Escola d'Enginyeria de Telecomunicació i
Aeroespacial de Castelldefels
UNIVERSITAT POLITÈCNICA DE CATALUNYA

IMPACT OF USING WIDE- OR NARROW-BODY AIRCRAFT ON SHORT-HAUL FLIGHTS

TITLE OF THE TFG: Impact of using wide- or narrow-body aircraft on short-haul flights

BACHELOR'S DEGREE: Grau en Enginyeria d'Aeronavegació

AUTHOR: Jessica Núñez Maturano

DIRECTOR: Roger Mulet Morato

DATE: 05-02-2021

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OVERVIEW

The aim of this project is to study whether is better to use wide- or narrow-body aircrafts in short-haul flights. Research into short-haul flights shows that there are multiple flights a day travelling the same journey, some of them within less than one-hour difference.

As a passenger, having a range of choices to plan a trip is a positive aspect, as any option would be suitable for their schedule. But, knowing that the airspace is reaching its maximum capacity and aviation is not environment friendly, the decision to make a study to determine if these problems could be diminished seemed mandatory.

The project will follow the next structure. First, an analysis of the evolution of the air traffic in Europe until the current moment and some predictions for the future will be made. Then, a research of what type of planes are preferably used for the different existing routes will be done. Later, the journey between *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport* will be studied and compared if it would be better performed with an A320 or an A330. This study will consist in stablishing the route travelled, examine the weight and balance of both planes and conduct an economical and environmental research. Finally, the results will be revealed and a final conclusion will be made.

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RESUMEN

El objetivo de este proyecto es estudiar la mejor opción entre usar aviones de fuselaje estrecho o de fuselaje ancho en vuelos de corto recorrido. Estudiando los vuelos de corto recorrido, se ha encontrado que hay múltiples vuelos al día realizando el mismo trayecto, muchos de ellos con diferencia de salida inferior a una hora.

Como pasajero, tener varias alternativas para planear un viaje es un aspecto positivo, ya que alguna de ellas encajara en sus horarios. Pero, sabiendo que el espacio aéreo está llegando a su límite de capacidad y la aviación es desfavorable para el medio ambiente, la decisión de hacer este estudio para saber si se pueden mitigar estos problemas parecía casi obligatoria.

El proyecto seguirá la siguiente estructura. Primero se realizará un análisis sobre la evolución del tráfico aéreo en Europa, donde también se incluirán predicciones de futuro. Además, se investigará que tipo de aviones se usan en las diferentes rutas existentes. Después, se estudiará el trayecto entre los aeropuertos de *Josep Tarradellas Barcelona-El Prat* y *Gran Canaria con* un avión A320 y un A330. El estudio consistirá en establecer una ruta, examinar la masa y centrado de cada avión y realizar un estudio económico y medioambiental de cada opción. Por último, se analizarán los resultados para ver que opción es preferible y se expondrán unas conclusiones finales.

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INTRODUCTION

Flying has experienced an immense change since the first commercial flight started. In the 20th century the first planes able to take off by their own means, sustainable and controlled by a pilot were constructed. Aviation became a focus point and it started to be more studied and advanced. Sadly, the arrival of the world wars helped and accelerated this development, although mainly for military reasons.

Shortly after, aviation converted into a very competitive means of transport. Travelling longer distances was required and transporting as many passengers as possible created a new goal. The construction of wide-body aircrafts became a reality. More targets as make travelling at supersonic speed reliable and affordable or even travelling to space are future aspirations. Nonetheless aviation is in constant research and evolution.

In the late 1900s with the creation of low-cost companies flying became affordable for everyone. In fact, the outcome was an increase of the demand, which created more competition among companies. Also, higher demand meant the expansion of the fleet of some airlines, the opening of new routes and the increment of flights in general.

In recent years, flying has changed our way of life. Business evolved into a way that business meetings can be anywhere, with people from different locations, who take a flight only to attend to that specific meeting. In personal terms, there has also been a behaviour modification. People travel to spend the day in another city or they just move out to another country without fearing to be far from their families as they are only one flight away. In the past, all of this was unthinkable but now it is a fact.

All of these behaviour patterns lead to a continuous increase of the air traffic. As a matter of fact, at *Josep Tarradellas Barcelona El-Prat airport*, the number of passengers transferred beats a new record year after year, getting its maximum in August of 2019 with 187.752 passengers in one day. [1] The same happens in many other airports in Europe.

