidation did not occurred immediately after market liberalization. While some mergers occurred in the wake of deregulation, some carriers took many years, or even decades, before merging or becoming subsidiaries of large airlines. Sometimes, in a first attempt to retain their position, smaller airlines focusing on domestic air services merged with other small airlines. However, the general trend towards consolidation brought many of them to either merge, be acquired, or cease operation. Many times, assets from those carriers have been integrated into the structure of parent carriers.

[8] Code-sharing is "the use of the flight designator code of one air carrier on a service performed by a second air carrier, whose service is usually also identified (and may be required to be identified) as a service of, and being performed by, the second air carrier". Source: ICAO. (2004). *Manual on the Regulation of International Air Transport (Doc 9626)*
[9] Wells, A.T. and Richey, F.D. (1996). *Commuter Airlines*. Krieger Publishing Company

Unlike large airlines, small domestic carriers have hardly ever become members of airline alliances. Many times, however, they have entered bilateral or multilateral agreements with larger carriers or with other small airlines, usually those giving them the opportunity to indirectly expand their network. Airline agreements also have the advantage of reducing competition by scheduling in such ways as not to overlap services offered by partner airlines.

Deregulation caused a differentiation of air transport market, with passengers benefiting from lower fares resulting from higher competition. Deregulation has been one of the most important milestones in commercial air transport. Three decades later, air transport market has transformed. Some airlines eventually failed to adapt to the new market, while others found their way to benefit from liberalization. The same force driving some carriers to failure eventually ended up fostering air transport demand, bolstering airlines' growth and market consolidation. Not surprisingly, the years following deregulation witnessed the rise of the first low-cost carriers in Europe.

1.2 The role of low-cost carriers in the short-haul market

The percentage of world population that can afford air travel has grown rapidly, due to several factors. One of the most important is definitely the rise of low-cost-carriers (LCCs). These carriers offer cheaper fares for many short- or medium-haul routes, thus giving more people the opportunity to fly. Most LCCs have in short- or medium-haul point-to-point flights their core business. IATA state that "LCCs accounted for 21% of global capacity in 2018, up from 11% in 2004"[10] . This phenomenon is more evident in some regions. Italy has witnessed a constant and strong growth of LCCs. ENAC data show that four of the top five carriers by number of passengers carried in Italy are LCCs[11] .

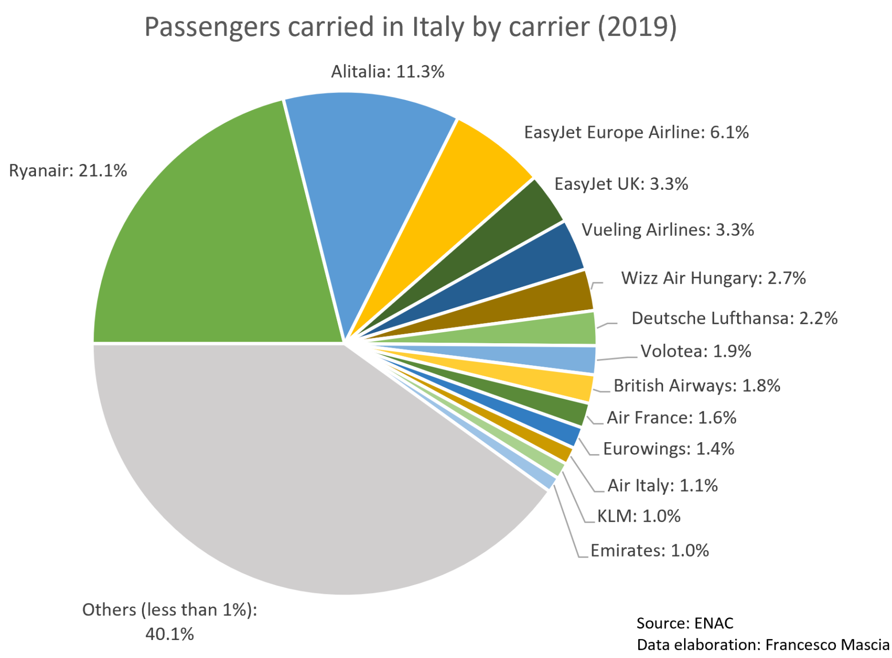

Figure 1.2: Passengers carried in Italy by carrier (2019)

[10] IATA. (31 July 2019). *More Connectivity and Improved Efficiency - 2018 Airline Industry Statistics Released*. IATA website

[11] ENAC. (2020). *Dati di Traffico 2019*

While LCCs have entered almost every domestic market in Europe, Italian domestic market shows a stronger presence of LCCs, if compared to other European markets. As of January 2020, Ryanair retained 27% of available seats on Italian routes, followed by Alitalia (17%) and easyJet (9%), Cirium schedules data shows. By comparison, Air France and Lufthansa retained 35% and 34% of available seats in France and Germany, respectively. From 2010 to 2020, Italian largest mainline carrier, Alitalia, lost 10% of its share of available seats, while Ryanair gained 12%, almost doubling its presence. While the general trend among European largest markets is favorable to low-cost carriers, LCCs have had a more rapid growth in Italy than in other European countries.

The market share of Italian seats retained by LCCs is similar to that of countries like Spain or Poland, rather than France or Germany. This is mainly due to prices passengers are willing to pay. The single-person average net earning in Italy is below average EU-27[12] and EU-28[13] values, while countries like France or Germany are above them, Eurostat data[14] show.
The other reason behind the heavy presence of LCCs in Italy is the absence of a strong mainline carrier. Alitalia has for many years gone through difficulties, eventually losing market share in favor of low-cost competitors. Many Italian carriers operating during the last two decades have either ceased operations or merged. It is interesting how consolidation has occurred among Italian carriers, with Alitalia and then second largest Italian carrier, Air One, merging in 2009[15]. Merging of Meridiana with Eurofly (2009) and Air Italy (2011) did not result in a carrier capable of retaining a large market share. Meridiana's attempt to gain market share by rebranding as Air Italy (2018) and focusing on international routes ended within two years, with Air Italy ceasing operations in February 2020. The trend towards consolidation has driven many carriers to merge without taking any real advantage in terms of market share. What has been dubbed the "second-carrier syndrome"[16] resulted in more than one carrier failing to gain strong presence in the Italian market. Being more agile than most mainline carriers, LCCs managed to enter markets left free or underserved by mainline carriers.

Even though many subcategories of LCCs do exists, most have a common structure. Single-type or single-family fleet is one of the most distinctive characteristics. Some of the largest LCCs have fleets exceeding 400 aircraft of the same type or family[17] [18]. Commonality has been a key factor in driving LCCs' success, since maintenance, training, and other aircraft-related expenses benefit from focusing on one single type or family. Moreover, single-type or single-family fleets give the operator the chance to deliver the same type of service through its network, no matter the route. On the other hand, relying on a single type may make a carrier prone to issues affecting the type. Had not the 2020 fall in air traffic demand occurred, carriers wishing to replace 737NGs with 737 MAX aircraft would have likely been more affected by grounding and subsequent delivery deferrals. Even though the risk of operating aircraft affected by issues is real and common to any carrier, large single-type or single-family fleets definitely expose the carrier to higher risk.

[12] European Union with 27 members as of February 1st, 2020
[13] EU-27 plus United Kingdom
[14] Eurostat. *Labour market earnings database*. Eurostat website
[15] Dunn, G. (19 December 2008). *Relaunched Alitalia flies into battle*. FlightGlobal website
[16] Dunn, G. (11 February 2020). *How low-cost carriers have capitalised on Italian airline failures*. FlightGlobal website
[17] Ryanair. *Ryanair fleet*. Ryanair website
[18] Southwest Airlines. (2020). *2019 One Report*

Another key factor is utilization. Comparison between three US majors (American Airlines, Delta Air Lines, and United Airlines) and US largest LCC[19] , Southwest Airlines, shows how the latter has higher utilization in terms of block hours per day[20] . LCCs' higher utilization than mainline carriers is a result of different networks and schedules. While mainline carriers usually offer flight schedules tailored to passenger needs, LCCs may trade schedules off against airport costs.

But there is more. Many European LCCs focus on secondary airports located in the catchment area[21] of one or more large cities. This has resulted in secondary airports growing their passenger volumes but, most importantly for LCCs, has given the carriers the opportunity to tackle markets without incurring expenses resulting from operating at major hubs or city airports. This phenomenon, causing the rapid growth of secondary airports, is clearly visible in some areas. Bergamo, in Italy, is a perfect example of a secondary airport expanding its passenger volumes thanks to LCCs. The chart below[22] shows that LCCs, mainly Ryanair[23] , have fostered the rapid growth of airports like Bergamo.

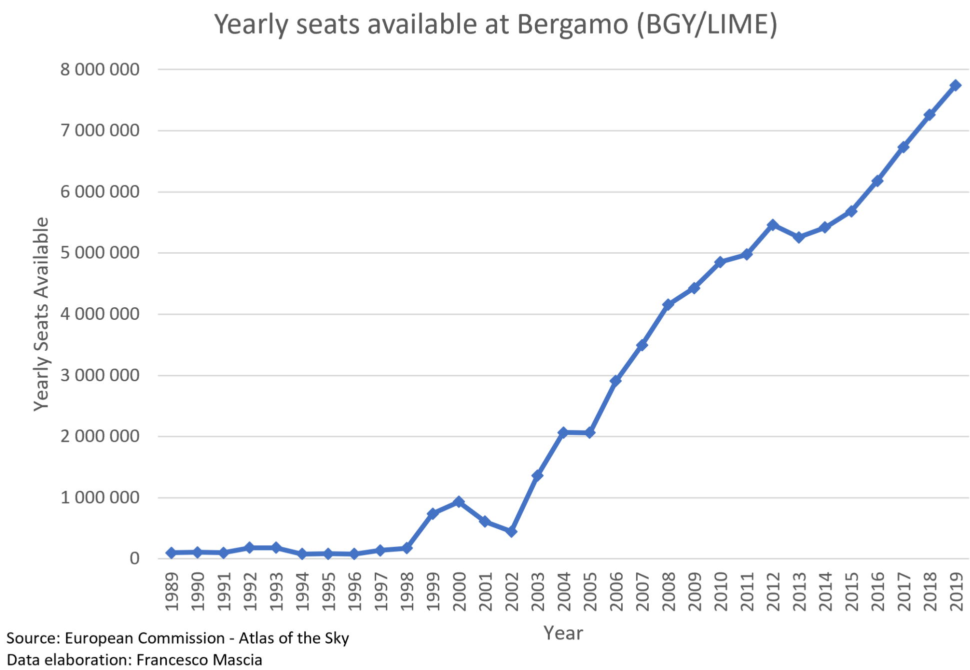

Figure 1.3: Yearly seats available at Bergamo (BGY/LIME)

After all, the most important factor driving LCCs' success is the one they are named after: low cost. Low cost is a consequence of the business model LCCs do implement. The main reason behind low fares is the constant pursuit for efficiency by LCCs. Low costs for passengers is a direct consequence of low costs for the carrier. The airline can deliver low-cost services thanks to a model aimed at reducing costs for the airline itself.

[19] ibid.
[20] ICAO. (February 2017). *Airline Operating Costs and Productivity*
[21] The catchment area may be defined as the area surrounding an airport from which the majority of passengers originate or to which the majority of passengers end their journey by air. A more comprehensive analysis of the concept of catchment area will be offered later on.
[22] European Commission. *Atlas of the sky - An atlas of air transport*. European Commission website
[23] ENAC. (2020). *Dati di Traffico 2019*

Many European mainline carriers have established their own low-cost subsidiaries or have entered agreements with LCCs. In some scenarios, low-cost subsidiaries have eventually ended up replacing mainline carriers on some short-haul routes, while mainline carriers have retained, or even expanded, their long-haul network. This shift in short-haul network has impacted regional subsidiaries of mainline carriers, as reported below.

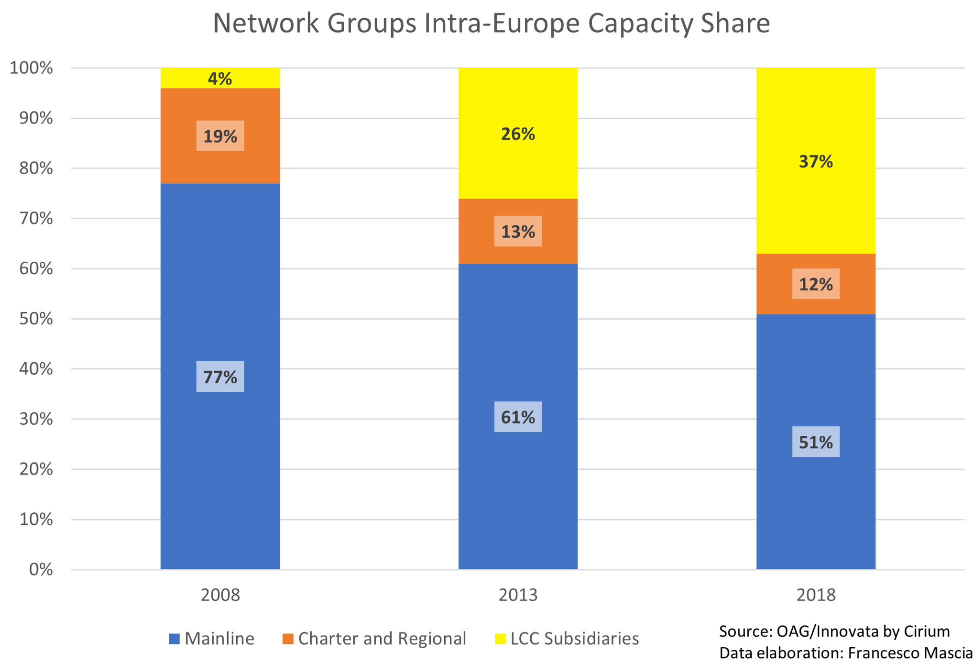

Figure 1.4: Network Groups Intra-Europe Capacity Share

The profound effects of LCCs entering the market have led to a different air transport pattern. Many times, LCCs have opened new routes[24] rather than cannibalizing routes previously operated by mainline carriers, especially on short distances[25]. This has led to a network scheme based on point-to-point, rather than on hub-and-spoke. It may be pointed out that mainline carriers could offer a point-to-point service too. Since mainline carriers usually have one or more hubs, flying point-to-point would simply skip the hub, thus making the hub itself redundant, at least for short-haul flights. This would be risky for the airline, since most large mainline carriers also fly long-haul, relying on their hub(s) to gather enough passengers to sustain long-haul operations.

As a consequence, many short-haul mainline carriers have been hit hard by LCCs. Some of them have managed to compete with LCCs in different ways, by adding long-haul routes to their network or by restructuring themselves to play LCCs' game. Some others have merged with larger airlines, thus becoming subsidiaries or feeders. Some have found their niche, be it leisure market, city-pairing, or a particular geographical area, while some others have simply ceased operations.

As far as very-short-haul market is concerned, the situation slightly differs from what previously said. Routes connecting secondary airports have seen the rise of LCCs and the opening of new routes. Mainline carriers have retained their stronghold positions in city

[24] Airbus S.A.S. (2019). *Global Market Forecast - Cities, Airports & Aircraft 2019-2038*

[25] Campisi D., Costa R., Mancuso P. (2010). *The Effects of Low Cost Airlines Growth in Italy*. Modern Economy, 01(02)

airports with higher percentage of business travelers and have kept operations to/from their hubs, sometimes competing with LCCs on these routes. However, a new competitor has emerged on these routes: high-speed trains. Increasing speed of new-generation trains, high fuel costs, especially in the early years of the decade, and shorter time required to reach terminals from many city centers have made the high-speed train a tough competitor on very-short-haul routes, especially on city-pairing routes. As a consequence, passengers have decreased on many city-pairing routes. Data show[26] that the number of passengers flying the route connecting Rome Fiumicino (FCO/LIRF) with Milan Linate (LIN/LIML) has more than halved from 2009 to 2019, even though the total number of passengers flying domestic routes has increased in Italy over the same period. The busiest domestic route in 2009, Rome Fiumicino - Milan Linate has been overtaken by routes connecting Rome and Milan with Catania, Palermo, or Cagliari. Not surprisingly, routes connecting airports located on islands and thus not affected by high-speed train competition have kept or grown their traffic volumes.

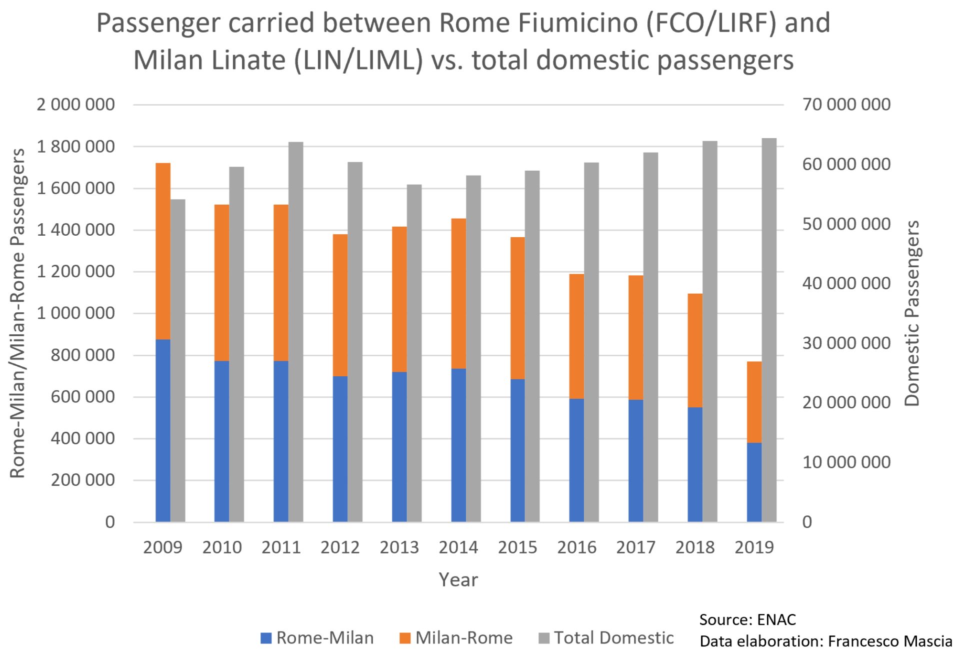

Figure 1.5: Passenger carried between Rome Fiumicino (FCO/LIRF) and Milan Linate (LIN/LIML) compared to total domestic passengers

The entry of LCCs into short-haul market has resulted in a different short-haul network through Europe. The higher traffic volumes have accelerated this process. With larger traffic volumes, narrow-body airliners in the range of 100-180 seats could be cost-effective on routes that have previously been unprofitable for them. Since many LCCs operate single-type or single-family fleets made up of aircraft in this category, the process has been self-feeding.

[26] ENAC. (2020). *Dati di Traffico 2019* and previous years

1.3 Present

In the last year aviation has been facing what has resulted to be one of the biggest challenges ever. Global RPKs shrank by an average 66% in 2020, according to IATA[27] .

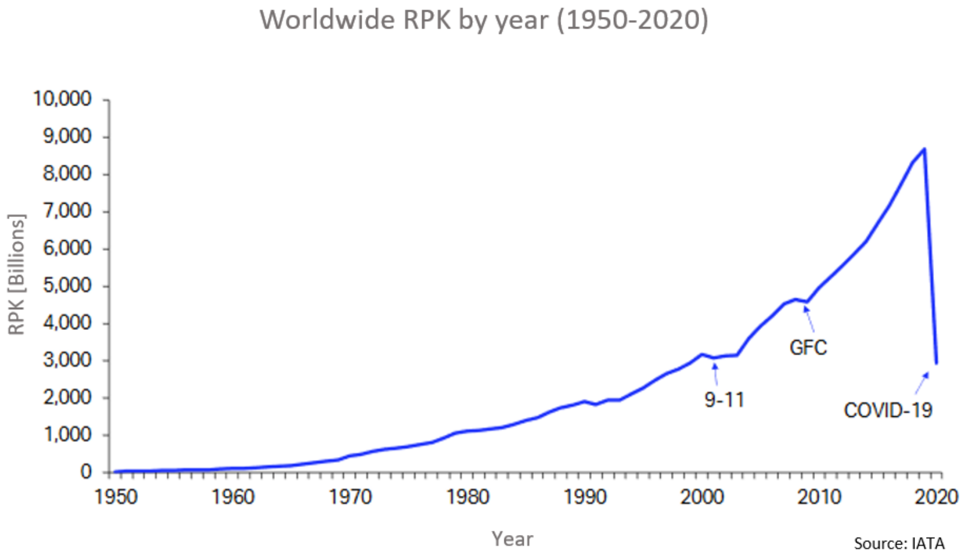

Figure 1.6: Worldwide Revenue Passenger Kilometers from 1950 to 2020

Global passengers and RPKs plunged in an unprecedented way. During crisis following 9/11 events many passengers opted not to fly, or to fly less, in response to possible security threats. Except for security restrictions implemented to minimize the risk of new threats, there were no obstacles preventing passengers from flying. The 2007 global financial crisis caused passenger demand to decrease. However, the decrease was a consequence of many passengers choosing either not to fly or to fly less, mainly due to economic reasons. Moreover, as these crises hit different areas and markets in different ways, the decrease in air transport demand was not uniform.
2003 SARS outbreak caused RPKs in Asia-Pacific to plunge 35% over pre-crisis levels at the height period, losing 8% annual RPKs year-on-year[28] . Similarly to COVID-19, SARS shrank load factors in a quick and drastic way, since many passengers felt uncomfortable about traveling. While similar to COVID-19 by some ways, 2003 SARS outbreak had modest consequences if compared to the 2020 pandemic. 2003 SARS crisis impacted mainly Asia-Pacific, but global RKPs experienced modest impact. Moreover, SARS came in as global traffic was still coping with the effects of 9/11 events.

COVID-19 outbreak impacted global RPKs worldwide. In the wake of the COVID-19 pandemic, almost all countries took countermeasures to try to stop the contagion by either limiting or halting flights. Governments an institutions imposed travel restrictions, or even bans, on air transport. Unlike previous crises, with the exception of 2003 SARS outbreak, passengers were prevented from flying by restrictions. Many times, restrictions imposed in the wake of COVID-19 pandemic have left little-to-no possibilities to passengers.

[27] Pearce, B. (24 November 2020). *Outlook for Air Transport and the Airline Industry*. IATA website
[28] IATA. (24 January 2020). *What can we learn from past pandemic episodes?*. IATA website

COVID-19 pandemic comprised all factors influencing travel demand during previous crises. Safety concerns have made passengers less comfortable about traveling. The economic recession has had the effect of reducing passengers propensity to spend, thus reducing demand for flights. Finally, restrictions have further hindered air travel. These three main factors, occurring at the same time, have led to the deepest fall in traffic and demand commercial air transport has ever faced since the beginning of the Jet Age.

2020 pandemic has hit air transport worldwide. However, some differences do exist among areas and markets. IATA stated that "while all regions are impacted by the crisis, those airlines with larger domestic markets [...] are performing better"[29] , since domestic movements have been less impacted by travel restrictions. Domestic passengers in Italy in the first half of 2020 fell by 67% year-on-year, while total passengers declined by 69.4%[30] . As a result of international restrictions, international tourist flows to Italy[31] [32] decreased by 60.3% year-on-year during 3Q2020, while domestic flows declined by 13.6% year-on-year. The difference between domestic and international passengers is clearly visible in the third quarter of 2020. International passengers declined by 80.5% year-on-year, while 44.9% on domestic routes[33] fostered a partial recovery. Even though -44.9% passengers year-on-year would have normally been considered catastrophic, it actually helped airlines and airports. Domestic travel proved to be less prone to restrictions, thus resulting in airlines with short-haul-oriented networks being less hit than those focused on international services. Not surprisingly, carriers with more point-to-point connections, especially those with leisure destinations in their network, benefited from 2020 summer holidays market.

Airlines have responded to the outbreak very fast. Measures taken by most airlines have been reducing both capacity and frequency. Airline chief executives agree[34] that the top priority for airlines has been minimizing cash outflow. Removing other-than-fundamental cost items has been one of the widest used recipes to reduce costs. Tailoring capacity to match demand without wasting resources has been pivotal to keep operations. However, the ways European airlines have implemented their strategies are diverse. Some of them entered a sort of "hibernation", grounding the majority of their fleet and furloughing much of their staff, while others have seized the chance to exploit market opportunities, especially during the third quarter of 2020. Some other airlines pursued a more balanced strategy, progressively reinstating capacity as partial recovery occurred during summer 2020.

Jet fuel price has partially helped airlines navigating through lower passenger demand, since low fuel prices have reduced losses caused by lower load factors. Thus, some airlines have had the possibility to profitably operate some of their older aircraft despite lower load factors. However, many carriers have elected to temporarily or permanently phase-out less fuel-efficient types, thus deploying newer-generation more fuel-efficient aircraft on their network. However, as recover in passenger demand will occur, fuel prices are likely to rise, eventually reaching pre-crisis levels.

[29] IATA. (24 November 2020). *Deep Losses Continue Into 2021*. IATA website
[30] ENAC. (2020). *Dati di Traffico 2020 - I Semestre*
[31] ISTAT. (29 December 2020). *Primi nove mesi del 2020: presenze dimezzate negli esercizi ricettivi*. ISTAT website
[32] ISTAT data include only the countries with the highest tourist flows to Italy.
[33] Assaeroporti. *Statistiche*. Assaeroporti website
[34] FlightGlobal. (2 April 2020). *Airline chiefs on surviving a crisis - FlightGlobal webinar*. FlightGlobal website

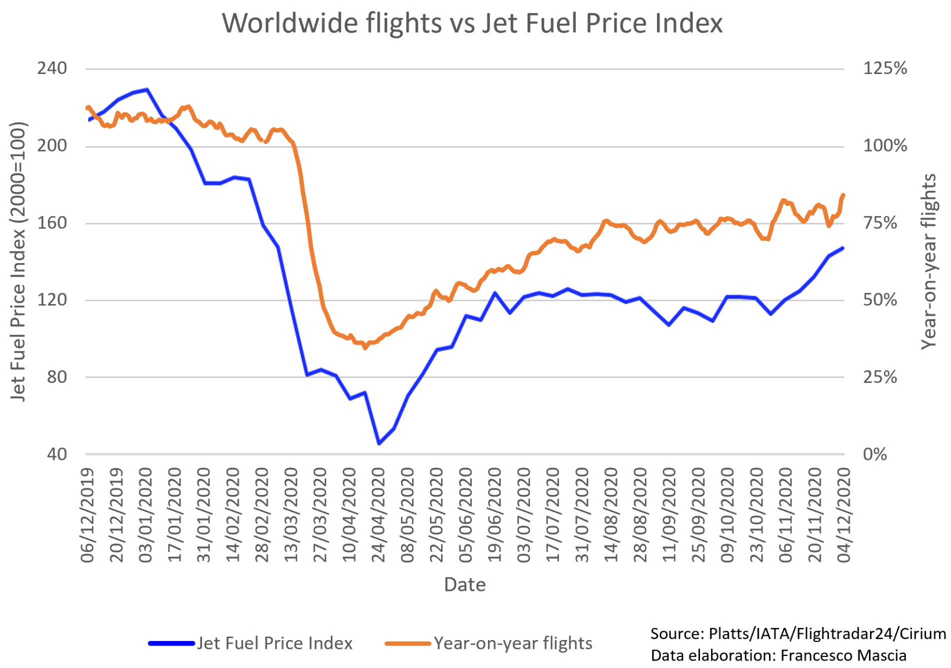

Figure 1.7: Comparison between worldwide flights and Jet Fuel Price Index (Dec-2019 to Dec-2020)

1.4 Near-term future

The deep impact of the pandemic is self-evident. However, the big challenge for airlines is not just surviving the crisis. Carriers must prepare for a new market that will be influenced, or even re-shaped, by the crisis. Many airlines have opted to phase out their older types before the pandemic. However, the fall in demand accelerated the process, similarly to what happened after 9/11 downturn, with many older types being retired. This has resulted in many aircraft being stored or phased-out ahead of schedule in the wake of fleet resizing or trimming.

Some aircraft that are currently grounded may not return to the sky again if market demand will not justify expenses required to keep them airworthy. On the other hand, aircraft manufactures are eager to get back to pre-crisis production rates[35] . Former airline CEO Christoph Mueller pointed out that airlines should "use the crisis as once-in-a-lifetime opportunity"[36] for restructuring. This includes phasing-out older aircraft that would have been retired in few years, as their residual values are nowadays minimal. Since short-haul market will likely be the first to recover[37] , manufacturers are ready to flood the market with new aircraft. While it will take some years to return to pre-crisis delivery rates, new-generation aircraft may see renewed interest as fuel prices will eventually rise again. Carriers operating less fuel-efficient aircraft will struggle to compete with those operating types with lower fuel consumption. However, for airlines burning cash to survive the crisis, acquisition of new aircraft may be too much. The solution adopted by many airlines set to receive new aircraft has been delivery deferrals. By putting back new entries into their fleets, carriers could operate their older aircraft while fuel prices are low, eventually taking delivery of new airplanes as market recovery occurs and fuel prices rise.

[35] Kaminski-Morrow, D. (25 March 2020). *A320neo overbooking will help steer Airbus through crisis: Faury*. FlightGlobal website
[36] FlightGlobal. (2 April 2020). *Airline chiefs on surviving a crisis - FlightGlobal webinar*. FlightGlobal website
[37] Dunn G. (24 June 2020). *European carriers put emphasis on reach in short-haul return*. FlightGlobal website

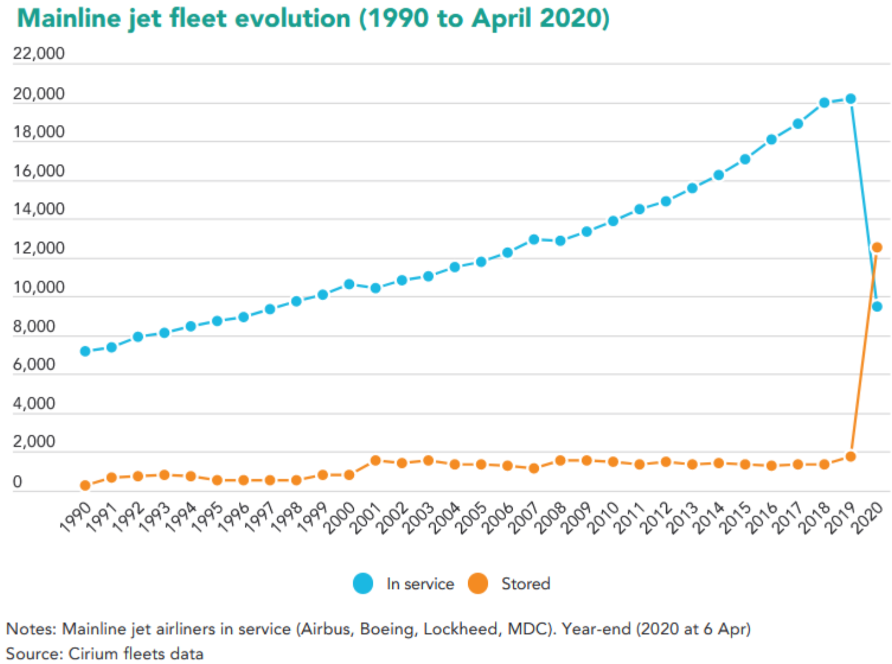

Figure 1.8: Evolution of active and stored fleet of mainline jets (1990-2020)

Many airlines may not return some of their aircraft to the skies. By the time demand will return to pre-crisis levels, acquiring new, more efficient types may be a better deal for airlines than take aircraft with but few years of service left out of long-term storage. However, some of the stored aircraft still have many years of service ahead, thus representing a potentially vast source of equipment for airlines. Since a considerable number of airlines is exiting some markets or sensibly reducing networks and fleets, many modern aircraft with just few years of service on their logbook may be available on the market. These aircraft offering lower than brand new airframes acquisition costs and short delivery time may be a good off-the-shelf solution for airlines wishing to take advantage of the opportunities the post-crisis environment will offer.

The 2020 crisis came as a big shock for the air transport industry, with some operators temporarily or permanently ceasing operations, and others filing for protective measures. Perhaps surprisingly, the number of carriers that collapsed in the wake of COVID-19 pandemic is relatively low if compared to the magnitude of the crisis. However, this is due to many airlines benefiting from aid or resources allocated to protect them. Moreover, with low passenger volumes and less competition on many routes, carriers have entered a sort of stasis[38] . The full scale of the impact the pandemic has had on airlines will emerge as thing will start to get better. When the pandemic will come towards its end, aid will stop flowing and competition levels will rise, eventually leaving carriers with two main options: navigating their way through the storm, or sinking. The ability to tackle the market with the right network and fleet mix will be pivotal to make a good restart. Airlines with strong domestic markets, and thus more opportunities to benefit form it, are likely to benefit from the early stages of traffic resumption[39] . Thus, the crisis may be a possible "new start" for many. Some carriers may prosper in a new market with fewer competitors. However, fewer competitors does not mean

[38] Dunn, G. (21 December 2020). *Will airline failures increase when crisis subsides?*. FlightGlobal website
[39] ibid.

less competition. With many struggling airlines desperately waiting for travel demand to come back, post-crisis months will be a now-or-never for many of them.

Industry insiders prospect that consolidation, after temporarily slowing its pace in the wake of the pandemic, will eventually occur. Former airline CEO Christoph Mueller said Europe will likely experience hub consolidation[40] , with airlines that used to have a large international network likely to focus on their hubs to reinstate long-haul services. Mueller also pointed out that national consolidation, rather than-cross border consolidation, may reshape European networks. Former IAG CEO Willie Walsh thinks that international consolidation may be hindered by governments protecting national carriers[41] . While agreeing that international consolidation will be difficult in the upcoming years, former Director General and CEO of IATA Tony Tyler pointed out that consolidation will take the shape of stronger airlines expanding their market shares at the expenses of smaller airlines or carriers that failed to manage through the crisis[42] .

The influence of prospected hub consolidation on short-haul and very-short-haul air services may lead to different scenarios. Before the 2020 crisis occurred, a general trend towards point-to-point services was emerging in several markets. Point-to-point flights in post-pandemic scenarios may be fostered by safety concerns among passengers, in that passengers may be less keen than before on transiting crowded hubs. However, feasibility of point-to-point services may be hindered by actual demand, in that low passenger volumes may not justify some routes. Moreover, since air traffic is expected to recover when the pandemic will come towards an end, the tendency to avoid hubs because of health safety concerns may be short-lived. Thus, if hub consolidation occurs, hub-and-spoke pattern may be the right solution to reach airports characterized by low demand. IATA's Brian Pierce pointed out that "we will see a concentration on efficient hubs and I think that will favor smaller aircraft"[43] .
Hub-and-spoke pattern may fit the needs of long-haul passengers, but may not suit short-haul travelers. As ticket fares are expected to remain low in response to lower demand, well established short-haul point-to-point carriers offering low fares, like LCCs, may be the first to benefit from recovery. This may result in a traffic pattern characterized by renewed importance of hubs for medium- or long-haul connections, while short-haul connections may be more focused on point-to-point than before. Small efficient aircraft are likely to be better positioned for both connections to/from hubs and for low-volume point-to-point flights.

[40] FlightGlobal. (2 April 2020). *Airline chiefs on surviving a crisis - FlightGlobal webinar*. FlightGlobal website
[41] EUROCONTROL. (22 September 2020). *EUROCONTROL Aviation Straight Talk Live with Willie Walsh*. EUROCONTROL website
[42] FlightGlobal. (2 April 2020). *Airline chiefs on surviving a crisis - FlightGlobal webinar*. FlightGlobal website
[43] Dunn, G. (27 November 2020). *Why hubs could be back in fashion in post-crisis network recovery*. FlightGlobal website

2. The regional air transport

2.1 Definition of regional air transport

The concept of regional air transport is not universal. Thus, the definition of regional air transport requires some considerations. ICAO defines regional air service[44] as:

> "Either *an air service offered on routes serving smaller cities within a region or between regions of a State;* or *an air service offered on secondary routes serving smaller cities in a regional area involving the territories of more than one State."*

However, the one-fits-all definition above covers a wide range of air services, both in terms of route length and traffic volumes. Some considerations for a specific area of interest are then required. First of all, the macro-region of interest shall be stated for this analysis. Since this analysis will focus on European air transport, the macro-region of interest will be Europe, with a strong focus on Italy. Europe is characterized by relatively short distances and high population density. Regions in Europe, especially in Western Europe, are small in size, thus making regional air routes few hundreds nautical miles long, or less.
Traffic volumes and density also play a role in defining regional air transport. Smaller-city airports usually have low or medium traffic volumes. However, this is not always true. The recent past has witnessed the rise of low-cost carriers (LCCs). Some of the busiest routes operated by LCCs connect small cities located in the catchment areas[45] surrounding larger cities. The main reason attracting passengers to these types of airport is usually the chance to obtain lower fares than those offered for flights to the main airport(s) serving the city of interest. An important point characterizing regional air service is then the possibility to choose, or, actually, the impossibility to choose. Passengers flying regional routes rely on that service to travel to/from a small city or region. Thus, for the purposes of this analysis, regional air service may be defined as:

> An air service offered on routes serving smaller cities or communities within a region or between regions of a State that rely on that service, either to reach cities of interest, or to connect to other destinations.

Since this analysis will focus on Italian domestic market, a definition comprising interstate regional service has been omitted. The importance of regional air service is stressed in case of isolated cities or communities, like those located on islands.

[44] ICAO. (2004). *Manual on the Regulation of International Air Transport (Doc 9626)*
[45] The catchment area may be defined as the area surrounding an airport from which the majority of passengers originate or to which the majority of passengers end their journey by air. A more comprehensive analysis of the concept of catchment area will be offered later on.

The term "commuter", usually in the phrases "commuter aircraft" or "commuter airlines", is generally used as a synonym of "regional". While some slight differences do exist between the two terms, they are commonly used to define the same types of air services. To avoid ambiguity, however, the term regional has been preferred for use in this work.

2.1.1 Scheduled and non-scheduled air operations

While mainline carriers and LCCs usually operate scheduled air services, regional air services, especially those operated with smaller aircraft, may be scheduled or not. ICAO state[46] that:

> "*A scheduled air service is typically an air service open to use by the general public and operated according to a published timetable or with such a regular frequency that it constitutes an easily recognizable systematic series of flights. [...] Any air service that is performed other than as a scheduled air service is regarded as a non-scheduled operation.*"

The definition of non-scheduled air service encompasses different types of service. Charter air service and air-taxi operations are examples of non-scheduled air service. The former is defined[47] as:

> a service operated as a consequence of and in compliance with "*a contractual arrangement between an air carrier and an entity hiring or leasing its aircraft*"

while the latter may have two meanings:

- "*a type of on-demand air service usually performed by small capacity aircraft on short notice in a very similar way to an automobile taxi service*"; or
- "*in some cases, a service operated on a scheduled basis with stops made only at points where passengers and cargo are to be picked up or discharged*"[48] .

National authorities provide more precise definitions of air-taxi service to be applied under their jurisdiction. Italian ENAC state that an air-taxi service[49] is:

> "*A non-scheduled air service operated with aircraft having a maximum operational passenger seating configuration not exceeding 19 passengers*".

[46] ICAO. (2004). *Manual on the Regulation of International Air Transport (Doc 9626)*
[47] ibid.
[48] ibid.
[49] ENAC. *Operazioni di volo - Flight Time Limitations (FTL) - Applicabilità.* ENAC website

2.2 The regulatory framework

EASA define and set requirements for civil aviation in the European Union. Regulations issued by EASA apply to both commercial and non-commercial civil aviation. Each regulation shall be applied in accordance with EASA directives.

Air operations are regulated by EASA Rules for Air Operations (Regulation (EU) No 965/2012). This set of regulations includes several Annexes defining and setting different types and aspects of air operations:

1. Annex I: Definitions. "Definitions for terms used in Annexes II to VIII"[50] .
2. Annex II: Part-ARO. “This Annex establishes requirements for the administration and management system to be fulfilled by the Agency and Member States for the implementation and enforcement of Regulation (EC) No 216/2008 and its Implementing Rules regarding civil aviation air operations”[51] .
3. Annex III: Part-ORO. “This Annex establishes requirements to be followed by an air operator conducting:
   (a) commercial air transport operations (CAT);
   (b) commercial specialised operations;
   (c) non-commercial operations with complex motor-powered aircraft;
   (d) non-commercial specialised operations with complex motor-powered aircraft”[52] .
4. Annex IV: Part-CAT. This Annex regulates commercial air transport. It consists of:
   (a) Subpart A: General Requirements;
   (b) Subpart B: Operating Procedures;
   (c) Subpart C: Aircraft Performance and Operating Limitations;
   (d) Subpart D: Instruments, Data, Equipment.
5. Annex V: Part-SPA. This Annex regulates air operations requiring Specific Approvals, e.g. Low-Visibility Operations (LVO) or Extended Range Operations with Two-Engined Aeroplanes (ETOPS). It consists of several Subparts that shall be applied according to the type of operations requiring Specific Approvals.
6. Annex VI: Part-NCC. This Annex regulates non-commercial air operations with complex motor-powered aircraft.
7. Annex VII: Part-NCO. This Annex regulates non-commercial air operations with other than complex motor-powered aircraft.
8. Annex VIII: Part-SPO. This Annex regulates Specialised Operations, e.g. agricultural flights, aerial photography flights, aerobatic flights, etc.

[50] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). Annex I*
[51] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). ARO.GEN.005 Scope*
[52] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). ORO.GEN.005 Scope*

Any Organization conducting air operations in the European Union shall then act in compliance with regulations issued by EASA. To conduct commercial air operations in the European Union an Organization must possess a valid Air Operator Certificate (AOC) issued by the competent authority (e.g. ENAC for Italy). The AOC may be limited, suspended, or revoked by the competent authority if the AOC holder does not comply with applicable regulations.

Aircraft operated by the Organization shall comply with regulations concerning initial and continuing airworthiness. Each aircraft type involved in operations shall possess a valid certification status issued by EASA. Aircraft used for regional air transport are certified in compliance with EASA CS-23 or CS-25. CS-25 applies to “turbine powered Large Aeroplanes”[53] (i.e. “an aircraft, classified as an aeroplane with a maximum take-off mass of more than 5 700 kg, or a multi-engined helicopter”[54]), while CS-23 applies to:

1. "Aeroplanes in the normal, utility and aerobatic categories that have a seating configuration, excluding the pilot seat(s), of nine or fewer and a maximum certificated take-off weight of 5 670 kg (12 500 lb) or less; and
2. Propeller-driven twin-engined aeroplanes in the commuter category that have a seating configuration, excluding the pilot seat(s), of nineteen or fewer and a maximum certificated take-off weight of 8 618 kg (19 000 lb) or less" [55] .

Aircraft characteristics influence applicable regulations in that “the aeroplane shall be operated in accordance with the applicable performance class requirements”[56] . Performance classes defined by EASA Rules for Air Operations – Annex I are:

1. performance class A aeroplanes: “multi-engined aeroplanes powered by turbo-propeller engines with an MOPSC of more than nine or a maximum take-off mass exceeding 5 700 kg, and all multi-engined turbo-jet powered aeroplanes”[57] ;
2. performance class B aeroplanes: "aeroplanes powered by propeller engines with an MOPSC of nine or less and a maximum take-off mass of 5 700 kg or less"[58] ;
3. performance class C aeroplanes: "aeroplanes powered by reciprocating engines with an MOPSC of more than nine or a maximum take-off mass exceeding 5 700 kg"[59] .

Many modern regional aeroplanes are classified as performance class A aeroplanes. However, there are some examples of performance class B aeroplanes operating scheduled or charter regional air services. Specific requirements and regulations for each performance class are detailed in Rules for Air Operations – Annex IV (Part-CAT) – Subpart C: Aircraft Performance and Operating Limitations.

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[53] EASA. (November 2018). *Easy Access Rules for Large Aeroplanes (CS-25) (Amendment 21). Subpart A - General - CS 25.1 Applicability*
[54] European Commission. (20 November 2003). *COMMISSION REGULATION (EC) No 2042/2003 of 20 November 2003. Article 2 (g)*
[55] EASA. (June 2018). *Easy Access Rules for Normal, Utility, Aerobatic and Commuter Category Aeroplanes (CS-23) (Amendment 4). Subpart A - General - CS 23.1 Applicability*
[56] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). CAT.POL.A.100 Performance classes*
[57] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). Annex I*
[58] ibid.
[59] ibid.

As already said before, operators shall comply with the aforementioned EASA regulations. Among those prescriptions, crew requirements and limitations deserve a mention. Crew regulations are defined and set by Rules for Air Operations (Regulation (EU) No 965/2012) and Rules for Aircrew (Regulation (EU) No 1178/2011). Prescriptions regarding crew requirements heavily influence the way air operations are conducted, in term of costs, performance, efficiency, and effectiveness. The main crew-related factors affecting air operations the Organization can control are number of personnel and training required. Even though crew per aircraft and training are defined by regulations, the Organization can still decide which aircraft to operate. For example, the Organization may operate an aircraft type certified for single-pilot operations instead of one requiring additional crew, or a type not requiring cabin crew may be preferred to reduce costs.

Airplane types can be broadly divided into two main categories: those requiring a type rating and those requiring a class rating[60] . The holder of a class or type rating has the privilege " to act as pilot on the class or type of aircraft specified in the rating"[61] . The main difference between class rating and type rating is that the first gives the holder the privilege to act as a pilot of all types belonging to the class he/she holds a class rating for, while the latter gives the holder the right to act as a pilot of the aircraft type(s) or variant(s) he/she holds a type rating for. Moreover, the operating environments may require additional ratings for aircrew, e.g. Instrument Rating. Since different regulations apply to different aircraft types or classes, specific information on regulations will be found further on where pertinent.

2.3 What, how, where...?

2.3.1 Network planning

A strong network is key for a successful airline. However, network planning poses some major challenges, in that there is not one method to do it. A successful airline, i.e. a profitable airline, can offer a service that makes customers keen to purchase it in return of the service provided. Even though this may look self-evident, it is worth noting that many airlines failed as the service they provided was not adequate for customers.
Due to the importance of network planning for airlines, success may be, and usually is, heavily driven by it. Hence, airlines are often jealous of their network planning techniques and strategies.

Network planning techniques shall focus on the market the carrier wants to enter. All aspects of the market shall be thoroughly assessed, in terms of market potential and demand, timing, scheduling, type of service, etc. Some scenarios may also have peculiar aspects to consider. For example, an airline may open a route as a consequence of a partnership with another carrier, or may be obliged to operate on a certain frequency due to agreements with other airlines or institutions. These examples show how complex network planning is, in terms of variables and players.

[60] EASA. (August 2020). *Easy Access Rules for Aircrew (Regulation(EU) No 1178/2011). Annex I (Part-FCL) - Subpart H - Section 1 - FCL.700 Circumstances in which class or type ratings are required*
[61] EASA. (August 2020). *Easy Access Rules for Aircrew (Regulation(EU) No 1178/2011). Annex I (Part-FCL) - Subpart H - Section 1 - FCL.705 Privileges of the holder of a class or type rating*

The first concern when planning a route is whether the route is open or restricted. Before deregulation, airlines had less freedom in planning their route network. This pattern protected airlines from competition, but offered few choices to passengers. As previously said, air transport deregulation was gradually introduced in Europe during the 1980s and the 1990s. As a consequence of deregulation, the way air traffic stakeholders interact has changed. Today, there are many players in the process of planning airlines' networks. In a liberalized market, five main players may be identified. The first one is the airline itself. Every airline is characterized by a strategy, which reflects on its fleet, target, and services offered. Hence, in planning their network, airlines focus on routes that could be operated by implementing the airline strategy. It is worth noting that the strategy shall not be a limitation. An airline may vary its strategy to better tackle a market if benefits generated by entering the market are greater than the effort required to adapt the strategy.

Passengers are a fundamental player in the air transport market, in that passengers are the real driver of any airline business. The ability to understand and predict passengers behavior is pivotal for network planners. Airlines interact with passengers in different ways, both directly and indirectly. Direct interaction is when the carrier provides the passengers a service, be it the carrier's core service, namely, air transport, or ancillary services, e.g. baggage handling or loyalty programs. Direct interaction may result in passengers feedback that can help the airline assess customers satisfaction. However, network planners shall assess passengers' needs before commencing service. Except for surveys, that are usually limited in sample and scope, direct interaction is not very effective for future planning. Hence, airlines focus on data to assess passengers' needs. Data are used to develop passenger demand models[62]. Variables used for modeling may vary with operating environment(s) considered, with some of them, like services offered or flight schedules, being more common than others among passenger demand models. Properly assessing different customer (i.e. passenger) groups is fundamental for network planning. Routes may serve different types of passengers with different needs. A route fitting the needs of a passenger group may not fit the needs of another group. For example, a route may suit the needs of leisure travelers but not business travelers, or Visiting Friends or Relatives (VFR) travelers. Thus, depending on company strategy, airlines focus on one or more passenger groups.

Airline deregulation has caused competition levels to rise. All airlines operating in the liberalized market face some form of competition. Many times, competitors are air carriers. Competing airlines will likely take actions to retain or increment revenues generated by the routes they operate. However, some scenarios may see other types of services entering competition with those offered by the airline. Competitors may offer similar or different types of services, different schedules, or even different means of transportation. The more the services offered by another carrier overlap with those offered by the airline under analysis, the more the carrier offering those services can be considered a competitor. However, not all (air) transport providers do enter competition with each other. Some scenarios may see the airline entering agreements with partners to increase or maintain its presence in a market. Alliances, code-sharing, and other types agreements may, if properly used, be pivotal for airlines. Some of these agreements are so powerful that airlines involved eventually become "symbiotic", with each airline relying on the other one to maintain its position in the market. An example of this

[62] Akartunalı, K. et al. (2013). *Airline planning benchmark problems - Part II: Passenger groups, utility and demand allocation*. Computers & operations research, 40(3)

type of relation is the trunk-feeder pattern, where the former is an airline with a network expanding from one or more hubs to many destinations, while the latter provides local air services, connecting the hub(s) with secondary airports. On the other hand, partners may enter competition if services offered by them do overlap. All those aforementioned players may be included in the group of carriers, that are companies offering transportation services whose provision may directly impact the airline performance on the market in either a positive or negative way.

Following air transport deregulation, airports have increased their influence on network planning. Like airlines, airports have their network and, consequently, their network strategies. Airlines wishing to open a route to/from an area may be offered the possibility to fly to more than one airport. Hence, choosing the right airport, in terms of facilities, traffic volumes, and prevalent passenger groups is of great importance. Many times, airports issue development analyses detailing routes that should be opened or increased in frequency. Airports have eventually offered airlines possible routes to operate, thus becoming active players in the route development process[63] . In some cases, airports do share with airlines the risk, or even the financial effort, of opening or developing routes. By sharing risk and financial effort, carriers and airports may leverage traffic volumes, and eventually revenues. Financial effort provided by airports may be of different types. Financial incentives issued by airports may cover payments for those activities involved in the successful launch of a new route, namely marketing, or may consist in reductions on airport fees. Studies conducted in 2012 showed that "of the 200 largest airports in the EU [...] airport incentive programmes are a common tool of airport pricing used at one-third of all airports [analyzed]"[64] . Incentives may also be non-financial. Airports may provide contracts or facilitate agreements with third parties, like airport handlers or tour operators.

In addition to the aforementioned players, other organizations may directly influence the air transport market. These organizations may have different roles and interests. National or international authorities have the power to directly influence air transport by promoting policies of issuing restrictions. National authorities may take actions to promote or protect a route or a market. On other occasions, authorities may act to restrict some markets. Public Service Obligations (PSOs) are an example of both. One or more carriers may be favored in operating a route, while other carriers may be limited in or prevented from operating the same route.
Regulators are players that have the power to directly influence air transport. Different regulations may apply to different airlines in different ways, thus changing the *status quo*. New regulations may prescribe different actions for different categories of aircraft, thus influencing airlines operating types in those categories. For example, ETOPS regulations influenced some airlines and some markets more than others.
Manufacturers and technology suppliers may directly influence air transport. Many times, manufacturers have co-developed new aircraft with carriers. Thus, carriers involved in design and development may take advantage of aircraft designed according to their needs.
All these players may be dubbed "environment players". Environment players have the power and the interest of directly influence air transport. It is worth noting that most of the times actions taken by these players are not aimed at favoring one or more airlines or hinder others.

[63] Halpern N., Graham A. (2015). *Airport route development: A survey of current practice*. Tourism management (1982), 46

[64] Malina, R., Albers, S., & Kroll, N. (2012). *Airport Incentive Programmes: A European Perspective*. Transport reviews, 32(4)

Environment players pursue their interests, be them safety and efficiency for regulators, public interest for national authorities, or profit for manufacturers. However, being directly involved in the air transport market, environment players do act considering the effects their actions will have on the industry.

When planning or analyzing current or future networks, airlines shall consider all the aforementioned players. Moreover, a thorough study would also consider the interactions between those players and the consequences the actions taken by the airline will likely have. It is worth noting that the previous analysis has been presented in a "static" way. However, the process of network planning in not static, nor linear. All the aforementioned factors shall be assessed as variables of the same system, rather than consecutive steps. Every change will cause changes in the whole system. Hence, network planning is an iterative process aimed at continuously and successfully positioning the airline in the market.

2.3.2 Catchment area

The concept of catchment area is fundamental for both airlines and airports networks. The catchment area may be defined as the area surrounding an airport from which the majority of passengers originate or to which the majority of passengers end their journey by air. It is worth noting that the concept of catchment area depends on the environment where it is applied. Hence, the boundaries of a catchment area may not be clearly defined. Moreover, different catchment areas for different groups of passengers may exist for the same airport. For example, a city airport and an international hub serving the same city may have catchment areas with similar boundaries, but different passenger groups. Many times, catchment areas do overlap, especially in places where several airports are serving a city or a region.
The aforementioned definition defines the catchment area as the area from which passengers originate or end their journey by air. However, large hubs may include in their catchment areas the catchment areas of airports from which transiting passengers originate. This type of catchment area is sometimes referred to as enlarged catchment area. Other subcategories of catchment areas may be identified to focus on one or more characteristics. Airlines and airports may define subcategories of catchment areas according to their needs.
Catchment areas characteristics and boundaries can be influenced by airlines or airports. Airlines and airports may take actions or implement policies to expand the catchment area of an airport. These actions may include supporting ground transport serving the airport or airline connections, implementing fare policies, marketing, etc.

2.3.3 Areas and markets of interest

European countries have few large cities, which correspond to few aviation mega-cities that "account for 40% of all passengers", as reported by Airbus[65]. In 2018, there were fifteen aviation mega-cities in Europe, two of which - Rome and Milan - in Italy[66]. Besides those aviation mega-cities, there are many medium or medium-to-large cities with little-to-no long-haul connections serving their airports. Some of those cities have large catchment areas in terms of number of residents, resulting in potentially large markets for direct domestic and short-haul connections.

[65] Airbus S.A.S. (2019). *Global Market Forecast - Cities, Airports & Aircraft 2019-2038*
[66] ibid.

To better address the problem of route analysis and selection, it is worth focusing on Italian domestic connections pattern. Passengers traveling by air on Italian domestic routes usually have two main options: flying a mainline carrier, namely Alitalia, usually stopping in Rome Fiumicino (FCO/LIRF) hub, or flying point-to-point with carriers operating direct flights between other-than-major airports. Most of the times, these flights are operated by LCCs. Some large LCCs have even created their hubs at secondary airports. However, rather than being used as hubs for hub-and-spoke flights, these airports may be considered focus cities. The main difference is that the former have high percentages of transiting passengers flying hub-and-spoke, while the latter are simply airports the airline focuses on for its operations. Point-to-point is definitely more time-efficient for domestic passengers than hub-and-spoke. However, a destination may not be reached with one direct flight, thus requiring a stop.

The sudden fall in air traffic demand in the wake of COVID-19 outbreak poses new challenges in analyzing how demand will recover. For many carriers, the first step to recover is reinstating their network, rather than focusing on pre-crisis frequency. This strategy is considered by both LCCs, Ryanair amongst others, and mainline carriers like KLM to be the best solution in the upcoming months[67]. For airlines with large networks, keeping their presence on many airports is vital. However, a 100% resumption, both in terms of presence and frequency, is still far away. Regional routes, because of their lower traffic volumes, are likely to be more affected by delays in traffic resumption. This leaves many potentially profitable routes poorly served or not served at all. However, the need for regional air services is vital for those regions that rely on it. This necessity is stressed in case of areas that may not be easily reached by other means of transportation, like islands. For this reason, this analysis will focus on two areas and on their airports: the area of Olbia, in northern Sardinia, and Elba Island, in Tuscany.

[67] Dunn G. (24 June 2020). *European carriers put emphasis on reach in short-haul return*. FlightGlobal website

3. The regional fleet

3.1 State of the art

As far as aircraft demand and deliveries are concerned, data[68] show that deliveries of narrow-body airliners have outpaced regional jet deliveries, thus leading to a focus on narrow-body airliners. With few exceptions, "older-style" regional jets have exited production or reduced production rates in the last two decades.
New-generation regional jets have eventually come out resembling narrow-body airliners, in terms of capacity and even range. This new generation of "once-regional" jets, i.e. Embraer E-Jets E2 and Airbus A220 (née Bombardier CSeries), have eventually entered competition with smaller members of well-established narrow-body families (Airbus A320 and Boeing 737). Not surprisingly, single-aisle aircraft market has seen many new types entering the market in the last five years, from projects designed from scratch like the Bombardier CSeries/Airbus A220 to re-engined variants of existing types, e.g A320neo, 737 MAX, and E-Jets E2.
On the other hand, the last years have seen a reduction of new aircraft types in the turboprop category. Many types have exited production, resulting in ATR retaining a quasi-monopoly in the industry, with 75% of turboprop market share[69] . Beside ATRs, the only large turboprop in significant commercial service in Western Europe is the De Havilland Canada Dash 8-400.

The ubiquitous single-aisle twin-jets are the market leaders for short-haul routes in the Italian market. Airbus A320s, Boeing 737s, and Embraer E-Jets are the most used aircraft in this category. These long-running workhorses of short-haul have cannibalized the Italian market, thanks to economy of operations and versatility.
The Boeing 737 is the backbone of the largest carrier by passengers flown on Italian routes, Ryanair[70] . While their blue and yellow tails are a common sight in Italian airports, there are several other carriers flying the 737, namely Neos, Blue Air, and Blue Panorama, among others. Air Italy also flew 737s on their network. Ryanair[71] , Neos[72] , and Blue Air[73] have announced they will operate the 737 MAX. A transition from 737NGs to 737 MAX aircraft is expected in the upcoming years.
The Airbus A320 is Boeing 737's main competitor. Airbus A320 "ceo"[74] family is the backbone of the largest Italian mainline carrier, Alitalia. Alitalia flies A319s, A320s, and A321s on many domestic routes, most of them connecting Italian airports to Alitalia's hubs. easyJet is

[68] Boeing. (2019). *Commercial Market Outlook 2019–2038*
[69] Perry, D. (13 March 2020). *ATR deliveries flat in 2020, says Leonardo*. FlightGlobal website
[70] ENAC. (2020). *Dati di Traffico 2019*
[71] Boeing. *Boeing - Commercial - Orders & Deliveries*. Boeing website
[72] Boeing. (21 June 2017). *Boeing, AerCap Announce Neos as New 737 MAX Operator*. Boeing website
[73] Boeing. *Boeing - Commercial - Orders & Deliveries*. Boeing website
[74] A320 family variants equipped with CFMI CFM 56 series engines or IAE V2500 series engines have been dubbed ceo (current engine option) by Airbus as opposed to neo (new engine option) variants.

another major player in the Italian market. easyJet and its subsidiaries fly a mixed fleet of A320 family aircraft, in both "ceo" and neo variants. Italian-domestic newbie Wizz Air operates a fleet of A320 and A321, with neos recently joining Wizz Air's fleet[75] . Volotea is currently replacing their aging Boeing 717s with a fleet of A319s[76] .
Lower-capacity Embraer E-Jets have been flying domestic routes in Italy for Alitalia's subsidiary Alitalia Cityliner. Air Dolomiti, a Lufthansa subsidiary, has been flying E-Jets for years, eventually operating a single-type fleet of E-195s.

While narrow-body jets have kept or grown their presence in Italian domestic routes, many operators have abandoned turboprop airliners in favor of jet airplanes. Large traffic volumes are probably the most important factor behind this change. As previously noted, the number of passengers has grown in many countries, including Italy. With larger traffic volumes, larger aircraft can be operated profitably. Another factor is that jetliners offer more expansion opportunities than turboprops. Airlines operating turboprops are limited by capacity, in that large turboprop airliners have a maximum capacity in the range of 75-90 passengers, while small modern regional jets seat 80 to 120 passengers. Moreover, turboprops fly slower than jetliners. More flights in less time return more stages per day, and, combined with higher passenger capacity, more RPKs. Hence, many airlines that used to operate turboprops have opted to renew their fleets with modern single-aisle jets rather than with modern turboprops. It may be pointed out that turboprops cannot compete with jetliners. In some ways, that is true. On the other hand jetliners are more prone to market instability than turboprops due to their higher capacity. Analyses by Cirium[77] note that traffic demand may not return to 2019 levels until 2023, while European air traffic demand may take up to five years (i.e. 2025) to completely recover. Lower-capacity aircraft may be better positioned in the upcoming years. Since load factors for narrow-body jets may not justify some point-to-point connections, propeller-driven aircraft may benefit from being the only categories of aircraft that can profitably operate those routes.

The use of piston-powered aircraft is not negligible in the North and Central American regional market, but is limited in Europe. The main reason is the different traffic pattern in America and Europe. European air transport demand may not justify routes operated with small aircraft (typically 9 seats or fewer) on short distances. The higher cost of AVGAS (typically 100LL) in Europe further hinders the wide use of piston aircraft for commercial air services. However, some small piston-powered aircraft have found their niche in low-demand connections that call for easy to operate aircraft, both in terms of operations and costs. It is worth noting that EASA regulations require a Type Rating for multi-engine turboprop aircraft types or models, while most multi-engine piston aircraft require a Class Rating (MEP (land) License) but not a Type Rating[78] . Moreover, many multi-engine piston aircraft are certified for single-pilot operations, thus resulting in lower costs due for crew salaries and training.
The number of new piston-powered transport aircraft types entering the market in the last decades has decreased. Unpressurized piston aircraft usually have longer operating lives than pressurized aircraft, in that fuselage fatigue due to pressurization loads is not present. This, together with simple design and maintainability, gives unpressurized piston aircraft long operating lives, eventually leading to longer replacement cycles than pressurized aircraft.

[75] Kaminski-Morrow, D. (7 March 2019). *PICTURE: Wizz receives first A321neo*. FlightGlobal website
[76] FlightGlobal. (10 March 2016). *Volotea to replace 717s with used A319s*. FlightGlobal website
[77] Cirium. (18 November 2020). *Where are we on the path to aviation industry recovery?*. FlightGlobal website
[78] EASA. (24 Feb 2021). *EASA type rating and licence endorsement list flight crew –all aircraft excluding helicopters*

3.2 The importance of efficiency for air transport

Environmental concerns have risen in the recent years. With more passengers less keen than before on traveling by air, airlines must focus on achieving environmental neutrality.

Commercial aviation has always been committed to efficiency. The pursuit of efficiency has led to many technological and operational achievements. Through aviation history, efficiency has had different shapes. In the early days of the Jet Age, more efficient meant faster. Efficiency gave shorter times, with benefits for passengers and operators. As high-subsonic speed became a benchmark for all passenger jets, focus moved to range. More efficient aircraft could fly longer routes without stopping, thus reducing times and costs. With the arrival of wide-body jets, capacity became a new way of conceiving efficiency. Large jets could accommodate more people, slashing operating costs per passenger. In the wake of the 1970s oil crises, airlines faced unprecedented fuel expenses. This led to a call for fuel efficiency. The arrival of large twin-jets, a phenomenon still present today, has been a direct consequence of this way of conceiving efficiency. However, fuel efficiency was a matter of cost, rather than environmental concerns. It was not until later years that aviation started addressing the problem of climate changes. Fuel efficiency is now one of the key factors to reduce emissions.

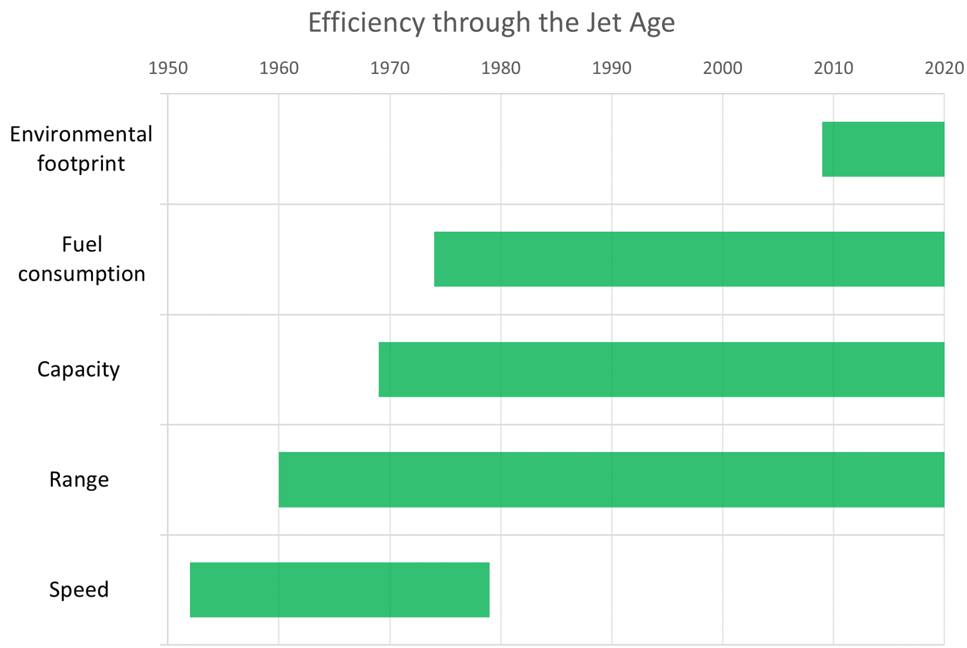

Figure 3.1: The concept of efficiency through the Jet Age

According to a study conducted by Intergovernmental Panel for Climate Change (IPCC), "estimates of CO_2 emissions from global aviation [...] accounted for about 2% of total anthropogenic CO_2 emissions"[79] , a relatively low percentage compared to other means of transportation[80] . However, aviation impact is not negligible, as the number of passengers flying worldwide has risen in the past years. Before the 2020 pandemic, environmental sustainability was the biggest concern for commercial aviation. Beside surviving the 2020 crisis, environmental sustainability is definitely the biggest challenge for modern aviation.

[79] IPCC. (2007). *Climate Change 2007: Mitigation of Climate Change*. Cambridge University Press
[80] ibid.

Thus, aviation industry has been focusing on reducing carbon footprint of its activities. Environment has emerged to become the fourth stakeholder[81] , the other three being customers, employees and shareholders.

A survey conducted for European Investment Bank in September-October 2019 asked European citizens from all 28 European Countries whether they were in favor of "a ban on short-distance flights" and of "a carbon tax on flights"[82] . 62% of respondents favored the ban, while 72% of them favored a carbon tax on flights. The results highlight two main issues. The first one is that a large number of people in the EU have a negative opinion of aviation as far as environmental impact is concerned. The second one is that there is some misconception about environmental impact of aviation. The challenge for airlines, manufacturers, and all stakeholders involved in commercial civil aviation is not just reducing carbon footprint. Aviation stakeholders shall also focus on addressing public opinion. For example, the survey focused on "short-distance flights". However, as previously noted, there is not one unanimous definition of short-distance flight. Hence, some people may have different opinions on whether a flight should be banned or not. Moreover, operating scenarios are different through Europe. Some short-haul flights, whatever they are, connect cities that could be easily reached by train, while others may connect islands or remote areas. Not surprisingly, respondents from countries located in central Europe, like France (67% for), Germany (67% for), and Belgium (65% for), favored the proposed ban more than respondents from countries with different geographical and morphological characteristics, like Italy (59% for), Ireland (44% for), or Sweden (55% for). A ban not considering special needs of different scenarios would be detrimental not just for the air transport industry, but primarily for communities served by such flights.

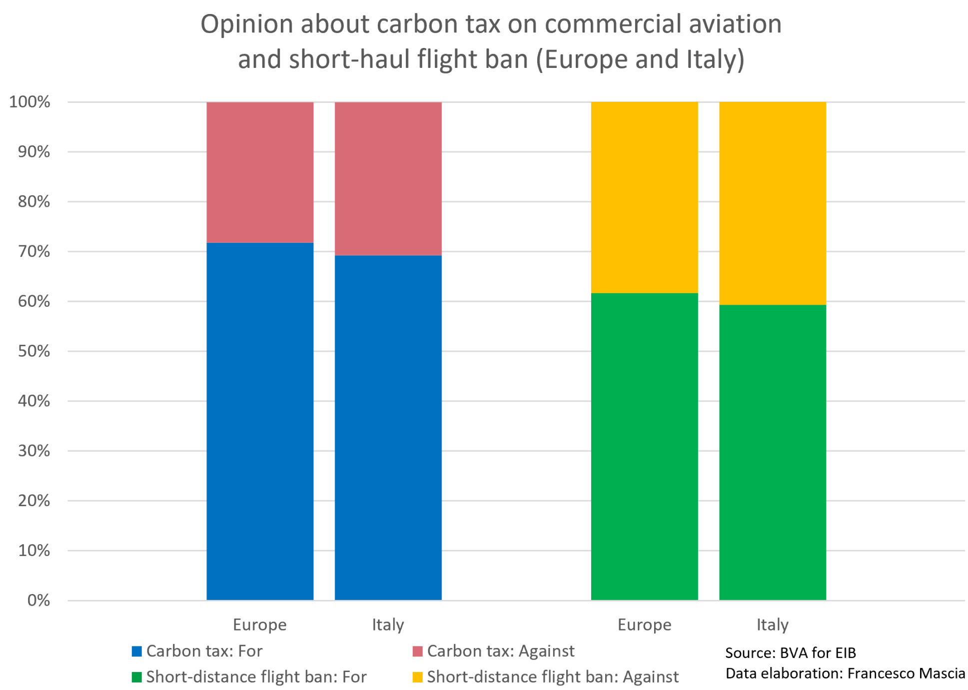

Figure 3.2: Opinion about carbon tax on commercial aviation and short-haul flight ban (Europe and Italy)

[81] Reals, K. (6 September 2019). *Flight shame is changing the face of travel*. FlightGlobal website
[82] EIB. *2019-2020 EIB climate survey*. EIB website

The survey also points out that 72% of respondents are in favor of a carbon tax on flights. It is worth noting that the survey was conducted in September-October 2019, before the fall in air traffic caused by 2020 pandemic. For many airlines struggling to survive the crisis, taxation on fuel would be too much to bear. However, even for a healthy industry, fuel taxation would not be the solution. Taxing fuel would cause ticket prices to rise. Hence, passengers who can afford higher ticket prices would fly anyway, while some others would simply not fly. This would result in airliners flying with lower load factors, thus increasing emissions per passenger. Definitely not a good result. Moreover, this may be effective to reduce short-haul air travel if other means of transportation, like train, are available, but would not be effective in scenarios where air travel is vital for communities. Rather than taxing fuel, civil aviation stakeholders shall invest in programs aimed at reducing net environmental impact.
Make public opinion aware of what is done to reduce carbon footprint is of utmost importance to better address the problem of aviation environmental impact. Efforts to create a sustainable aviation would be ineffective if no effort is made to inform passengers about what airlines, manufacturers, and all stakeholder have done to make their flight sustainable.

The call for a reduction of carbon emissions related to aviation activities has been received by ICAO, with the creation of Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), approved by ICAO in 2018.
According to ICAO, the CORSIA program and the use of sustainable aviation fuels (SAFs) represent more than half of the effort to achieve carbon neutral international flights. Interest in sustainable aviation fuel has grown in the latest years as synthetic aviation fuels may offer smoother transition to sustainable aviation than other proposed solutions. SAF is made by blending kerosene with synthetic fuels or biofuels[83] . The main difference is that biofuels are produced from biological resources, like plants or algae, while synthetic fuels may be produced from inorganic sources. While an in-depth analysis of synthetic aviation fuels is not among the purposes of this work, benefits potentially deriving from those fuels are to be considered. The main advantage of synthetic aviation fuels is the possibility to reduce carbon dioxide net emissions over their life cycle. The quantity of CO_2 emitted by combustion engines burning SAF is approximately equivalent to that absorbed by plants used to produce them, making their life-cycle almost carbon neutral. Taking into account equipment and facilities required for production, storage, and distribution, sustainable aviation fuels allow up to 80% reduction in overall life-cycle CO_2 emissions[84] .
Costs deriving from wide use of synthetic aviation fuels are difficult to determine, in that current estimations are based on costs for limited production[85] . Preliminary estimations based on cost of vegetable oils already in large production estimate biofuels to cost one and a half to twice more than aviation fossil fuels, as of 2016. Estimations are made difficult since mass production has not been implemented yet. Thus, a high degree of uncertainty is inherent in estimations[86] . Costs for synthetic aviation fuels produced in large quantities would likely be lower than limited-production SAFs. However, costs required to implement large-scale production are yet to be determined.
While accurate cost estimations are not yet available, introduction of synthetic aviation fuels in commercial aviation would likely induce higher costs than using fossil fuels. Industry insiders have called for government aid to address the problem considering both environmental and

[83] ATAG. (November 2017). *Beginner's Guide to Sustainable Aviation Fuel*
[84] IATA. *What is SAF?*. IATA website
[85] IRENA. (January 2017). *Biofuels for aviation - Technology brief*
[86] IATA. (2015). *IATA Sustainable Aviation Fuel Roadmap*. IATA

economical sustainability. Lufthansa Group CEO Carsten Spohr highlighted the need for a "strong, joint commitment from industry and politics to promoting sustainable fuels"[87]. IATA's Director of Aviation Environment Michael Gill echoed Spohr's words, stressing the need for governments support to promote SAFs[88]. European Union targets sustainable aviation fuels implementation to reach 40% of total jet fuel demand by 2050[89]. The target is a mean forecast based on 2015 estimation of 2050 fuel demand. A high forecast could see SAFs to cover up to 80% of estimated jet fuel demand by 2050. It is worth noting that the aforementioned estimations were made before 2020 crisis. Post-2020 estimations expect lower demand in the next decades. Moreover, increasing concerns for environmental sustainability and investments could foster production of SAFs.

Another key factor to reduce carbon emissions is implementing more efficient technologies allowing more efficient aircraft. Talking about sustainable aviation, Lufthansa Group CEO noted that while SAF may be a good solution in the mid-term, "in the short term, the biggest lever [to reduce carbon emissions] is in fuel-efficient aircraft, which emit up to a quarter less CO_2 than their predecessor models"[90]. While fuel efficiency has been a key focus for aviation industry for decades, with modern jets consuming over 80% less fuel per seat-kilometer than 1960s jets[91], the latest generations of aircraft have brought great fuel efficiency achievements. Moreover, implementing a Single European Sky preventing aircraft from flying around State borders would help reducing unnecessary fuel consumption. Fuel efficient aircraft, combined with optimized air spaces, are the most powerful drivers to reduce aviation emissions in the short term.

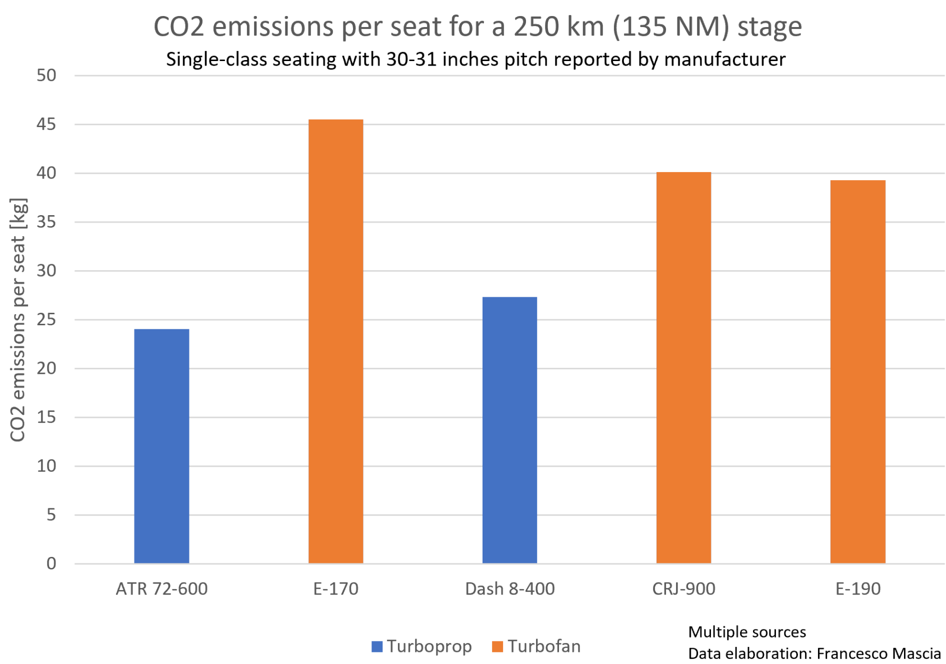

Figure 3.3: CO_2 emissions per seat for a 250 km (135 NM) stage

[87] Robins, J. (21 August 2019). *Lufthansa chief urges governments to support carbon-neutral fuels*. FlightGlobal website
[88] Harper, L. (20 November 2020). *Crisis CO2 levels highlight scale of airline challenge: IATA sustainability chief*. FlightGlobal website
[89] IATA. (2015). *IATA Sustainable Aviation Fuel Roadmap*. IATA
[90] Robins, J. (21 August 2019). *Lufthansa chief urges governments to support carbon-neutral fuels*. FlightGlobal website
[91] ATAG. *Facts & Figures*. ATAG website

By design, turboprop engines are inherently more efficient than turbofans. Moreover, they emit less CO_2 than turbofan engines. For example, an Embraer E-190 seating 114 passengers emits circa 63% more CO_2 per seat than an ATR 72-600 with 72 seats on a 250 km (135 NM) stage. Lower emissions per passenger result in lower expenses for carbon offsetting. While there is not a comprehensive estimation of carbon offsetting costs per ton, these may vary from 5-11 €/ton to 18-36 €/ton[92] [93] .

Possible ways to discourage tankering[94] without inducing higher fuel costs for airlines should also be considered. Then IAG chief executive Willie Walsh stressed the issue[95] , calling for integration of environmental consideration into business strategies. A study conducted in 2019 by EUROCONTROL in 44 European Civil Aviation Conference (ECAC) member States[96] showed that additional fuel consumption due to tankering causes 286 millions kilograms of fuel to be burnt annually, generating 901 million kilograms of carbon dioxide emissions. On the other hand, savings on fuel costs deriving from tankering are not negligible for airlines.

[92] Petri, J. (16 March 2020). *Airline Carbon Plan Takes a Step Forward While Carriers Suffer*. Bloomberg website
[93] The conversion rate used is 1 US Dollar = 0.8958 Euro as reported by *Il Sole 24 Ore* website for date of publication of data source.
[94] Tankering refers to the practice of refueling at home base or where fuel prices are lower, flying more than one sector before refueling. This may be economically efficient for airlines, but requires surplus fuel to be carried aboard, increasing aircraft weight and fuel consumption.
[95] Kaminski-Morrow, D. (8 November 2019). *IAG's Walsh highlights environmental dilemma over tankering*. FlightGlobal website
[96] ECAC. *ECAC member states*. ECAC website

3.3 Aircraft characteristics

Several criteria may be considered when analyzing aircraft performance. The criteria considered for this analysis derive from studies conducted among regional airlines[97] . These criteria are usually common to every regional airline. However, their relative influence and importance may vary according to scenarios, strategies, or environment. The table below reports the criteria listed by regional airlines as the most important for aircraft selection.

Regional Aircraft Selection Criteria	
Economy of operation	Is the aircraft the most economical in its class? Is it the best aircraft to maximize profits?
Acquisition cost	Is the aircraft affordable? Are purchase, financing, or leasing costs sustainable?
Cost and ease of maintenance	Is the aircraft economic and easy to maintain?
Support capability of manufacturer	Does the aircraft manufacturer provide readily available support facilities? Is crew training made easily available by the manufacturer?
All-weather operational capabilities	Is the aircraft certified for all-weather operations? To which extent?
Internal size of cabin and baggage space	How much space for passengers and baggage does the aircraft offer?
Normal operational range	Is the aircraft capable of operating routes without refueling away from home base? How many stages can be operated before refueling?
Airport requirements	Is the aircraft capable of operating out of all airports in the airline current or proposed network?
Passenger comfort	Which level of passenger comfort does the aircraft offer? Is the aircraft pressurized? Does it have stand-up room?
Aircraft operational speed	What is the aircraft operational speed? How many stages can be operated in a typical day?
Environmental footprint	What is the aircraft environmental footprint, in terms of carbon emissions and noise?

Table 3.1: Regional aircraft selection criteria

It is worth noting that some of the aforementioned criteria have been taken without any change, while others have been adapted or added to better suit the operating environment. The most noticeable addition, in terms of importance gained by the matter, is the environmental footprint of the aircraft.

[97] Wells, A.T. and Richey, F.D. (1996). *Commuter Airlines*. Krieger Publishing Company

This analysis will focus on regional air services operated with turboprop and piston-powered aircraft. The main points driving the choice are:

- Turboprops and piston-powered aircraft can be profitably operated with lower passenger volumes.
- Turboprop engines are inherently more efficient than turbofans. Propeller-driven aircraft burn less fuel and emit less carbon dioxide per passenger than turbofan aircraft of similar size. Moreover, piston engines may offer lower operating costs than turboprop engines of similar size.
- Turboprops and piston-powered aircraft can operate at airports with shorter runways and require fewer ground facilities than jetliners of similar size.
- Differences in flight time between turboprop and turbofan aircraft are marginal on very-short-haul flights.
- Turboprops and piston-powered aircraft are likely to be the first aircraft category to implement new technologies aimed at de-carbonizing air transport.

A brief overview of the types considered will be offered. Further details are listed in *Appendix C. Aircraft specifications*.

ATR 42-600

The ATR 42 is a high-wing, twin-turboprop aircraft certified in compliance with EASA CS-25[98] . The ATR 42-600, officially named ATR 42-500 "600 version", is the latest version of the regional turboprop aircraft first flown in 1984. Launched in 2007 and first flown in 2010, the 42-600 is the highest performing member of the ATR 42 family. "600 version" aircraft feature the highest maximum take-off weight, maximum zero fuel weight, and maximum operational passenger seating configuration of all ATR 42 versions. ATR 42-500 "600 version" aircraft may be certified in two weight variants with different maximum zero fuel weight values. The basic version has been chosen for this analysis.
The ATR 42-600 features a 2.57 m wide and 1.91 m high pressurized cabin certified for an MOPSC of 60 passengers, but it is usually configured in a single-class layout with 29” - 30” (74 cm - 76 cm) seat pitch seating 48-50 passengers. A single-class layout seating 48 passengers has been assumed for this analysis.
The ATR 42-500 "600 version" is equipped with two Pratt & Whitney Canada PW127 engines. ATR 42-500 "600 version" aircraft equipped with PW127E and PW127M are certified for 120 minutes ETOPS. Each engine is equipped with one Hamilton Sundstrand 568F-1 constant-speed, variable-pitch six-blades propeller. The propellers can be feathered and reversed. Eligible fuel types are kerosene blends and additives approved in compliance with Pratt & Whitney Canada specifications. PW127 installed on 42-500 "600 version" aircraft may be rated for different power settings. Each rating gives the opportunity to operate at rated power in different environmental conditions. The ATR 42-600 maximum cruise speed is 300 KTAS.

[98] TYPE-CERTIFICATE DATA SHEET No. EASA.A.084 for ATR 42 and ATR 72

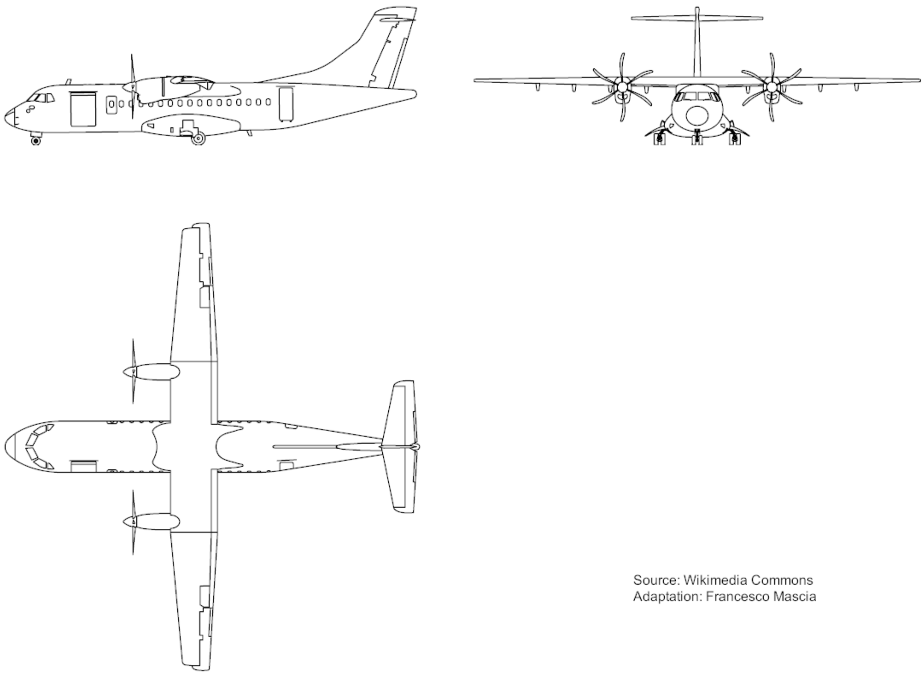

Figure 3.4: ATR 42-600 three-view drawing

ATR 72-600

The ATR 72 is a high-wing, twin-turboprop aircraft certified in compliance with EASA CS-25[99] . Launched in 1986 as a stretched version of the ATR 42, the ATR 72 features a 4.5 m longer fuselage and more seats than its sibling, while retaining the same design. ATR 72-600 is the commercial designation of the ATR 72-212A "600 version", ATR 72 latest version launched in 2007 and first flown in 2009. The 72-212A is the highest performing member of the ATR 72 family, featuring the highest maximum take-off weight and the highest maximum zero fuel weight of ATR 72 family members. Several weight variants are certified for ATR 72-212A aircraft. ATR 72-212A Mod 6219 (WV50) has been chosen for this analysis.

ATR 72-600 aircraft retain the same 2.57 m wide, 1.91 m high pressurized fuselage as the ATR 42. The stretched length gives ATR 72-212A aircraft a maximum operational passenger seating configuration of 78 passengers. However, "600 version" aircraft typically feature a single-class cabin with 29” - 30” (74 cm - 76 cm) seat pitch seating 70 - 72 passengers. A single-class layout seating 70 passengers has been assumed for this analysis.

The ATR 72-212A is equipped with two Pratt & Whitney Canada PW127 engines. PW127 engines installed on 72-212A "600 version" aircraft may be rated for different power settings. Each rating gives the opportunity to operate at rated power in different environmental conditions. Thus, higher-rated versions like PW127M are suited for hot-and-high or short-field operations, while PW127F are suited for standard operations. ATR 72-600 aircraft may be equipped with Reserve Take-Off Torque option, allowing for higher torque during take-off from short runways. ATR 72-212A equipped with PW127F, PW127M, and PW127N are certified for 120 minutes ETOPS. Each engine is equipped with one Hamilton Sundstrand 568F-1 constant-speed, variable-pitch six-blades propeller. The propellers can be feathered and reversed. Eligible fuel types are kerosene blends and additives approved in compliance with Pratt & Whitney Canada specifications. The ATR 72-600 maximum cruise speed is 275 KTAS.

[99] ibid.

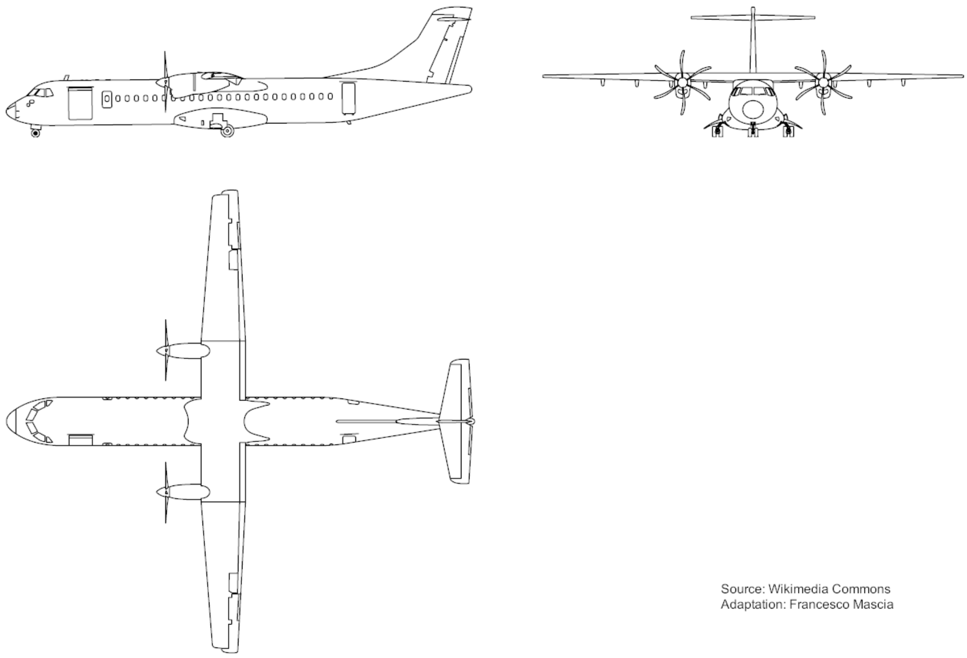

Figure 3.5: ATR 72-600 three-view drawing

Dash 8-400

The De Havilland Canada Dash 8-400, officially DHC-8-402[100] , is a high-wing, twin-turboprop aircraft certified in compliance with EASA CS-25, the largest member of the Dash 8 turboprop aircraft family. The type has been marketed with different commercial names by several manufacturers. The DCH-8-402 is currently marketed by De Havilland Canada as Dash 8-400.

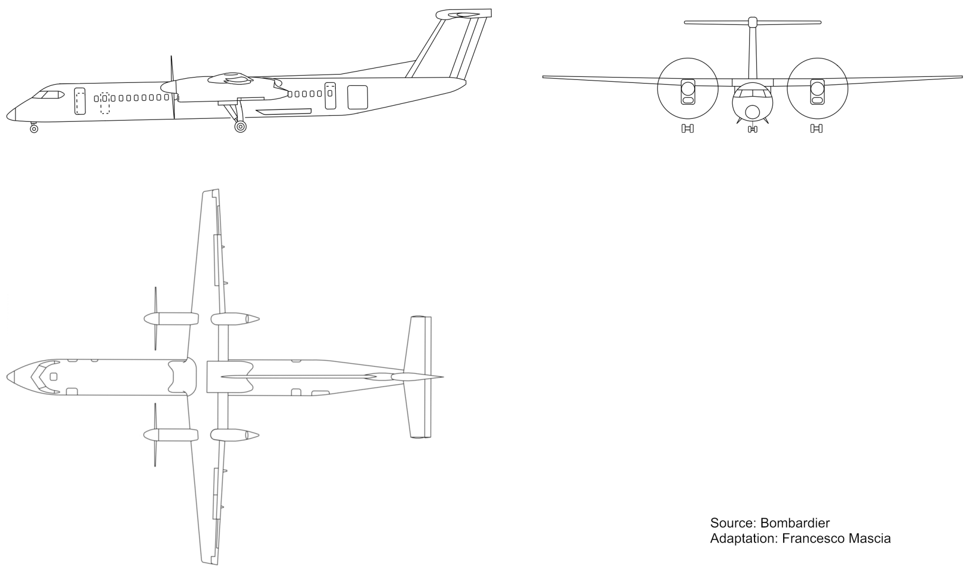

Figure 3.6: Dash 8-400 three-view drawing

The Dash 8-400 features a 2.49 m wide, 1.93 m high pressurized cabin. DHC-8-402 aircraft are certified for a maximum operational passenger seating configuration of 80 passengers, but are usually configured in a single-class layout with 29” - 31” (74 cm - 79 cm) seat pitch ranging

[100] TYPE-CERTIFICATE DATA SHEET No. EASA.IM.A.191 For DHC-8

from 74 to 78 passengers. A single-class layout seating 76 passengers has been assumed for this analysis.

The DHC-8-402 may be certified with several maximum weights. The High Gross Weight (HGW) version has been chosen for this analysis. The DHC-8-402 is equipped with two Pratt & Whitney Canada PW150A engines. Each engine is equipped with one Dowty Aerospace Model R408/6-123-F/17 constant-speed, variable-pitch six-blades propeller. The propellers can be feathered and reversed. Eligible fuel types are kerosene blends and additives approved in compliance with Pratt & Whitney Canada specifications. The Dash 8-400 may fly at different cruise speeds depending on the type of operations. Long range cruise speed is 300 KTAS, while maximum cruise speed is 360 KTAS.

L 410 UVP-E20

The Aircraft Industries, marketed as Let, L 410 UVP-E20 is an EASA CS-23 commuter category high-wing, twin-turboprop aircraft[101] . The L 410 UVP-E20 is an upgraded version of the Let L-410 family launched in 1969. The L 410 UVP-E20 features a 1.90 m wide, 1.65 m high unpressurized cabin. The aircraft is certified for up to 19 passengers. Typical layouts range from 15 to 19 passengers, depending on seat pitch and baggage compartment configuration. A 30” (76 cm) pitch cabin layout seating 17 has been chosen for this analysis. The aircraft requires a flight crew of two pilots, but does not require any cabin crew.