The problem of the non-stop increase of passengers and flights can create a problem if airports and airspace reach their maximum capacity. At *Josep Tarradellas Barcelona El-Prat airport* the capacity limitation is due to the limitations of the runways. The limitations in the airspace are because of the navigation system used. New ways of organization and navigation are being studied to increase the capacity.

Knowing that this situation of overcapacity exists and the number of flights and demand keeps increasing, the study to know whether it is better to use wide- or narrow-body aircrafts in short-haul flights seems important. If using wide-body instead of narrow-body aircrafts would be better, a new consideration of change in aviation could come up and it would represent a way to diminish the existing capacity problems. Also, a study of the environmental effects that this would trigger will be done to see if it would be more environmentally friendly to do such a change.

The project will be divided into three chapters. The first one will show a research of the evolution of the air traffic in Europe and it will show future predictions. Then a comparison of what type of planes are preferably used for the different existing routes will be done. To conclude, a case of study between *Josep Tarradellas Barcelona El-Prat airport* and *Gran Canaria airport* will be accomplished. This study will compare if it would be better to perform such a route with A320s or A330s. For that, the route, weight and balance, the economical- and the environmental point of view will be studied. The results and conclusions will be shown at the end of the project.

CHAPTER 1. EVOLUTION OF AIR TRAFFIC IN EUROPE

Air traffic is the number of passengers, planes and cargo carried by aircrafts and handled by airports. Since the beginning of aviation, air traffic has been evolving. The reasons of this evolution, come together with history.

After WWII, Europe was facing a terrible post-war period, but technology kept developing. This meant the growth of aviation and it brought down the cost of jet travel. The result of it, is reflected in the evolution of air traffic over the years, which kept growing and growing.

For this project it was possible to collect the data of the that evolution by the different countries of Europe over the period 1993-2019. The tables with such information are in annex 1 and annex 2. [2] Being aware that air traffic and economic growth are closely related, it is important to keep in mind the historical background of every country.

This chapter is divided into the evolution of the carried passengers and the freight and mail transported to have a more accurate result.

1.1. PASSENGER TRAFFIC EVOLUTION

Figure 1.1 shows the evolution of the passengers carried at every European country. The difference between countries is clear, but it is even more clear that there are five countries where the movement of people is much higher and growing faster than the rest.

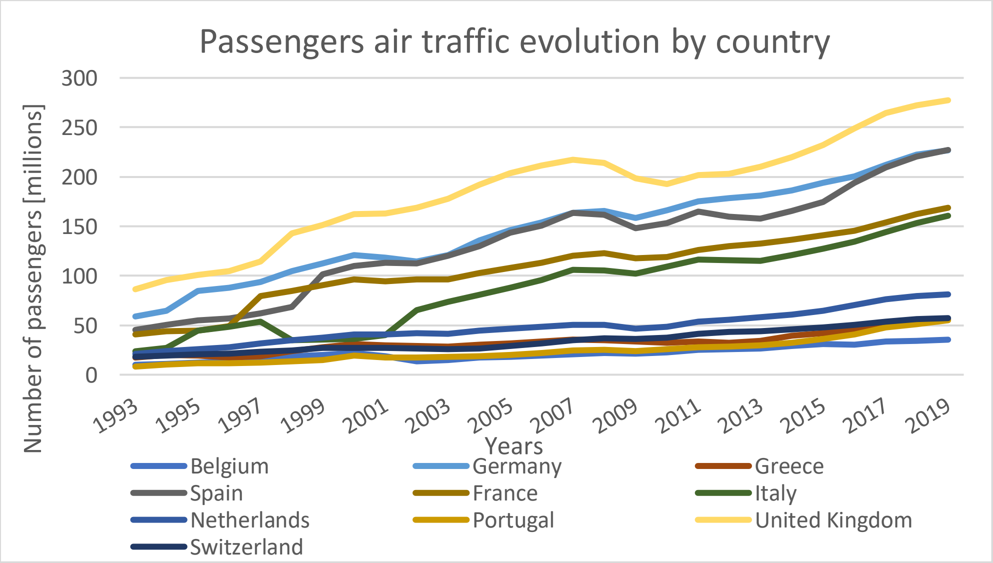


Figure 1.1 Passengers air traffic evolution by country

Looking into the graphic of figure 1.1, the trendline of every country approaches a lineal behaviour. The slope of the five leading countries is steeper and the shape of the lines is less smooth than the others.