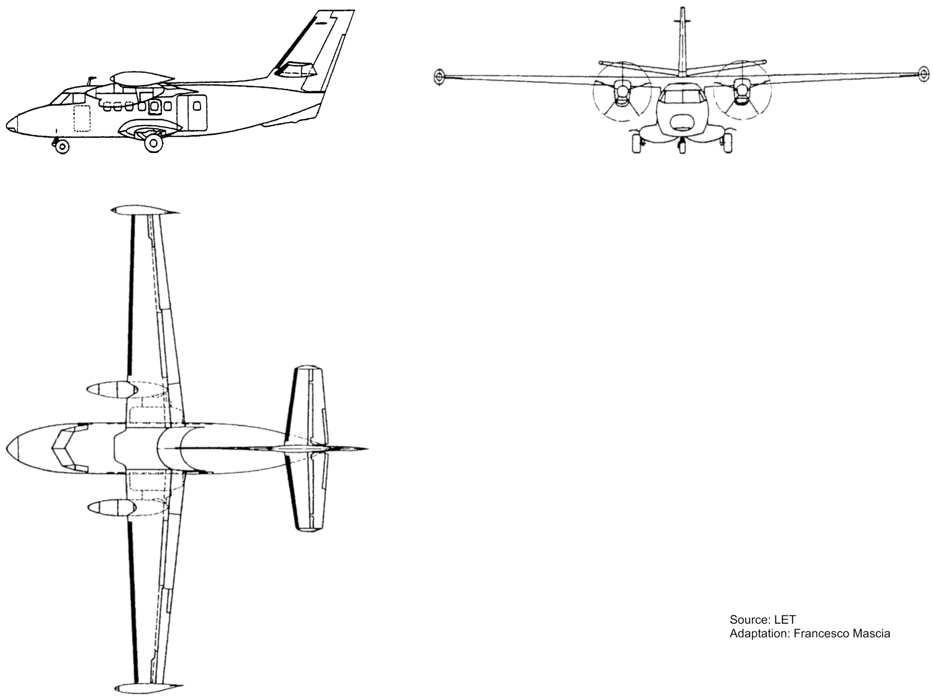

Figure 3.7: Let 410 UVP-E20 three-view drawing

The L 410 UVP-E20 is powered by two GE H80-200 turboprop engines. Each engine is equipped with one Avia AV-725 constant-speed, variable-pitch five-blades propeller. The propellers can be feathered and reversed. Eligible fuel types are kerosene blends and additives approved in compliance with EASA TCDS for L-410. The maximum cruise speed for the L 410 UVP-E20 is 219 KTAS. However, typical cruise speed ranges between 170 KTAS and 190 KTAS.

[101] TYPE-CERTIFICATE DATA SHEET No. EASA.A.026 for L-410

P2012

The TECNAM P2012 is a high-wing, twin-piston aircraft certified in compliance with EASA CS-23 Normal Category[102]. The P2012 is a new type certified in December 2019. The aircraft features a 1.47 m wide, 1.35 m high unpressurized cabin. The P2012 is certified for an MOPSC of up to 9 passengers. The 9 passengers configuration features a 1-1 layout with 32" (81 cm) seat pitch. The aircraft is certified for single-pilot operations and does not require any cabin crew.

The P2012 is powered by two Lycoming TEO-540-C1A horizontally opposed six-cylinder, turbocharged engines with direct fuel injection. The engines feature electronic engine control with fuel injection timing and fuel mixture control. Each engine is equipped with one MT Propeller MTV-14-B-C-F/CF195-30 constant-speed, variable-pitch four-blades propeller. The propellers can be feathered. Eligible fuel type is AVGAS 100LL. The maximum cruise speed for the P2012 is 194 KTAS. However, typical cruise speed at 10 000 ft (3 048 m) with 75% throttle is 173 KTAS.

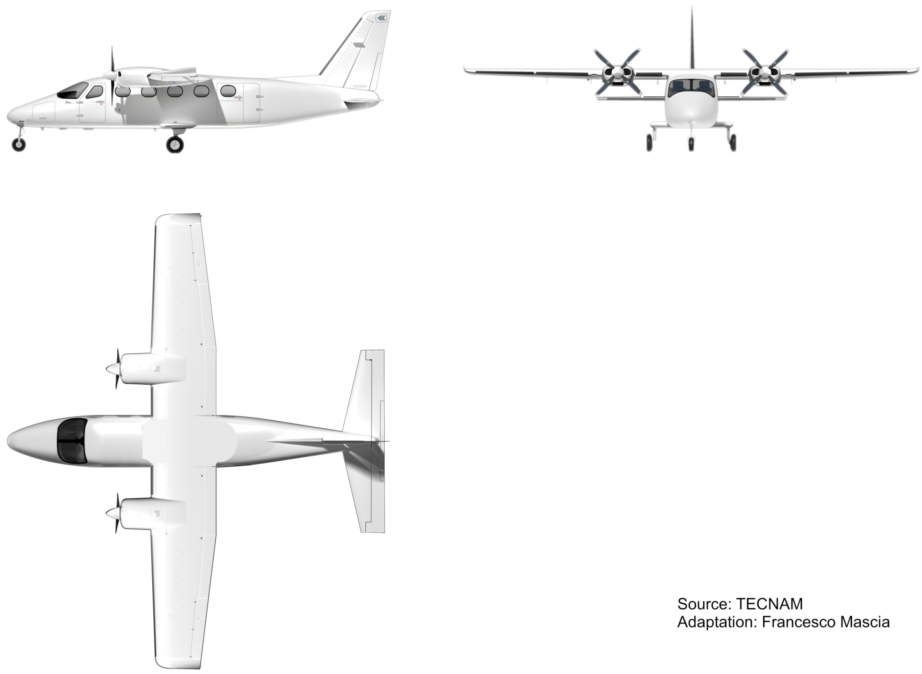

Figure 3.8: P2012 three-view drawing

[102] TYPE-CERTIFICATE DATA SHEET NO. EASA.A.637 for P2012

Aircraft Characteristics			
Type	**ATR 42-600**	**ATR 72-600**	**Dash 8-400**
Length	22.67 m	27.17 m	32.83 m
Wingspan	24.57 m	27.05 m	28.42 m
Height	7.59 m	7.65 m	8.30 m
Cabin Width	2.57 m	2.57 m	2.49 m
Cabin Height	1.91 m	1.91 m	1.93 m
Typical Seating (Y Class, 4 abreast)	48 - 50 Seats	70 - 72 Seats	74 - 78 Seats
Seat Pitch (Y Class)	29” - 30” (74 cm - 76 cm)	29” - 30” (74 cm - 76 cm)	29” - 31” (74 cm - 79 cm)
Seat Width (Y Class)	18” (46 cm)	18” (46 cm)	17” (44 cm)
MTOW	18 600 kg	23 000 kg	29 257 kg
MLW	18 300 kg	22 350 kg	28 009 kg
MFW	4 550 kg	5 050 kg	5 318 kg
Engine Type	Pratt & Whitney Canada PW127	Pratt & Whitney Canada PW127	Pratt & Whitney Canada PW150A
Engine Shaft Power (Max T/O)	1 790 kW (PW127E) 2 051 kW (PW127F/M)	2 051 kW	3 781 kW
Engine Shaft Power (Max Cont)	1 790 kW (PW127E) 1 864 kW (PW127F/M)	1 864 kW	3 781 kW
Propeller	Hamilton Sundstrand 568F-1	Hamilton Sundstrand 568F-1	Dowty model R408
Propeller Specifications	Blades: 6 Diameter: 3.93 m	Blades: 6 Diameter: 3.93 m	Blades: 6 Diameter: 4.11 m
Fuel	Kerosene-type	Kerosene-type	Kerosene-type
Cruise Speed	300 KTAS (Max)	275 KTAS (Max)	300 KTAS (LR) 360 KTAS (Max)
Average Fuel Flow at Cruise Speed*	811 kg/hr	762 kg/h	930 kg/h
All Weather Capability	Day/Night VFR, IFR FIKI, CAT II	Day/Night VFR, IFR FIKI, CAT II	Day/Night VFR, IFR FIKI, CAT II
Take-Off Distance (MTOW, SL, ISA)	1 107 m	1 304 m	1 580 m
Landing Distance (MLW, SL, ISA)	966 m	915 m	1 280 m

Type	**L 410 UVP-E20**	**P2012**
Length	14.42 m	11.80 m
Wingspan	19.48 m / 19.98 m**	14.00 m
Height	5.83 m	4.40 m
Cabin Width	1.90 m	1.47 m
Cabin Height	1.65 m	1.35 m
Typical Seating (Y Class)	15 - 19 Seats (3 abreast)	9 Seats (2 abreast)
Seat Pitch (Y Class)	29” - 31” (74 cm - 79 cm)	32” (81 cm)
Seat Width (Y Class)	16” (41 cm)	18.5” (47 cm)
MTOW	6 600 kg	3 680 kg
MLW	6 400 kg	3 630 kg
MFW	1 002 kg / 1 313 kg**	540 kg
Engine Type	GE H80-200	Lycoming TEO-540-C1A
Engine Shaft Power (Max T/O)	597 kW	280 kW
Engine Shaft Power (Max Cont)	522 kW	280 kW
Propeller	Avia AV-725	MT Propeller MTV-14-B-C-F/CF195-30
Propeller Specifications	Blades: 5 Diameter: 2.30 m	Blades: 4 Diameter: 1.95 m
Fuel	Kerosene-type	AVGAS 100LL
Cruise Speed	219 KTAS (Max)	194 KTAS (Max)
Average Fuel Flow at Cruise Speed*	305 kg/h (Lower Power Setting) 336 kg/h (Higher Power Setting)	79 kg/h (60% Power Setting) 99 kg/h (75% Power Setting)
All Weather Capability	Day/Night VFR, IFR FIKI	Day/Night VFR, IFR FIKI (MOD2012/002)
Take-Off Distance (MTOW, SL, ISA)	930 m	654 m
Landing Distance (MLW, SL, ISA)	835 m	546 m

* Values may vary depending on operating conditions

** With wing tip tanks

Table 3.2: Aircraft characteristics

Part II
Performance, profitability and efficiency analysis

4. Performance, profitability and efficiency model

The aircraft selection process is of uttermost importance, since success or failure may depend on choosing the right aircraft. There are many factors involved in the aircraft selection process. Some of them are inherently related to aircraft characteristics, like fuel consumption or passenger capacity, while others derive from cultural or political concerns. The aircraft selection process involves many disciplines, in that many different factors are to be considered.

The main purpose of commercial air operations is to generate profit by providing remunerated services. Hence, reducing aircraft operating costs is fundamental to assure continuous and profitable operations, especially when operating in high competitive or price-sensitive markets. Not surprisingly, selection of cost-effective aircraft is considered by regional airlines to be one of the most important strategic decisions[103] .

Any process or model aimed at selecting the best aircraft is meaningless. The process or model shall focus on selecting the right aircraft for one or more scenarios, strategies, or environments. Before choosing the variables involved in aircraft selection process, initial conditions shall be stated. The table below summarizes the focus points of the case studies.

Case Studies		
Focus airport	Olbia Costa Smeralda (OLB/LIEO)	Elba Marina di Campo (EBA/LIRJ)
Network	Domestic connections from/to Olbia Costa Smeralda (OLB/LIEO) to/from Italian mainland cities	Domestic connections from/to Elba Marina di Campo (EBA/LIRJ) to/from Italian mainland cities
Aircraft category	Medium or large turboprop airliners (EASA CS-25)	Small turboprop or piston-powered airliners (EASA CS-23)
Seating (Y class)	40 to 80 standard economy seats	9 to 19 standard economy seats
Fleet	Single type	Single type

Table 4.1: Case studies

[103] Wells, A.T. and Richey, F.D. (1996). *Commuter Airlines*. Krieger Publishing Company

4.1 Model preparation

Model construction requires some preliminary steps. First of all, purpose and scope of the model shall be clearly stated. Purpose and scope are fundamental, in that imprecision, flaws, or ambiguity in purpose and scope may lead to misinterpretation of given results or misapplication of the model itself. Once the purpose and scope have been thoroughly defined, an overview of hypotheses and assumptions will be presented. Hypotheses and assumption influence both model structure and data used for estimations and calculations. Hypotheses and assumptions are required for every model, in that, by nature, models inherently retain some form of approximation. The extent to which approximation influences validity of results is a consequence of purpose, scope, hypotheses, and assumptions.

4.1.1 Purpose and scope

The first step in developing a model is the definition of purpose and scope. The purpose of every model is to help the analysts evaluate and assess the behavior of output variables against possible scenarios and plans. However, each model has a specific purpose deriving from what analysts want to obtain from it. Hence, the purpose of this model is:

> to estimate, assess, and evaluate performances and costs related to commercial air transport operations, and revenues required to profitably perform those operations, in order to identify the aircraft type(s) best fitting given requirements.

However, the purpose does not thoroughly defines the model. A scope is then required. The scope of a model defines to which extent the model may be applied. The scope of the model shall consider the needs of the user, in that it defines the applicability of the model. Hence, the scope shall consider the input data, in terms of availability, precision and accuracy, and the results the model will eventually provide.

The scope is defined as follows:

- The model is intended to be applied to regional turboprop and piston-powered airliners.
- The model shall obtain operating costs related to commercial aircraft operations starting from single cost items.
- The model shall include operating costs directly related to commercial aircraft operations. The model does not include costs that are not directly related to commercial aircraft operations, including, but not limited to, equipment acquisition costs, or administration costs.
- The model shall give average operating costs over a period of time, a total amount of flight hours, or a total number of stages. Hence, cost deriving from a single flight may differ from the average value.

The model is structured as a comparative analysis of two or more aircraft. The model is formatted as a tabular comparison among cost items of different aircraft types or variants. As stated in the scope, the analysis covers operating costs only. Hence, it does not include costs deriving from the whole value chain. However, company-related costs, e.g. management or administration costs, are not heavily dependent on which aircraft type of the same category the airlines operates. Since aircraft related costs are the major expenditure for airlines, especially for smaller ones, results are considered valid for the purpose of aircraft selection.

Comparison among aircraft types or variants is based on a break-even model. Cost items related to each aircraft are individually estimated, and total costs are computed. Total costs are then compared with revenues to obtain the break-even point (BEP). Aircraft are analyzed according to their break-even point on given scenarios. It is worth noting that revenues are dependent on two main factors: prices per passenger, and number of passengers.
The best aircraft type for a given scenario is neither the one with lower operating costs, nor the one maximizing revenues, but the one that allows for the lower BEP and the highest profits. This is fundamental for airline operations. Some struggling airlines have ended up worsening their situation by acquiring aircraft offering lower operating or acquisition costs. While this may seem a logic decision, aircraft offering lower costs are but a placebo if they do not foster higher profit margins than those they replace.

4.1.2 Definitions

This paragraph contains some terms that may induce ambiguity if not properly explained. While some of them may be self-evident, some others may require a definition to be univocally defined and understood. A synopsis of definitions is reported below.

- Block Fuel (BF): Fuel consumed over a given block time (*see Block Time*)[104] .
- Block Speed (BS): The average aircraft speed obtained by dividing the distance flown by the related block hours (*see Block Time*)[105] .
- Block Time (BT): The period of time elapsed from the moment the aircraft door closes at departure of a revenue flight until the moment the aircraft door opens at the arrival gate following its landing[106] .
- Flight Time (FT): The period of time elapsed from the moment the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the next point of landing[107] .
- Great Circle Distance (GCD): An arc of a circle on the surface of the earth connecting two terrestrial points that constitutes the shortest distance on the earth's surface between them[108] .
- Operating Time (OT): The period of time comprising the time during which the aircraft is flying and all other activities when the aircraft is under the responsibility of the airline's operations. This includes boarding and unboarding, servicing, taxiing and turnaround time[109] .
- Service Time *or* Time in service (ST): With respect to maintenance time records, is the time from the moment an aircraft leaves the surface of the earth until it touches down at the next point of landing[110] .
- Stage: Operation of an aircraft from take-off to its next landing[111] . Also referred to as *Sector*.

[104] ibid.
[105] Adapted from *Speed flown* reported by ICAO. *Glossary*.
[106] MIT. *Airline Data Project*. MIT website
[107] FAA. *Glossary terms*. FAA website
[108] Adapted from *Great circle* reported by Merriam-Webster. *great circle*. Merriam-Webster website
[109] IATA. (2018). *Aircraft Operational Availability*
[110] FAA. *Glossary terms*. FAA website
[111] ICAO. (2004). *Manual on the Regulation of International Air Transport (Doc 9626)*

- Turn-round Time *or* Turnaround Time (TRT *or* TAT): The time taken for arrival, unloading, and preparation for the return journey of an aircraft[112] .
- Utilization: Measure of aircraft productivity, calculated by dividing aircraft block hours by the number of aircraft days assigned to service on air carrier routes[113] .

4.1.3 Hypotheses and assumptions

Hypotheses and assumptions, along with data accuracy, are the main factors affecting accuracy of results. Choosing the right hypotheses and assumptions is thus pivotal for the model. Hypotheses and assumptions influence accuracy of results, in that the latter is a direct consequence of the former. First of all, it is worth stressing that every model, being based on hypotheses and assumptions, inherently retains some form of approximation. The degree of approximation of the final or intermediate outputs is influenced by the degree of approximation of the hypotheses and assumptions used.
Some hypotheses and assumptions are common to several aircraft or scenarios, while others may differ. It could be pointed out that, by using different hypotheses or assumptions, the results given may not be consistent. However, possible differences in hypotheses or assumptions are due to the necessity to consider the inherent differences among different types or scenarios. Ignoring those differences may lead to inconsistent or inaccurate results.
It is worth noting that hypotheses or assumptions may be varied to perform sensitivity or what-if analyses. However, any change in the aforementioned hypotheses or assumptions will be compared with initial hypotheses and assumptions, and results will be evaluated against the results obtained with the initial hypotheses and assumptions.

Fuel cost

Fuel cost is one of the main single cost items in airlines operating costs[114] . Hence, estimating fuel costs is pivotal for airlines. Fuel cost is heavily dependent on many factors, most of them not under the control of carriers. However, airlines do have the opportunity to negotiate or manage fuel-related expenses. This may include fuel provision agreements with one or more suppliers, or acquisition of large stocks of fuel. Many times, airlines elect to refuel at home base only, refueling away from home base only when no other options are available. For short-haul operations, the possibility to complete more than one stage, or at least one round trip, before refueling at home base can result in considerable savings.
Value used for kerosene-type fuel (jet fuel) cost is taken from IATA Jet Fuel Price Monitor[115] . The jet fuel price used for calculations is 0.3455 $/kg, or 0.2923 €/kg. For conversion from US Dollars to Euros see *Money value* paragraph. This price was the average price for Europe & CIS reported by IATA[116] on October 23rd, 2020. While choosing one single value for fuel price estimation may lead to inaccurate results, it is worth noting that the price index for that date is consistent with average fuel price index for 3Q2020. Fuel prices have remained rather constant from May 2020, when many European countries lifted tighter travel restrictions, to November 2020. However, average fuel prices have been rising since November 2020, eventually becoming rather constant through January 2021.

[112] Adapted from EUROCONTROL. (July 2016). *Turn-round*. EUROCONTROL ATM Lexicon website
[113] MIT. *Airline Data Project*. MIT website
[114] Wells, A.T. and Richey, F.D. (1996). *Commuter Airlines*. Krieger Publishing Company
[115] IATA. *Jet Fuel Price Monitor*. IATA website
[116] ibid.

The piston-powered type considered for this analysis uses AVGAS 100LL[117] . AVGAS prices are higher than kerosene-type fuel. Since the use of 100LL for commercial air transport is limited in Europe, if compared to other markets, thorough records may not be easily available. Moreover, 100LL price is heavily dependent on where fuel is purchased. The estimation based on 100LL prices in airports of interest during 2H2020 gives an average value of 2.80 €/kg. Thus, this value has been assumed for calculations.
Oil and lubricants costs have been assumed to be 2% of fuel costs.

Money value

Since the analysis focuses on Italian domestic air transport, currency used is Euro (€). One of the main concerns when operating outside the USA is the different currency used. The value of many air operations cost items are either in US Dollars or dependent on US Dollar value. For example, fuel prices are dependent on crude oil price, which is marketed in US Dollars. Hence, money value conversion has frequently been required. Conversion rate from US Dollars to Euros has been set to 1 \$ = 0.8460 €. The conversion rate used is the opening value reported by the European Central Bank (ECB)[118] for October 23rd, 2020. The value is consistent with that used for fuel price. As previously said, choosing one single value for money value conversion rate could lead to unacceptable approximation errors. However, currency may be purchased in advance when conversion rates are considered good by the acquirer.
The chart below shows average jet fuel price in US Dollars and Euros compared to US Dollar to Euro conversion rate. It is worth noting that jet fuel price in Euros has a rather constant value compared to jet fuel price in US Dollars. The reasons behind these trends are not among the purposes of this study. However, fuel-related expenses may benefit from this phenomenon.

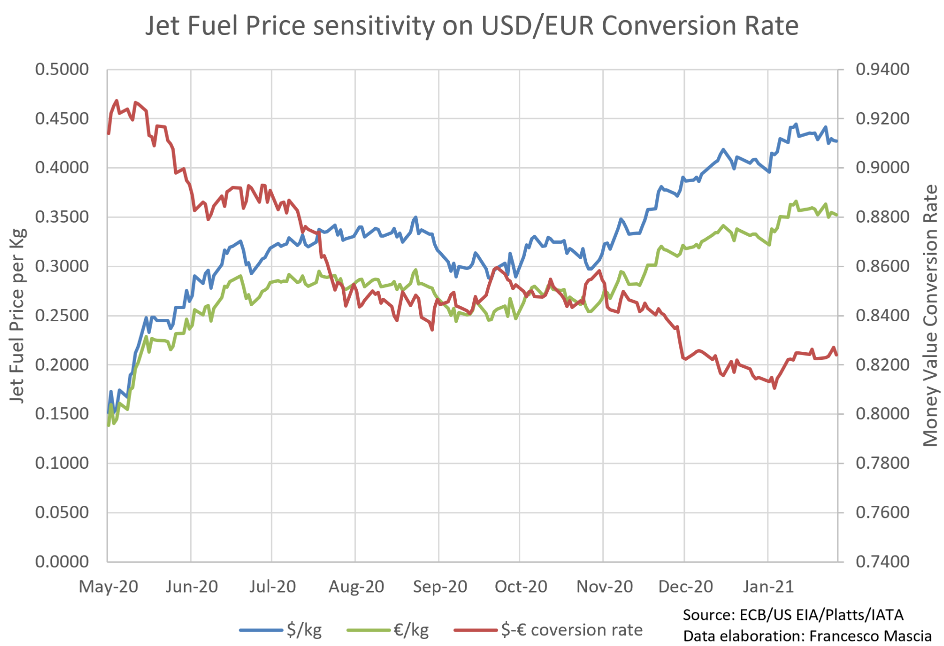

Figure 4.1: Comparison between average jet fuel price and US Dollar to Euro conversion rate

[117] EASA. (14 December 2020). *TYPE-CERTIFICATE DATA SHEET NO. EASA.A.637 for P2012*
[118] European Central Bank. *US Dollar (USD)*. European Central Bank website

Some data used for calculations have been retrieved from older (i.e. before 2020) money values. Those values had to be converted to actual values to be consistent with other data used. The conversion is required in that inflation changes money values. Reasons and phenomena influencing inflation are not among the purposes of this analysis. However, calculating actual value of money is required for costs estimations.
Actual value has been calculated using two formulae. These two formulae use different values that are not perfectly equivalent. Hence, they may give results that are slightly different. However, results given have been used for this analysis only when differences were negligible. The first formula uses average inflation rate (i) between the year money value refers to (Present Value), and the year of interest (Actual Value). n is the difference in years between the two dates.

$$\mathrm{AV} = \mathrm{PV} \cdot (1 + \mathrm{i})^{\mathrm{n}}$$

The second formula uses a factor given by Consumer Price Index (CPI) for US Dollars, or Harmonized Index of Consumer Prices (HICP) for Euros.

$$\mathrm{AV}\,[\$] = \mathrm{PV}\,[\$] \cdot \frac{\mathrm{CPI}_{\mathrm{final}}}{\mathrm{CPI}_{\mathrm{initial}}} \qquad \mathrm{AV}\,[€] = \mathrm{PV}\,[€] \cdot \frac{\mathrm{HICP}_{\mathrm{final}}}{\mathrm{HICP}_{\mathrm{initial}}}$$

Tables for CPI are published by U.S. Bureau of Labor Statistics, part of U.S. Department of Labor[119] , while HICP are published by European Central Bank[120] . It is worth noting that these two indices present some differences in calculation methodology. However, they may be assumed to be equivalent for the scope of this analysis.

Crew duty periods and limitations

Choosing the right number of crew members is very important. Too many crew members may result in unjustifiable expenses related to salaries and training. On the other hand, an excessively low number of crew members may limit the carrier ability to deliver a reliable service. Depending on network, schedule, and types in the fleet, airlines may elect to hire the number of crew members for each aircraft in their fleet they consider the best. However, airlines must at all times comply with regulations imposed on flight duty periods by EASA (for operations in EASA member States).
Flight duty periods (FDPs) are of uttermost importance for commercial flight, and indeed for any type of flying-related activity. EASA regulations set limitations for FDP and crew rest. The table reported below[121] lists maximum daily FDPs for acclimatised[122] crew members. Since regional air service usually covers distances within one or two time zones, FDPs for acclimatised crew can be assumed.

[119] U.S. Bureau of Labor and Statistics. *Economic News Release - Consumer Price Index*. U.S. Bureau of Labor and Statistics website
[120] European Central Bank. *Measuring inflation - HICP*. European Central Bank website
[121] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012) ORO.FTL.205 Flight duty period (FDP)*
[122] "A crew member is considered to be acclimatised to a 2-hour wide time zone surrounding the local time at the point of departure" as reported by EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). ORO.FTL.105 Definitions*

Maximum Daily FDP for Acclimatised Crew Members									
Start of FDP at reference time	**Number of Sectors**								
	1 – 2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
06:00 – 13:29	13:00	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00
13:30 – 13:59	12:45	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00
14:00 – 14:29	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00
14:30 – 14:59	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00
15:00 – 15:29	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00
15:30 – 15:59	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00	09:00
16:00 – 16:29	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00	09:00
16:30 – 16:59	11:15	10:45	10:15	09:45	09:15	09:00	09:00	09:00	09:00
17:00 – 04:59	11:00	10:30	10:00	09:30	09:00	09:00	09:00	09:00	09:00
05:00 – 05:14	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00	09:00
05:15 – 05:29	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00	09:00
05:30 – 05:44	12:30	12:00	11:30	11:00	10:30	10:00	09:30	09:00	09:00
05:45 – 05:59	12:45	12:15	11:45	11:15	10:45	10:15	09:45	09:15	09:00

Table 4.2: Maximum daily FDP for acclimatised crew members

Maximum duty periods for crew member shall also comply with EASA regulations on flight times and duty periods[123] . EASA prescribe the maximum number of flight hours for each crew member:

(a) "The total duty periods to which a crew member may be assigned shall not exceed:

  (1) 60 duty hours in any 7 consecutive days;

  (2) 110 duty hours in any 14 consecutive days; and

  (3) 190 duty hours in any 28 consecutive days, spread as evenly as practicable throughout that period.

(b) The total flight time of the sectors on which an individual crew member is assigned as an operating crew member shall not exceed:

  (1) 100 hours of flight time in any 28 consecutive days;

  (2) 900 hours of flight time in any calendar year; and

  (3) 1 000 hours of flight time in any 12 consecutive calendar months"[124] .

[123] EASA. (October 2019). *Easy Access Rules for Air Operations (Regulation (EU) No 965/2012). ORO.FTL.210 Flight times and duty periods*
[124] ibid.

Flight times and duty periods limitations heavily influence number of crew members the operator employs. Thus, choosing the right number of crew members is highly desirable to keep costs low. However, a suitable margin shall be provided to cope with possible disruption to air operations resulting from poor rostering, both in terms of safety and customer satisfaction.

Flight plans and routes

Great circle routes are a good indicator of distance between two points on the earth's surface. However, great circle distance may not be adequate for some uses. A more precise calculation of distance flown is then required.
Aircraft flying commercially shall issue a flight plan in accordance with ICAO Annex 2 - Rules of the Air. Flight planning rules and techniques are not among the purposes of this analysis. However, route planning can help evaluating flight efficiency and performance. All flights are assumed to be conducted under Instrumental Flight Rules (IFR), except where otherwise mandated by procedures, e.g. final approaches to some aerodromes.
The tool used for route planning is SkyVector[125] . SkyVector is a website that provides charts for route planning. All route plans feature departure aerodrome, STAR, waypoints, SID, and arrival aerodrome. The route plans used reflect paths that may actually be flown by an aircraft operating those connections. Assumptions have been made for runways in use, STARs, SIDs, and other procedures. The assumptions made are consistent, in that the SIDs used are suitable for the assumed departure runways, and the STARs used are suitable for the assumed arrival runways. Procedures and runways are suitable for the aircraft considered, both in terms of performance and limits. Aeronautical charts provided by either SkyVector or Jeppesen have also been used to integrate or verify information.

Airport fees

Airport fees are due for operations of commercial flights. Depending on traffic density, airport facilities, location, and many other factors, airport may charge different fees. In Italy, airport fees are applied by airport authorities in accordance with ENAC, and published by airport authorities. Values used for this analysis are taken from these publications. The airport fees used refer to year 2020. While some airports publish fees for more than one year, some others do not. Thus, all values are for 2020, even when fees relative to other years were available. This assumption is consistent with the other assumptions made. Moreover, airport fees are rather constant year over year, thus resulting in negligible differences.
Each airport publishes its fee tables. While most cost items are recurrent among airports, some may differ. A brief overview of airport costs is reported below.

- Landing and take-off: fees due for each landing and take-off. They are usually due for each ton or fraction thereof of aircraft MTOM. Different fees per ton may be applied depending on aircraft MTOM. Some airports, like Rome Fiumicino (FCO/LIRF) charge a fixed fee per movement in addition to mass-dependent fees, while others, like Turin (TRN/LIMF), apply different charges for winter and summer.

[125] SkyVector website

- Aircraft parking: fees due for aircraft parking. They are usually charged for each hour or fraction thereof of parking time, and for each ton or fraction thereof of aircraft MTOM. Hence an aircraft with a MTOM of 10 tons parked for two hours will be charged twenty times the per-hour, per-ton fee. Parking fees are usually not charged for the first two hours. Some airports, like Olbia (OLB/LIEO), exempt based airliners from parking fees. Some airports apply overnight parking fees. Nighttime fees may be lower than daytime fees.

- Passenger boarding: fees due for each passenger boarding the plane. They may vary depending on passenger age (adults or children), and on flight destination (domestic, EU-domestic, extra-EU). Some airports, like Rome Fiumicino (FCO/LIRF), apply different fees for passengers originating at the airport and transfer passengers.

- Passenger security: fees due for each passenger going through security checks.

- Baggage security: fees due for each checked baggage going through security checks.

- Check-in desk: fees due for the use of check-in and boarding facilities. They are usually charged per hour or fraction thereof. Some airports do offer the possibility to purchase yearly use of check-in desks in advance at a fixed price. Depending on the number of flights operated from the airport, airlines may elect to purchase yearly access.

- Fueling: fees due for fueling services. They are usually charged on a per-liter or per-kilogram basis.

- Noise charge and other additional fees. Noise charges are due for noise emitted by aircraft. Noise class is assessed in accordance with ICAO Annex 16, Volume I. Noise class for each type or version is reported by EASA Type-Certificate Data Sheet for Noise. Other fees and taxes may be charged by airport authorities on behalf of local authorities.

Some assumptions have been necessary to estimate airport fees. The assumptions are consistent with the other assumptions made in this analysis. Thus, the assumptions listed below are valid for all estimations and calculations, except where otherwise stated.

- All passengers are adult. All passengers carried by the airline are adults with an average mass of 88 kg for Olbia case study, including carry-on baggage. Values used are recommended by *Survey on standard weights of passengers and baggage*[126], conducted for EASA. The average mass for Elba case study is assumed to be 75 kg per passenger plus 5 kg of carry-on baggage. Values for Elba case study have been obtained using data from the aforementioned source. However, due to the different types used for this case study, recommended values could not be taken. It is worth noting that, since all passengers are assumed to be adult, the average passenger mass is possibly slightly higher than real values, in that children masses are much lower. However, assuming adult passengers only makes calculations more consistent, in that child passengers masses are heavily dependent on age, while adult passengers masses are less dependent on age. Adult passengers only is nevertheless a possible scenario.

[126] Berdowski, Z. et al. (May 2009). *Survey on standard weights of passengers and baggage - Final report*. NEA

- All passengers check baggage. Depending on route, season, airline, and fare policy, passengers may or may not check their baggage. However, due to the nature of service provided, the possibility to check baggage shall be offered[127] . Checked baggage mass is assumed to be 17 kg[128] for Olbia case study, 10 kg for Elba case study.

- All passengers originate at the considered departure airport. A considerable percentage of passengers flying regional routes is transferring to/from other flights. Assuming that all passengers are originating at the airport the flight is departing from is then prone to criticism. However, assuming transferring passengers would require further assumptions about fares and baggage policies of carriers passengers are connecting with, and about the area passengers are originating from or bound for. The assumptions made give precise results, while assuming transferring passengers would induce higher accuracy in results, but lower precision.

- All passengers are domestic. This assumption is a consequence of all passengers originating at the airport of departure, in that all considered flights are domestic.

- Seasonal fees. Some airports, like Turin (TRN/LIMF), apply different fees for summer and winter. Expenses due for airport fees are then dependent on the number of flights for each season. The number of flights operated during summer to/from airports charging fees on a seasonal basis have been assumed to be 2/3 of the total number of yearly flights to/from the considered airport (i.e. winter flights are 1/3 of the total yearly flights). This assumption is valid only for airport fees estimation, in that flight schedules may have a different percentage of flights for each season. However, since differences in results are negligible, this assumption can be accepted.

- Flights do not carry freight. While passenger aircraft may also carry freight in the cargo bay, no freight has been assumed for this analysis. This assumption is aimed at focusing on passengers only, thus preventing other cost items and relative incomes from biasing results.

- Aircraft are refueled only at home base. As previously said, refueling at home base only may reduce fuel expenses. Even though average values provided by IATA[129] have been used for calculations, thus making fuel cost independent of airport, fueling fees do depend on where the aircraft is fueled.

- Turnaround time has been assumed to be 90 minutes for flights operated with ATR 42-600, ATR 72-600, or Dash 8-400 aircraft, 60 minutes for flights operated with L 410 UVP-E20 or P2012, except where otherwise stated.

The fees used for calculations are taken from airport fees sheets published by airport authorities. Airlines operating scheduled flights to/from an airport may negotiate agreements with airport authorities. Agreements between airlines and airports may result in a consistent reduction of airport fees. Hence, the estimated values are to be considered as the maximum applicable values.

[127] Airlines, especially mainline carriers and airlines under PSO agreements, providing services to peripheral regions may offer fares with included checked baggage.
[128] Berdowski, Z. et al. (May 2009). *Survey on standard weights of passengers and baggage - Final report*. NEA
[129] IATA. *Jet Fuel Price Monitor*. IATA website

Ground handling operations

Ground handling operations (GHO) comprise all activities performed and services provided while on ground before and after flight operations. Handling activities may vary depending on airport, aircraft type, type of services required, and other circumstances. The handling activities assumed for this analysis are reported below.

- Passenger handling. It includes activities related to passenger enplaning and deplaning. It may comprise loading bridges or boarding stairs, and apron bus. Since aircraft being analyzed are equipped with airstairs, passenger handling only includes apron bus and passenger assistance.
- Baggage handling. It includes baggage loading and unloading.
- Marshalling. It includes activities performed to guide aircraft in and out of designated parking position.
- Ramp personnel. It includes personnel performing ramp operations.
- Ground power. Ground power units (GPUs) supply energy when engines are not running.
- Pushback. It comprises activities required to move the aircraft from its parking position to a position from which it can move using its own power. Pushback may not be required if aircraft is capable, and cleared for, powerback, which consists in moving backward using aircraft own power.
- Deicing. Deicing is required to remove ice and prevent its formation on aircraft surface. Deicing may be required under some weather conditions. Since deicing costs depend on how much deicing fluid is used, estimation may greatly vary depending on weather conditions. Deicing has been assumed to be included in total ground handling costs, in that any *a priori* estimation would most likely be inaccurate.
- Air conditioning. Air conditioning is required to cool aircraft cabin down if outside temperature is too high. Air conditioning may be required under some weather conditions.
- Aircraft cleaning.
- Fire protection.
- Lighting.

Ground handling costs are more difficult to determine than airport fees. While airport fees are published by airport authorities, ground handling costs are usually negotiated with ground handling companies operating at the airport.
Ground handling costs have been estimated using available data. Since ground handling costs data for some airports were not easily accessible, available data have been scaled to estimate ground handling costs. Scale coefficients have been obtained by calculating airport fees for two movements (one inbound and one outbound). Costs due for airport fees have been compared with available ground handling costs data, thus obtaining a relationship between airport fees and ground handling costs. Ground handling costs have been estimated with linear proportionality by multiplying available airport costs by the scale coefficients calculated for each airport.

4.2 Model structure

The performance, profitability and efficiency model is divided into two main parts: performance and efficiency model, and profitability model. The two parts are not independent, in that values computed by one part are used by the other one. However, the distinction makes it easier to build and understand the model.
The model comprises several sub-models and tools. Each sub-model or tool has specific tasks and outputs that may be collected or used as inputs by other sub-models. The top-level structure of the model is described by the following scheme.

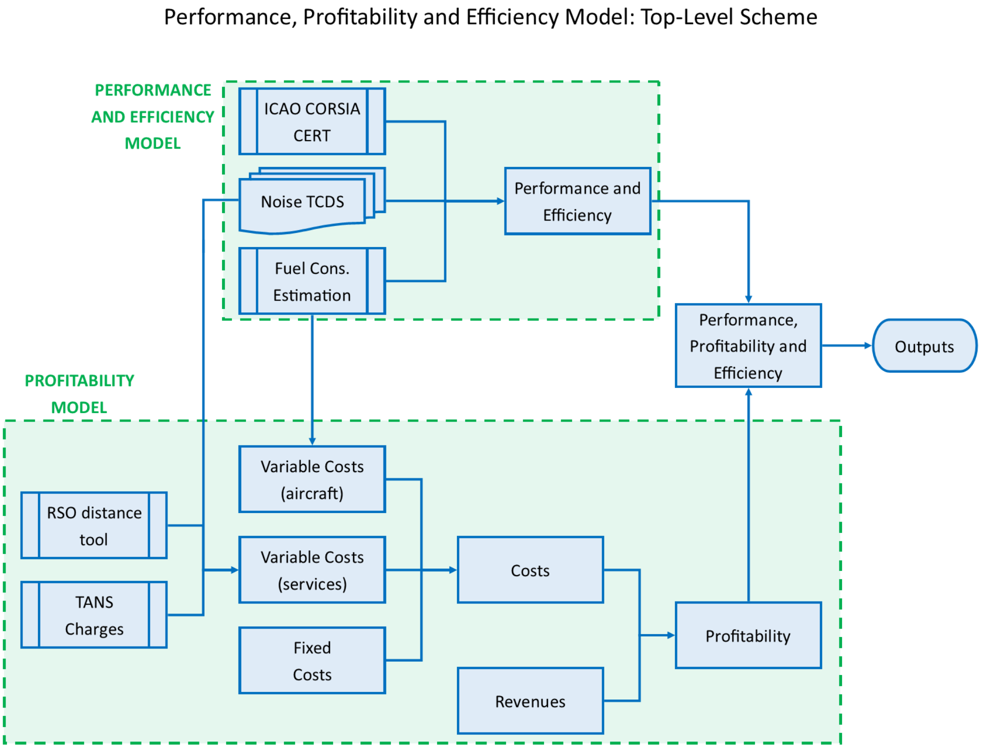

Figure 4.2: Top-level scheme of performance, profitability and efficiency model

4.3 Performance and efficiency model

4.3.1 Fuel consumption estimation

Fuel consumption estimation is critical for aircraft operations. Fuel consumption may depend on several factors. Thus, an accurate estimate of fuel consumed for a single flight is very difficult, if no further data, like weather or aircraft weight, are available. An estimate of the average fuel required to perform several flights over a period of time gives better results.
Required fuel has then been estimated using average consumption. Data have been retrieved from different manufacturer sources. These provide both discrete values of block fuel per given distance and block speed, and fuel planning charts. By combining data, it is possible to obtain fuel consumption estimations. Raw data have been gathered and processed to obtain fuel consumption estimation relationships. These relationships have been obtained by interpolating discrete data either from block fuel data or fuel planning charts. To better fit data, only those relative to flights shorter than 751 NM have been considered in the interpolation.

This assumption is justified in that all the connections being analyzed are shorter than 751 NM. Considering longer distances would have reduced accuracy of results.
Choosing the interpolating curve that best fits data heavily influences output accuracy. Thus, different interpolating curves have been evaluated to minimize discrepancy between raw data and interpolating curves. Power regression has resulted to be the best fitting curve for considered aircraft. The curves obtained have quasi-linear behavior for longer distances (with regard to the considered distances), while retaining a less straight shape for shorter routes. This behavior is a consequence of different fuel consumption for different flight phases. Shorter flights tend to have higher fuel consumption per nautical mile, in that take-off and climb phases represent a higher percentage of total distance flown than longer flights. Since fuel consumption is much higher during those phases than cruise, specific fuel consumption per nautical mile increases on shorter flights.
Fuel consumption estimations are based on route plan distance, rather than on great circle distance. This choice makes fuel consumption estimate sensitive to which route plan has been chosen. Since route plans are dispatched according to present and future conditions, route plans may change from flight to flight. Distance covered by two aircraft operating the same route with two different route plans may thus change. However, assuming the same route plan for all flights operating the same route gives a much more accurate estimation of fuel consumption than using great circle distance. Therefore, route plan distances have been used for fuel consumption estimations.

4.3.2 CO_2 emissions estimation

Estimating CO_2 emissions of aircraft operating commercial flights is rather difficult, in that CO_2 emissions are a consequence of fuel consumption, which is influenced by many factors. As previously done for fuel consumption estimations, CO_2 emissions estimations are average values over several flights.
The tool used to calculate CO_2 emissions for the model is CO_2 Estimation & Reporting Tool (CERT). CERT is a powerful tool created by CORSIA, an ICAO program, to assess carbon emissions of commercial flights. Even though CORSIA is intended for international flights, the results are valid for both international and domestic flights. Purpose and scope of CERT are defined by ICAO Annex 16, Volume IV, Appendix 3. The estimates given by CERT are derived from ICAO CORSIA CERT database. The database comprises data for many commercial aircraft. Data for all turboprop aircraft considered for this analysis are available in the database.
Input data required for CO_2 estimation are ICAO type designator (aircraft type), origin and destination aerodromes, and number of flights. Great circle distance is calculated using origin and departure aerodromes. The distance covered by an aircraft flying between two aerodromes is at least equal to the great circle distance. However, an aircraft flying a route will most likely fly a longer distance than the great circle distance. This is due to several factors. Route plans are longer than GCD, in that aircraft shall follow navigation procedures, like SIDs and STARs. While en-route, aircraft shall fly along an assigned path that is inherently longer than, or at least equal to, the great circle distance between the two waypoints. Aircraft may perform holding patterns, thus increasing distance flown. Moreover, weather may call for specific procedures or flight paths to be followed. To take into account longer-than-GCD routes, CERT uses correction factors[130] . Correction factors are reported below.

[130] ICAO. (June 2017). *ICAO Carbon Emissions Calculator Methodology - Version 10*

GCD		Correction to GCD	
km	NM	km	NM
GCD $<$ 550 km	GCD $<$ 297 NM	+50 km	+27 NM
550 km $\leq$ GCD $\leq$ 5550 km	297 NM $\leq$ GCD $\leq$ 2970 NM	+100 km	+54 NM
GCD $>$ 5550 km	GCD $>$ 2970 NM	+125 km	+67 NM

Table 4.3: Correction factors to GCD for CO_2 emissions estimation

Block time (in hours) may be required if relative input method is preferred by the user. Date is optional, and has not been input for this analysis. Jet-A1 has been selected for all flights operated with turboprop types.

4.3.3 Noise assessment

Acoustic impact of aircraft has been assessed in accordance with ICAO Annex 16, Volume I. ICAO Annex 16, Volume I defines applicability and procedures for acoustic impact of airplanes. Part 4 comprises different Chapters, each specifying noise standards for eligible types. Types are classified according to their category (e.g. propeller driven aeroplanes over 8 618 kg) and year application for Type Certificate was issued.

Applicable Chapter for aircraft class and acoustic performance is reported by Type-Certificate Data Sheet for Noise, issued by EASA. Effective Perceived Noise Level (EPNL) is assessed in accordance with EASA CS-36. Noise TCDS details Lateral/Full Power EPNL, Flyover EPNL, and Approach EPNL, along with relative limits. Compliant aircraft shall emit lower EPNL than maximum limits reported by TCDS for Noise. Applicable Chapters for the types considered in this analysis are reported below. Values are taken from TCDS for Noise issued by EASA[131] .

Type Version	Noise Certification Basis	Chapter
ATR 42-500	ICAO Annex 16, Volume I	3 (standard) 4 (with additional modification 4540)
ATR 72-212A	ICAO Annex 16, Volume I	4
DHC-8-402	ICAO Annex 16, Volume I	4
L-410 UVP-E20	ICAO Annex 16, Volume I	10
P2012	ICAO Annex 16, Volume I	10

Table 4.4: Applicable Chapter in accordance with ICAO Annex 16, Volume I

[131] EASA. *Type Certificate Data Sheets for Noise (TCDSN)*. EASA website

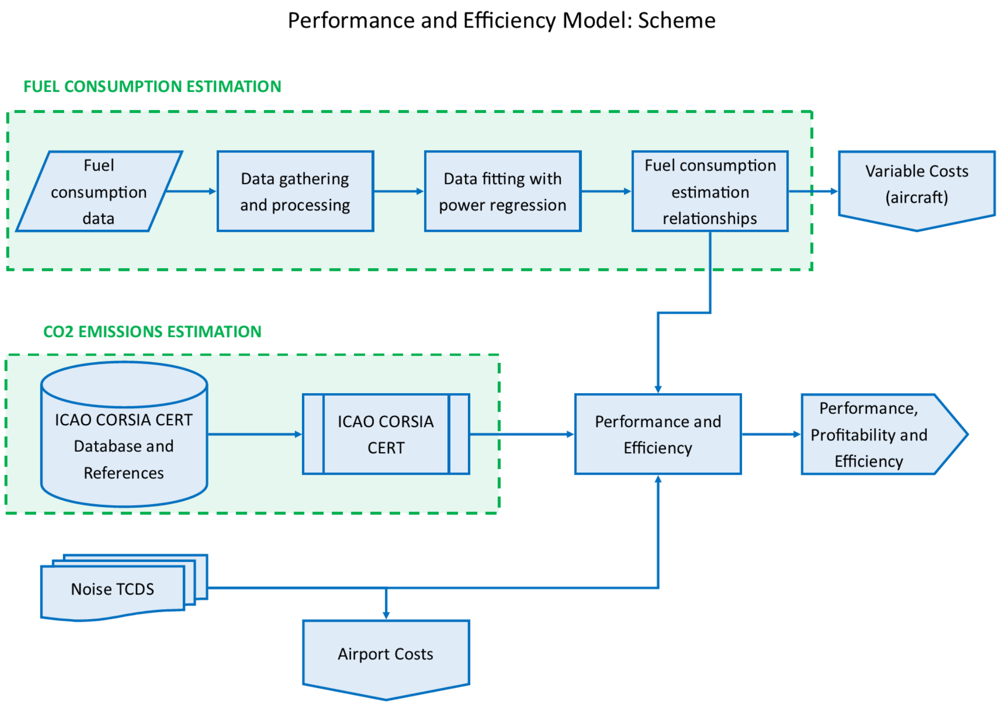

Figure 4.3: Scheme of performance and efficiency model

4.4 Profitability model

4.4.1 Cost model

A cost model is of utmost importance to estimate costs related to aircraft operations. The model has been developed with a bottom-up pattern, thus cost items are estimated and summed to obtain total values. The main advantage of a bottom-up cost model is the chance to evaluate each cost item and its influence on total costs. With a bottom-up cost model it is possible to see which cost items foster profitability and which cost items may be improved. The main drawback of bottom-up cost models is input data availability. Some data were easily accessible, while some others require further analyses and estimations.

The cost model is developed into several levels. The top level is represented by the total cost related to aircraft operations. The total cost is broken down into three items: aircraft-related variable costs, services-related variable costs, and fixed costs. The main difference among these items is that the first two depend on number of hours (or stages) flown, while fixed costs do not. Both aircraft-related variable costs and services-related variable costs do vary with the number of stages flown. However, aircraft-related variable costs are directly dependent on flight hours, while services-related variable costs depend on flight hours to the extent the number of stages influences the number of flight hours. In other words, a higher number of flight hours resulting from higher block time does not influence services-related variable costs, while a higher number of stages resulting in a higher number of flight hours does influence services-related variable costs.

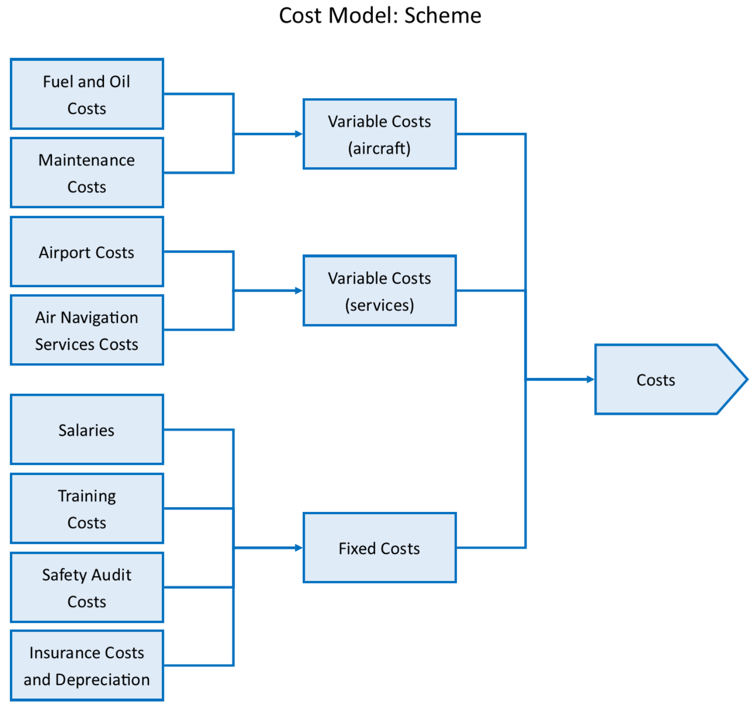

Figure 4.4: Scheme of cost model

Fixed costs

Fixed costs are not dependent on number of flight hours or stages. They include those cost items that are required for air operations but have little-to-no dependence on flight hours. Main fixed cost items are listed below.

- Salaries. Assumed salaries are in line with job market offers. Salaries were retrieved from values of flight and cabin crews of regional turboprop aircraft.
- Training costs. Training costs comprise flight simulator training, theory courses, travel, and accommodation. Flight simulator costs are in line with prices of full flight simulators. Costs of weekly theory courses have been assumed to be the equal to weekly salary of a captain.
- Safety audit costs. Safety audit costs are due for safety assurance and compliance with safety regulations. Safety audit costs have been assumed to be constant for all considered types.
- Insurance costs. Insurance costs comprise liability insurance and hull insurance. Liability insurance costs have been assumed to be 5‰ of aircraft acquisition cost. Hull insurance costs have been assumed to be 3.5‰ of aircraft acquisition cost.
- Depreciation. Depreciation per year is given by straight line depreciation over a period corresponding to the expected operative life of the aircraft. No residual value has been assumed at the end of the operative life. The expected operative life has been assumed to be twenty years for all considered types. It is worth noting that the operative life may greatly vary depending on the type, the operating environment, and many other factors. However, assuming the same expected operative life for all the types under analysis gives more consistent results.

Variable costs

Variable costs include those costs items that are influenced by flight hours or stages flown. Variable costs may be broken down into aircraft-related variable costs and services-related variable costs. Aircraft-related variable costs are directly influenced by flight hours or stages flown. They include all those expenses a flying aircraft incurs, like fuel and maintenance. Services-related variable costs are not directly influenced by flight hours, but depend on the number of stages flown. In other words, aircraft-related variable costs may be described as "the more you fly, the more you pay". Services-related costs may be described as "the more stages you fly, the more you pay". While this may seem an overly simplistic definition, it is helpful to understand the fundamental difference between aircraft-related variable costs and services-related variable costs.
The choice to break variable costs down is a consequence of the different behavior they show depending on the variable of interest. Aircraft-related variable costs and services-related variable costs are dependent variables that show different behaviors depending on the independent variable. Since the independent variable may be either flight hours or number of stages flown (or simply stages), separating the different types of variable costs may be helpful to assess the influence each cost item has on total costs.

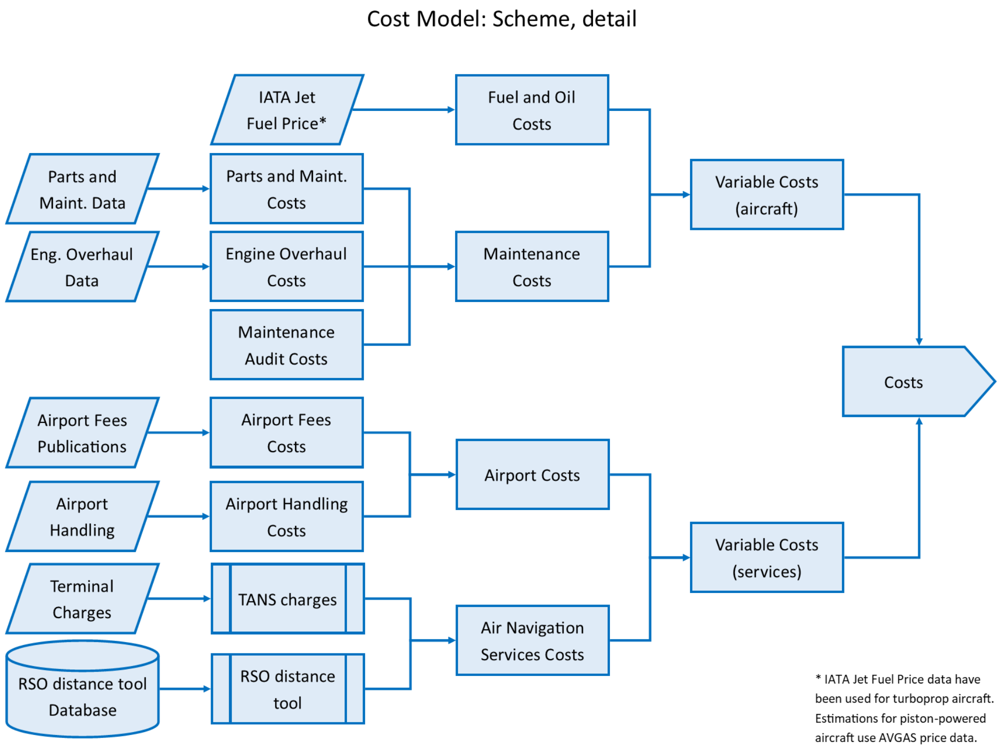

Figure 4.5: Scheme of cost model, detail

Aircraft-related variable costs may vary with flight hours in different ways. As previously said in *Fuel consumption estimation* paragraph, fuel consumption shows power law dependency on distance flown at average block speed, thus depending on flight hours. However, linear approximation may be used for cruise segment with high confidence, in that fuel consumption during cruise is rather constant. Dependency of fuel consumption on stages flown is obtained by using block distance or block time as inputs for fuel estimation relationships.

Parts and maintenance costs and engine overhaul costs may be assumed to be linearly dependent on flight hours. Linear dependence may be achieved by implementing maintenance plans. These plans may be precisely scheduled to efficiently and effectively perform maintenance operations. The maintenance plan may be funded according to number of expected flight hours, flight schedules, technical publications, and all the factors influencing maintenance operations. Linear dependency of parts and maintenance costs and engine overhaul costs is then a consequence of a maintenance plan allowing the definition of maintenance costs per flight hour with an adequate level of confidence. Maintenance audit cost has been assumed to be 5% of total maintenance costs, thus being linearly dependent on flight hours. Dependence of maintenance costs on stages flown is obtained by using block time to assess maintenance costs per stage. Assuming linear dependence of maintenance costs on flight hours is valid as aircraft fly a number of flight hours close to expectations. While a limit for "close to" may not be quantitatively defined, it is easy to understand how maintenance programs may not be effectively and efficiently implemented as flight hours decrease beyond a certain limit.

Services-related variable costs are due per stage. While some lower-level cost items may be deducted from laws or formulae, a discrete approach is more advisable for higher-level cost items. Thus, services-related variable costs are assessed per stage and then transformed into time-dependent variables using block time.
Lower-level cost items making up services-related variable costs may be linearly dependent on stages. For example, some airport fees are due per movement, thus making them linearly dependent on stages flown to/from that airport. However, some other airport fees may be charged on time bases, thus showing different dependencies.
Either flight hours or stages may be used as independent variables, according to which aspect the analysis is focusing on. For example, flight hours may suit a comprehensive analysis of aircraft utilization, while stages may better suit analyses focusing on one single route.

Air Navigation Services charges

Air traffic services are made available to air traffic users in exchange of a charge. EUROCONTROL's Central Route Charges Office state that "on behalf of EUROCONTROL's Member States, the Central Route Charges Office (CRCO) bills and collects route charges that fund air navigation facilities and services and supports Air Traffic Management developments. [...] The CRCO also bills and collects, on a bilateral basis, terminal charges on behalf of Member States"[132] . EUROCONTROL airspace is divided into charging zones. A flight operated within EUROCONTROL airspace may cross one or more charging zones. Flights operated within airspaces controlled by EUROCONTROL are charged for route and terminal air services.

Route charges are levied for en-route services. For this analysis, route charges have been calculated with EUROCONTROL's Route per State Overflown (RSO) distance tool, made available by EUROCONTROL. RSO distance tool is a software that computes estimated route charges, given the route plan, the aircraft MTOM, and the date the flight is operated. All flights have been assumed to take place on October 23th, 2020. Since route charges are applicable as from January 1st of each year and monthly adjusted in case of flight operated in countries

[132] Central Route Charges Office. (January 2020). *Customer Guide to Charges*. EUROCONTROL

with currencies other than Euro, the estimate is consistent with the other assumptions made. Route charge is dependent on three parameters: distance factor, aircraft weight factor, and unit rate of charge. Distance factor is directly proportional to the great circle distance between the aerodrome (or waypoint, in case of multi-zone flight) of departure and the aerodrome (or waypoint, in case of multi-zone flight) of arrival. From January 1st, 2020 flights charges are calculated with distance factors based on actual route flown, instead of the distance reported on route plan. However, for pre-flight estimations, distance factor can be calculated using route plan distance, in that the flight has not been operated yet. Aircraft weight factor is proportional to the square root of aircraft MTOM, as reported on the Aircraft Flight Manual (AFM). The unit rate of charge is the charge in Euros applied by a charging zone to a flight operated by an aircraft of 50 metric tonnes. That is, a flight with a MTOM of 50 metric tonnes will be applied a unit rate of charge of 1. The unit rate of charge is applied to each zone crossed by the flight.

Terminal charges are levied for the services provided by Terminal Air Navigation Services (TANS). The cost of terminal services is related to the following services:

- "airport control services, airport flight information services including air traffic advisory services, and alerting services;
- air traffic services related to the approach and departure of aircraft within a certain distance of an airport on the basis of operational requirements;
- an appropriate allocation of all other air navigation services components, reflecting a proportionate attribution between en-route and terminal services"[133] .

As of January 1st, 2020, charges for terminal air navigation services are billed and collected by EUROCONTROL on behalf of the participating States[134] . The terminal charge is levied upon the departing flight only. It is calculated with the formula below.

$$\text{Terminal Charge [€]} = \text{Weight Factor} \cdot \text{Unit Rate [€]} = \left(\frac{\text{MTOM}}{50}\right)^{0.7} \cdot \text{Unit Rate [€]}$$

The exponent of the weight factor is equal to 0.7 for Italy, but may change for other EUROCONTROL Member States[135] . The unit rate is dependent on the airport of departure. Terminal unit rates are taken from Information circulars governing terminal charges in 2020, Terminal Charges in Italy (Ref. LI 2020/01), published by EUROCONTROL[136] . Airports subject to terminal charges are divided into three categories with different unit rates. The table below lists unit charges for each charging zone.

Unit Rates for Terminal Charge		
Charging zone 1	Charging zone 2	Charging zone 3
167.33 €	167.56 €	298.93 €

Table 4.5: Unit rates for terminal charge

[133] EUROCONTROL. *Terminal ANS Costs*. Single European Sky Data Portal website
[134] Central Route Charges Office. (January 2020). *Customer Guide to Charges*. EUROCONTROL
[135] ibid.
[136] EUROCONTROL. *Key documents*. EUROCONTROL website

4.4.2 Revenues model

The revenues model is aimed at assessing revenues deriving from commercial air operations. The revenues model has two main objectives: to estimate break-even point (BEP), and to assess profit margins.

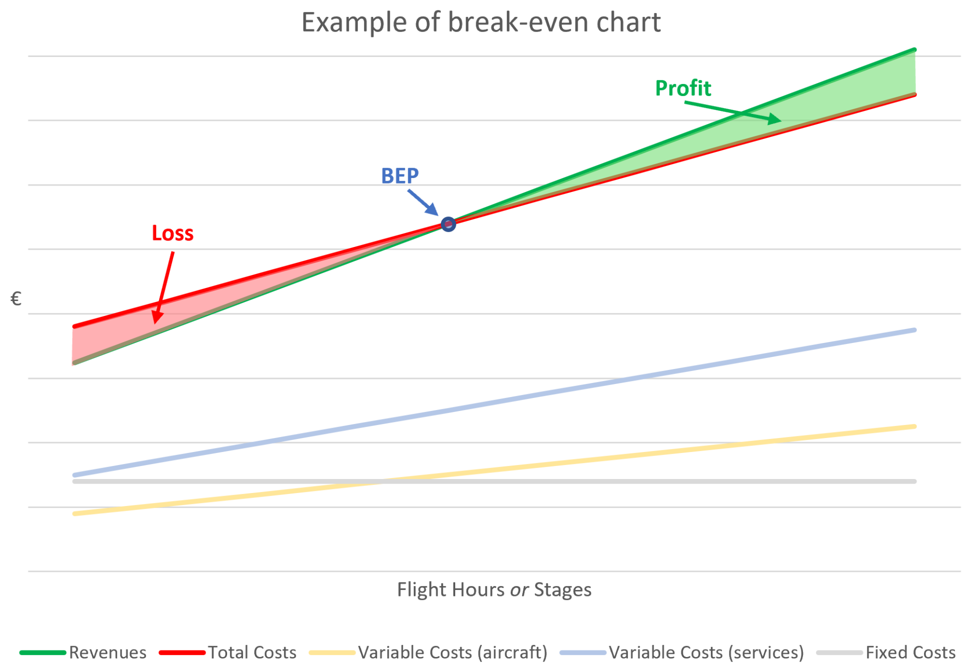

Figure 4.6: Example of break-even chart

Break-even point (BEP) is defined as the intersection between costs and revenues, i.e. the point where revenues equal costs. Break-even (point) price is defined as the price per passenger when revenues equal costs (i.e. the cost per passenger when revenues equal costs). Profits margins are achieved as revenues exceed costs. Break-even charts feature money values on their vertical axis and quantity values on their horizontal axis. Depending on the focus of the analysis, a break-even chart may feature different quantity values. For the purposes of this analysis, break-even analyses are based on flight hours or stages, in that flight hours and stages have been taken as independent variables.

Total costs are defined by a line with positive slope on break-even charts. Total costs are obtained by summing aircraft-related variable costs, services-related variable costs, and fixed costs. Aircraft-related variable costs and services-related variable costs are defined by two lines with positive slope, in that they increase with the independent variable. Strictly speaking, aircraft-related variable costs and services-related variable costs do vary with the independent variable. Thus, they may be included in the same category. However, they have been broken down to stress the differences between them. Fixed costs are described by a constant function, since they do not vary with the independent variable.
Break-even charts are a powerful tool to quickly assess the influence parameters have on overall results. As parameters vary, curves change accordingly, thus showing the influence on costs and revenues. Changes in aircraft-related or services-related variable costs affect the slope of total costs line, while changes in fixed costs affect the y-intercept ot the total costs line.

Yield is a metric frequently used in the air transport industry. Defined as the ratio between passenger revenues and RPKs, yield is a useful metric relating revenues to number of passengers flown on a route. It may be considered as the contribution given by passengers enplaned on a route to revenues generated by the route. In market analysis, yield may be used as an indicator of average fares per passenger on a route.

Traffic analysis and forecasting

The estimated market volume for a route influences the way airlines wishing to operate that route schedule and organize operations. Market volumes may be measured with different metrics, the most used being number of passengers enplaned, RPKs, or currency. Number of passengers enplaned, referred to as passenger volume, and RPKs have the advantage of not being dependent on money value, and thus inherently consistent in time.
One of the most important concepts is the concept of demand. Market demand may be defined as "the total volume that would be bought by a defined customer group in a defined area in a defined time period in a defined marketing environment under a defined marketing program"[137] . The definition needs some clarification. The customer group the airline focuses on may comprise more than one passenger group, in that the airline may focus on one or more passenger groups (for example, an airline may focus both on leisure and VFR travelers). The marketing environment takes into account all those variables that may not be controlled by airlines, like economy or politics. Marketing program is the strategy defined by carriers to plan and implement their marketing effort, i.e. all those actions taken to stimulate market demand. Each effort will result in a different market demand. Depending on market elasticity, i.e. the responsiveness of market demand to marketing effort, the demand curve will show different shapes. Market forecast is the market demand given by the expected marketing effort. Market potential is "the limit approached by market demand as marketing effort goes to infinity"[138] .
These definitions are relative to the whole market, but can be easily related to the airline. Company demand is the function representing the portion of market demand retained by the company. Thus, company demand is given by the product of market demand and market share. Company forecast is "the expected level of company sales based on a chosen marketing plan and assumed marketing environment"[139] . Consequently, company potential is the limit approached by company demand as company marketing effort goes to infinity with respect to competitors' effort.

Market demand estimation techniques are countless, since analysts have developed estimating models to fit different scenarios.
Time-series models interpolate historical data to obtain estimation relationships. The estimation relationships are then used to forecast passenger volumes. These models are based on the assumption that past trends will be valid in the future. Consequently, the higher the confidence in data and in the assumption the trend will continue, the higher the precision of results. Time-series models may offer good outlooks on cyclic or seasonal phenomena, especially if factors driving these phenomena are quite sure to occur (e.g. increase in demand during high season), but may be biased by single-time events. Time-series analyses describe what happened in the past and give future outlooks based on the assumption that past trends will still be valid. However, they do not take into account causal relations.

[137] Wells, A.T. and Richey, F.D. (1996). *Commuter Airlines*. Krieger Publishing Company
[138] ibid.
[139] ibid.

Causal models are developed to define causal relationships among variables. Different models may be developed using different techniques. Basically, the rationale behind causal model is fitting historical data to develop causal relationships describing the effects of variables affecting results. Causal models may be extremely complex, depending on desired outputs, available data, and resources allocated. Complex models take into account many variables. ICAO's Manual on Air Traffic Forecasting states that "demand for air travel is primarily determined by socio-economic variables such as income, demographics and the cost of air travel"[140] . Econometric analyses may give much more comprehensive and accurate outlooks, but require more detailed data. The rationale of forecasting models considering econometric variables is that air transport, offering customers a product, is influenced by economical, demographic, and geopolitical variables. While an analysis of these variables is not among the purposes of this work, the influence they have on air transport is to be considered when analyzing passenger volumes.
Judgmental methods may be used in addition to statistical analyses. These methods are based on intuition, experience, and evaluations. Judgmental methods are easy to implement and may be used when historical data are not available or not suitable, but they are easily prone to bias and may lack objectivity. Thus, they are usually used to check, validate, or integrate analyses conducted with other methods.

Market demand estimations offer outlooks on a given market. However, more than one carrier may operate in that market. Consequently, each carrier will retain its market share. Market share estimations are then required to assess company demand. Market share retained by a carrier is heavily influenced by services offered by carriers operating in the considered environment. Market share may be increased by fostering market demand or by increasing the carrier's marketing effort in relation to competitors'. ICAO's Manual on Air Traffic Forecasting[141] provides the formula below for market share calculations:

$$MS_x = \frac{F_x \cdot C_x \cdot S_x \cdot P_x \cdot A_x}{\sum_{i=1}^{N} F_i \cdot C_i \cdot S_i \cdot P_i \cdot A_i}$$

F is flight frequency, C is passenger capacity, S is stop factor (direct or stopping flight), P is average price, and A is airline's market appeal. The terms above the line refer to the airline being analyzed (x), while terms below the line refer to all carriers in the environment (from 1 to N, being N the number of carriers in the environment). Airline frequency, capacity, and stop factor may be the easiest terms to estimate, in that they may be retrieved using flight schedules and operated aircraft types. Airline's market appeal may be difficult to estimate, in that perceived appeal may change depending on passenger groups or even on single passengers. Airline's appeal is also influenced by quality of services offered. Average price estimation is challenging, since fares are heavily influenced by demand and are subjected to changes in time. Properly assessing prices is made difficult by complex pricing strategies and fare structures. Estimating a good price index representing future prices with high confidence is thus very difficult, since it requires a thorough analysis of fare strategies implemented by airlines. When price index estimations retain a high degree of uncertainty, the use of yield may be preferred. While actual fares are inherently more accurate than yield, the latter may be a good proxy for the former.

[140] ICAO. (2006). *Manual on Air Traffic Forecasting (Doc. 8991)*
[141] ibid.

It is worth noting that these terms may influence market share calculations in different ways. For example, stop factor may be omitted if all considered carriers offer direct flights. Other terms, like airlines' appeal, may have different influence depending on airlines and routes being analyzed. For example, short-haul or very-short-haul flights operated by low-cost or regional airlines may be less influenced by airlines' appeal than long-haul flight operated by full-service carriers.

2020 plunge in air traffic has posed new challenges to forecasting. Most of the times, time-series analyses may not be implemented, since the magnitude and impact of COVID-19 outbreak simply have no equivalent in the past. Time-series analyses also lack available data, with 2020 being the only year affected by the pandemic. A causal model may help assessing future development of air transport. Being based on causal relations, causal models may take into account factors driving possible recovery. It is worth noting that many models developed during the last months offer different results for different scenarios that may occur. Vaccines availability and efficacy are widely agreed to be the main factors influencing recovery. EUROCONTROL details three possible scenarios for passenger recovery[142] , depending on vaccines availability and efficacy. While assessing possible scenarios is not among the purposes of this work, outcomes of different scenarios are to be considered when estimating passenger demand.
In environments affected by a high degree of uncertainty, judgmental analyses may be of great help. Since judgmental analyses are based on human reasoning, rather than on mathematical models, they may adapt more easily to sudden changes. However, as previously noted, they may lack objectivity.

Passenger volume estimation was carried out starting from historical data (i.e. 2019 and years before). Historical data were used to assess market volumes for each route. The assumption behind the choice of using historical data is that routes will likely retain the relative passenger demand they had before 2020. This assumption is valid for domestic routes only, in that international routes may be affected by international travel restrictions affecting international passenger volumes. Thus, domestic routes will likely retain volumes consistent with historical data in terms of share of domestic market, but lower volumes in terms of absolute values.
Passenger volumes may then be estimated by delta. Estimating the delta between historical data and future data requires some effort. Several factors influence the delta between past and future traffic volumes. As previously said, historical data have been considered to assess the future domestic market share routes are likely to retain. However, other data are required to estimate absolute values. Traffic recovery forecast are made available by agencies or organizations (e.g. EUROCONTROL) to assess relative values in the upcoming years. These estimations use historical data as a baseline for base forecast (i.e. without 2020 crisis). 2020 data and forecasting models are then used to estimate traffic volumes in the upcoming years. EUROCONTROL's forecast for Italy has been used to assess relative traffic volumes in the upcoming years. Data have been processed to obtain relative values based on 2019 data. It is worth noting that data provided by EUROCONTROL take into account all flights operated within Italian airspace. However, since relative values are calculated using 2019 data from the same database, outcomes are consistent. As previously noted, EUROCONTROL's forecast details three different scenarios, depending on vaccine availability. The scenario assuming vaccine availability from 2021 has been used for estimations.

[142] EUROCONTROL. (November 2020). *EUROCONTROL Five-Year Forecast 2020-2024*. EUROCONTROL

While based on high-confidence data, this estimation may lead to inaccurate data, since it does not take into account factors related to specific areas or markets. It has already been pointed out that domestic market is key for recovery. For example, domestic passengers to/from Olbia (OLB/LIEO) make up 77.7% of total passengers during 2020, up 12.8% from 2019[143]. While this trend is unlike to last for many years, it may be envisaged as an important contribution to market demand. Thus, focus on domestic market shall be considered. It is worth noting that the higher market share retained by domestic passengers is not driven by an increase in absolute values. The increase related to higher market share retained by domestic traffic applies to relative values only. The assumption that the higher relative share retained by domestic flights will cause an increase in absolute passenger volumes would lead to inconsistent results.

Passenger volumes may then be estimated by adapting regression curves obtained from time-series data with deltas estimated from EUROCONTROL data. This estimation may then be adjusted to take into account the higher focus on domestic market. It is worth noting that this estimation inherently retains some approximation. First of all, it is based on the assumption that positive growth rates will occur in the upcoming years. Moreover, it uses results from more than one model, and it is thus prone to the uncertainty inherently retained by such models. However, since estimations are made difficult by extreme uncertainty and variability deriving from unprecedented events, building an estimating model by adding one after another the factors having affected air transport demand during the last month gives the opportunity to clearly identify the role different factors have.

Profit margins and pricing

Profit margin analysis requires more effort. While pricing strategies are not among the purposes of this analysis, a brief overview of airlines fares definition strategies may be of interest. It is worth noting that the following strategy is adopted, with some "in-house" changes, mainly by low-cost carriers. Fares obtained this way show higher variability than those usually offered by mainline carriers.

Airlines pricing strategies are aimed at maximizing profits by maximizing revenues. Counterintuitively, pricing strategies may not be based on actual operating costs. The main driver of these pricing strategies consists in pitching tickets at the highest possible price. The true focus of the pricing analysis consists in finding the best price to maximize revenues. The price shall take into account passenger demand and competition. Passenger demand may be driven by several factors. Seasonality is definitely one of the most important. Prices tend to rise when higher passenger volumes are expected. Thus, depending on the route, some periods or days may have higher demand than average, while some other may be characterized by lower demand. The airline will then pitch higher prices to passengers willing to fly during high season. On the other hand, lower demand periods will see lower prices.
Competition is a main driver in fare definition. Many routes are operated by more than one carrier. However, services offered by two carriers flying the same route may differ. For example, a mainline carrier and a LCC flying the same route will likely target different passenger groups, with different expectations and different needs. In other words, competing airlines may or may not offer the same type of service. Airlines offering higher-quality services,

[143] Direzione Generale dei trasporti - Regione Sardegna. (2019-2021). *Statistiche flussi passeggeri degli aeroporti sardi*. Opendata Sardegna website

whatever they are, will likely offer tickets at higher prices. While this is usually true, especially when considering the same travel class, there are some exceptions. For example, low-cost carriers, characterized by higher variations in ticket prices, may offer higher prices than mainline carriers on some flights. The reason is that mainline carriers tend to have lower variations in ticket prices, especially on short-haul routes, while low-cost carriers' strategy is aimed at offering the highest prices analysts assume passengers are willing to pay. The goal of the pricing strategy is defining those prices.

Prices definition starts from base prices definition. Base prices may be defined in different ways. One of the most used techniques is using historical data for the route. Data may perfectly match the operated route, in that the airline or competitors offering similar services have already operated the route, or may require some processing. If no historical data are available for the route, base prices are obtained by performing analogy estimations using data from similar routes. The base price may be the average price the airline is expecting to sell tickets, but mostly depends on marketing strategies. All fares offered shall always consider the estimated price passengers are willing to pay. Base prices are then offered for booking. Depending on passengers' demand, fares are risen or lowered accordingly. Thus, fares may vary within days or even hours.

A slightly different technique for prices definition may also take into account BEP prices. BEP prices may be considered to define an average price tickets must be sold to achieve profitability. Base prices may be adjusted according to demand taking into account average price and possible profit margins.

One of the most surprising aspects of this pricing strategy is that some tickets may be sold at prices lower than operating costs per passenger. While this may seem, and actually is, unprofitable, profitability is achieved as average prices of all tickets sold are higher than average costs per passenger. From the airline's perspective, an empty seat is lost forever. Thus, selling a ticket at a lower price than average costs per passenger may be better than flying an empty seat. Depending on overall results and period reports, airlines may decide to maintain, adjust, change, or cancel routes, possibly increasing capacity on more lucrative routes.

As the fall in demand occurred due to 2020 pandemic, airlines faced lower traffic volumes. Lower prices have been a direct consequence of lower demand. The pricing strategy has not changed, though. Let aside route cancellations and frequency reductions, lower traffic volumes influenced fares offered by airlines, in that airlines had to lower average prices to retain competitiveness. It may be pointed out that, by lowering ticket prices, airlines have likely achieved net losses on more flights than before. While this is generally true, offering fares in line with pre-pandemic prices would have most likely resulted in higher losses.

5. Case studies

The model has been used to estimate and assess costs and revenues of operations with different aircraft. Different scenarios have been analyzed for each case study. This choice offers the possibility to assess results against different input values. Each scenario is defined by its network and schedule, and by its hypotheses and assumptions.
The first scenario of each case study is the baseline scenario, while the other scenarios offer the possibility to assess the influence the independent variable and parameters have on results.
The other scenarios offer the opportunity to change hypotheses, assumptions, and parameters to assess the consequences they have on results. Changing hypotheses, assumptions, and parameters gives the chance to simulate real-world situations. Since boundary conditions may vary, assessing the consequences they have is paramount. A static model would be ineffective in evaluating what-if scenarios, thus resulting in poor estimation capabilities. It is worth noting that the analyzed scenarios are but few of the countless that analysts may face. Different scenarios may be developed depending on the focus(es) of the analysis, on the boundary conditions, and on the hypotheses and assumptions made.
Profitability is assessed using break-even charts and numerical values. Break-even charts are a powerful tool to evaluate costs and revenues at a glance, while numerical values give a more detailed picture of the results.
For the sake of brevity, only some of the analyzed routes have been reported in this chapter.

5.1 Operations from Olbia with given passenger volumes

This scenario is based on the following assumptions:

- The passenger volume is estimated in terms of number of passengers per year on a seasonal basis. Thus, total yearly passengers are obtained by summing estimated passengers for each season. The average load factor is calculated from the number of passengers and the number of stages operated.
- Costs depending on the number of passengers flown have been assessed using estimated passenger volumes.
- Revenues are calculated at break-even point price. Thus, net profits are identically zero, and total costs curve overlaps revenues curve. This assumption gives the opportunity to assess the effects of the number of stages or flight hours on average costs per passenger.

Number of stages (Olbia case study)				
Route		**Total Stages**		**Total stages per year**
Origin	Dest	Summer	Winter	
OLB	MXP	248	147	395
MXP	OLB	248	147	395
OLB	FCO	248	147	395
FCO	OLB	248	147	395
OLB	VRN	155	63	218
VRN	OLB	155	63	218
OLB	TRN	124	42	166
TRN	OLB	124	42	166
OLB	CUF	62	0	62
CUF	OLB	62	0	62
Total		**1 674**	**798**	**2 472**

Table 5.1: Number of stages (Olbia case study)

Estimated passenger volumes per year (Olbia case study)				
Route		**ATR 42-600**	**ATR 72-600**	**Dash 8-400**
Origin	Dest			
OLB	MXP	16 100	20 600	20 600
MXP	OLB	16 100	20 600	20 600
OLB	FCO	16 100	19 800	19 800
FCO	OLB	16 100	19 800	19 800
OLB	VRN	9 200	11 800	11 800
VRN	OLB	9 200	11 800	11 800
OLB	TRN	6 900	8 600	8 600
TRN	OLB	6 900	8 600	8 600
OLB	CUF	2 600	3 200	3 200
CUF	OLB	2 600	3 200	3 200
Total		101 800	128 000	128 000

Table 5.2: Estimated passenger volumes per year (Olbia case study)

It is worth noting that the estimated passenger volume may vary depending on the type, due to differences in passenger capacity among types. It may be pointed out that the type used for the operations should be driven by market demand. While this is true, airlines plan their schedules on company demand and potential. Company demand is influenced by market share, which is dependent on airline's capacity. Thus, some differences may arise in market demand and potential depending on aircraft passenger capacity. While company demand may be considered linearly dependent on passenger capacity, this assumption is not acceptable, since passenger demand may vary with non-linear laws. Assuming linear dependency may cause load factors to reach higher than 100% values on some flights, thus leading to inconsistent results.

5.1.1 ATR 42-600

Total operating costs of a fleet of two ATR 42-600 with given passenger volumes					
	Per Year	**Per Stage**	**Per Flt Hr**	**Per ASK**	**Per RPK**
Variable Costs (aircraft)					
Fuel, oil	537 240 €	217 €	176 €	1.06 €c	1.23 €c
Parts & Maintenance	*1 452 531 €*	*588 €*	*477 €*	*2.86 €c*	*3.33 €c*
Engine overhaul	*1 282 554 €*	*519 €*	*421 €*	*2.52 €c*	*2.94 €c*
Maintenance audit	*136 754 €*	*55 €*	*45 €*	*0.27 €c*	*0.31 €c*
Maintenance total	2 871 839 €	1 162 €	943 €	5.65 €c	6.58 €c
Total Variable Costs (aircraft)	**3 409 079 €**	**1 379 €**	**1 120 €**	**6.71 €c**	**7.81 €c**
Variable Costs (services)					
Airport costs	5 255 514 €	2 126 €	1 726 €	10.34 €c	12.04 €c
ANS costs	705 036 €	285 €	232 €	1.39 €c	1.61 €c
Total Variable Costs (services)	**5 960 550 €**	**2 411 €**	**1 958 €**	**11.73 €c**	**13.65 €c**
Fixed Costs					
Salaries total	951 000 €	385 €	312 €	1.87 €c	2.18 €c
Crew training	60 800 €	25 €	20 €	0.12 €c	0.14 €c
Safety audit	48 000 €	19 €	16 €	0.09 €c	0.11 €c
Insurance total	280 400 €	113 €	92 €	0.55 €c	0.64 €c
Depreciation	1 649 700 €	667 €	542 €	3.25 €c	3.78 €c
Total Fixed Costs	**2 989 900 €**	**1 210 €**	**982 €**	**5.88 €c**	**6.85 €c**
TOTAL COSTS	**12 359 528 €**	**5 000 €**	**4 060 €**	**24.33 €c**	**28.31 €c**

Table 5.3: Total operating costs of a fleet of two ATR 42-600 with given passenger volumes

Costs and revenues for OLB-MXP route: ATR 42-600						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
395	**609 780 €**	**920 736 €**	**534 387 €**	**2 064 903 €**	**2 064 903 €**	**128 €**
360	555 749 €	857 960 €	534 387 €	1 948 096 €	1 948 096 €	121 €
365	563 467 €	866 928 €	534 387 €	1 964 782 €	1 964 782 €	122 €
370	571 186 €	875 896 €	534 387 €	1 981 469 €	1 981 469 €	123 €
375	578 905 €	884 864 €	534 387 €	1 998 156 €	1 998 156 €	124 €
380	586 623 €	893 832 €	534 387 €	2 014 843 €	2 014 843 €	125 €
385	594 342 €	902 800 €	534 387 €	2 031 529 €	2 031 529 €	126 €
390	602 061 €	911 768 €	534 387 €	2 048 216 €	2 048 216 €	127 €
395	609 780 €	920 736 €	534 387 €	2 064 903 €	2 064 903 €	128 €
400	617 498 €	929 704 €	534 387 €	2 081 590 €	2 081 590 €	129 €
405	625 217 €	938 672 €	534 387 €	2 098 276 €	2 098 276 €	130 €
410	632 936 €	947 640 €	534 387 €	2 114 963 €	2 114 963 €	131 €
415	640 655 €	956 608 €	534 387 €	2 131 650 €	2 131 650 €	132 €

Table 5.4: Costs and revenues for OLB-MXP route: ATR 42-600

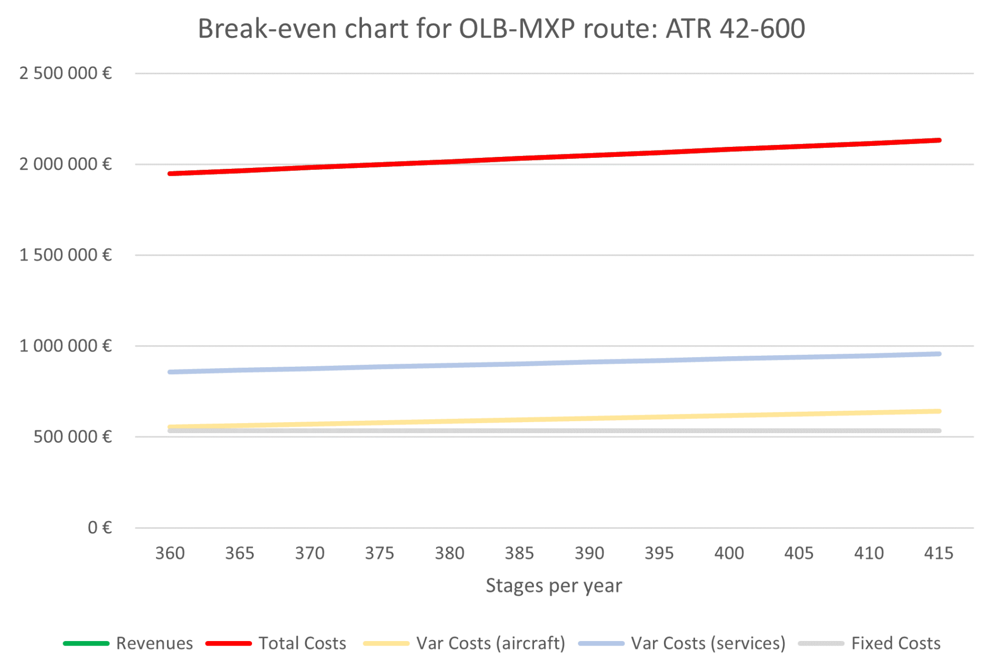

Figure 5.1: Break-even chart for OLB-MXP route: ATR 42-600

Costs and revenues for TRN-OLB route: ATR 42-600						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
166	**261 333 €**	**377 635 €**	**228 982 €**	**867 951 €**	**867 951 €**	**126 €**
150	236 145 €	355 396 €	228 982 €	820 522 €	820 522 €	119 €
154	242 442 €	360 956 €	228 982 €	832 379 €	832 379 €	121 €
158	248 739 €	366 516 €	228 982 €	844 236 €	844 236 €	122 €
162	255 036 €	372 075 €	228 982 €	856 094 €	856 094 €	124 €
166	261 333 €	377 635 €	228 982 €	867 951 €	867 951 €	126 €
170	267 630 €	383 195 €	228 982 €	879 808 €	879 808 €	128 €
174	273 928 €	388 755 €	228 982 €	891 665 €	891 665 €	129 €
178	280 225 €	394 315 €	228 982 €	903 522 €	903 522 €	131 €
182	286 522 €	399 875 €	228 982 €	915 379 €	915 379 €	133 €
186	292 819 €	405 435 €	228 982 €	927 236 €	927 236 €	134 €
190	299 116 €	410 994 €	228 982 €	939 093 €	939 093 €	136 €
194	305 414 €	416 554 €	228 982 €	950 950 €	950 950 €	138 €

Table 5.5: Costs and revenues for TRN-OLB route: ATR 42-600

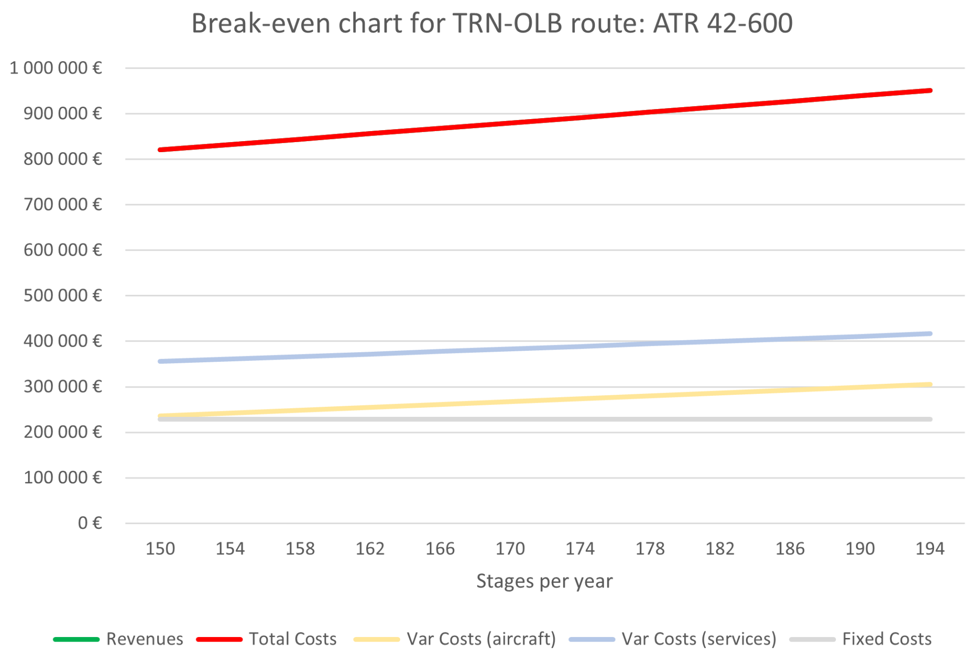

Figure 5.2: Break-even chart for TRN-OLB route: ATR 42-600

5.1.2 ATR 72-600

Total operating costs of a fleet of two ATR 72-600 with given passenger volumes					
	Per Year	**Per Stage**	**Per Flt Hr**	**Per ASK**	**Per RPK**
Variable Costs (aircraft)					
Fuel, oil	588 449 €	238 €	187 €	0.79 €c	1.07 €c
Parts & Maintenance	*1 521 781 €*	*616 €*	*484 €*	*2.05 €c*	*2.76 €c*
Engine overhaul	*1 324 907 €*	*536 €*	*421 €*	*1.79 €c*	*2.40 €c*
Maintenance audit	*142 334 €*	*58 €*	*45 €*	*0.19 €c*	*0.26 €c*
Maintenance total	2 989 022 €	1 209 €	950 €	4.03 €c	5.42 €c
Total Variable Costs (aircraft)	**3 577 471 €**	**1 447 €**	**1 138 €**	**4.83 €c**	**6.49 €c**
Variable Costs (services)					
Airport costs	6 598 679 €	2 669 €	2 098 €	8.91 €c	11.96 €c
ANS costs	800 396 €	324 €	255 €	1.08 €c	1.45 €c
Total Variable Costs (services)	**7 399 074 €**	**2 993 €**	**2 353 €**	**9.99 €c**	**13.41 €c**
Fixed Costs					
Salaries total	1 191 000 €	482 €	379 €	1.61 €c	2.16 €c
Crew training	60 800 €	25 €	19 €	0.08 €c	0.11 €c
Safety audit	48 000 €	19 €	15 €	0.06 €c	0.09 €c
Insurance total	394 800 €	160 €	126 €	0.53 €c	0.72 €c
Depreciation	2 322 270 €	939 €	738 €	3.13 €c	4.21 €c
Total Fixed Costs	**4 016 870 €**	**1 625 €**	**1 277 €**	**5.42 €c**	**7.28 €c**
TOTAL COSTS	**14 993 415 €**	**6 065 €**	**4 768 €**	**20.24 €c**	**27.18 €c**

Table 5.6: Total operating costs of a fleet of two ATR 72-600 with given passenger volumes

Costs and revenues for OLB-MXP route: ATR 72-600						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
395	**643 065 €**	**1 143 785 €**	**722 033 €**	**2 508 883 €**	**2 508 883 €**	**122 €**
360	586 085 €	1 066 437 €	722 033 €	2 374 554 €	2 374 554 €	115 €
365	594 225 €	1 077 487 €	722 033 €	2 393 744 €	2 393 744 €	116 €
370	602 365 €	1 088 536 €	722 033 €	2 412 934 €	2 412 934 €	117 €
375	610 505 €	1 099 586 €	722 033 €	2 432 124 €	2 432 124 €	118 €
380	618 645 €	1 110 636 €	722 033 €	2 451 314 €	2 451 314 €	119 €
385	626 785 €	1 121 686 €	722 033 €	2 470 503 €	2 470 503 €	120 €
390	634 925 €	1 132 735 €	722 033 €	2 489 693 €	2 489 693 €	121 €
395	643 065 €	1 143 785 €	722 033 €	2 508 883 €	2 508 883 €	122 €
400	651 205 €	1 154 835 €	722 033 €	2 528 073 €	2 528 073 €	123 €
405	659 345 €	1 165 885 €	722 033 €	2 547 263 €	2 547 263 €	124 €
410	667 485 €	1 176 934 €	722 033 €	2 566 453 €	2 566 453 €	125 €
415	675 625 €	1 187 984 €	722 033 €	2 585 642 €	2 585 642 €	126 €

Table 5.7: Costs and revenues for OLB-MXP route: ATR 72-600

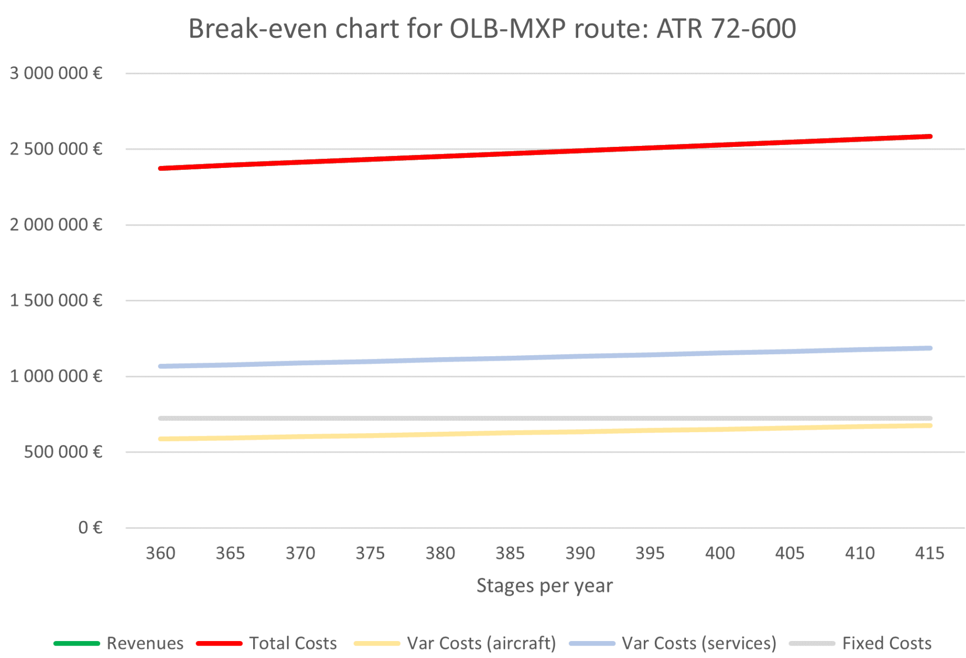

Figure 5.3: Break-even chart for OLB-MXP route: ATR 72-600

Costs and revenues for TRN-OLB route: ATR 72-600						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
166	**275 906 €**	**466 797 €**	**309 785 €**	**1 052 488 €**	**1 052 488 €**	**122 €**
150	249 313 €	439 452 €	309 785 €	998 550 €	998 550 €	116 €
154	255 961 €	446 288 €	309 785 €	1 012 035 €	1 012 035 €	118 €
158	262 609 €	453 125 €	309 785 €	1 025 519 €	1 025 519 €	119 €
162	269 258 €	459 961 €	309 785 €	1 039 004 €	1 039 004 €	121 €
166	275 906 €	466 797 €	309 785 €	1 052 488 €	1 052 488 €	122 €
170	282 554 €	473 633 €	309 785 €	1 065 973 €	1 065 973 €	124 €
174	289 203 €	480 469 €	309 785 €	1 079 458 €	1 079 458 €	126 €
178	295 851 €	487 306 €	309 785 €	1 092 942 €	1 092 942 €	127 €
182	302 499 €	494 142 €	309 785 €	1 106 427 €	1 106 427 €	129 €
186	309 148 €	500 978 €	309 785 €	1 119 911 €	1 119 911 €	130 €
190	315 796 €	507 814 €	309 785 €	1 133 396 €	1 133 396 €	132 €
194	322 444 €	514 651 €	309 785 €	1 146 880 €	1 146 880 €	133 €

Table 5.8: Costs and revenues for TRN-OLB route: ATR 72-600

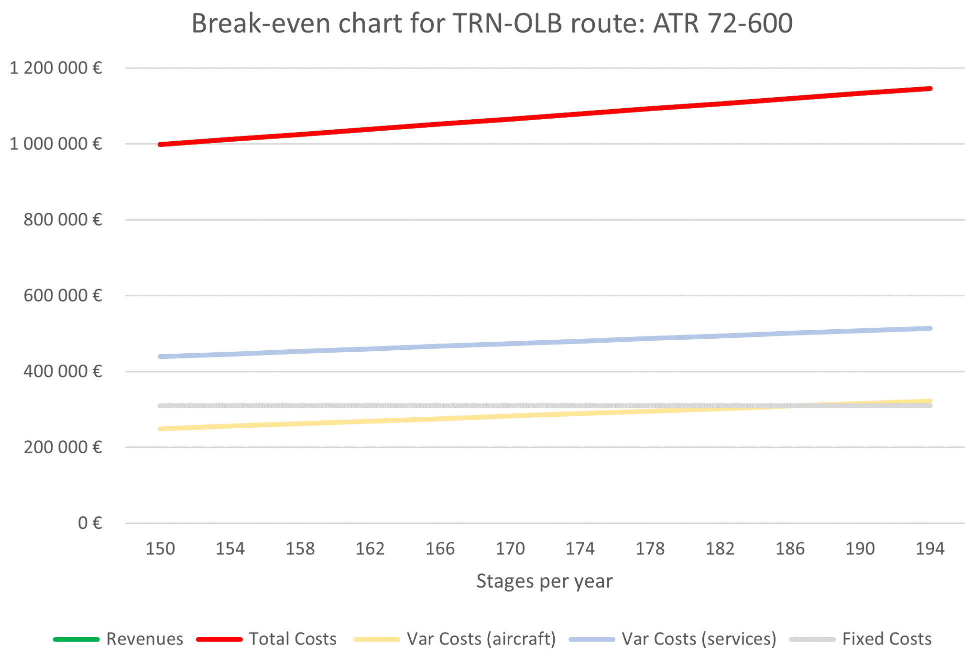

Figure 5.4: Break-even chart for TRN-OLB route: ATR 72-600

5.1.3 Dash 8-400

Total operating costs of a fleet of two Dash 8-400 with given passenger volumes					
	Per Year	**Per Stage**	**Per Flt Hr**	**Per ASK**	**Per RPK**
Variable Costs (aircraft)					
Fuel, oil	811 018 €	328 €	327 €	1.01 €c	1.47 €c
Parts & Maintenance	*1 315 036 €*	*532 €*	*530 €*	*1.63 €c*	*2.38 €c*
Engine overhaul	*1 088 161 €*	*440 €*	*438 €*	*1.35 €c*	*1.97 €c*
Maintenance audit	*120 160 €*	*49 €*	*48 €*	*0.15 €c*	*0.22 €c*
Maintenance total	2 523 357 €	1 021 €	1 016 €	3.14 €c	4.57 €c
Total Variable Costs (aircraft)	**3 334 376 €**	**1 349 €**	**1 343 €**	**4.14 €c**	**6.05 €c**
Variable Costs (services)					
Airport costs	6 899 129 €	2 791 €	2 778 €	8.58 €c	12.51 €c
ANS costs	923 306 €	374 €	372 €	1.15 €c	1.67 €c
Total Variable Costs (services)	**7 822 435 €**	**3 164 €**	**3 150 €**	**9.72 €c**	**14.18 €c**
Fixed Costs					
Salaries total	1 191 000 €	482 €	480 €	1.48 €c	2.16 €c
Crew training	65 600 €	27 €	26 €	0.08 €c	0.12 €c
Safety audit	48 000 €	19 €	19 €	0.06 €c	0.09 €c
Insurance total	489 000 €	198 €	197 €	0.61 €c	0.89 €c
Depreciation	2 876 400 €	1 164 €	1 158 €	3.58 €c	5.21 €c
Total Fixed Costs	**4 670 000 €**	**1 889 €**	**1 881 €**	**5.81 €c**	**8.47 €c**
TOTAL COSTS	**15 826 811 €**	**6 402 €**	**6 374 €**	**19.67 €c**	**28.69 €c**

Table 5.9: Total operating costs of a fleet of two Dash 8-400 with given passenger volumes

Costs and revenues for OLB-MXP route: Dash 8-400						
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Cost per Pax
395	**596 730 €**	**1 210 715 €**	**839 968 €**	**2 647 413 €**	**2 647 413 €**	**129 €**
360	543 856 €	1 127 436 €	839 968 €	2 511 260 €	2 511 260 €	122 €
365	551 409 €	1 139 333 €	839 968 €	2 530 710 €	2 530 710 €	123 €
370	558 963 €	1 151 230 €	839 968 €	2 550 161 €	2 550 161 €	124 €
375	566 516 €	1 163 127 €	839 968 €	2 569 611 €	2 569 611 €	125 €
380	574 070 €	1 175 024 €	839 968 €	2 589 062 €	2 589 062 €	126 €
385	581 623 €	1 186 921 €	839 968 €	2 608 512 €	2 608 512 €	127 €
390	589 177 €	1 198 818 €	839 968 €	2 627 963 €	2 627 963 €	128 €
395	596 730 €	1 210 715 €	839 968 €	2 647 413 €	2 647 413 €	129 €
400	604 284 €	1 222 612 €	839 968 €	2 666 864 €	2 666 864 €	129 €
405	611 838 €	1 234 509 €	839 968 €	2 686 315 €	2 686 315 €	130 €
410	619 391 €	1 246 406 €	839 968 €	2 705 765 €	2 705 765 €	131 €
415	626 945 €	1 258 303 €	839 968 €	2 725 216 €	2 725 216 €	132 €

Table 5.10: Costs and revenues for OLB-MXP route: Dash 8-400

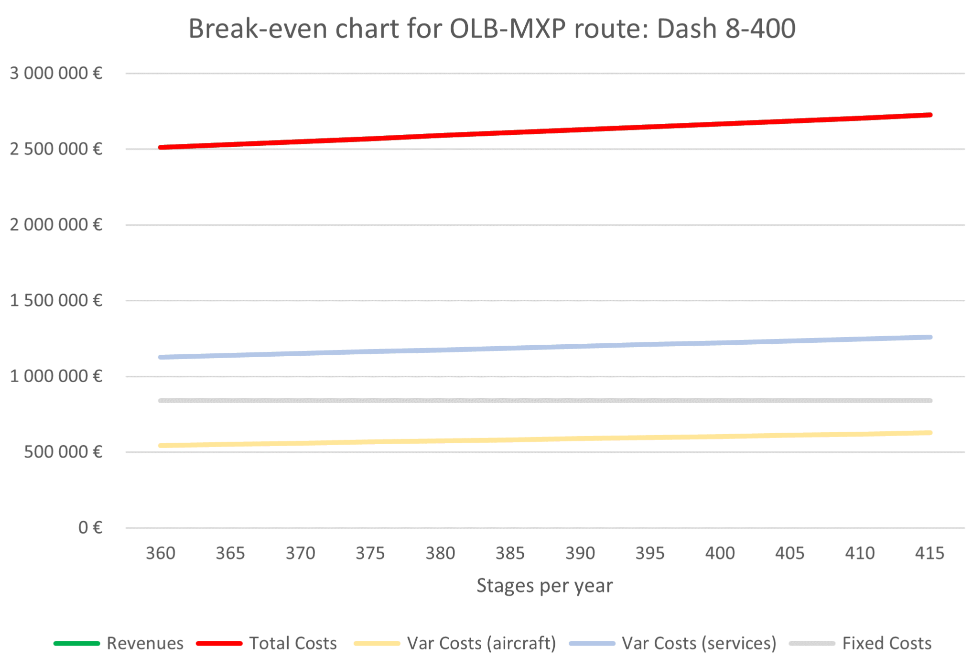

Figure 5.5: Break-even chart for OLB-MXP route: Dash 8-400

Costs and revenues for TRN-OLB route: Dash 8-400						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
166	**255 786 €**	**498 516 €**	**360 438 €**	**1 114 739 €**	**1 114 739 €**	**130 €**
150	231 132 €	468 114 €	360 438 €	1 059 683 €	1 059 683 €	123 €
154	237 295 €	475 714 €	360 438 €	1 073 447 €	1 073 447 €	125 €
158	243 459 €	483 315 €	360 438 €	1 087 211 €	1 087 211 €	126 €
162	249 622 €	490 915 €	360 438 €	1 100 975 €	1 100 975 €	128 €
166	255 786 €	498 516 €	360 438 €	1 114 739 €	1 114 739 €	130 €
170	261 949 €	506 116 €	360 438 €	1 128 503 €	1 128 503 €	131 €
174	268 113 €	513 717 €	360 438 €	1 142 267 €	1 142 267 €	133 €
178	274 276 €	521 317 €	360 438 €	1 156 032 €	1 156 032 €	134 €
182	280 440 €	528 918 €	360 438 €	1 169 796 €	1 169 796 €	136 €
186	286 603 €	536 518 €	360 438 €	1 183 560 €	1 183 560 €	138 €
190	292 767 €	544 119 €	360 438 €	1 197 324 €	1 197 324 €	139 €
194	298 930 €	551 719 €	360 438 €	1 211 088 €	1 211 088 €	141 €

Table 5.11: Costs and revenues for TRN-OLB route: Dash 8-400

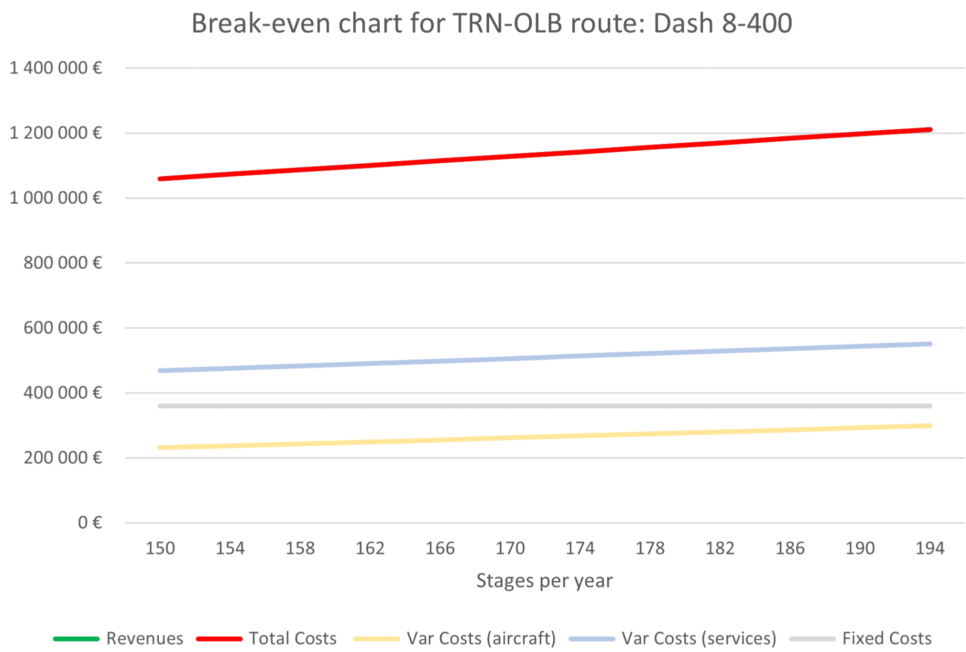

Figure 5.6: Break-even chart for TRN-OLB route: Dash 8-400

5.2 Operations from Olbia with variable load factors

This scenario is based on the following assumptions:

- The number of stages per year has been used as the independent variable.
- Average load factor and average price per passenger have been assumed as variable parameters.
- The passenger volume is estimated in terms of average load factor. Thus, total yearly passengers are obtained by multiplying estimated average load factor for each route by the number of available seats. The average load factor is varied to assess its effects on results.
- Costs depending on the number of passengers flown have been assessed using the number of passengers given by variable load factors.
- Revenues are calculated by multiplying average price per passenger by the number of passengers given by variable load factors. Net profits are given by the difference between revenues and total operating costs. This assumption gives the opportunity to assess the effects the independent variable (number of stages) and the parameters (average load factor and average price per passenger) have on results.

5.2.1 ATR 42-600

Costs and revenues for OLB-MXP route: ATR 42-600						
Average Load Factor: 75%				Average Price per Pax: 145 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	470 843 €	692 650 €	534 387 €	1 697 879 €	1 592 100 €	(105 779) €
315	486 280 €	715 273 €	534 387 €	1 735 940 €	1 644 300 €	(91 640) €
325	501 717 €	737 896 €	534 387 €	1 774 000 €	1 696 500 €	(77 500) €
335	517 155 €	760 519 €	534 387 €	1 812 061 €	1 748 700 €	(63 361) €
345	532 592 €	783 142 €	534 387 €	1 850 122 €	1 800 900 €	(49 222) €
355	548 030 €	805 766 €	534 387 €	1 888 182 €	1 853 100 €	(35 082) €
365	563 467 €	828 389 €	534 387 €	1 926 243 €	1 905 300 €	(20 943) €
375	578 905 €	851 012 €	534 387 €	1 964 304 €	1 957 500 €	(6 804) €
385	594 342 €	873 635 €	534 387 €	2 002 364 €	2 009 700 €	7 336 €
395	609 780 €	896 259 €	534 387 €	2 040 425 €	2 061 900 €	21 475 €
405	625 217 €	918 882 €	534 387 €	2 078 486 €	2 114 100 €	35 614 €
415	640 655 €	941 505 €	534 387 €	2 116 547 €	2 166 300 €	49 753 €

Table 5.12: Costs and revenues for OLB-MXP route: ATR 42-600

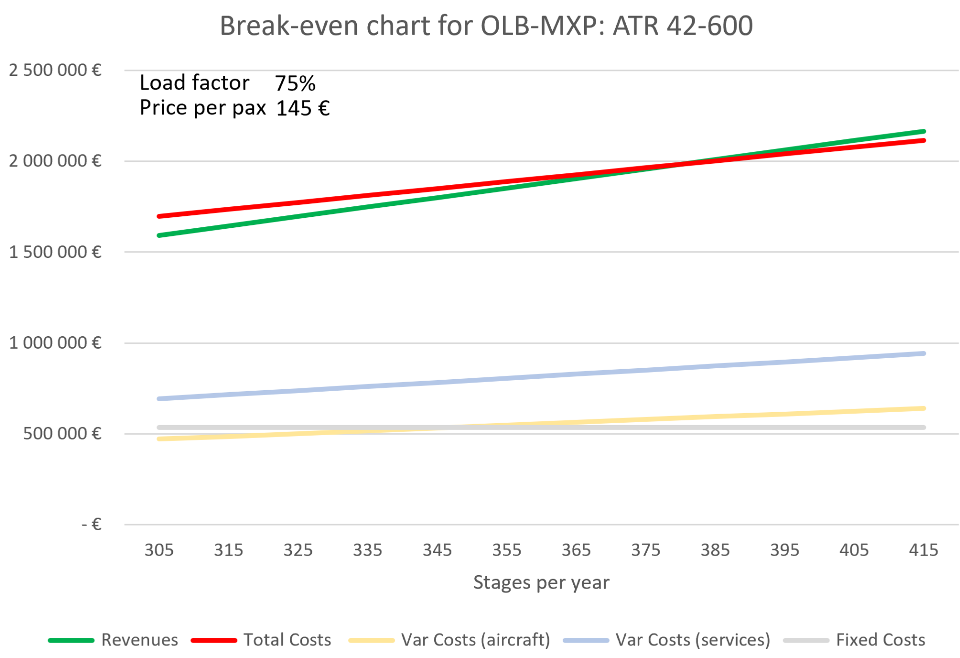

Figure 5.7: Break-even chart for OLB-MXP route: ATR 42-600

Costs and revenues for OLB-MXP route: ATR 42-600						
Average Load Factor: 85%			Average Price per Pax: 132 €			
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	470 843 €	711 711 €	534 387 €	1 716 940 €	1 642 608 €	(74 332) €
315	486 280 €	734 959 €	534 387 €	1 755 626 €	1 696 464 €	(59 162) €
325	501 717 €	758 207 €	534 387 €	1 794 312 €	1 750 320 €	(43 992) €
335	517 155 €	781 455 €	534 387 €	1 832 997 €	1 804 176 €	(28 821) €
345	532 592 €	804 704 €	534 387 €	1 871 683 €	1 858 032 €	(13 651) €
355	548 030 €	827 952 €	534 387 €	1 910 369 €	1 911 888 €	1 519 €
365	563 467 €	851 200 €	534 387 €	1 949 054 €	1 965 744 €	16 690 €
375	578 905 €	874 448 €	534 387 €	1 987 740 €	2 019 600 €	31 860 €
385	594 342 €	897 696 €	534 387 €	2 026 425 €	2 073 456 €	47 031 €
395	609 780 €	920 944 €	534 387 €	2 065 111 €	2 127 312 €	62 201 €
405	625 217 €	944 193 €	534 387 €	2 103 797 €	2 181 168 €	77 371 €
415	640 655 €	967 441 €	534 387 €	2 142 482 €	2 235 024 €	92 542 €

Table 5.13: Costs and revenues for OLB-MXP route: ATR 42-600

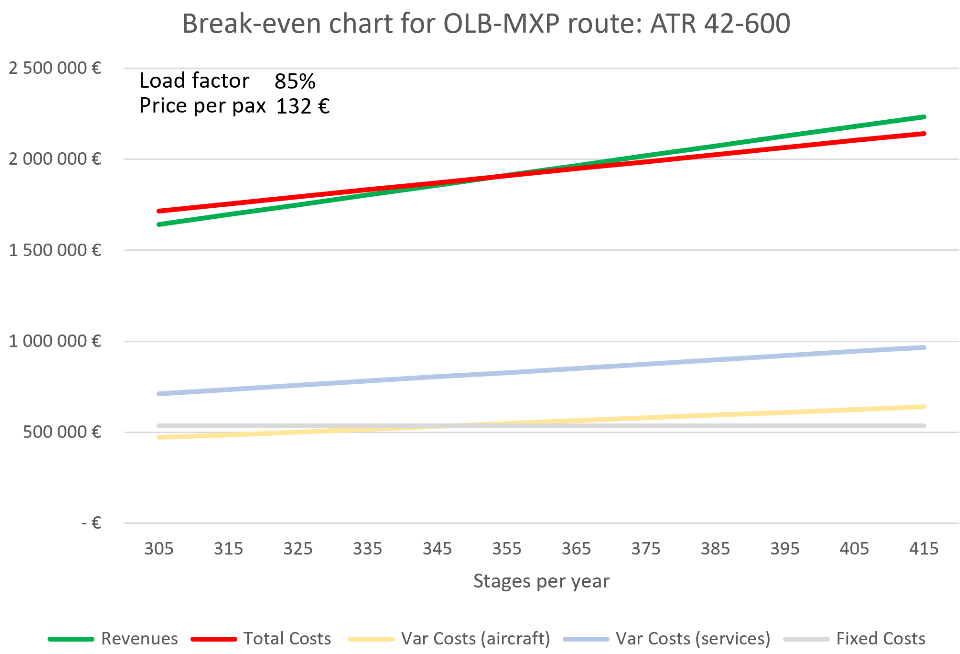

Figure 5.8: Break-even chart for OLB-MXP route: ATR 42-600

Costs and revenues for TRN-OLB route: ATR 42-600						
Average Load Factor: 75%				Average Price per Pax: 145 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	198 361 €	271 707 €	228 982 €	699 051 €	657 720 €	(41 331) €
132	207 807 €	284 646 €	228 982 €	721 435 €	689 040 €	(32 395) €
138	217 253 €	297 584 €	228 982 €	743 819 €	720 360 €	(23 459) €
144	226 699 €	310 522 €	228 982 €	766 203 €	751 680 €	(14 523) €
150	236 145 €	323 461 €	228 982 €	788 587 €	783 000 €	(5 587) €
156	245 590 €	336 399 €	228 982 €	810 972 €	814 320 €	3 348 €
162	255 036 €	349 338 €	228 982 €	833 356 €	845 640 €	12 284 €
168	264 482 €	362 276 €	228 982 €	855 740 €	876 960 €	21 220 €
174	273 928 €	375 215 €	228 982 €	878 124 €	908 280 €	30 156 €
180	283 373 €	388 153 €	228 982 €	900 508 €	939 600 €	39 092 €
186	292 819 €	401 091 €	228 982 €	922 893 €	970 920 €	48 027 €
192	302 265 €	414 030 €	228 982 €	945 277 €	1 002 240 €	56 963 €

Table 5.14: Costs and revenues for TRN-OLB route: ATR 42-600

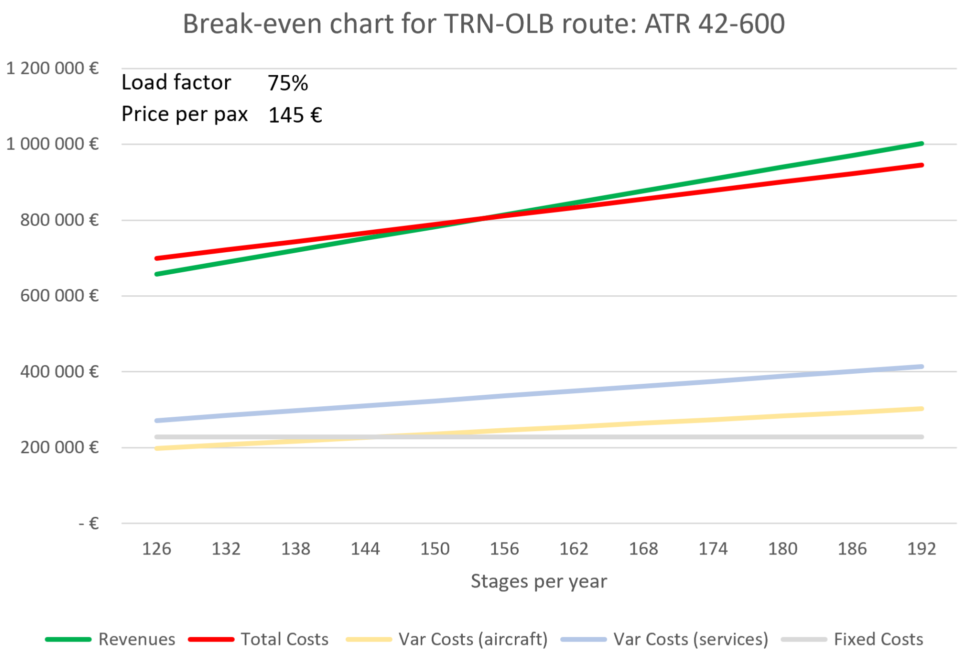

Figure 5.9: Break-even chart for TRN-OLB route: ATR 42-600

Costs and revenues for TRN-OLB route: ATR 42-600						
Average Load Factor: 85%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	198 361 €	284 583 €	228 982 €	711 927 €	678 586 €	(33 341) €
132	207 807 €	298 135 €	228 982 €	734 924 €	710 899 €	(24 025) €
138	217 253 €	311 686 €	228 982 €	757 921 €	743 213 €	(14 709) €
144	226 699 €	325 238 €	228 982 €	780 919 €	775 526 €	(5 392) €
150	236 145 €	338 790 €	228 982 €	803 916 €	807 840 €	3 924 €
156	245 590 €	352 341 €	228 982 €	826 914 €	840 154 €	13 240 €
162	255 036 €	365 893 €	228 982 €	849 911 €	872 467 €	22 556 €
168	264 482 €	379 444 €	228 982 €	872 908 €	904 781 €	31 873 €
174	273 928 €	392 996 €	228 982 €	895 906 €	937 094 €	41 189 €
180	283 373 €	406 548 €	228 982 €	918 903 €	969 408 €	50 505 €
186	292 819 €	420 099 €	228 982 €	941 900 €	1 001 722 €	59 821 €
192	302 265 €	433 651 €	228 982 €	964 898 €	1 034 035 €	69 137 €

Table 5.15: Costs and revenues for TRN-OLB route: ATR 42-600

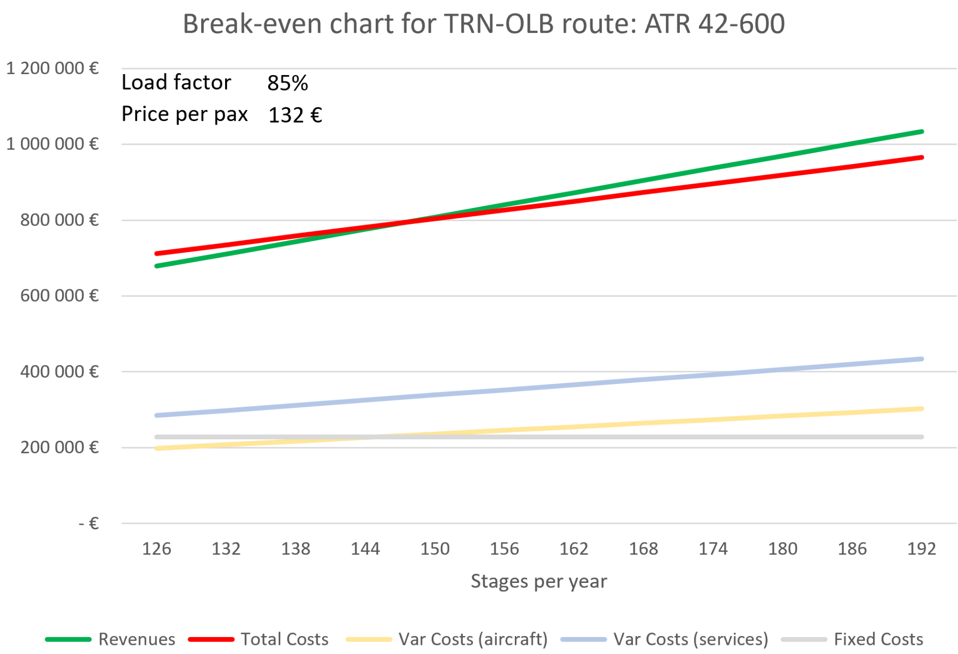

Figure 5.10: Break-even chart for TRN-OLB route: ATR 42-600

5.2.2 ATR 72-600

Costs and revenues for OLB-MXP route: ATR 72-600						
Average Load Factor: 70%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	496 544 €	871 261 €	722 033 €	2 089 838 €	1 972 740 €	(117 098) €
315	512 824 €	899 741 €	722 033 €	2 134 597 €	2 037 420 €	(97 177) €
325	529 104 €	928 220 €	722 033 €	2 179 357 €	2 102 100 €	(77 257) €
335	545 384 €	956 699 €	722 033 €	2 224 116 €	2 166 780 €	(57 336) €
345	561 665 €	985 179 €	722 033 €	2 268 876 €	2 231 460 €	(37 416) €
355	577 945 €	1 013 658 €	722 033 €	2 313 635 €	2 296 140 €	(17 495) €
365	594 225 €	1 042 137 €	722 033 €	2 358 395 €	2 360 820 €	2 425 €
375	610 505 €	1 070 617 €	722 033 €	2 403 154 €	2 425 500 €	22 346 €
385	626 785 €	1 099 096 €	722 033 €	2 447 914 €	2 490 180 €	42 266 €
395	643 065 €	1 127 575 €	722 033 €	2 492 673 €	2 554 860 €	62 187 €
405	659 345 €	1 156 055 €	722 033 €	2 537 433 €	2 619 540 €	82 107 €
415	675 625 €	1 184 534 €	722 033 €	2 582 192 €	2 684 220 €	102 028 €

Table 5.16: Costs and revenues for OLB-MXP route: ATR 72-600

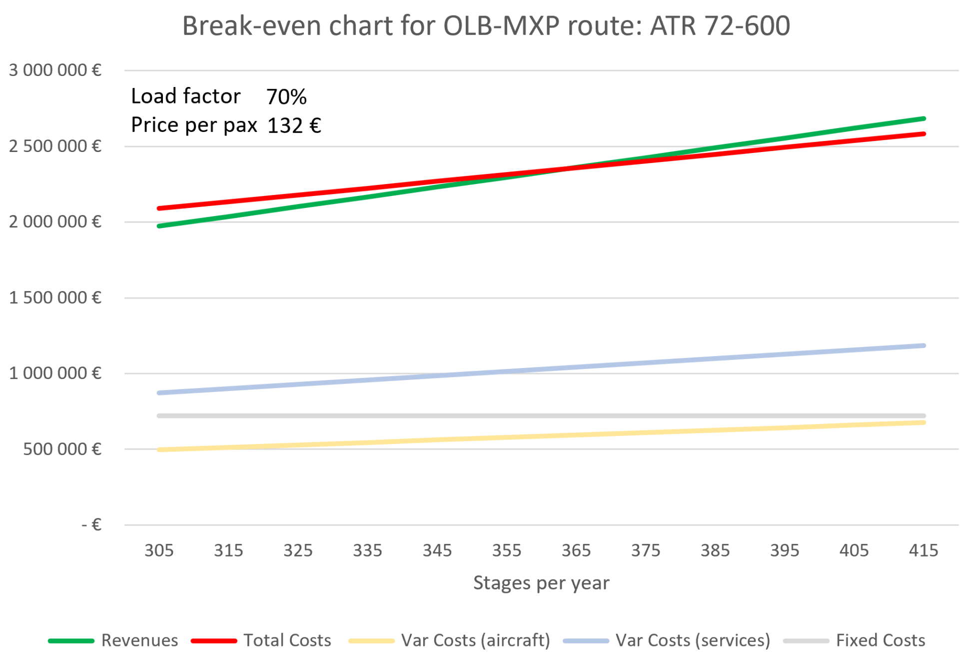

Figure 5.11: Break-even chart for OLB-MXP route: ATR 72-600

Costs and revenues for OLB-MXP route: ATR 72-600						
Average Load Factor: 80%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	496 544 €	899 059 €	722 033 €	2 117 636 €	2 032 520 €	(85 116) €
315	512 824 €	928 450 €	722 033 €	2 163 307 €	2 099 160 €	(64 147) €
325	529 104 €	957 840 €	722 033 €	2 208 977 €	2 165 800 €	(43 177) €
335	545 384 €	987 231 €	722 033 €	2 254 648 €	2 232 440 €	(22 208) €
345	561 665 €	1 016 622 €	722 033 €	2 300 319 €	2 299 080 €	(1 239) €
355	577 945 €	1 046 013 €	722 033 €	2 345 990 €	2 365 720 €	19 730 €
365	594 225 €	1 075 403 €	722 033 €	2 391 661 €	2 432 360 €	40 699 €
375	610 505 €	1 104 794 €	722 033 €	2 437 332 €	2 499 000 €	61 668 €
385	626 785 €	1 134 185 €	722 033 €	2 483 003 €	2 565 640 €	82 637 €
395	643 065 €	1 163 576 €	722 033 €	2 528 673 €	2 632 280 €	103 607 €
405	659 345 €	1 192 966 €	722 033 €	2 574 344 €	2 698 920 €	124 576 €
415	675 625 €	1 222 357 €	722 033 €	2 620 015 €	2 765 560 €	145 545 €

Table 5.17: Costs and revenues for OLB-MXP route: ATR 72-600

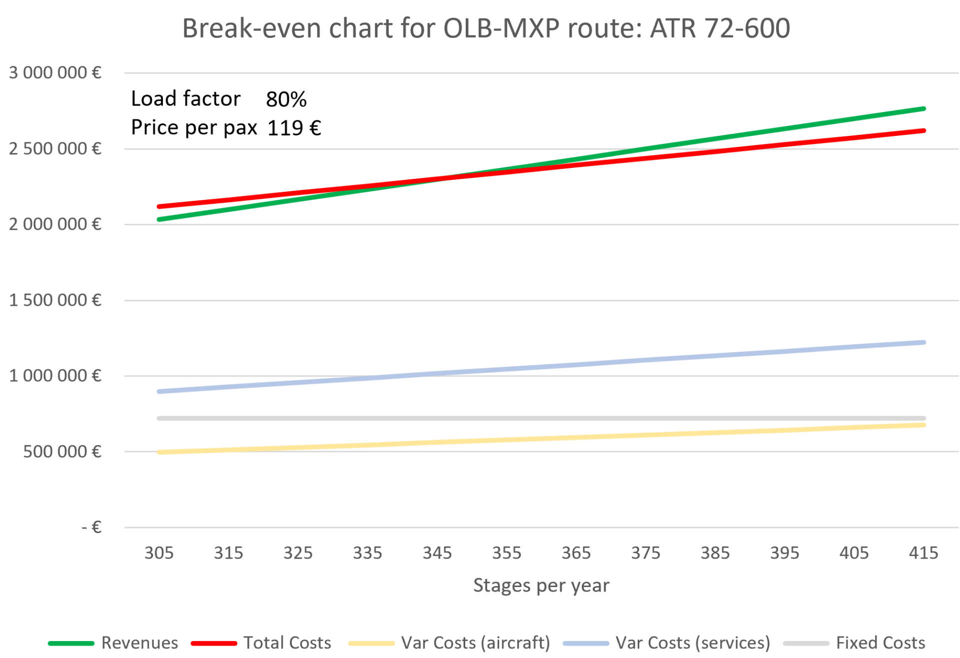

Figure 5.12: Break-even chart for OLB-MXP route: ATR 72-600

Costs and revenues for TRN-OLB route: ATR 72-600						
Average Load Factor: 70%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	209 423 €	346 785 €	309 785 €	865 993 €	814 968 €	(51 025) €
132	219 395 €	363 299 €	309 785 €	892 479 €	853 776 €	(38 703) €
138	229 368 €	379 812 €	309 785 €	918 966 €	892 584 €	(26 382) €
144	239 340 €	396 326 €	309 785 €	945 452 €	931 392 €	(14 060) €
150	249 313 €	412 840 €	309 785 €	971 938 €	970 200 €	(1 738) €
156	259 285 €	429 353 €	309 785 €	998 424 €	1 009 008 €	10 584 €
162	269 258 €	445 867 €	309 785 €	1 024 910 €	1 047 816 €	22 906 €
168	279 230 €	462 380 €	309 785 €	1 051 396 €	1 086 624 €	35 228 €
174	289 203 €	478 894 €	309 785 €	1 077 882 €	1 125 432 €	47 550 €
180	299 175 €	495 408 €	309 785 €	1 104 368 €	1 164 240 €	59 872 €
186	309 148 €	511 921 €	309 785 €	1 130 854 €	1 203 048 €	72 194 €
192	319 120 €	528 435 €	309 785 €	1 157 340 €	1 241 856 €	84 516 €

Table 5.18: Costs and revenues for TRN-OLB route: ATR 72-600

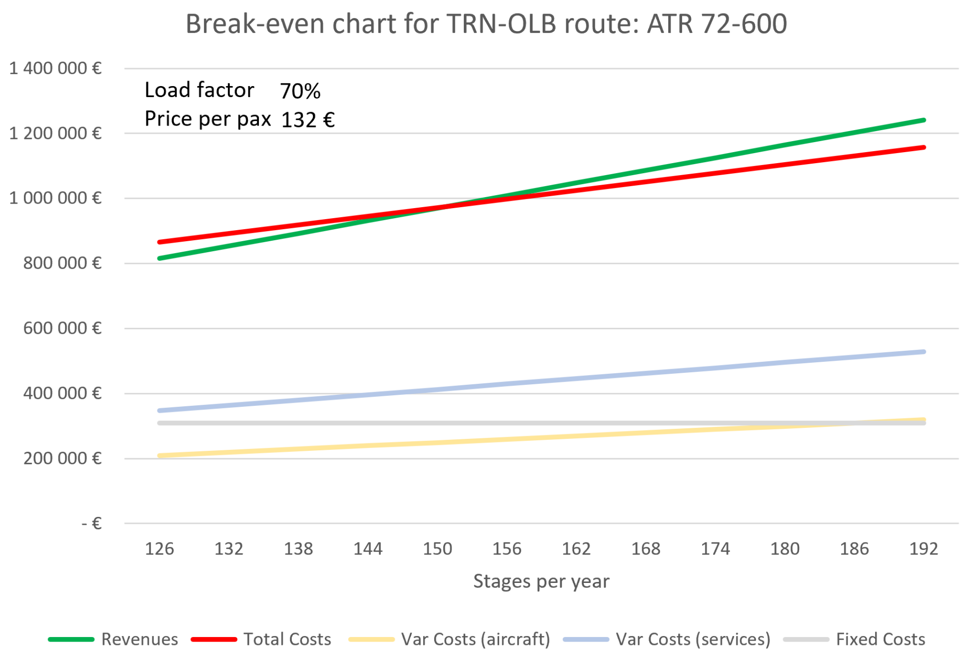

Figure 5.13: Break-even chart for TRN-OLB route: ATR 72-600

Costs and revenues for TRN-OLB route: ATR 72-600						
Average Load Factor: 80%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	209 423 €	365 563 €	309 785 €	884 771 €	839 664 €	(45 107) €
132	219 395 €	382 971 €	309 785 €	912 151 €	879 648 €	(32 503) €
138	229 368 €	400 379 €	309 785 €	939 532 €	919 632 €	(19 900) €
144	239 340 €	417 786 €	309 785 €	966 912 €	959 616 €	(7 296) €
150	249 313 €	435 194 €	309 785 €	994 292 €	999 600 €	5 308 €
156	259 285 €	452 602 €	309 785 €	1 021 672 €	1 039 584 €	17 912 €
162	269 258 €	470 010 €	309 785 €	1 049 053 €	1 079 568 €	30 515 €
168	279 230 €	487 417 €	309 785 €	1 076 433 €	1 119 552 €	43 119 €
174	289 203 €	504 825 €	309 785 €	1 103 813 €	1 159 536 €	55 723 €
180	299 175 €	522 233 €	309 785 €	1 131 194 €	1 199 520 €	68 326 €
186	309 148 €	539 641 €	309 785 €	1 158 574 €	1 239 504 €	80 930 €
192	319 120 €	557 048 €	309 785 €	1 185 954 €	1 279 488 €	93 534 €

Table 5.19: Costs and revenues for TRN-OLB route: ATR 72-600

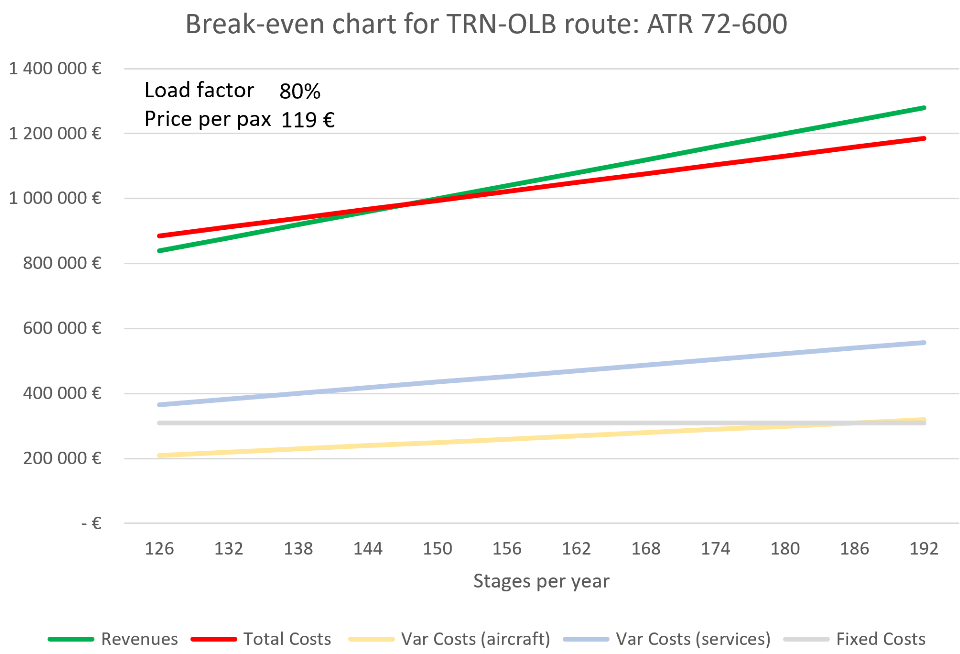

Figure 5.14: Break-even chart for TRN-OLB route: ATR 72-600

5.2.3 Dash 8-400

Costs and revenues for OLB-MXP route: Dash 8-400						
Average Load Factor: 70%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	460 767 €	939 620 €	839 968 €	2 240 355 €	2 141 832 €	(98 523) €
315	475 874 €	970 340 €	839 968 €	2 286 182 €	2 212 056 €	(74 126) €
325	490 981 €	1 001 061 €	839 968 €	2 332 010 €	2 282 280 €	(49 730) €
335	506 088 €	1 031 781 €	839 968 €	2 377 838 €	2 352 504 €	(25 334) €
345	521 195 €	1 062 502 €	839 968 €	2 423 665 €	2 422 728 €	(937) €
355	536 302 €	1 093 223 €	839 968 €	2 469 493 €	2 492 952 €	23 459 €
365	551 409 €	1 123 943 €	839 968 €	2 515 321 €	2 563 176 €	47 855 €
375	566 516 €	1 154 664 €	839 968 €	2 561 148 €	2 633 400 €	72 252 €
385	581 623 €	1 185 384 €	839 968 €	2 606 976 €	2 703 624 €	96 648 €
395	596 730 €	1 216 105 €	839 968 €	2 652 804 €	2 773 848 €	121 044 €
405	611 838 €	1 246 826 €	839 968 €	2 698 631 €	2 844 072 €	145 441 €
415	626 945 €	1 277 546 €	839 968 €	2 744 459 €	2 914 296 €	169 837 €

Table 5.20: Costs and revenues for OLB-MXP route: Dash 8-400

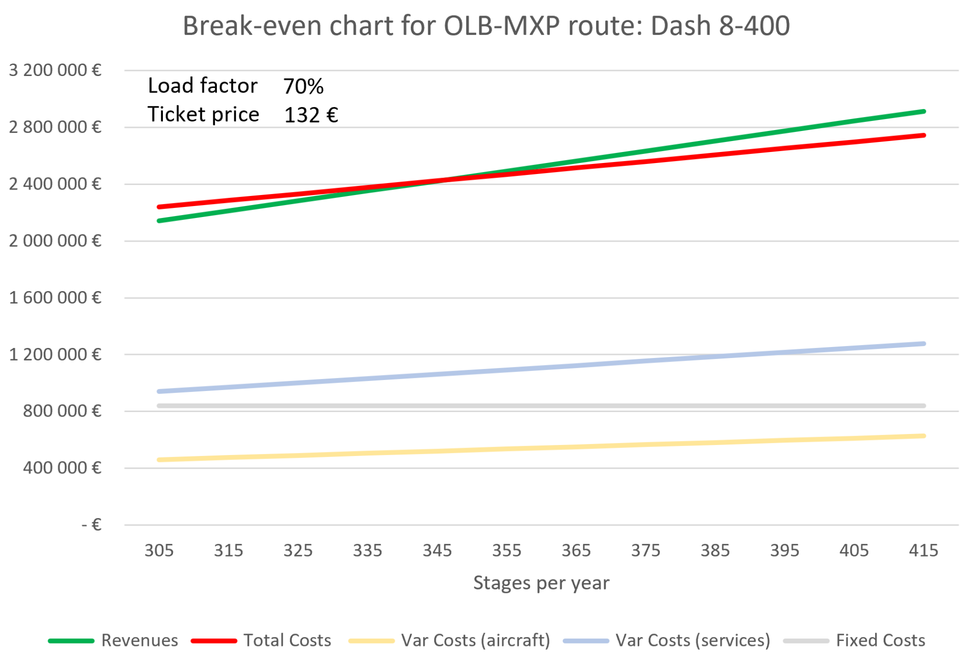

Figure 5.15: Break-even chart for OLB-MXP route: Dash 8-400

Costs and revenues for OLB-MXP route: Dash 8-400						
Average Load Factor: 80%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
305	460 767 €	969 800 €	839 968 €	2 270 535 €	2 206 736 €	(63 799) €
315	475 874 €	1 001 510 €	839 968 €	2 317 352 €	2 279 088 €	(38 264) €
325	490 981 €	1 033 220 €	839 968 €	2 364 169 €	2 351 440 €	(12 729) €
335	506 088 €	1 064 930 €	839 968 €	2 410 987 €	2 423 792 €	12 805 €
345	521 195 €	1 096 641 €	839 968 €	2 457 804 €	2 496 144 €	38 340 €
355	536 302 €	1 128 351 €	839 968 €	2 504 621 €	2 568 496 €	63 875 €
365	551 409 €	1 160 061 €	839 968 €	2 551 438 €	2 640 848 €	89 410 €
375	566 516 €	1 191 771 €	839 968 €	2 598 255 €	2 713 200 €	114 945 €
385	581 623 €	1 223 481 €	839 968 €	2 645 073 €	2 785 552 €	140 479 €
395	596 730 €	1 255 191 €	839 968 €	2 691 890 €	2 857 904 €	166 014 €
405	611 838 €	1 286 901 €	839 968 €	2 738 707 €	2 930 256 €	191 549 €
415	626 945 €	1 318 611 €	839 968 €	2 785 524 €	3 002 608 €	217 084 €

Table 5.21: Costs and revenues for OLB-MXP route: Dash 8-400

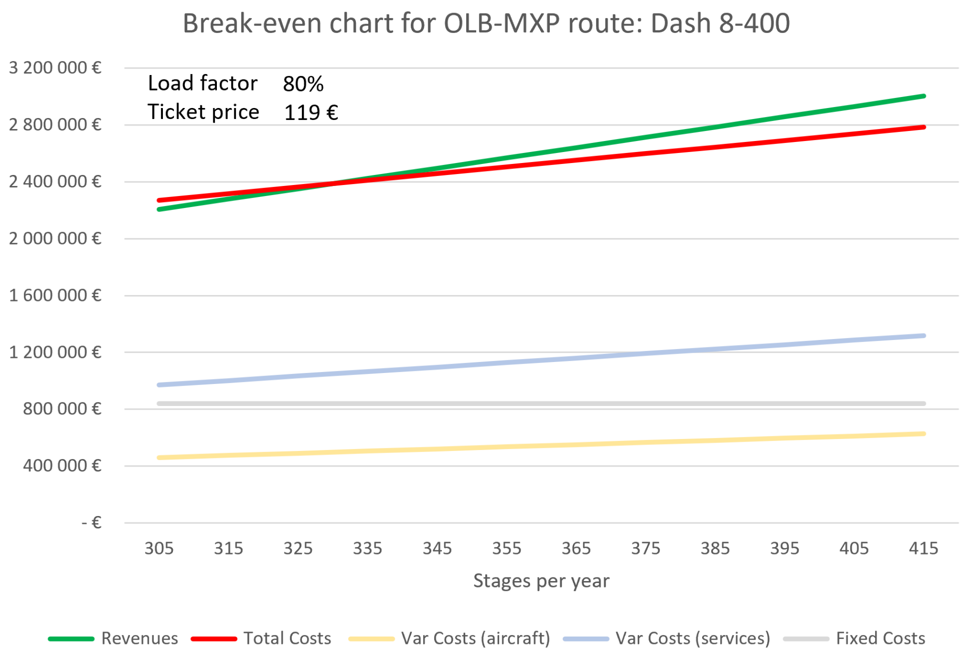

Figure 5.16: Break-even chart for OLB-MXP route: Dash 8-400

Costs and revenues for TRN-OLB route: Dash 8-400						
Average Load Factor: 70%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	194 151 €	382 128 €	360 438 €	936 716 €	884 822 €	(51 894) €
132	203 396 €	400 324 €	360 438 €	964 158 €	926 957 €	(37 201) €
138	212 641 €	418 521 €	360 438 €	991 600 €	969 091 €	(22 509) €
144	221 886 €	436 717 €	360 438 €	1 019 042 €	1 011 226 €	(7 816) €
150	231 132 €	454 914 €	360 438 €	1 046 483 €	1 053 360 €	6 877 €
156	240 377 €	473 110 €	360 438 €	1 073 925 €	1 095 494 €	21 569 €
162	249 622 €	491 307 €	360 438 €	1 101 367 €	1 137 629 €	36 262 €
168	258 867 €	509 503 €	360 438 €	1 128 809 €	1 179 763 €	50 954 €
174	268 113 €	527 700 €	360 438 €	1 156 251 €	1 221 898 €	65 647 €
180	277 358 €	545 896 €	360 438 €	1 183 693 €	1 264 032 €	80 339 €
186	286 603 €	564 093 €	360 438 €	1 211 134 €	1 306 166 €	95 032 €
192	295 849 €	582 290 €	360 438 €	1 238 576 €	1 348 301 €	109 725 €

Table 5.22: Costs and revenues for TRN-OLB route: Dash 8-400

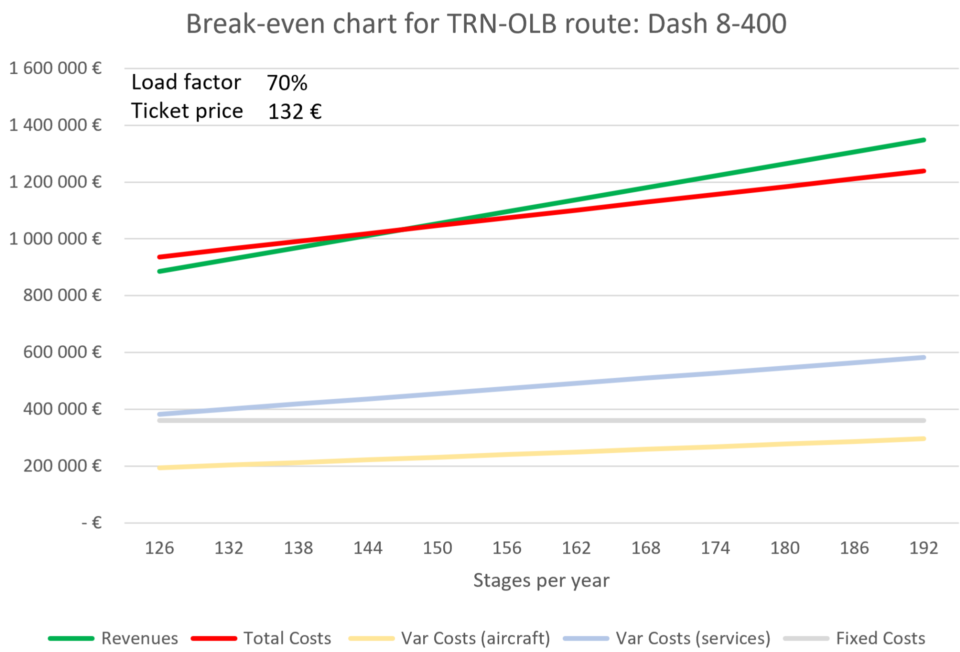

Figure 5.17: Break-even chart for TRN-OLB route: Dash 8-400

Costs and revenues for TRN-OLB route: Dash 8-400						
Average Load Factor: 80%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
126	194 151 €	402 515 €	360 438 €	957 104 €	911 635 €	(45 468) €
132	203 396 €	421 682 €	360 438 €	985 516 €	955 046 €	(30 470) €
138	212 641 €	440 850 €	360 438 €	1 013 929 €	998 458 €	(15 471) €
144	221 886 €	460 017 €	360 438 €	1 042 341 €	1 041 869 €	(473) €
150	231 132 €	479 184 €	360 438 €	1 070 754 €	1 085 280 €	14 526 €
156	240 377 €	498 352 €	360 438 €	1 099 167 €	1 128 691 €	29 524 €
162	249 622 €	517 519 €	360 438 €	1 127 579 €	1 172 102 €	44 523 €
168	258 867 €	536 686 €	360 438 €	1 155 992 €	1 215 514 €	59 522 €
174	268 113 €	555 854 €	360 438 €	1 184 405 €	1 258 925 €	74 520 €
180	277 358 €	575 021 €	360 438 €	1 212 817 €	1 302 336 €	89 519 €
186	286 603 €	594 189 €	360 438 €	1 241 230 €	1 345 747 €	104 517 €
192	295 849 €	613 356 €	360 438 €	1 269 643 €	1 389 158 €	119 516 €

Table 5.23: Costs and revenues for TRN-OLB route: Dash 8-400

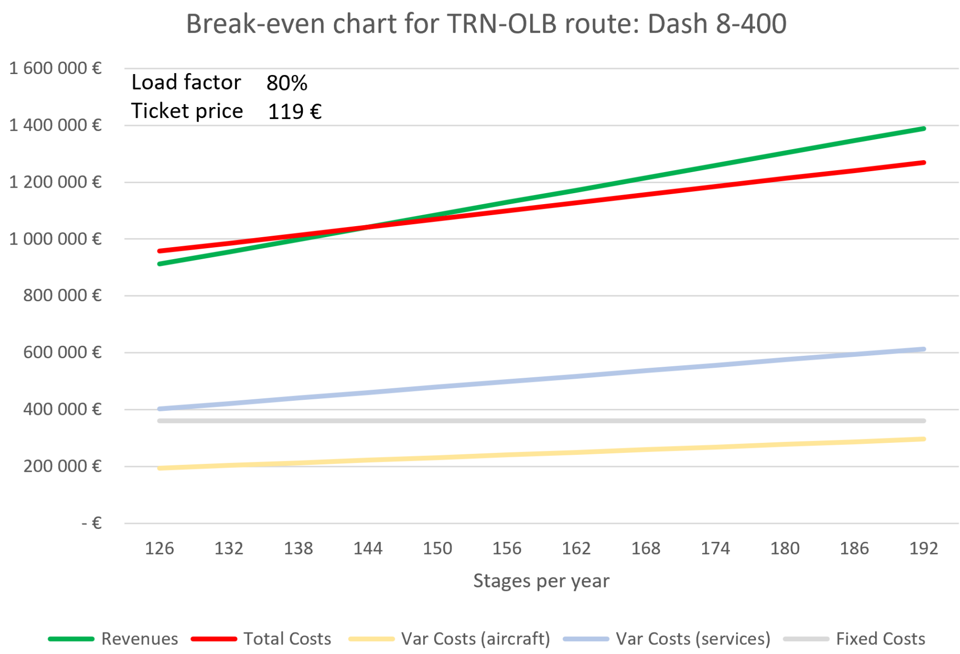

Figure 5.18: Break-even chart for TRN-OLB route: Dash 8-400

5.3 Summer operations from Olbia with variable load factors

This scenario is based on the following assumptions:

- Operations are conducted during summer season only.
- The number of stages per season (i.e. per year) has been used as the independent variable.
- Average load factor and average price per passenger have been assumed as variable parameters.
- The passenger volume is estimated in terms of average load factor. Thus, total yearly (i.e. seasonal) passengers are obtained by multiplying estimated average load factor for each route by the number of available seats. The average load factor is varied to assess its effects on results.
- Costs depending on the number of passengers flown have been assessed using the number of passengers given by variable load factors.
- Revenues are calculated by multiplying average price per passenger by the number of passengers given by variable load factors. Net profits are given by the difference between revenues and total operating costs. This assumption gives the opportunity to assess the effects the independent variable (number of stages) and the parameters (average load factor and average price per passenger) have on results.

5.3.1 ATR 42-600

Costs and revenues for OLB-MXP summer route: ATR 42-600						
Average Load Factor: 85%				Average Price per Pax: 145 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
190	293 312 €	444 357 €	491 788 €	1 229 456 €	1 124 040 €	(105 416) €
197	304 118 €	460 631 €	491 788 €	1 256 536 €	1 165 452 €	(91 084) €
204	314 924 €	476 904 €	491 788 €	1 283 616 €	1 206 864 €	(76 752) €
211	325 730 €	493 178 €	491 788 €	1 310 696 €	1 248 276 €	(62 420) €
218	336 537 €	509 452 €	491 788 €	1 337 776 €	1 289 688 €	(48 088) €
225	347 343 €	525 725 €	491 788 €	1 364 856 €	1 331 100 €	(33 756) €
232	358 149 €	541 999 €	491 788 €	1 391 936 €	1 372 512 €	(19 424) €
239	368 955 €	558 273 €	491 788 €	1 419 016 €	1 413 924 €	(5 092) €
246	379 762 €	574 547 €	491 788 €	1 446 096 €	1 455 336 €	9 240 €
253	390 568 €	590 820 €	491 788 €	1 473 176 €	1 496 748 €	23 572 €
260	401 374 €	607 094 €	491 788 €	1 500 256 €	1 538 160 €	37 904 €
267	412 180 €	623 368 €	491 788 €	1 527 336 €	1 579 572 €	52 236 €

Table 5.24: Costs and revenues for OLB-MXP summer route: ATR 42-600

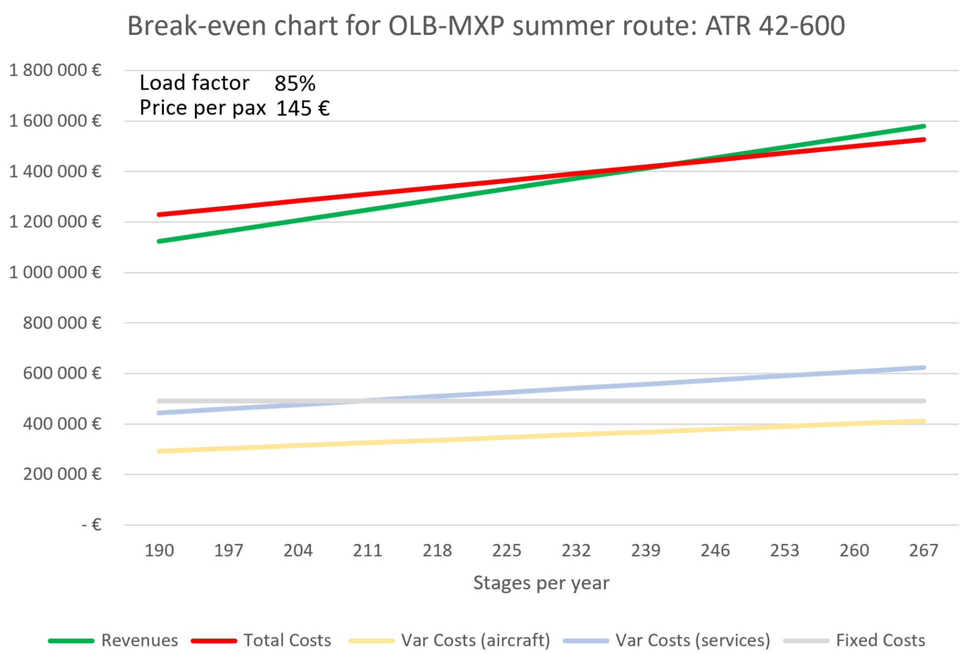

Figure 5.19: Break-even chart for OLB-MXP summer route: ATR 42-600

Costs and revenues for OLB-MXP summer route: ATR 42-600						
Average Load Factor: 95%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
190	293 312 €	456 231 €	491 788 €	1 241 330 €	1 143 648 €	(97 682) €
197	304 118 €	472 942 €	491 788 €	1 268 848 €	1 185 782 €	(83 065) €
204	314 924 €	489 654 €	491 788 €	1 296 365 €	1 227 917 €	(68 448) €
211	325 730 €	506 365 €	491 788 €	1 323 883 €	1 270 051 €	(53 831) €
218	336 537 €	523 076 €	491 788 €	1 351 400 €	1 312 186 €	(39 214) €
225	347 343 €	539 787 €	491 788 €	1 378 917 €	1 354 320 €	(24 597) €
232	358 149 €	556 498 €	491 788 €	1 406 435 €	1 396 454 €	(9 980) €
239	368 955 €	573 209 €	491 788 €	1 433 952 €	1 438 589 €	4 636 €
246	379 762 €	589 921 €	491 788 €	1 461 470 €	1 480 723 €	19 253 €
253	390 568 €	606 632 €	491 788 €	1 488 987 €	1 522 858 €	33 870 €
260	401 374 €	623 343 €	491 788 €	1 516 505 €	1 564 992 €	48 487 €
267	412 180 €	640 054 €	491 788 €	1 544 022 €	1 607 126 €	63 104 €

Table 5.25: Costs and revenues for OLB-MXP summer route: ATR 42-600

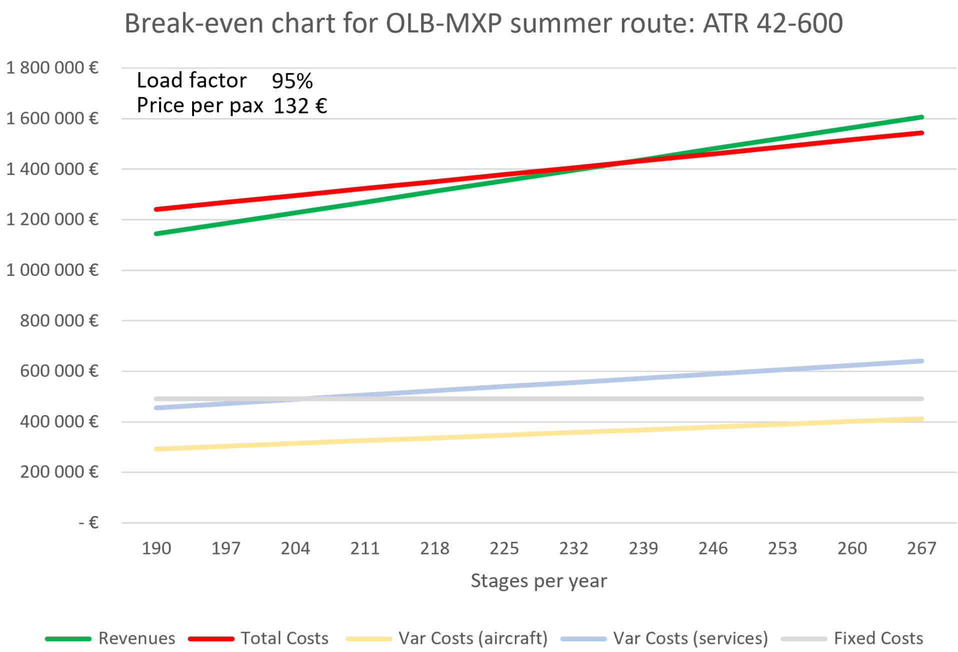

Figure 5.20: Break-even chart for OLB-MXP summer route: ATR 42-600

Costs and revenues for TRN-OLB summer route: ATR 42-600						
Average Load Factor: 85%				Average Price per Pax: 145 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
94	147 984 €	212 308 €	250 716 €	611 008 €	556 104 €	(54 904) €
98	154 281 €	221 343 €	250 716 €	626 340 €	579 768 €	(46 572) €
102	160 578 €	230 377 €	250 716 €	641 671 €	603 432 €	(38 239) €
106	166 875 €	239 411 €	250 716 €	657 003 €	627 096 €	(29 907) €
110	173 173 €	248 446 €	250 716 €	672 334 €	650 760 €	(21 574) €
114	179 470 €	257 480 €	250 716 €	687 666 €	674 424 €	(13 242) €
118	185 767 €	266 514 €	250 716 €	702 998 €	698 088 €	(4 910) €
122	192 064 €	275 549 €	250 716 €	718 329 €	721 752 €	3 423 €
126	198 361 €	284 583 €	250 716 €	733 661 €	745 416 €	11 755 €
130	204 659 €	293 618 €	250 716 €	748 992 €	769 080 €	20 088 €
134	210 956 €	302 652 €	250 716 €	764 324 €	792 744 €	28 420 €
138	217 253 €	311 686 €	250 716 €	779 655 €	816 408 €	36 753 €

Table 5.26: Costs and revenues for TRN-OLB summer route: ATR 42-600

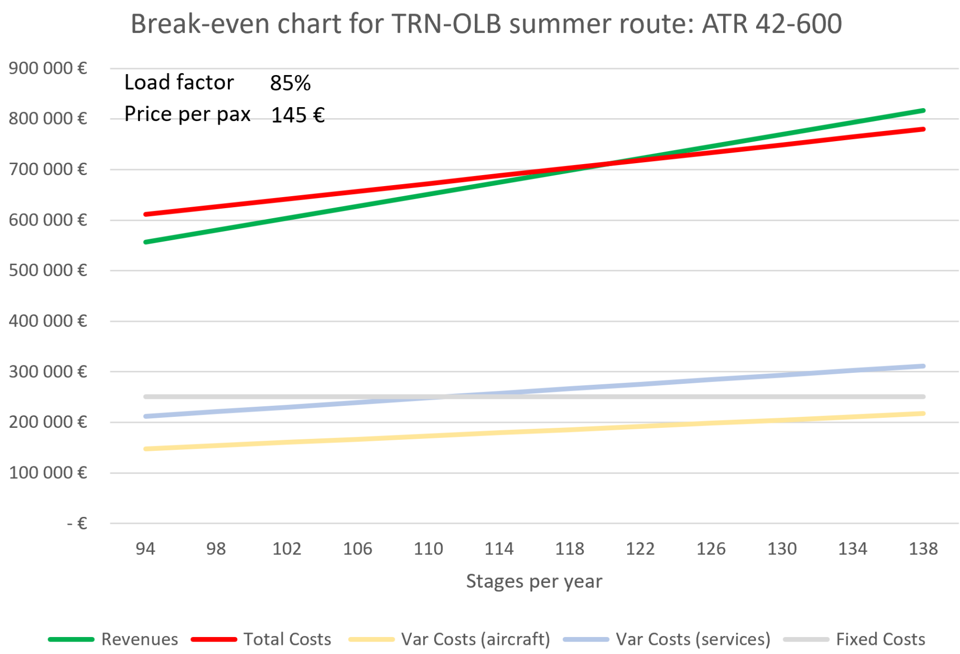

Figure 5.21: Break-even chart for TRN-OLB summer route: ATR 42-600

Costs and revenues for TRN-OLB summer route: ATR 42-600						
Average Load Factor: 95%				Average Price per Pax: 132 €		
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Profit
94	147 984 €	221 914 €	250 716 €	620 614 €	565 805 €	(54 809) €
98	154 281 €	231 357 €	250 716 €	636 354 €	589 882 €	(46 473) €
102	160 578 €	240 801 €	250 716 €	652 095 €	613 958 €	(38 136) €
106	166 875 €	250 244 €	250 716 €	667 835 €	638 035 €	(29 800) €
110	173 173 €	259 687 €	250 716 €	683 575 €	662 112 €	(21 463) €
114	179 470 €	269 130 €	250 716 €	699 316 €	686 189 €	(13 127) €
118	185 767 €	278 573 €	250 716 €	715 056 €	710 266 €	(4 791) €
122	192 064 €	288 016 €	250 716 €	730 797 €	734 342 €	3 546 €
126	198 361 €	297 459 €	250 716 €	746 537 €	758 419 €	11 882 €
130	204 659 €	306 903 €	250 716 €	762 277 €	782 496 €	20 219 €
134	210 956 €	316 346 €	250 716 €	778 018 €	806 573 €	28 555 €
138	217 253 €	325 789 €	250 716 €	793 758 €	830 650 €	36 892 €

Table 5.27: Costs and revenues for TRN-OLB summer route: ATR 42-600

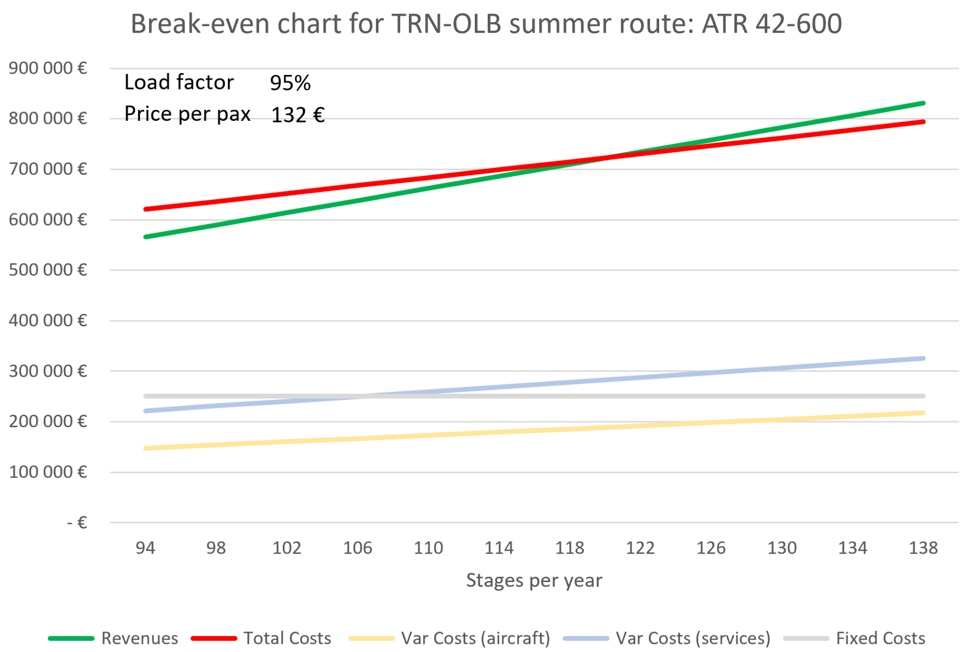

Figure 5.22: Break-even chart for TRN-OLB summer route: ATR 42-600

5.3.2 ATR 72-600

Costs and revenues for OLB-MXP summer route: ATR 72-600						
Average Load Factor: 80%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
190	309 323 €	561 066 €	664 224 €	1 534 612 €	1 404 480 €	(130 132) €
197	320 719 €	581 639 €	664 224 €	1 566 581 €	1 456 224 €	(110 357) €
204	332 115 €	602 213 €	664 224 €	1 598 551 €	1 507 968 €	(90 583) €
211	343 511 €	622 786 €	664 224 €	1 630 521 €	1 559 712 €	(70 809) €
218	354 907 €	643 360 €	664 224 €	1 662 490 €	1 611 456 €	(51 034) €
225	366 303 €	663 933 €	664 224 €	1 694 460 €	1 663 200 €	(31 260) €
232	377 699 €	684 507 €	664 224 €	1 726 429 €	1 714 944 €	(11 485) €
239	389 095 €	705 080 €	664 224 €	1 758 399 €	1 766 688 €	8 289 €
246	400 491 €	725 654 €	664 224 €	1 790 369 €	1 818 432 €	28 063 €
253	411 887 €	746 227 €	664 224 €	1 822 338 €	1 870 176 €	47 838 €
260	423 283 €	766 801 €	664 224 €	1 854 308 €	1 921 920 €	67 612 €
267	434 680 €	787 374 €	664 224 €	1 886 277 €	1 973 664 €	87 387 €

Table 5.28: Costs and revenues for OLB-MXP summer route: ATR 72-600

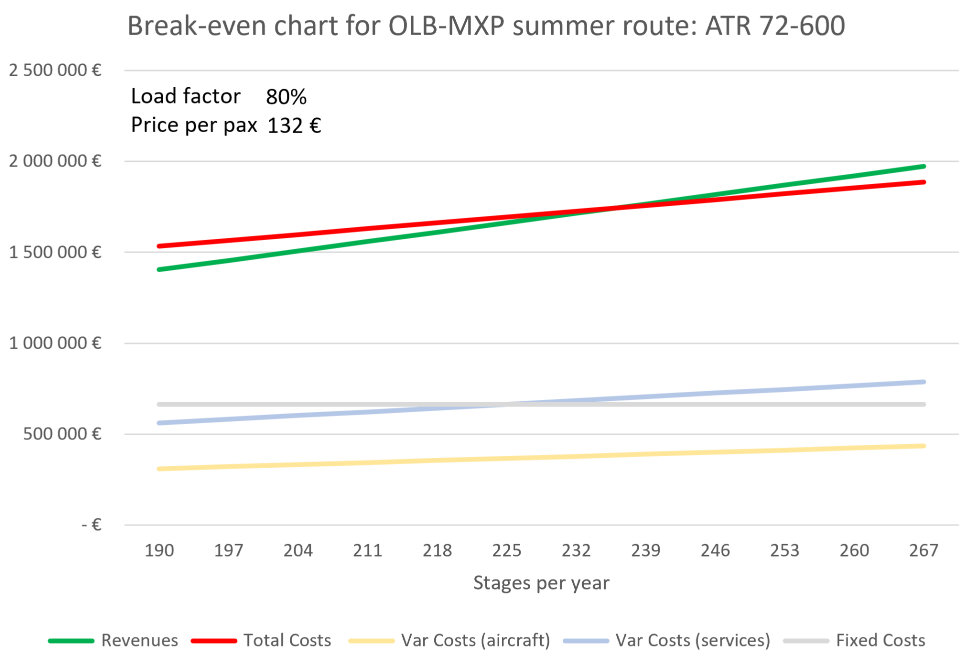

Figure 5.23: Break-even chart for OLB-MXP summer route: ATR 72-600

Costs and revenues for OLB-MXP summer route: ATR 72-600						
Average Load Factor: 90%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
190	309 323 €	578 382 €	664 224 €	1 551 928 €	1 424 430 €	(127 498) €
197	320 719 €	599 594 €	664 224 €	1 584 536 €	1 476 909 €	(107 627) €
204	332 115 €	620 805 €	664 224 €	1 617 143 €	1 529 388 €	(87 755) €
211	343 511 €	642 017 €	664 224 €	1 649 751 €	1 581 867 €	(67 884) €
218	354 907 €	663 228 €	664 224 €	1 682 359 €	1 634 346 €	(48 013) €
225	366 303 €	684 440 €	664 224 €	1 714 966 €	1 686 825 €	(28 141) €
232	377 699 €	705 651 €	664 224 €	1 747 574 €	1 739 304 €	(8 270) €
239	389 095 €	726 863 €	664 224 €	1 780 181 €	1 791 783 €	11 602 €
246	400 491 €	748 074 €	664 224 €	1 812 789 €	1 844 262 €	31 473 €
253	411 887 €	769 286 €	664 224 €	1 845 397 €	1 896 741 €	51 344 €
260	423 283 €	790 497 €	664 224 €	1 878 004 €	1 949 220 €	71 216 €
267	434 680 €	811 709 €	664 224 €	1 910 612 €	2 001 699 €	91 087 €

Table 5.29: Costs and revenues for OLB-MXP summer route: ATR 72-600

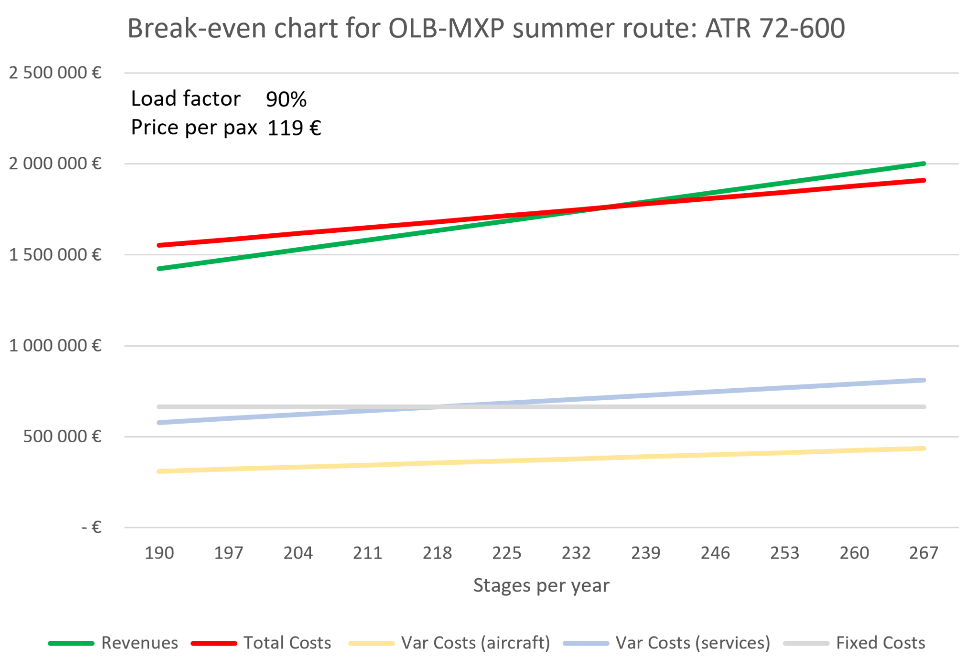

Figure 5.24: Break-even chart for OLB-MXP summer route: ATR 72-600

Costs and revenues for TRN-OLB summer route: ATR 72-600						
Average Load Factor: 80%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
94	156 236 €	272 722 €	339 061 €	768 018 €	694 848 €	(73 170) €
98	162 884 €	284 327 €	339 061 €	786 272 €	724 416 €	(61 856) €
102	169 533 €	295 932 €	339 061 €	804 525 €	753 984 €	(50 541) €
106	176 181 €	307 537 €	339 061 €	822 779 €	783 552 €	(39 227) €
110	182 829 €	319 142 €	339 061 €	841 032 €	813 120 €	(27 912) €
114	189 478 €	330 748 €	339 061 €	859 286 €	842 688 €	(16 598) €
118	196 126 €	342 353 €	339 061 €	877 539 €	872 256 €	(5 283) €
122	202 774 €	353 958 €	339 061 €	895 793 €	901 824 €	6 031 €
126	209 423 €	365 563 €	339 061 €	914 046 €	931 392 €	17 346 €
130	216 071 €	377 168 €	339 061 €	932 300 €	960 960 €	28 660 €
134	222 719 €	388 773 €	339 061 €	950 553 €	990 528 €	39 975 €
138	229 368 €	400 379 €	339 061 €	968 807 €	1 020 096 €	51 289 €

Table 5.30: Costs and revenues for TRN-OLB summer route: ATR 72-600

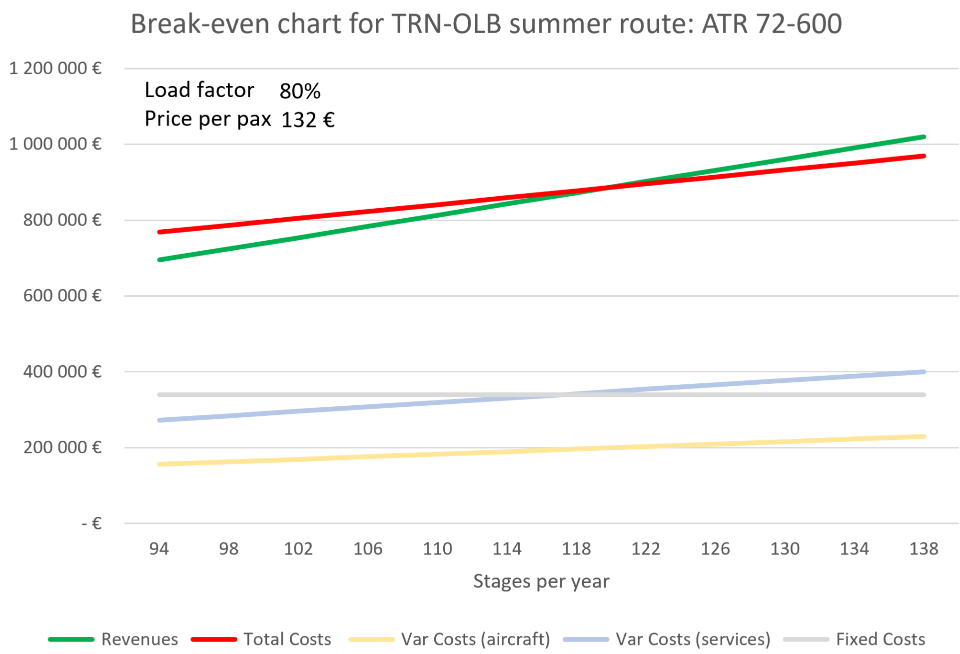

Figure 5.25: Break-even chart for TRN-OLB summer route: ATR 72-600

Costs and revenues for TRN-OLB summer route: ATR 72-600						
Average Load Factor: 90%				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
94	156 236 €	286 730 €	339 061 €	782 027 €	704 718 €	(77 309) €
98	162 884 €	298 932 €	339 061 €	800 877 €	734 706 €	(66 171) €
102	169 533 €	311 133 €	339 061 €	819 726 €	764 694 €	(55 032) €
106	176 181 €	323 334 €	339 061 €	838 576 €	794 682 €	(43 894) €
110	182 829 €	335 536 €	339 061 €	857 426 €	824 670 €	(32 756) €
114	189 478 €	347 737 €	339 061 €	876 275 €	854 658 €	(21 617) €
118	196 126 €	359 938 €	339 061 €	895 125 €	884 646 €	(10 479) €
122	202 774 €	372 140 €	339 061 €	913 975 €	914 634 €	659 €
126	209 423 €	384 341 €	339 061 €	932 824 €	944 622 €	11 798 €
130	216 071 €	396 542 €	339 061 €	951 674 €	974 610 €	22 936 €
134	222 719 €	408 743 €	339 061 €	970 523 €	1 004 598 €	34 075 €
138	229 368 €	420 945 €	339 061 €	989 373 €	1 034 586 €	45 213 €

Table 5.31: Costs and revenues for TRN-OLB summer route: ATR 72-600

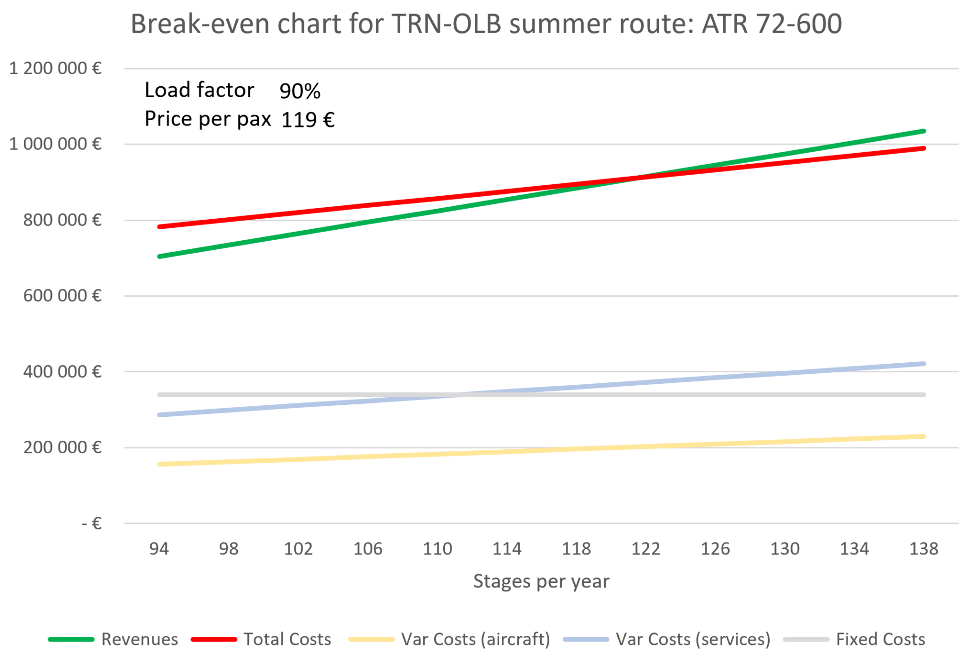

Figure 5.26: Break-even chart for TRN-OLB summer route: ATR 72-600

5.3.3 Dash 8-400

Costs and revenues for OLB-MXP summer route: Dash 8-400						
Average Load Factor: 80%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
190	287 035 €	605 134 €	772 684 €	1 664 853 €	1 524 864 €	(139 989) €
197	297 610 €	627 331 €	772 684 €	1 697 625 €	1 581 043 €	(116 582) €
204	308 185 €	649 528 €	772 684 €	1 730 397 €	1 637 222 €	(93 174) €
211	318 760 €	671 725 €	772 684 €	1 763 169 €	1 693 402 €	(69 767) €
218	329 335 €	693 922 €	772 684 €	1 795 941 €	1 749 581 €	(46 360) €
225	339 910 €	716 119 €	772 684 €	1 828 713 €	1 805 760 €	(22 953) €
232	350 485 €	738 316 €	772 684 €	1 861 485 €	1 861 939 €	454 €
239	361 060 €	760 513 €	772 684 €	1 894 257 €	1 918 118 €	23 861 €
246	371 635 €	782 710 €	772 684 €	1 927 029 €	1 974 298 €	47 268 €
253	382 210 €	804 907 €	772 684 €	1 959 801 €	2 030 477 €	70 676 €
260	392 785 €	827 105 €	772 684 €	1 992 573 €	2 086 656 €	94 083 €
267	403 360 €	849 302 €	772 684 €	2 025 345 €	2 142 835 €	117 490 €

Table 5.32: Costs and revenues for OLB-MXP summer route: Dash 8-400

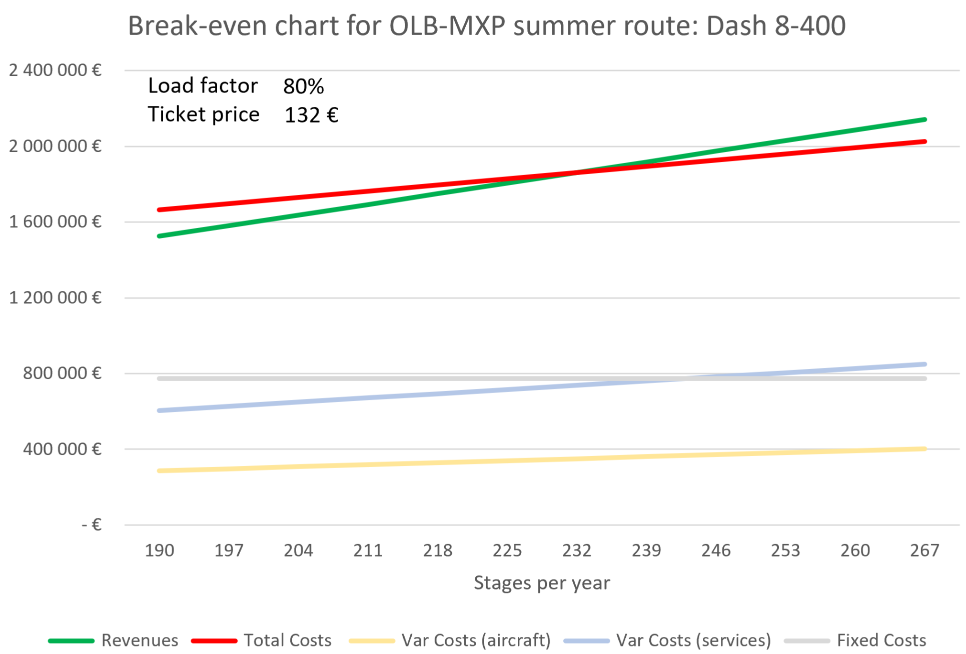

Figure 5.27: Break-even chart for OLB-MXP summer route: Dash 8-400

Costs and revenues for OLB-MXP summer route: Dash 8-400						
Average Load Factor: 90%				Average Price per Pax: 119 €		
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Profit
190	287 035 €	623 935 €	772 684 €	1 683 654 €	1 546 524 €	(137 130) €
197	297 610 €	646 824 €	772 684 €	1 717 118 €	1 603 501 €	(113 617) €
204	308 185 €	669 714 €	772 684 €	1 750 583 €	1 660 478 €	(90 105) €
211	318 760 €	692 604 €	772 684 €	1 784 048 €	1 717 456 €	(66 592) €
218	329 335 €	715 494 €	772 684 €	1 817 512 €	1 774 433 €	(43 080) €
225	339 910 €	738 383 €	772 684 €	1 850 977 €	1 831 410 €	(19 567) €
232	350 485 €	761 273 €	772 684 €	1 884 442 €	1 888 387 €	3 945 €
239	361 060 €	784 163 €	772 684 €	1 917 907 €	1 945 364 €	27 458 €
246	371 635 €	807 053 €	772 684 €	1 951 371 €	2 002 342 €	50 970 €
253	382 210 €	829 942 €	772 684 €	1 984 836 €	2 059 319 €	74 483 €
260	392 785 €	852 832 €	772 684 €	2 018 301 €	2 116 296 €	97 995 €
267	403 360 €	875 722 €	772 684 €	2 051 765 €	2 173 273 €	121 508 €

Table 5.33: Costs and revenues for OLB-MXP summer route: Dash 8-400

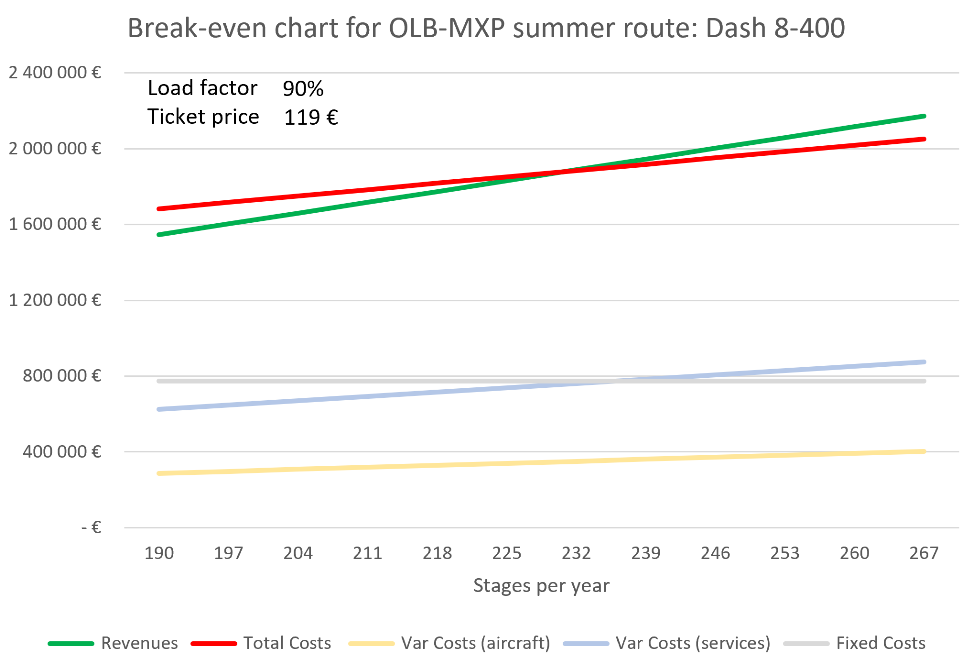

Figure 5.28: Break-even chart for OLB-MXP summer route: Dash 8-400

Costs and revenues for TRN-OLB summer route: Dash 8-400						
Average Load Factor: 80%				Average Price per Pax: 132 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
94	144 843 €	300 289 €	394 483 €	839 615 €	754 406 €	(85 208) €
98	151 006 €	313 067 €	394 483 €	858 557 €	786 509 €	(72 048) €
102	157 170 €	325 845 €	394 483 €	877 498 €	818 611 €	(58 887) €
106	163 333 €	338 624 €	394 483 €	896 440 €	850 714 €	(45 726) €
110	169 497 €	351 402 €	394 483 €	915 382 €	882 816 €	(32 566) €
114	175 660 €	364 180 €	394 483 €	934 324 €	914 918 €	(19 405) €
118	181 824 €	376 958 €	394 483 €	953 265 €	947 021 €	(6 245) €
122	187 987 €	389 737 €	394 483 €	972 207 €	979 123 €	6 916 €
126	194 151 €	402 515 €	394 483 €	991 149 €	1 011 226 €	20 077 €
130	200 314 €	415 293 €	394 483 €	1 010 091 €	1 043 328 €	33 237 €
134	206 478 €	428 071 €	394 483 €	1 029 032 €	1 075 430 €	46 398 €
138	212 641 €	440 850 €	394 483 €	1 047 974 €	1 107 533 €	59 559 €

Table 5.34: Costs and revenues for TRN-OLB summer route: Dash 8-400

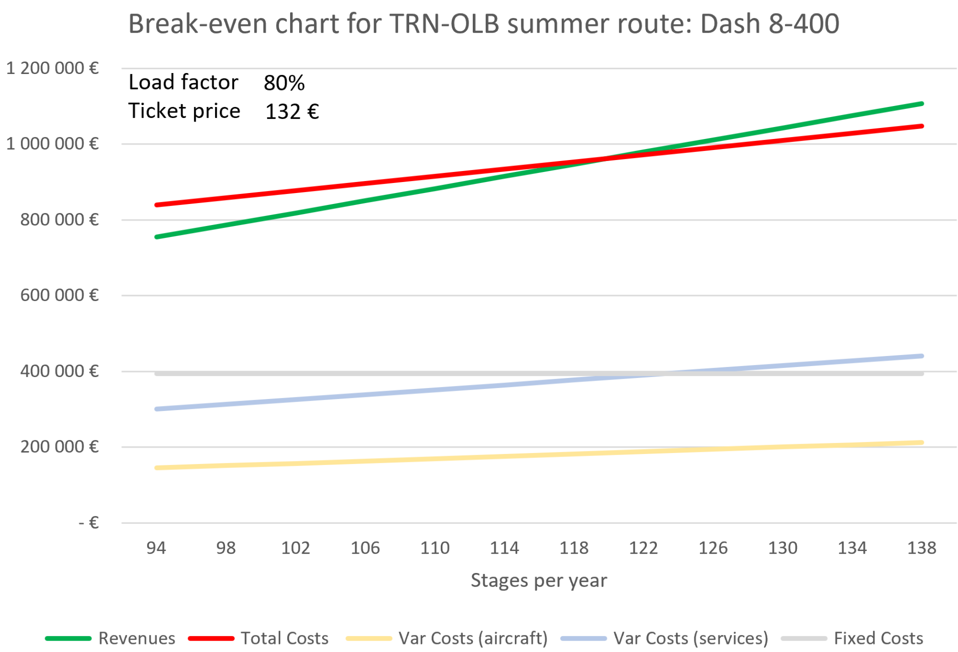

Figure 5.29: Break-even chart for TRN-OLB summer route: Dash 8-400

Costs and revenues for TRN-OLB summer route: Dash 8-400						
Average Load Factor: 90%				Average Price per Pax: 119 €		
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Profit
94	144 843 €	315 498 €	394 483 €	854 824 €	765 122 €	(89 702) €
98	151 006 €	328 924 €	394 483 €	874 413 €	797 681 €	(76 733) €
102	157 170 €	342 349 €	394 483 €	894 002 €	830 239 €	(63 763) €
106	163 333 €	355 775 €	394 483 €	913 591 €	862 798 €	(50 794) €
110	169 497 €	369 200 €	394 483 €	933 180 €	895 356 €	(37 824) €
114	175 660 €	382 626 €	394 483 €	952 769 €	927 914 €	(24 855) €
118	181 824 €	396 051 €	394 483 €	972 358 €	960 473 €	(11 885) €
122	187 987 €	409 477 €	394 483 €	991 947 €	993 031 €	1 084 €
126	194 151 €	422 902 €	394 483 €	1 011 536 €	1 025 590 €	14 053 €
130	200 314 €	436 328 €	394 483 €	1 031 125 €	1 058 148 €	27 023 €
134	206 478 €	449 753 €	394 483 €	1 050 714 €	1 090 706 €	39 992 €
138	212 641 €	463 179 €	394 483 €	1 070 303 €	1 123 265 €	52 962 €

Table 5.35: Costs and revenues for TRN-OLB summer route: Dash 8-400

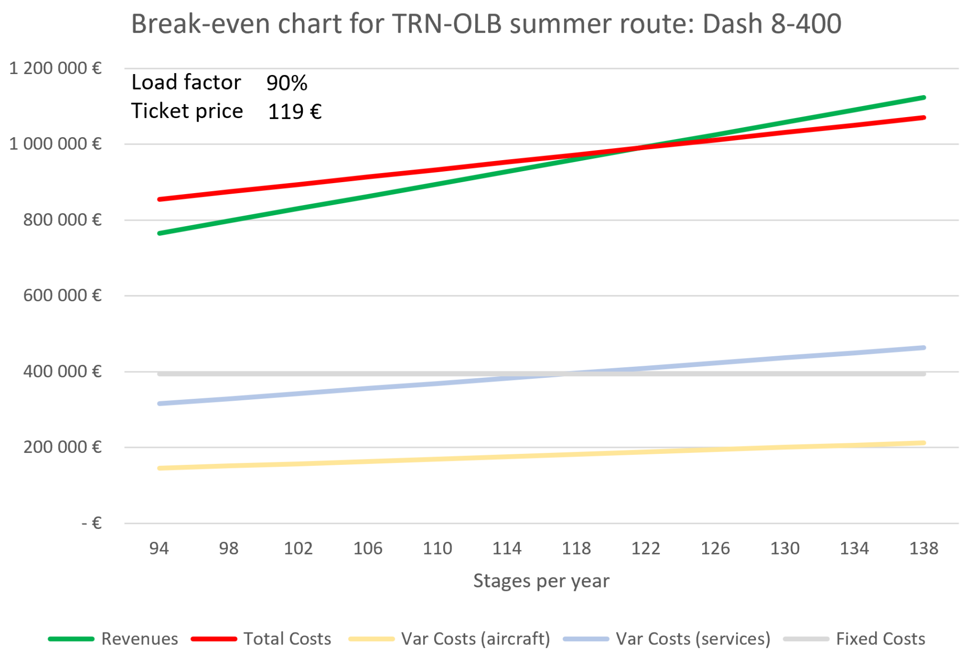

Figure 5.30: Break-even chart for TRN-OLB summer route: Dash 8-400

5.4 Operations from Elba with given passenger volumes

This scenario is based on the following assumptions:

- The passenger volume is estimated in terms of number of passengers per year on a seasonal basis. Thus, total yearly passengers are obtained by summing estimated passengers for each season. The average load factor is calculated from the number of passengers and the number of stages operated.
- Costs depending on the number of passengers flown have been assessed using estimated passenger volumes.
- Revenues are calculated at break-even point price. Thus, net profits are identically zero, and total costs curve overlaps revenues curve. This assumption gives the opportunity to assess the effects of the number of stages or flight hours on average costs per passenger.

Number of stages (Elba case study)				
Route		**Total Stages**		**Total stages per year**
Origin	Dest	Summer	Winter	
EBA	MXP	217	105	322
MXP	EBA	217	105	322
EBA	FCO	217	105	322
FCO	EBA	217	105	322
Total		**868**	**420**	**1 288**

Table 5.36: Number of stages (Elba case study)

Estimated passenger volumes per year (Elba case study)			
Route		**P2012**	**L 410 UVP-E20**
Origin	Dest		
EBA	MXP	2 150	2 750
MXP	EBA	2 150	2 750
EBA	FCO	2 150	2 750
FCO	EBA	2 150	2 750
Total		8 600	11 000

Table 5.37: Estimated passenger volumes per year (Elba case study)

5.4.1 L 410 UVP-E20

Total operating costs of a fleet of one L 410 UVP-E20 with given passenger volumes					
	Per Year	**Per Stage**	**Per Flt Hr**	**Per ASK**	**Per RPK**
Variable Costs (aircraft)					
Fuel, oil	123 186 €	96 €	75 €	2.09 €c	4.17 €c
Parts & Maintenance	*441 767 €*	*343 €*	*269 €*	*7.51 €c*	*14.94 €c*
Engine overhaul	*373 696 €*	*290 €*	*228 €*	*6.35 €c*	*12.64 €c*
Maintenance audit	*40 773 €*	*32 €*	*25 €*	*0.69 €c*	*1.38 €c*
Maintenance total	856 237 €	665 €	521 €	14.55 €c	28.97 €c
Total Variable Costs (aircraft)	**979 423 €**	**760 €**	**596 €**	**16.65 €c**	**33.13 €c**
Variable Costs (services)					
Airport costs	1 257 274 €	976 €	766 €	21.37 €c	42.53 €c
ANS costs	96 218 €	75 €	59 €	1.64 €c	3.26 €c
Total Variable Costs (services)	**1 353 492 €**	**1 051 €**	**824 €**	**23.00 €c**	**45.79 €c**
Fixed Costs					
Salaries total	310 500 €	241 €	189 €	5.28 €c	10.50 €c
Crew training	33 522 €	26 €	20 €	0.57 €c	1.13 €c
Safety audit	48 000 €	37 €	29 €	0.82 €c	1.62 €c
Insurance total	37 400 €	29 €	23 €	0.64 €c	1.27 €c
Depreciation	220 000 €	171 €	134 €	3.74 €c	7.44 €c
Total Fixed Costs	**649 422 €**	**504 €**	**395 €**	**11.04 €c**	**21.97 €c**
TOTAL COSTS	**2 982 338 €**	**2 315 €**	**1 816 €**	**50.69 €c**	**100.89 €c**

Table 5.38: Total operating costs of a fleet of one L 410 UVP-E20 with given passenger volumes

Costs and revenues for EBA-MXP route: L 410 UVP-E20						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
322	**272 235 €**	**330 990 €**	**180 056 €**	**783 281 €**	**783 281 €**	**285 €**
310	262 090 €	320 295 €	180 056 €	762 441 €	762 441 €	277 €
315	266 317 €	324 751 €	180 056 €	771 124 €	771 124 €	280 €
320	270 544 €	329 208 €	180 056 €	779 808 €	779 808 €	284 €
325	274 771 €	333 664 €	180 056 €	788 491 €	788 491 €	287 €
330	278 999 €	338 121 €	180 056 €	797 175 €	797 175 €	290 €
335	283 226 €	342 577 €	180 056 €	805 859 €	805 859 €	293 €
340	287 453 €	347 033 €	180 056 €	814 542 €	814 542 €	296 €
345	291 680 €	351 490 €	180 056 €	823 226 €	823 226 €	299 €
350	295 908 €	355 946 €	180 056 €	831 910 €	831 910 €	303 €
355	300 135 €	360 402 €	180 056 €	840 593 €	840 593 €	306 €
360	304 362 €	364 859 €	180 056 €	849 277 €	849 277 €	309 €
365	308 589 €	369 315 €	180 056 €	857 960 €	857 960 €	312 €

Table 5.39: Costs and revenues for EBA-MXP route: L 410 UVP-E20

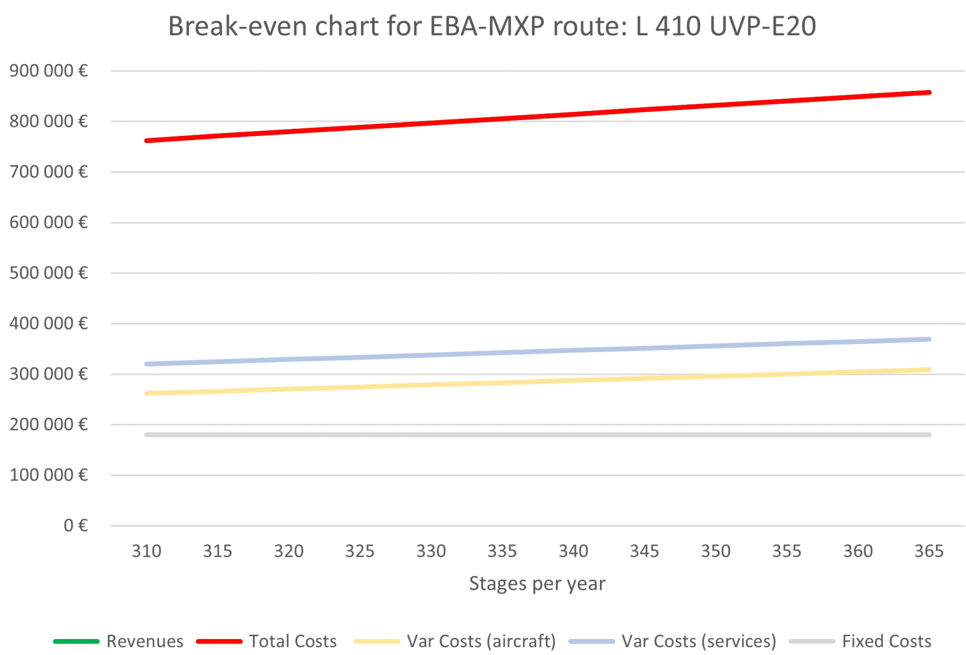

Figure 5.31: Break-even chart for EBA-MXP route: L 410 UVP-E20

5.4.2 P2012

Total operating costs of a fleet of one P2012 with given passenger volumes					
	Per Year	**Per Stage**	**Per Flt Hr**	**Per ASK**	**Per RPK**
Variable Costs (aircraft)					
Fuel, oil	436 680 €	339 €	248 €	14.02 €c	18.90 €c
Parts & Maintenance	*184 842 €*	*144 €*	*105 €*	*5.93 €c*	*8.00 €c*
Engine overhaul	*146 113 €*	*113 €*	*83 €*	*4.69 €c*	*6.32 €c*
Maintenance audit	*16 548 €*	*13 €*	*9 €*	*0.53 €c*	*0.72 €c*
Maintenance total	347 503 €	270 €	197 €	11.16 €c	15.04 €c
Total Variable Costs (aircraft)	**784 183 €**	**609 €**	**445 €**	**25.17 €c**	**33.93 €c**
Variable Costs (services)					
Airport costs	784 791 €	609 €	446 €	25.19 €c	33.96 €c
ANS costs	69 895 €	54 €	40 €	2.24 €c	3.02 €c
Total Variable Costs (services)	**854 686 €**	**664 €**	**486 €**	**27.44 €c**	**36.98 €c**
Fixed Costs					
Salaries total	205 500 €	160 €	117 €	6.60 €c	8.89 €c
Crew training	14 297 €	11 €	8 €	0.46 €c	0.62 €c
Safety audit	48 000 €	37 €	27 €	1.54 €c	2.08 €c
Insurance total	19 975 €	16 €	11 €	0.64 €c	0.86 €c
Depreciation	117 500 €	91 €	67 €	3.77 €c	5.08 €c
Total Fixed Costs	**405 272 €**	**315 €**	**230 €**	**13.01 €c**	**17.54 €c**
TOTAL COSTS	**2 044 142 €**	**1 587 €**	**1 161 €**	**65.62 €c**	**88.45 €c**

Table 5.40: Total operating costs of a fleet of one P2012 with given passenger volumes

Costs and revenues for EBA-MXP route: P2012						
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Cost per Pax**
322	**217 792 €**	**191 755 €**	**112 831 €**	**522 379 €**	**522 379 €**	**243 €**
310	209 676 €	185 891 €	112 831 €	508 398 €	508 398 €	236 €
315	213 058 €	188 335 €	112 831 €	514 224 €	514 224 €	239 €
320	216 440 €	190 778 €	112 831 €	520 049 €	520 049 €	242 €
325	219 821 €	193 221 €	112 831 €	525 874 €	525 874 €	245 €
330	223 203 €	195 665 €	112 831 €	531 699 €	531 699 €	247 €
335	226 585 €	198 108 €	112 831 €	537 525 €	537 525 €	250 €
340	229 967 €	200 552 €	112 831 €	543 350 €	543 350 €	253 €
345	233 349 €	202 995 €	112 831 €	549 175 €	549 175 €	255 €
350	236 731 €	205 438 €	112 831 €	555 000 €	555 000 €	258 €
355	240 113 €	207 882 €	112 831 €	560 826 €	560 826 €	261 €
360	243 495 €	210 325 €	112 831 €	566 651 €	566 651 €	264 €
365	246 876 €	212 769 €	112 831 €	572 476 €	572 476 €	266 €

Table 5.41: Costs and revenues for EBA-MXP route: P2012

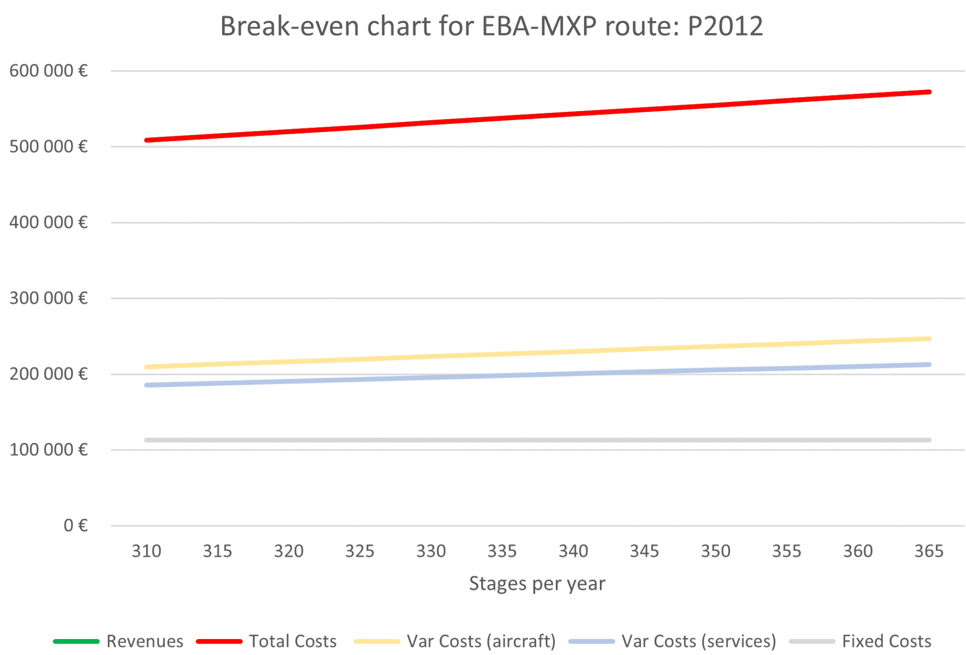

Figure 5.32: Break-even chart for EBA-MXP route: P2012

5.5 Operations from Elba with variable load factors

This scenario is based on the following assumptions:

- The number of stages per year has been used as the independent variable.
- Average load factor and average price per passenger have been assumed as variable parameters.
- The passenger volume is estimated in terms of average load factor. Thus, total yearly passengers are obtained by multiplying estimated average load factor for each route by the number of available seats. The average load factor is varied to assess its effects on results.
- Costs depending on the number of passengers flown have been assessed using the number of passengers given by variable load factors.
- Revenues are calculated by multiplying average price per passenger by the number of passengers given by variable load factors. Net profits are given by the difference between revenues and total operating costs. This assumption gives the opportunity to assess the effects the independent variable (number of stages) and the parameters (average load factor and average price per passenger) have on results.

5.5.1 L 410 UVP-E20

Costs and revenues for EBA-MXP route: L 410 UVP-E20						
Average Load Factor: 47% (8 pax)				Average Price per Pax: 299 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
310	262 090 €	315 925 €	180 056 €	758 071 €	740 593 €	(17 478) €
315	266 317 €	321 021 €	180 056 €	767 394 €	752 538 €	(14 856) €
320	270 544 €	326 117 €	180 056 €	776 717 €	764 483 €	(12 233) €
325	274 771 €	331 212 €	180 056 €	786 039 €	776 428 €	(9 611) €
330	278 999 €	336 308 €	180 056 €	795 362 €	788 373 €	(6 989) €
335	283 226 €	341 403 €	180 056 €	804 685 €	800 318 €	(4 367) €
340	287 453 €	346 499 €	180 056 €	814 008 €	812 263 €	(1 745) €
345	291 680 €	351 594 €	180 056 €	823 331 €	824 208 €	878 €
350	295 908 €	356 690 €	180 056 €	832 654 €	836 154 €	3 500 €
355	300 135 €	361 786 €	180 056 €	841 976 €	848 099 €	6 122 €
360	304 362 €	366 881 €	180 056 €	851 299 €	860 044 €	8 744 €
365	308 589 €	371 977 €	180 056 €	860 622 €	871 989 €	11 367 €

Table 5.42: Costs and revenues for EBA-MXP route: L 410 UVP-E20

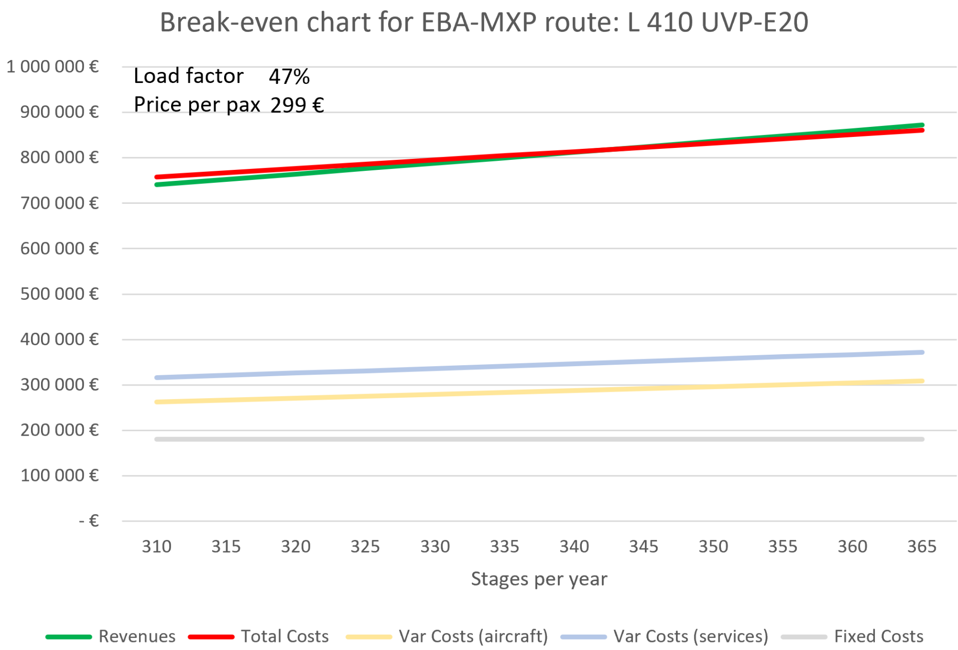

Figure 5.33: Break-even chart for EBA-MXP route: L 410 UVP-E20

Costs and revenues for EBA-MXP route: L 410 UVP-E20						
Average Load Factor: 77% (13 pax)				Average Price per Pax: 190 €		
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Profit
310	262 090 €	341 221 €	180 056 €	783 367 €	771 001 €	(12 366) €
315	266 317 €	346 725 €	180 056 €	793 098 €	783 437 €	(9 661) €
320	270 544 €	352 229 €	180 056 €	802 829 €	795 872 €	(6 957) €
325	274 771 €	357 732 €	180 056 €	812 559 €	808 308 €	(4 252) €
330	278 999 €	363 236 €	180 056 €	822 290 €	820 743 €	(1 547) €
335	283 226 €	368 739 €	180 056 €	832 021 €	833 179 €	1 157 €
340	287 453 €	374 243 €	180 056 €	841 752 €	845 614 €	3 862 €
345	291 680 €	379 746 €	180 056 €	851 483 €	858 050 €	6 567 €
350	295 908 €	385 250 €	180 056 €	861 214 €	870 485 €	9 271 €
355	300 135 €	390 754 €	180 056 €	870 944 €	882 921 €	11 976 €
360	304 362 €	396 257 €	180 056 €	880 675 €	895 356 €	14 681 €
365	308 589 €	401 761 €	180 056 €	890 406 €	907 792 €	17 385 €

Table 5.43: Costs and revenues for EBA-MXP route: L 410 UVP-E20

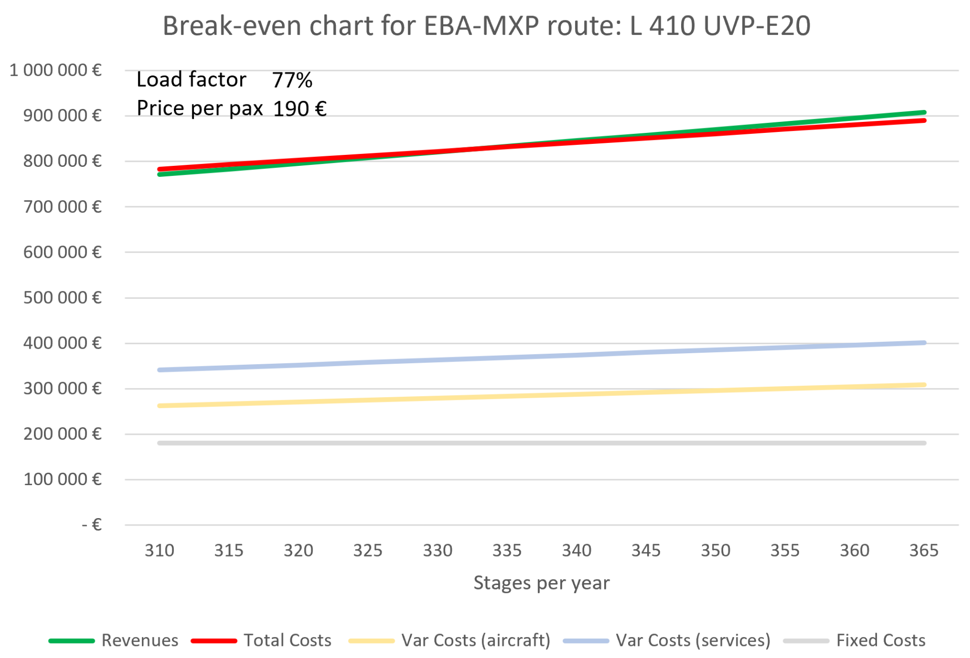

Figure 5.34: Break-even chart for EBA-MXP route: L 410 UVP-E20

5.5.2 P2012

Costs and revenues for EBA-MXP route: P2012						
Average Load Factor: 67% (6 pax)				Average Price per Pax: 265 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
310	209 676 €	181 400 €	112 831 €	503 907 €	495 365 €	(8 543) €
315	213 058 €	184 326 €	112 831 €	510 215 €	503 354 €	(6 860) €
320	216 440 €	187 252 €	112 831 €	516 522 €	511 344 €	(5 178) €
325	219 821 €	190 177 €	112 831 €	522 830 €	519 334 €	(3 496) €
330	223 203 €	193 103 €	112 831 €	529 138 €	527 324 €	(1 814) €
335	226 585 €	196 029 €	112 831 €	535 445 €	535 313 €	(132) €
340	229 967 €	198 955 €	112 831 €	541 753 €	543 303 €	1 550 €
345	233 349 €	201 881 €	112 831 €	548 061 €	551 293 €	3 232 €
350	236 731 €	204 806 €	112 831 €	554 368 €	559 283 €	4 914 €
355	240 113 €	207 732 €	112 831 €	560 676 €	567 272 €	6 596 €
360	243 495 €	210 658 €	112 831 €	566 984 €	575 262 €	8 278 €
365	246 876 €	213 584 €	112 831 €	573 291 €	583 252 €	9 960 €

Table 5.44: Costs and revenues for EBA-MXP route: P2012

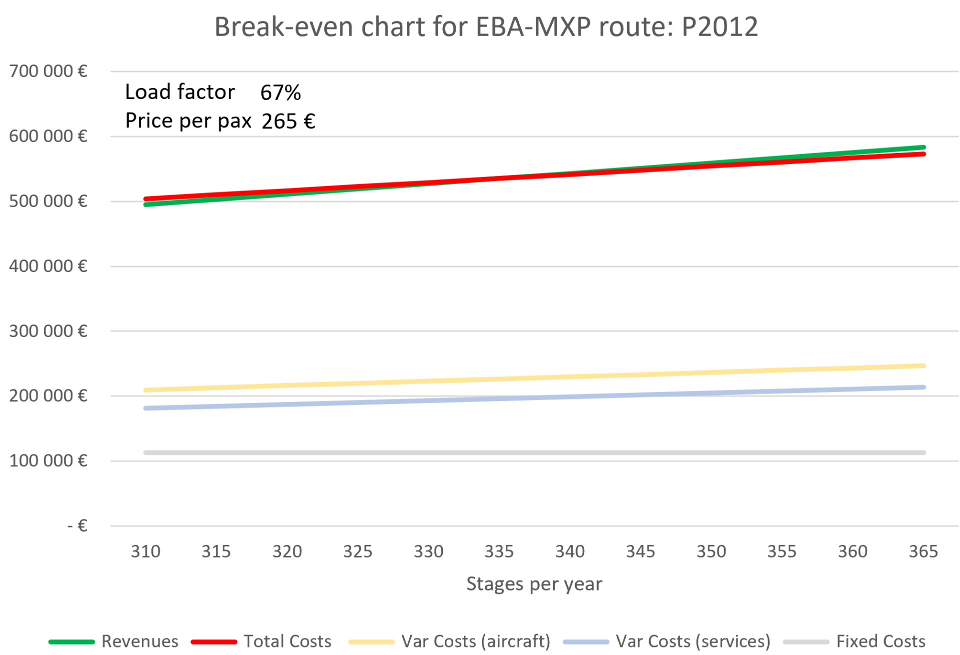

Figure 5.35: Break-even chart for EBA-MXP route: P2012

Costs and revenues for EBA-MXP route: P2012						
Average Load Factor: 89% (8 pax)				Average Price per Pax: 205 €		
Stages per year	Var Costs (aircraft)	Var Costs (services)	Fixed Costs	Total Costs	Revenues	Profit
310	209 676 €	191 221 €	112 831 €	513 728 €	509 036 €	(4 692) €
315	213 058 €	194 305 €	112 831 €	520 194 €	517 246 €	(2 948) €
320	216 440 €	197 389 €	112 831 €	526 660 €	525 456 €	(1 204) €
325	219 821 €	200 473 €	112 831 €	533 126 €	533 666 €	540 €
330	223 203 €	203 558 €	112 831 €	539 592 €	541 877 €	2 284 €
335	226 585 €	206 642 €	112 831 €	546 058 €	550 087 €	4 029 €
340	229 967 €	209 726 €	112 831 €	552 524 €	558 297 €	5 773 €
345	233 349 €	212 810 €	112 831 €	558 990 €	566 507 €	7 517 €
350	236 731 €	215 894 €	112 831 €	565 456 €	574 718 €	9 261 €
355	240 113 €	218 979 €	112 831 €	571 922 €	582 928 €	11 005 €
360	243 495 €	222 063 €	112 831 €	578 389 €	591 138 €	12 749 €
365	246 876 €	225 147 €	112 831 €	584 855 €	599 348 €	14 494 €

Table 5.45: Costs and revenues for EBA-MXP route: P2012

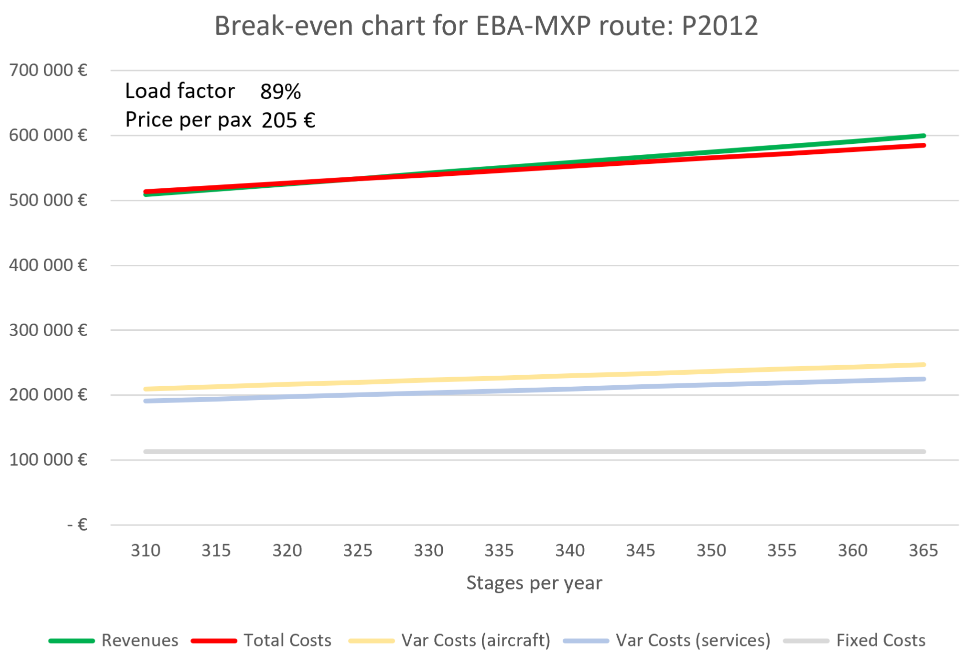

Figure 5.36: Break-even chart for EBA-MXP route: P2012

5.6 Operations from Elba with variable load factors and different network

This scenario is based on the following assumptions:

- The number of stages per year has been used as the independent variable.
- Average load factor and average price per passenger have been assumed as variable parameters.
- The passenger volume is estimated in terms of average load factor. Thus, total yearly passengers are obtained by multiplying estimated average load factor for each route by the number of available seats. The average load factor is varied to assess its effects on results.
- Costs depending on the number of passengers flown have been assessed using the number of passengers given by variable load factors.
- Revenues are calculated by multiplying average price per passenger by the number of passengers given by variable load factors. Net profits are given by the difference between revenues and total operating costs. This assumption gives the opportunity to assess the effects the independent variable (number of stages) and the parameters (average load factor and average price per passenger) have on results.
- The network has been expanded to include round-trip connections between Elba (EBA/LIRJ) and Pisa (PSA/LIRP). The frequency of the flights on the schedule has been reduced to schedule the new route.

5.6.1 L 410 UVP-E20

Costs and revenues for PSA-EBA route: L 410 UVP-E20						
Average Load Factor: 47% (8 pax)				Average Price per Pax: 165 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
160	68 286 €	86 731 €	63 358 €	218 375 €	210 936 €	(7 439) €
165	70 420 €	89 441 €	63 358 €	223 220 €	217 528 €	(5 692) €
170	72 554 €	92 151 €	63 358 €	228 064 €	224 120 €	(3 944) €
175	74 688 €	94 862 €	63 358 €	232 908 €	230 711 €	(2 197) €
180	76 822 €	97 572 €	63 358 €	237 752 €	237 303 €	(449) €
185	78 956 €	100 282 €	63 358 €	242 597 €	243 895 €	1 298 €
190	81 090 €	102 993 €	63 358 €	247 441 €	250 487 €	3 046 €
195	83 224 €	105 703 €	63 358 €	252 285 €	257 078 €	4 793 €
200	85 358 €	108 413 €	63 358 €	257 129 €	263 670 €	6 541 €
205	87 492 €	111 124 €	63 358 €	261 974 €	270 262 €	8 288 €
210	89 626 €	113 834 €	63 358 €	266 818 €	276 854 €	10 035 €
215	91 760 €	116 544 €	63 358 €	271 662 €	283 445 €	11 783 €

Table 5.46: Costs and revenues for PSA-EBA route: L 410 UVP-E20

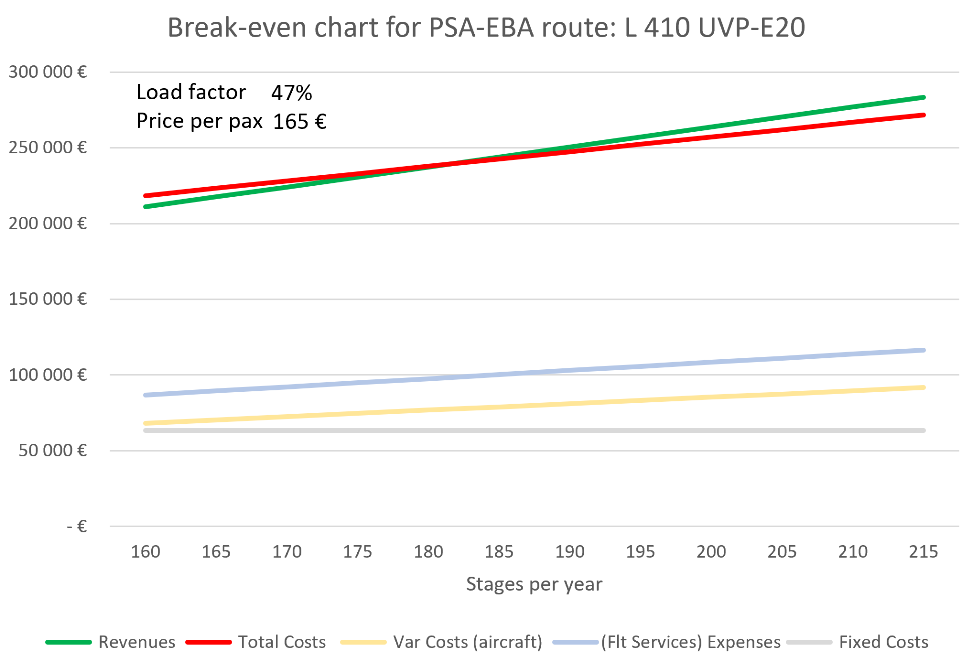

Figure 5.37: Break-even chart for PSA-EBA route: L 410 UVP-E20

Costs and revenues for PSA-EBA route: L 410 UVP-E20						
Average Load Factor: 77% (13 pax)				Average Price per Pax: 105 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
160	68 286 €	93 960 €	63 358 €	225 605 €	219 912 €	(5 693) €
165	70 420 €	96 897 €	63 358 €	230 675 €	226 784 €	(3 891) €
170	72 554 €	99 833 €	63 358 €	235 745 €	233 657 €	(2 089) €
175	74 688 €	102 769 €	63 358 €	240 816 €	240 529 €	(287) €
180	76 822 €	105 705 €	63 358 €	245 886 €	247 401 €	1 515 €
185	78 956 €	108 642 €	63 358 €	250 956 €	254 273 €	3 317 €
190	81 090 €	111 578 €	63 358 €	256 026 €	261 146 €	5 119 €
195	83 224 €	114 514 €	63 358 €	261 096 €	268 018 €	6 921 €
200	85 358 €	117 450 €	63 358 €	266 167 €	274 890 €	8 723 €
205	87 492 €	120 387 €	63 358 €	271 237 €	281 762 €	10 525 €
210	89 626 €	123 323 €	63 358 €	276 307 €	288 635 €	12 327 €
215	91 760 €	126 259 €	63 358 €	281 377 €	295 507 €	14 129 €

Table 5.47: Costs and revenues for PSA-EBA route: L 410 UVP-E20

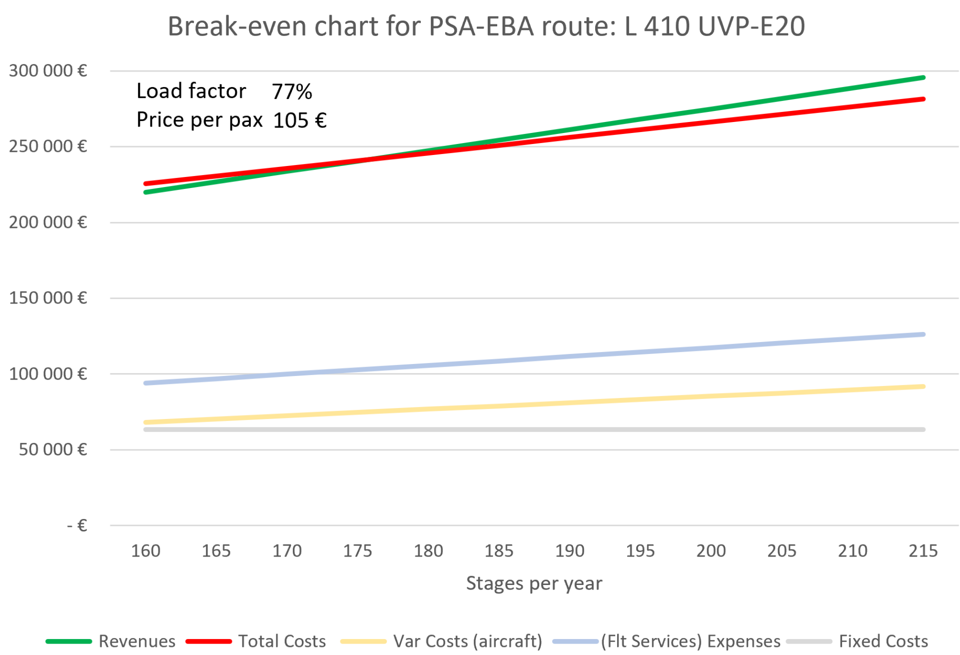

Figure 5.38: Break-even chart for PSA-EBA route: L 410 UVP-E20

5.6.2 P2012

Costs and revenues for PSA-EBA route: P2012						
Average Load Factor: 67% (6 pax)				Average Price per Pax: 150 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
160	56 083 €	55 927 €	39 261 €	151 270 €	144 720 €	(6 550) €
165	57 835 €	57 674 €	39 261 €	154 771 €	149 243 €	(5 528) €
170	59 588 €	59 422 €	39 261 €	158 271 €	153 765 €	(4 506) €
175	61 341 €	61 170 €	39 261 €	161 771 €	158 288 €	(3 484) €
180	63 093 €	62 917 €	39 261 €	165 272 €	162 810 €	(2 462) €
185	64 846 €	64 665 €	39 261 €	168 772 €	167 333 €	(1 439) €
190	66 598 €	66 413 €	39 261 €	172 272 €	171 855 €	(417) €
195	68 351 €	68 161 €	39 261 €	175 772 €	176 378 €	605 €
200	70 104 €	69 908 €	39 261 €	179 273 €	180 900 €	1 627 €
205	71 856 €	71 656 €	39 261 €	182 773 €	185 423 €	2 649 €
210	73 609 €	73 404 €	39 261 €	186 273 €	189 945 €	3 672 €
215	75 361 €	75 151 €	39 261 €	189 774 €	194 468 €	4 694 €

Table 5.48: Costs and revenues for PSA-EBA route: P2012

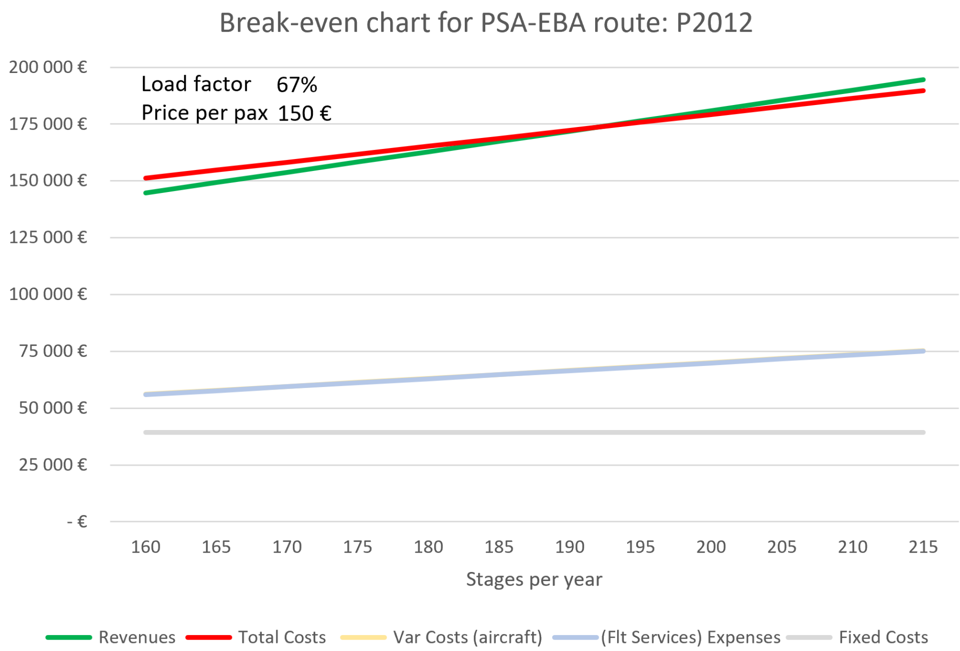

Figure 5.39: Break-even chart for PSA-EBA route: P2012

Costs and revenues for PSA-EBA route: P2012						
Average Load Factor: 89% (8 pax)				Average Price per Pax: 119 €		
Stages per year	**Var Costs (aircraft)**	**Var Costs (services)**	**Fixed Costs**	**Total Costs**	**Revenues**	**Profit**
160	56 083 €	58 733 €	39 261 €	154 077 €	152 510 €	(1 567) €
165	57 835 €	60 569 €	39 261 €	157 665 €	157 276 €	(389) €
170	59 588 €	62 404 €	39 261 €	161 253 €	162 042 €	789 €
175	61 341 €	64 240 €	39 261 €	164 841 €	166 808 €	1 967 €
180	63 093 €	66 075 €	39 261 €	168 429 €	171 574 €	3 145 €
185	64 846 €	67 911 €	39 261 €	172 017 €	176 340 €	4 323 €
190	66 598 €	69 746 €	39 261 €	175 605 €	181 106 €	5 501 €
195	68 351 €	71 581 €	39 261 €	179 193 €	185 872 €	6 679 €
200	70 104 €	73 417 €	39 261 €	182 781 €	190 638 €	7 857 €
205	71 856 €	75 252 €	39 261 €	186 369 €	195 404 €	9 035 €
210	73 609 €	77 088 €	39 261 €	189 957 €	200 170 €	10 213 €
215	75 361 €	78 923 €	39 261 €	193 545 €	204 936 €	11 391 €

Table 5.49: Costs and revenues for PSA-EBA route: P2012

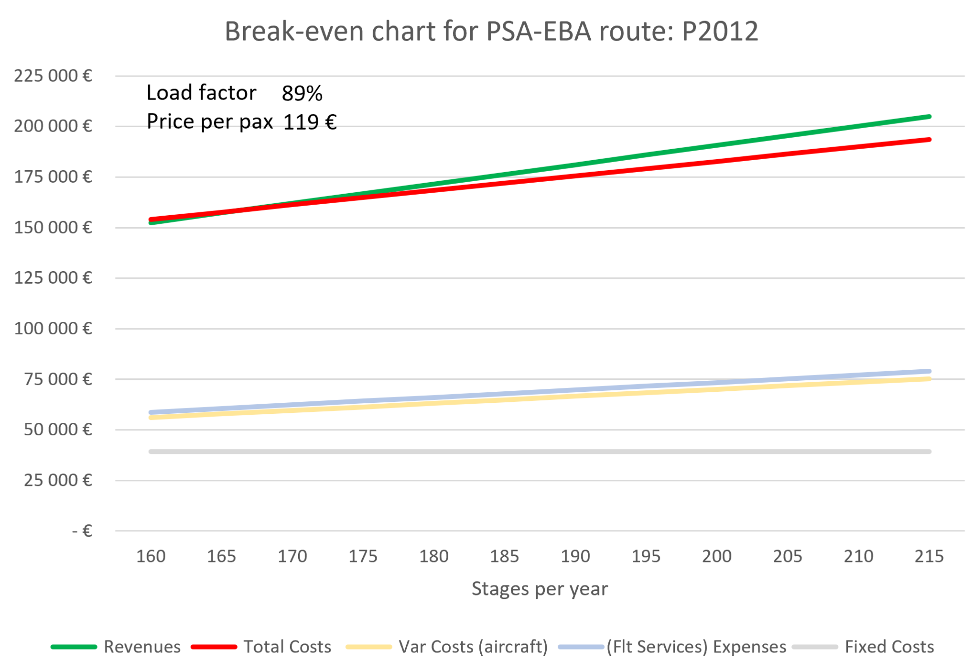

Figure 5.40: Break-even chart for PSA-EBA route: P2012

6. Outcomes and conclusions

6.1 Olbia case study

The results of Olbia case study show different behaviors among different aircraft types. Considering the scenario with given passenger volumes, total operating costs have different values for different types. Not surprisingly, larger types with higher seating capacity, namely Dash 8-400 and ATR 72-600, have higher total operating costs than the smaller ATR 42-600, since many cost items are dependent on aircraft dimensions, for example in terms of capacity, weights, and fuel consumption. Total operating costs show the effort required to operate a type, but they are not a good indicator of how well the aircraft performs in given environments. Costs per stage and costs per flight hour may be more suited to assess aircraft performance. Costs per stage are given by the total operating costs spread over the total number of stages flown. Thus, costs per stage are average costs and may differ from route to route. However, costs per stage are a good baseline to assess costs due for each route. Costs per flight hour may be better suited to assess operating costs, since they take into account en-route performance. In other words, costs per flight hour show how aircraft characteristics (e.g. en-route performance or maintainability) influence operating costs. Costs per stage are a good indicator of how services-related variable costs influence operating costs, while costs per flight hour are better suited to analyze the effects aircraft-related variable costs have on operating costs.
It is worth noting that the ratio between costs per stage and costs per flight hour varies among aircraft types. The Dash 8-400 shows lower ratios between costs per stage and costs per flight hour than ATR aircraft due to its higher cruise speed. The Dash 8-400 flies a lower number of hours than the ATR 42-600 and the ATR 72-600 while operating the same network. Dash 8-400 costs per flight hour are thus much higher than those due for ATR aircraft, since total operating costs are spread over a lower number of hours. However, the lower number of flight hours is not the only reason behind higher costs per flight hour. The Dash 8-400 higher cruise speed is achieved with higher fuel consumption, thus leading to higher fuel costs. Not surprisingly, fuel costs per stage and per flight hour due for the Dash 8-400 are considerably higher than those due for ATR aircraft.

Costs per available seat kilometer (ASK) and costs per revenue passenger kilometer (RPK) show different behaviors. It is worth noting that, since the different types operate the same network, costs per ASK and costs per RPK are linearly dependent on costs per seat and costs per passenger, respectively. Thus, as far as trends and behaviors are concerned, costs per ASK are equivalent to costs per seat, while costs per RPK are equivalent to costs per passenger. Metrics like ASK and RPK have been preferred since they may be used to compare aircraft performance on different networks.

Costs per ASK and costs per RPK show different behaviors among types. Costs per ASK decrease with aircraft capacity since the total operating costs are spread over a higher number of seats, thus reducing costs per seat, and consequently costs per ASK. The results show that costs per RPK have different behaviors. It may be pointed out that costs per RKP should decrease with capacity, since total operating costs are spread over a higher number of passengers. However, costs per RPK are influenced by the actual number of passengers flown, but not by the aircraft seating capacity. Types seating more passengers are more prone to lower average load factors, especially during lower-demand periods. It is worth noting that costs per RPK may show different trends. For example, higher demand may cause passenger volumes to rise, eventually leading to lower costs per RPK. Obviously, the lower the costs per RPK, the better for the airline.
Costs per RPK are a good metric to assess profitability, while costs per ASK may be used to assess potential profitability. In other words, the higher the costs per RPK, the higher the average price per passenger required to achieve the break-even point for that passenger volume, network, schedule, etc. Costs per ASK are the lower limit of costs per RPK as the average load factor goes to 100%. Obviously, achieving 100% average load factor over a high number of stages is very unlikely. However, costs per ASK, and thus per seat on a given network, may be considered as the lower limit of the average price per passenger required to achieve the break-even point. Lower-than-costs per seat prices will cause losses even with 100% load factors.

When analyzing costs per ASK (or per seat) and costs per RPK (or per passenger), it is worth noting that these metrics may lead to seemingly inconsistent results. Considering the scenario with given passenger volumes, it can be observed that costs per passenger, and thus prices per passenger in this scenario, tend to increase with the number of stages. The reason behind this behavior is that this scenario considers a given number of passengers for each route. Thus, when operating more stages, aircraft-related variable costs and services-related variable costs increase, thus increasing total operating costs. However, since the number of passengers is kept constant, higher costs are spread over a constant number of passengers, eventually increasing costs per passenger with the number of stages.
Another seemingly inconsistent result is the behavior of fixed costs per ASK and fixed costs per RPK when varying the number of stages. As previously said, variable costs depend on stages or flight hours, while fixed costs do not. However, fixed costs per ASK and fixed costs per RPK vary with the number of stages. The reason behind this behavior is that a constant value, fixed costs, is divided by a value dependent on the number of stages. Thus, fixed costs per ASK and fixed costs per RPK are not to be considered as a way to express fixed costs, but as a figure relating fixed costs to ASK and RPK, respectively. Fixed costs per ASK and fixed costs per RPK are the share of fixed costs for each available seat kilometer or revenue passenger kilometer.

The results show that services-related variable costs make up a large part of total operating costs. It is worth noting that airport costs, which include airport fees and ground handling operations costs, have been estimated as costs per movement multiplied by the number of movements. However, estimating airport costs due for a high number of stages is rather difficult, in that they are often negotiated with airport authorities and ground handling providers. Thus, airport costs values are to be considered as a conservative estimate. The actual value of airport costs is difficult to estimate, in that much depends on the negotiation power and ability, the number of flights the carrier has planned, the expected number of passengers, the passenger groups, the types of services provided, and many other factors. High numbers of flights and passengers carried may lead to consistent reductions in airport costs. As previously noted in *Network planning* paragraph, airports may also share risk and financial effort of commercial air operations with carriers. The benefits resulting from lower operating costs may lead to lower fares for passengers and eventually higher passenger volumes, with benefits for both carriers and airports.

The three types have similar operating costs per RPK under the given conditions. However, ATR 42-600 costs per RPK are achieved with lower passenger volumes than the ATR 72-600 and Dash 8-400. This may give the ATR 42-600 the opportunity to profitably operate under conditions that may not justify operations with larger types. The ATR 42-600 has the highest operating costs per ASK due to its lower passenger capacity, resulting more profitable than the larger ATR 72-600 and Dash 8-400 only if passenger volumes are low. However, since passenger volumes are expected to rise in the upcoming years[144] , lower capacity may hinder ATR 42-600 competitiveness. Moreover, the seasonal traffic pattern characterizing connections to/from Olbia causes traffic peaks during high season. Low passenger capacity may limit the possibility to take advantage of the high season, both in terms of passenger volumes and fares. Thus, the ATR 42-600 offers fewer opportunities in the upcoming years than the larger ATR 72-600 and Dash 8-400. This does not mean that the ATR 42-600 is not to be considered for these types of operations. However, its low passenger capacity makes it suited for scenarios where traffic volumes are expected to remain unprofitable for larger types for years to come.
Total operating costs per ASK for the ATR 72-600 and the Dash 8-400 are similar, while being lower than ATR 42-600 costs per ASK. The ATR 72-600 and the Dash 8-400 offer more opportunities in scenarios characterized by high seasonality, since larger aircraft may benefit from higher passenger volumes during high season. Moreover, they may retain a larger market share as passenger demand recovery occurs. Thus, growing passenger demand will likely make larger types like the ATR 72-600 and the Dash 8-400 more profitable than the ATR 42-600 for the routes under analysis.

Considering the scenario with summer operations only, the ATR 72-600 and the Dash 8-400 return similar costs per ASK and per RPK, while the ATR 42-600 returns higher values for both figures. These results stress the difference among the types. The ATR 42-600 has higher operating costs per ASK and RPK with similar load factors, since its costs are spread over a lower number of seats or passengers. On the other hand, the larger types may exploit their higher capacity to maximize revenues. Results show that the Dash 8-400 appears to be the most suited aircraft for summer operations only, since its larger capacity benefits from high summer load factors. It is worth noting that the comparison among the types have been made considering load factors, not passenger volumes. Since passenger capacities differ among types, considering the same load factor value causes differences in the number of passengers flown. However, using a metric like load factor instead of the number of passengers can help assessing results as parameters vary.
It is worth noting that assuming summer operations only leads to unexpected changes in some values. Fixed costs due per route are different for this scenario, because of the way fixed costs are calculated. The portion of fixed costs allocated to each route is dependent on the

[144] Dunn G. (24 June 2020). *European carriers put emphasis on reach in short-haul return*. FlightGlobal website

percentage of total flight time the route retains. Thus, fixed costs allocated to each route change with schedule. The effects of fixed costs on the results given by this scenario pose an issue, in that the aircraft utilization in terms of hours per year is lower than its possibilities, eventually leading to higher fixed costs for each route.

Not surprisingly, the larger the type, the larger the fuel consumption and the carbon dioxide emissions for a given network. However, total fuel consumption and emissions are not a good indicator of the aircraft specific performance and efficiency, in that they do not take into account how well the types perform in their operating environment. Similarly to costs analysis, CO_2 emissions are better assessed in terms of per-ASK (or per-seat) and per-RPK (or per-passenger) emissions.

The ATR 72-600 has the lowest carbon dioxide emissions per ASK of the three types. By comparison, the ATR 42-600 emits circa 37% more CO_2 while operating Olbia (OLB/LIEO) - Milan Malpensa (MXP/LIMC) route, while the Dash 8-400 emits circa 11% more. Considering the scenario with given passenger volumes, the ATR 72-600 is the most efficient aircraft of the three types in terms of emissions per RPK. The ATR 42-600 and the Dash 8-400 emit 20% and 21% more carbon dioxide per RPK, respectively, under the same conditions, while operating Olbia (OLB/LIEO) - Milan Malpensa (MXP/LIMC) route. The main reason behind these results is the lower fuel consumption per ASK - and per RPK under the given conditions - the ATR 72-600 has. The ATR 42-600 and its larger sibling retain the same design and may feature the same engines. However, the ATR 72-600 higher capacity returns lower fuel consumption per ASK, and eventually lower emissions per ASK. On the other hand, the Dash 8-400 has more powerful engines and higher cruise speed, boasting better en-route performance in terms of speed and payload-range capabilities, but it has higher emissions.

It is worth noting that per-RPK emissions depend on the actual number of passengers carried, and on all factors affecting actual fuel consumption. Moreover, seasonal traffic pattern may lead to differences in actual per-RPK emissions depending on the season.

To sum up, the ATR 42-600 has lower total operating costs, lower total fuel consumption and emissions, and requires lower passenger volumes to achieve its break-even point. The ATR 42-600 performs better in scenarios where larger types may not profitably operate or may be subject to high risks of not achieving break-even passenger volumes. However, its limited capacity and its higher costs per ASK may limit its possibilities when passenger volumes will eventually grow.

The ATR 72-600 has the lower costs and emissions per RPK, thus resulting the most profitable type under the given conditions. The Dash 8-400 has the lowest costs per ASK, higher cruise speed and better payload-range performance. On short routes, however, the difference in cruise speed does not heavily influence en-route time. The higher capacity of the ATR 72-600 and the Dash 8-400 makes them better suited to benefit from growing passenger volumes in the upcoming years. However, the possibilities they offer are slightly different. The ATR 72-600, with its lower total operating costs and cruise speed, may be better suited for very-short-haul connections. On the other hand, the Dash 8-400 appears to offer more possibilities to expand the network to further destinations. Its higher cruise speed may make the difference on longer routes, reducing flight time and eventually allowing more flights on the schedule. In other words, the ATR appears better suited for a regional domestic network, while the Dash 8-400 may be advantaged in a network where speed and payload-range capabilities can make the difference.

6.2 Elba case study

Similarly to what previously observed in *Olbia case study*, the larger L 410 UVP-E20 has higher operating costs than the smaller P2012. However, the cost items most influencing the total operating costs differ between the types. The P2012, thanks to its simple design, returns lower maintenance costs than the L 410. However, while being smaller, the P2012 has higher costs due for fuel. The reason behind this seemingly inconsistent result is that AVGAS is much more expensive than jet fuel. Thus, while being inherently more fuel efficient than the L 410 UVP-E20, the P2012 has higher fuel costs. However, as previously noted in *Fuel cost* paragraph, jet fuel costs are likely to rise in the upcoming months.
Thanks to its lower dimensions and weight, the P2012 has lower services-related variable costs. It is worth noting that a large percentage of these costs is due for airport costs, which include airport fees and ground handling operations. The impact of these costs and the way they may be negotiated have already been discussed. However, the low seating capacity of the types analyzed in this case study may reduce the carrier's negotiation power. Thus, the importance of keeping services-related variable costs down is stressed in this case study.
Fixed costs show a fundamental difference between the two types: costs due for crew training and salaries are higher for the L 410 UVP-E20. The L 410 UVP-E20 is certified for a flight crew of two pilots[145] , while the P2012 is certified for single-pilot operations[146] . Moreover, the L 410 UVP-E20 requires a type-rating, while the P2012 only requires a MEP class-rating[147] . These differences help reduce operating costs due for crew training and salaries.

Considering the scenario with given passenger volumes, the L 410 UVP-E20 has lower costs per ASK, but the P2012 offers lower costs per RPK. The P2012 benefits from its lower capacity, in that it may achieve break-even point load factors with lower passenger volumes. The scenario with variable load factors stresses the difference between the two types. The P2012 can operate with lower load factors and lower costs per passenger on the same network. This gives the chance to operate year round or with higher frequency while offering lower fares when passenger volumes are low. The L 410 UVP-E20 has higher operating costs, thus requiring higher passenger volumes to achieve its break-even point.
Low load factors show that the P2012 performs better than the L 410, thus appearing more suited for the network under analysis. The P2012 appears better suited to provide connections between the island and the Italian mainland. However, the scenario also shows that higher load factors foster L 410 profitability. Higher average load factors give the L 410 UVP-E20 the chance to achieve higher profits than the P2012. The extent to which the L 410 may benefit from this possibility depends on the capacity to achieve higher passenger volumes.
The possibility to reduce frequency to achieve higher average load factors have been analyzed in the scenario with variable load factors and different network. The results show that the L 410 offers higher profits than the P2012 with similar load factors. However, it is worth considering that the two types have different capacities. Thus, the number of passengers required to achieve higher load factors for the L 410 (e.g. more than 70%) is large enough to sell the P2012 out. Reducing frequency may be a good way to achieve higher load factors and to maximize efficiency. However, the necessity to offer a reliable service, both in terms of availability and frequency, may clash with the decision to reduce the number of flights.

[145] EASA. (19 November 2020). *TYPE-CERTIFICATE DATA SHEET No. EASA.A.026 for L-410*
[146] EASA. (14 December 2020). *TYPE-CERTIFICATE DATA SHEET No. EASA.A.637 for P2012*
[147] EASA. (24 February 2021). *EASA type rating and licence endorsement list flight crew – all aircraft excluding helicopters*

Lower frequencies may reduce the advantages offered by air services, in that the advantages deriving from short travel times may be hindered by the lower number of flights available to passengers. Moreover, the passenger volumes may decrease if fewer flights are offered by the airline, in that some passengers may choose not to fly if the schedule does not fit their needs.
Finally, it is worth considering that turboprops are more affected than piston aircraft by the number of cycles they operate. Let aside pressurization loads, that are not present on the L 410 and on the P2012, each cycle stresses the airframe and the engines. The higher the ratio between cycles and flight hours, the higher the impact on the aircraft. Short flights, like those considered for this case study, impact aircraft maintenance programs and maintainability, eventually influencing dependability and maintenance costs.

The environmental footprint is difficult to assess, in that piston engines aircraft are not included in major environmental programs. Thus, only the turbine engines emissions can be quantitatively estimated. Comparison is made difficult by the different engines adopted by the two types. However, the P2012 has lower per-hour, per-seat fuel consumption in terms of kilograms on the same network.
It is worth noting that per-seat (or per-ASK) fuel consumption and emissions are a good indicator of the footprint the aircraft has. However, per-passenger (or per-RPK) emissions indicate the actual impact of moving each passenger on a route. Thus, achieving high load factors is not just a matter of reducing or sharing total costs, but it is also desirable to reduce the footprint of each passenger and to maximize efficiency.
Also, given their size and the lengths of the routes they operate, types in this category may be electrified in a near future, thus slashing emissions, noise footprint, and fuel costs. Lower footprint and fuel costs can reduce operating costs, eventually fostering sustainable operations with lower load factors. This may give the chance to increase frequency and/or reduce prices, offering a more reliable and affordable air service. An electrified regional aircraft would likely deliver higher benefits for the communities served, for the environment, and for the carrier.

To sum up, the two types are suited for different strategies. The P2012 appears to be better suited to offer higher-frequency, lower-capacity services. Its low seating capacity and operating costs and its single-pilot capability give the chance to offer more frequent air services while keeping costs down. On the other hand, the L 410 UVP-E20 offers more profit opportunities with higher passenger volumes. Its higher capacity gives the L 410 UVP-E20 the opportunity to benefit from higher demand and higher fares more than the P2012. However, in terms of profitability the L 410 UVP-E20 may not sustain the same frequency as the P2012 if passenger volumes are not large enough.
Similarly to what said for Olbia case study, the lower capacity of the P2012 poses lower risks but offers fewer growth opportunities than the L 410. However, the prospected passenger volumes for Elba case study mark a substantial difference from Olbia case study. Traffic volumes for Elba are much lower than Olbia. Moreover, they offer fewer growth opportunities, mainly due to the different traffic pattern the two case studies retain. Thus, the advantages of operating aircraft that may benefit from much higher passenger volumes are not so relevant. An increase in passenger demand may be covered with an increase in frequency, tailoring the schedule to passenger demand. On the other hand, the number of flights may be reduced to keep costs down as passenger volumes decrease. This strategy may give smaller types like the P2012 the chance to benefit from higher passenger volumes during high season without incurring high expenses during off-peak season.

Finally, it is worth noting that in both case studies the average prices per passenger, either calculated at break-even point or assumed, are influenced by the way total costs are calculated. Since total costs do not take into account any reduction deriving from agreements with airports or suppliers, they are to be considered as a conservative estimate. Hence, average prices per passenger are to be considered as a conservative estimate too. Moreover, these prices are full fares for adult passengers with checked baggage included. As previously noted in *Profit margins and pricing* paragraph, the actual fares applied are defined according to the airline's pricing strategies.

6.3 Off-nominal scenarios

Commercial aviation is committed to safety and reliability. Each flight shall be planned to assure the highest levels of safety and comfort for passengers and crews. However, carriers are aware of the possible concerns, mishaps, and issues that may arise during operations. Let aside incidents, accidents, and any safety-related issue, airlines face different kinds of problems that may disrupt or halt operations. Concerns for commercial air services operators may come from different sources. While some may be controlled, most of them can only be mitigated. Thus, preparing for off-nominal scenarios is critical for airlines.

Most modern aircraft are inherently safe and reliable by design. Reliability, in all its forms, may or may not relate to safety. An aircraft may be safe but not reliable, in that it may suffer from reliability issues that do not induce safety hazards. Before going deeper, some definitions are required. Reliability (more specifically, basic reliability) is the probability for a system to have no failures over a given mission. However, as far as conduction of operations is concerned, basic reliability is not a good indicator of how well the mission may be accomplished. Mission reliability is inherently related to mission accomplishment, in that it represents the probability that a system has no failures causing the mission not to be accomplished. Dispatch reliability is the probability for a system to have no failures that may cause a departure delay.
The different ways of conceiving reliability reflect the different types of failures that may occur. A generic failure is any off-nominal event that leads to an off-nominal status of the system(s) involved. Generic failures affect basic reliability, while failures preventing on-time departure and failures preventing mission accomplishment affect dispatch and mission reliability, respectively. It is worth noting that a failure preventing on-time departure may not interfere with mission accomplishment, and a failure preventing mission accomplishment may not cause a late departure.

The effects of failures affecting mission accomplishment and those affecting on-time departure may go beyond a delayed or canceled flight. Schedules may be heavily affected by off-nominal scenarios, in that a delayed flight may cause delays to other flights operated by either the aircraft involved or by other aircraft. Moreover, failures may affect airport operations. Airlines shall take countermeasures to reduce failure probability, thus increasing reliability. Even though this may be self-evident, the best solution is operating reliable aircraft. There may be several ways for an aircraft to prove not reliable. For example, an aircraft may be poorly maintained. Let aside safety-related maintenance, an airline may perform poor maintenance on parts or systems not affecting safety. Even though this may temporarily reduce maintenance costs, it may result in issues affecting mission accomplishment or on-time departure. Consequent effects may require expenses for repair, rescheduling, and other mishaps that are much higher than savings coming from poor maintenance. Thus, airlines shall take actions to assure the aircraft is operating at its best.

A well-maintained aircraft may be inherently prone to reliability issues. Few or no aircraft have a clear operational history. However, some types or versions have proven less reliable than others. There are countless examples of aircraft suffering from recurrent and/or inherent reliability issues. Airlines operating those aircraft may be heavily hindered by such issues. There could be several reasons behind airlines operating unreliable aircraft. Many new types or versions do suffer from early operational issues. This has to be considered if you are one of the launch customers of new types or versions. Recently introduced regional jet Bombardier CSeries/Airbus A220 suffered from engine issues that led launch operator SWISS to ground their entire fleet for further inspections. The grounding forced the airline to reschedule operations and flights[148] . The issues have been addressed and the CSeries/A220 has eventually ended up becoming a reliable type, with a dispatch reliability of about 99% according to Airbus, which is working on increasing the value[149] . Another new regional type, the Sukhoi Superjet 100, suffered from maintenance issues too. Mechanical issues affecting the Superjet were not completely solved, forcing Interjet to first partially ground[150] and then phase-out their fleet[151] . The effects of disruption following Superjet issues hit the airline hard. Capacity and profits plummeted amid partial fleet grounding, with Interjet losing part of their market share in favor of their competitors[152] in the wake of Superjet issues.

These two examples show how important reliability is for airline operations. As previously said, manufacturers and airlines may work on increasing reliability, eventually assuring very high reliability factors. However, achieving 100% reliability factors is nearly impossible. Hence, airlines shall prepare to cope with disruption resulting from delays and cancellations.

Many different aspects of airline operations are affected when a flight is delayed or canceled. The first concern for the airline is to assure safety for passengers and crews. After that, a carrier facing disruption shall cope with passengers, crews, and aircraft rescheduling. Depending on the type of disruption, different countermeasures may be taken. As a consequence of delays, crew flight duty will likely be extended. Since FDPs shall comply with regulations issued by EASA, delays may call for a crew swap. This is especially true for long-haul operations. In short-haul operations, crew swaps may be less likely to occur, in that short flights may allow the crew to complete the round-trip or return to the home base, thus giving the airline more time to dispatch a new crew. As a good practice, airlines shall roster their crews in such a way as to comply with EASA FDPs regulations while being agile in coping with possible issues.

Delayed departures may cause problems with airport slots, especially in highly congested airports. Due to the nature of regional air transport, many flights operate to/from secondary airports with less tight slot schedules. Moreover, since regional aircraft usually require less ground service equipment, airport delays resulting from delayed departures may be less disrupting than those caused by larger aircraft, both in terms of passengers and ground operations, at least when operating at less congested airports. However, off-nominal scenarios shall be properly assessed. Airlines may schedule flights in such a way as to retain some margin to reduce disruption caused by delayed flights. The margin may be used to

[148] Aviation Week. (15 October 2019). *Swiss To Return All Its A220s After New Engine Incident*. Aviation Week website
[149] FlightGlobal. (4 February 2020). *What Airbus has done since taking on the A220*. FlightGlobal website
[150] Yeo, G.L. (26 March 2019) *Interjet grounds two-thirds of SSJ100 fleet*. FlightGlobal website
[151] Yeo, G.L. (12 September 2018). *Interjet in talks with Sukhoi to sell SSJ100 fleet*. FlightGlobal website
[152] Yeo, G.L. (2 October 2018). *ANALYSIS: Sukhoi offers Superjet upgrades to appease Interjet*. FlightGlobal website

prevent the following scheduled flight from departing late, thus interrupting the "delay chain". This practice is known as schedule padding. Schedule padding is aimed at increasing on-time performance (OTP), which is an important metric to measure airline punctuality[153]. According to the commonly accepted rule, a flight is considered to be late if its actual time exceeds scheduled time by more than fifteen minutes. Depending on the business model, the operating scenario(s), and other factors, airlines may "pad" their schedules to the extent required to suit their strategies. Short-haul airlines operating a high number of sectors per day and/or tight schedules may have less interest in padding schedules, in that it would go against their strategy. Tight schedules turn into more flights per day, and eventually more RPKs. On the other hand, too tight schedules may cause OTP to plummet, especially when operating at congested airports or in scenarios affected by inherent or recurrent obstacles, like adverse weather. Core passenger groups may also influence the way schedules are padded. Choosing the best way to pad schedules to suit airlines strategy is complex and requires an accurate trade-off among all variables involved.

Most industry insiders consider an OTP good if it is between 80% and 90%, and excellent if it is over 90%. It may be easy to think that OTP is just a way for airlines and airports to measure their efficiency. While this is true, consequences deriving from achieving high OTP go beyond statistics. Airlines with good OTP prove to be efficient and capable of managing their schedule. Airports may be keener on working with airlines that are less likely to cause operative disruption. From airlines' point of view, airports achieving higher OTP may allow more accurate and precise schedules. It is worth noting that the best OTP are achieved when airports and airlines work together to assure efficient and effective schedules.

The most important consequence of on-time performance is the effect of airline operations on passengers. On-time performance, either real or perceived, may have a profound influence on passengers' opinion. While much depends on what passengers expect from the airline, disservicing passengers may have the consequence of losing customers in favor of competitors, especially in highly competitive markets. A delayed flight from a secondary airport to a major hub may cause some passengers to miss their connection. Airlines may incur expenses related to refunds or compensations for late flights.

Some failures may result in faults preventing mission accomplishment. These may occur either before take-off or when airborne. Their safety implications are not among the purposes of this analysis. However, the consequences on flight schedules shall be taken into account.

A failure occurring while airborne may prompt a diversion. Let aside safety implications, measures shall be taken to resume operations as soon as possible. Since regional flights cover very short distances, diverting aircraft may either continue to their final destination or return to the aerodrome of departure. However, diversions to alternate airports are to be considered as a real possibility. Depending on fault severity, the aircraft may or may not be able to return to flight within hours. If it is not, a replacement aircraft may be required to fly passengers to their final destination or to operate the next flights, if the aircraft landed at its intended aerodrome of arrival. A replacement flight would need both a crew and an aircraft. Except for the unlikely circumstances where both a replacement aircraft and a replacement crew are available on-site, a new aircraft has to be ferried to the site by a new crew.

[153] OAG. *On-Time Performance*. OAG website

A replacement may be arranged within hours by large airlines with many aircraft and many crews. However, small airlines with few aircraft and crews may not have the possibility to resume operations within a short time. While a "spare" crew may be ready to enter service within hours, airlines with small fleets may simply not have enough aircraft to send a replacement. Obviously, using one aircraft as spare in case of diversions is not feasible. Hence, some other measures shall be taken. Partner airlines may come to the rescue. Passengers may be flown to their destination by either a scheduled or chartered flight operated by another airline. The airline that suffered a diversion will likely incur further expenses. Depending on agreements with other carriers, these expenses may vary. To reduce disruption and expenses, airlines tend to divert to airports where either the airline itself or partner airlines do operate, when possible.

A failure occurring before departure may have consequences ranging from those following a diversion to those resembling a delayed departure. Much depends on where the failure occurs, its severity, and on the airline's schedule. If another aircraft is readily available, that aircraft may be assigned to the flight. The faulty aircraft may be repaired and eventually assigned to the flight originally scheduled for the other aircraft. For regional airlines operating out of a home base, this solution may be a good way to minimize disruption and consequent expenses. Intuitively, the looser the schedule and the larger the fleet available at the airport, the easier it may be to minimize disruption. However, rescheduling a large fleet requires a big effort and accurate planning, while a loose schedule reduces utilization, and eventually revenues. Moreover, this solution may work if the fault can be repaired within few hours. Faults requiring more time to repair may disrupt the airline schedule more severely, thus requiring different solutions.

If an aircraft suffers a failure preventing the regular operations of several flights, a replacement may not be available in the airline's fleet for all flights originally scheduled for that aircraft. The airline then faces two possibilities: cancel flights or wet lease another aircraft. Wet lease is the practice of leasing an aircraft with additional services included, such as flight crew and/or cabin crew, or ancillary services. Wet lease may be an effective, while usually not so efficient, way to fill gaps in disrupted schedules, thus avoiding cancellations and consequent expenses. Wet lease expenses are almost always much higher than costs sustained by the airline to operate its own aircraft. Moreover, fixed costs are still present for grounded aircraft. However, expenses related to refunds and loss of customers caused by disservice may justify the use of wet leased aircraft.

Effects of operations conducted with wet leased aircraft must be carefully assessed. Passengers expectations may not be met, since services offered by the wet lessor may differ from those usually offered by the airline. Choosing a wet lessor offering services not meeting passengers expectations may result in losing passengers. On the other hand, choosing a wet lessor offering a higher class of service will likely cause higher wet lease rates.

Wet lessors have their own fleets that may feature types different from those operated by the airline. While not finding any aircraft of the same type available for wet lease is unlikely, those aircraft may not be readily available. Airlines struggling to resume service as soon as possible may elect to wet lease a different type in the same category of the aircraft being replaced. Operating a different type may impact air operations and services provided. For example, the replacement aircraft may have a different seating configuration. Aircraft with fewer seats may force the airline to refund or reschedule some of the seats sold, while load factors may plunge if too many seats remain unsold. Maintenance may also be a concern. While maintenance, repair, and overhaul (MRO) may be provided by the wet lessor, MRO facilities may need to be arranged at the airline's base airport. Even though related expenses may be included in the wet lease contract, flight schedule and dependability may be affected by different maintenance schedules and activities.

A slightly different alternative may be wet leasing aircraft from partner airlines. Some carriers members of airline groups or alliances may operate flights for partner airlines to fill gaps in schedule or capacity. While types may differ from carrier to carrier, services offered may be of similar class, thus minimizing differences perceived by passengers. Moreover, lease rates may be lower, especially if lessor and lessee are part of the same group or holding. Obviously, the prerequisite for this type of agreement is the lessor's capacity to reschedule its services without the leased aircraft.

Appendices

A. Glossary

- A/C: Aircraft
- AFM: Aircraft Flight Manual
- ANS: Air Navigation Services
- AOC: Air Operator Certificate
- ASK: Available Seat Kilometer
- AV: Actual Value
- AVGAS: AViation GASoline
- BEP: Break-Even Point
- BF: Block Fuel
- BS: Block Speed
- BT: Block Time
- CAT: Commercial Air Transport
- CERT: CO_2 Estimation & Reporting Tool
- CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation
- CPI: Consumer Price Index
- CRCO: Central Route Charges Office
- CS may refer to:
  - CS: Certification Specification
  - CS: Cruise Speed
- EASA: European Union Aviation Safety Agency
- EC: European Commission
- ECAC: European Civil Aviation Conference
- ECB: European Central Bank
- ENAC: Ente Nazionale per l’Aviazione Civile [Italian Civil Aviation Authority]
- ENAV: Ente Nazionale di Assistenza al Volo [Italian Air Navigation Services Provider]

- EPNL: Effective Perceived Noise Level
- ETOPS: Extended-Range Twin-Engine Operations
- EU: European Union
- FAA: Federal Aviation Administration
- FDP: Flight Duty Period
- FIKI: Flight Into Known Icing [Conditions]
- Flt: Flight
- FT: Flight Time
- GCD: Great-Circle Distance
- GHO: Ground Handling Operations
- GPU: Ground Power Unit
- HGW: High Gross Weight
- HICP: Harmonised Index of Consumer Prices
- Hr(s): Hour(s)
- IATA: International Air Transport Association
- ICAO: International Civil Aviation Organization
- IFR: Instrumental Flight Rules
- ISA: International Standard Atmosphere
- IPCC: International Panel for Climate Change
- KIAS: Knots Indicated Airspeed
- KTAS: Knots True Airspeed
- LCC: Low-Cost Carrier
- LF: Load Factor
- LR: Long Range
- LVO: Low-Visibility Operations
- MEP: Multi-Engine Piston
- (M)FM: (Maximum) Fuel Mass
- (M)FW: (Maximum) Fuel Weight
- (M)LM: (Maximum) Landing Mass
- (M)LW: (Maximum) Landing Weight
- MOPSC: Maximum Operational Passenger Seating Configuration

- MP: Multi-Pilot
- MPO: Multi-Pilot Operations
- (M)PM: (Maximum) Payload Mass
- (M)PW: (Maximum) Payload Weight
- (M)RM: (Maximum) Ramp Mass
- MRO: Maintenance, Repair, and Overhaul
- (M)RW: (Maximum) Ramp Weight
- (M)TOM: (Maximum) Take-Off Mass
- (M)TOW: (Maximum) Take-Off Weight
- (M)ZFM: (Maximum) Zero Fuel Mass
- (M)ZFW: (Maximum) Zero Fuel Weight
- NS: Northern Summer
- NW: Northern Winter
- OD (*a.s.a.* O/D *or* O-D): Origin Destination
- OEM: Operational (*or* Operating) Empty Mass
- OEW: Operational (*or* Operating) Empty Weight
- OT: Operating Time
- OTP: On-Time Performance
- Pax: Passenger
- PSO: Public Service Obligation
- PV: Present Value
- RPK: Revenue Passenger Kilometer
- RSO distance tool: Route per State Overflown distance tool
- SAF: Sustainable Aviation Fuel
- SID: Standard Instrument Departure [Route]
- SL: Sea Level
- SP: Single-Pilot
- SPO: Single-Pilot Operations
- ST: Service Time
- STAR: Standard Arrival Route
- T/O (*a.s.a.* T-O): Take-Off

- TANS: Terminal Air Navigation Services
- TCDS: Type-Certificate Data Sheet
- TCDSN: Type-Certificate Data Sheet for Noise
- TRT (*a.s.a.* TAT): Turn-Round Time *or* Turnaround Time
- UL: Useful Load
- VFR may refer to:
  - VFR [traveler]: [A traveler] Visiting Friends or Relatives *or*
  - VFR: Visual Flight Rules
- WV: Weight Variant
- YOY: Year On Year

B. List of Italian airports

List of Italian airports open to commercial air traffic as of 1H2020[154] .

Airport	IATA Code	ICAO Code
Albenga	ALL	LIMG
Alghero Fertilia	AHO	LIEA
Ancona Falconara	AOI	LIPY
Aosta	AOT	LIMW
Bari Palese Macchie	BRI	LIBD
Bergamo Orio al Serio	BGY	LIME
Bologna Borgo Panigale	BLQ	LIPE
Bolzano	BZO	LIPB
Brescia Montichiari	VBS	LIPO
Brindisi Casale	BDS	LIBR
Cagliari Elmas	CAG	LIEE
Catania Fontanarossa	CTA	LICC
Comiso	CIY	LICB
Crotone S. Anna	CRV	LIBC
Cuneo Levaldigi	CUF	LIMZ
Firenze Peretola	FLR	LIRQ
Foggia	FOG	LIBF
Forlì	FRL	LIPK
Genova Sestri	GOA	LIMJ
Grosseto	GRS	LIRS
Lamezia Terme	SUF	LICA

[154] ENAC. (2020). *Dati di Traffico 2020 - I Semestre*

Airport	**IATA Code**	**ICAO Code**
Lampedusa	LMP	LICD
Marina di Campo (Elba)	EBA	LIRJ
Milano Linate	LIN	LIML
Milano Malpensa	MXP	LIMC
Napoli Capodichino	NAP	LIRN
Olbia Costa Smeralda	OLB	LIEO
Palermo Punta Raisi	PMO	LICJ
Pantelleria	PNL	LICG
Parma	PMF	LIMP
Perugia	PEG	LIRZ
Pescara	PSR	LIBP
Pisa S. Giusto	PSA	LIRP
Reggio Calabria	REG	LICR
Rimini Miramare	RMI	LIPR
Roma Ciampino	CIA	LIRA
Roma Fiumicino	FCO	LIRF
Salerno Pontecagnano	QSR	LIRI
Taranto Grottaglie	TAR	LIBG
Torino Caselle	TRN	LIMF
Trapani Birgi	TPS	LICT
Treviso S. Angelo	TSF	LIPH
Trieste Ronchi dei Legionari	TRS	LIPQ
Venezia Tessera	VCE	LIPZ
Verona Villafranca	VRN	LIPX

Table B.1: List of Italian airports open to commercial air traffic as of 1H2020

C. Aircraft specifications

C.1 ATR 42-600

ATR 42-500 "600 version" Dimensions	
Length	22.67 m
Wingspan	24.57 m
Height	7.59 m
Cabin Width	2.57 m
Cabin Height	1.91 m
Typical Seating (Y Class, 4 abreast)	48 - 50 Seats
Seat Pitch (Y Class)	29” - 30” (74 cm - 76 cm)
Seat Width (Y Class)	18” (46 cm)

Table C.1: ATR 42-500 "600 version" dimensions

Certified Weights for ATR 42-500 "600 version"				
MRW	MTOW	MLW	MZFW	MFW
18 770 kg	18 600 kg	18 300 kg	16 700 kg	4 550 kg

Table C.2: Certified weights for ATR 42-500 "600 version"

Maximum payload weight (MPW) and operational empty weight (OEW) are not reported by EASA TCDS for ATR 42[155] , but may be retrieved from manufacturer documentation. Typical in-service OEW is 11 700 kg, while MPW is 5 300 kg. It is worth noting that these values may vary since they are dependent on operational weights on board.

[155] TYPE-CERTIFICATE DATA SHEET No. EASA.A.084 for ATR 42 and ATR 72

ATR 42-500 "600 version" Field Performance			
Take-Off		Landing	
Weight	MTOW	Weight	MLW
Environmental Conditions	ISA SL	Environmental Conditions	ISA SL
Take-Off Distance	1 107 m	Landing Distance	966 m

Table C.3: ATR 42-500 "600 version" field performance

Certified Powerplants for ATR 42-500 "600 version"				
Rating		**PW127E**	**PW127F**	**PW127M**
Max T/O	Shaft Power (kW)	1 790	2 051	2 051
	Max Air Temp for Rated Power (°C)	ISA + 30 °C	ISA + 20 °C	ISA + 24 °C
	Torque (Nm)	17 354	17 354	17 354
Normal T/O	Shaft Power (kW)	1 611	1 846	1 846
	Max Air Temp for Rated Power (°C)	ISA + 30 °C	ISA + 20 °C	ISA + 24 °C
	Torque (Nm)	17 354	17 354	17 354
Max Cont	Shaft Power (kW)	1 790	1 864	1 864
	Max Air Temp for Rated Power (°C)	ISA + 30 °C	ISA + 29 °C	ISA + 33 °C
	Torque (Nm)	17 354	17 354	17 354
Transient	Torque (Nm)	19 578	19 578	19 578

Table C.4: Certified powerplants for ATR 42-500 "600 version"

C.2 ATR 72-600

ATR 72-212A "600 version" Dimensions	
Length	27.17 m
Wingspan	27.05 m
Height	7.65 m
Cabin Width	2.57 m
Cabin Height	1.91 m
Typical Seating (Y Class, 4 abreast)	70 - 72 Seats
Seat Pitch (Y Class)	29” - 30” (74 cm - 76 cm)
Seat Width (Y Class)	18” (46 cm)

Table C.5: ATR 72-212A "600 version" dimensions

Certified Weights for ATR 72-212A "600 version" Mod 6219 (WV50)				
MRW	MTOW	MLW	MZFW	MFW
23 170 kg	23 000 kg	22 350 kg	21 000 kg	5 050 kg

Table C.6: Certified weights for ATR 72-212A "600 version" Mod 6219 (WV50)

Maximum payload weight (MPW) and operational empty weight (OEW) are not reported by EASA TCDS for ATR 72[156] , but may be retrieved from manufacturer documentation. Typical in-service OEW is 13 450 kg, while MPW is 7 550 kg. It is worth noting that these values may vary since they are dependent on operational weights on board.

ATR 72-212A "600 version" Field Performance			
Take-Off		Landing	
Weight	MTOW	Weight	MLW
Environmental Conditions	ISA SL	Environmental Conditions	ISA SL
Take-Off Distance	1 304 m	Landing Distance	915 m

Table C.7: ATR 72-212A "600 version" field performance

[156] TYPE-CERTIFICATE DATA SHEET No. EASA.A.084 for ATR 42 and ATR 72

Certified Powerplants for ATR 72-212A "600 version"				
Rating		**PW127F**	**PW127M**	**PW127N**
Max T/O	Shaft Power (kW)	2 051	2 051	2 051
	Max Air Temp for Rated Power (°C)	ISA + 20 °C	ISA + 24 °C	ISA + 29 °C
	Torque (Nm)	17 354	17 354	17 354
Normal T/O	Shaft Power (kW)	1 846	1 846	1 846
	Max Air Temp for Rated Power (°C)	ISA + 20 °C	ISA + 24 °C	ISA + 29 °C
	Torque (Nm)	17 354	17 354	17 354
Max Cont	Shaft Power (kW)	1 864	1 864	1 864
	Max Air Temp for Rated Power (°C)	ISA + 29 °C	ISA + 33 °C	ISA + 33 °C
	Torque (Nm)	17 354	17 354	17 354
Transient	Torque (Nm)	19 578	19 578	19 578

Table C.8: Certified powerplants for ATR 72-212A "600 version"

C.3 Dash 8-400

DHC-8-402 Dimensions	
Length	32.83 m
Wingspan	28.42 m
Height	8.30 m
Cabin Width	2.49 m
Cabin Height	1.93 m
Typical Seating (Y Class, 4 abreast)	74 - 78 Seats
Seat Pitch (Y Class)	29" - 31" (74 cm - 79 cm)
Seat Width (Y Class)	17" (44 cm)

Table C.9: DHC-8-402 dimensions

Certified Weights for DHC-8-402 (HGW)				
MRW	MTOW	MLW	MZFW	MFW
29 347 kg	29 257 kg	28 009 kg	25 855 kg	5 318 kg

Table C.10: Certified weights for DHC-8-402 (HGW)

Maximum payload weight (MPW) and operational empty weight (OEW) are not reported by EASA TCDS for DCH-8[157] , but may be retrieved from planning manuals published by the manufacturer. Typical in-service OEW is 17 148 kg, while MPW is 8 481 kg. It is worth noting that these values may vary since they are dependent on operational weights on board.

DHC-8-400 Field Performance			
Take-Off		Landing	
Weight	MTOW	Weight	MLW
Environmental Conditions	ISA SL	Environmental Conditions	ISA SL
Take-Off Distance	1 580 m	Landing Distance	1 280 m

Table C.11: DHC-8-402 field performance

[157] TYPE-CERTIFICATE DATA SHEET No. EASA.IM.A.191 For DHC-8

Certified Powerplants for DHC-8-402		
Rating		**PW150A**
Max T/O	Shaft Power (kW)	3 781
	Max Air Temp for Rated Power (°C)	ISA + 22 °C
	Torque (Nm)	37 529
Normal T/O	Shaft Power (kW)	3 415
	Max Air Temp for Rated Power (°C)	ISA + 22 °C
	Torque (Nm)	35 404
Max Cont	Shaft Power (kW)	3 781
	Max Air Temp for Rated Power (°C)	ISA + 22 °C
	Torque (Nm)	35 404
Transient	Torque (Nm)	47 795

Table C.12: Certified powerplants for DHC-8-402

C.4 L 410 UVP-E20

L 410 UVP-E20 Dimensions	
Length	14.42 m
Wingspan	19.48 m 19.98 m*
Height	5.83 m
Cabin Width	1.90 m
Cabin Height	1.65 m
Typical Seating (Y Class, 3 abreast)	15 - 19 Seats
Seat Pitch (Y Class)	29” - 31” (74 cm - 79 cm)
Seat Width (Y Class)	16” (41 cm)

* With wing tip tanks

Table C.13: L 410 UVP-E20 dimensions

Certified Weights for L 410 UVP-E20				
MRW	MTOW	MLW	MZFW	MFW
6 620 kg	6 600 kg	6 400 kg	6 000 kg 6 060 kg*	1 002 kg 1 313 kg*

* With wing tip tanks

Table C.14: Certified weights for L 410 UVP-E20

Maximum payload weight (MPW) and operational empty weight (OEW) are not reported by EASA TCDS for L-410[158] , but may be retrieved from planning manuals published by the manufacturer. Typical in-service OEW is 4 260 kg, while MPW is 1 800 kg. It is worth noting that these values may vary since they are dependent on operational weights on board and on wing tip tanks, if present.

L 410 UVP-E20 Field Performance			
Take-Off		Landing	
Weight	MTOW	Weight	MLW
Environmental Conditions	ISA SL	Environmental Conditions	ISA SL
Take-Off Distance	930 m	Landing Distance	835 m

Table C.15: L 410 UVP-E20 field performance

[158] TYPE-CERTIFICATE DATA SHEET No. EASA.A.026 for L-410

Certified Powerplant for L 410 UVP-E20		
Rating		**H80-200**
Max T/O	Shaft Power (kW)	597
	Max Air Temp for Rated Power (°C)	ISA + 26 °C
	Torque (Nm)	2 740
Max Cont	Shaft Power (kW)	522
	Max Air Temp for Rated Power (°C)	ISA + 26 °C
	Torque (Nm)	2 740

Table C.16: Certified powerplant for L 410 UVP-E20

C.5 P2012

P2012 Dimensions	
Length	11.80 m
Wingspan	14.00 m
Height	4.40 m
Cabin Width	1.47 m
Cabin Height	1.35 m
Typical Seating (Y Class, 2 abreast)	9 Seats
Seat Pitch (Y Class)	32” (81 cm)
Seat Width (Y Class)	18.5” (47 cm)

Table C.17: P2012 dimensions

Certified Weights for P2012 (MOD 2012/017)		
MTOW	MLW	MFW
3 680 kg	3 630 kg	540 kg

Table C.18: Certified weights for P2012 (MOD 2012/017)

Useful load (UL), zero fuel weight (ZFW), and operational empty weight (OEW) are not reported by EASA TCDS for P2012[159] , but may be retrieved from manufacturer documentation. Typical in-service OEW is 2 268 kg, while UL and ZFW are 1 414 kg and 3 160 kg, respectively. It is worth noting that these values may vary since they are dependent on operational weights on board.

P2012 Field Performance			
Take-Off		Landing	
Weight	MTOW	Weight	MLW
Environmental Conditions	ISA SL	Environmental Conditions	ISA SL
Take-Off Distance	654 m	Landing Distance	546 m

Table C.19: P2012 field performance

[159] TYPE-CERTIFICATE DATA SHEET NO. EASA.A.637 for P2012

<table>
<tr><th colspan="3">Certified Powerplant for P2012</th></tr>
<tr><th colspan="2">Rating</th><th>TEO-540-C1A</th></tr>
<tr><td rowspan="3">Max T/O</td><td>Shaft Power (kW)</td><td>280</td></tr>
<tr><td>Revolutions per Minute (rpm)</td><td>2 575</td></tr>
<tr><td>Environmental Conditions</td><td>ISA</td></tr>
<tr><td rowspan="3">Max Cont</td><td>Shaft Power (kW)</td><td>280</td></tr>
<tr><td>Revolutions per Minute (rpm)</td><td>2 575</td></tr>
<tr><td>Environmental Conditions</td><td>ISA</td></tr>
<tr><td colspan="2">Displacement</td><td>8 873 cm^3</td></tr>
<tr><td colspan="2">Bore x Stroke</td><td>13.0175 cm x 11.1125 cm</td></tr>
</table>

Table C.20: Certified powerplant for P2012

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