Focusing now at the five leading countries: United Kingdom, Germany, Spain, France and Italy, figure 1.2 shows the evolution of their air traffic. It is certain that every graph line is different and with a different slope, but they have some aspects in common. They are all ascending and they have some stagnation or even descending fragments, where sometimes it is shown at all five lines during the same period. For that, and as it is mentioned before, a look into the background history is needed.

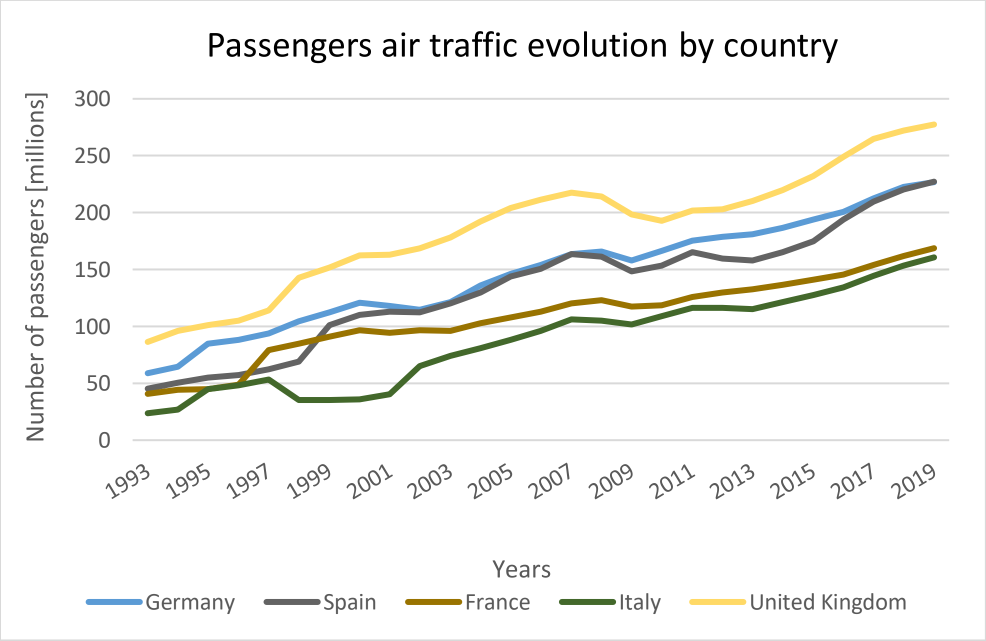


Figure 1.2 Passengers air traffic of the top five European countries

In 1991, the Gulf war started, having a big impact in aviation. A dramatic slump in the number of people flying followed, but the recovery was very fast. That is the reason why this graph starts with a slow growth for all the countries. Furthermore, the implementation of the “Schengen Agreement” in 1995, turned out into a good tendency of carrying passengers. The next important bump for aviation is in 2001 with the 9/11 attacks. Globally it took 1.5 years to recover to previous levels. Afterwards, it can be seen a very similar and lineal growing behaviour in the five countries until 2006-2007, depending on the country. Aviation already started noticing what was coming in 2008, the Great Financial Crisis. This generated a 3-year recession and it took 8 years to recover to the levels prior to the crisis. After that, traffic kept growing until 2020 when the arrival of Covid-19 provoked the worse crisis ever with more than 6 million flights lost and with a big uncertainty of the recovery time to previous levels.

The United Kingdom, on top of the graph, is the country that transports the biggest number of passengers all over the years, with a difference of more than 20.000 thousand passengers from the second one. In fact, London-Heathrow airport has been the airport with the most passenger traffic all over the years. This is somehow possible due to the high number of long-haul flights with wide-body planes where more passengers can be carried plus the so called “minute of Heathrow”. By virtue of the logistics of the airport, flights can take off within 1-minute difference instead the 2 minutes of a normal procedure, so the capacity is incremented. The outcome of all this keeps London Heathrow Airport at the top busiest airports of Europe, and second of the world.

Second in the ranking is Germany, followed very closely by Spain. Germany is a powerful country with a strong and stable economy. Their citizens income and stability allow them to travel and spend money on holidays, which is an important factor of passenger exchange. In general, the people form the north of Europe are attracted to travel to the south, as the good weather and food are very attractive. This positions Spain, France and Italy on the top of the list. The arrival of tourists to these regions, rises the number of flights between the north and the south, and consequently the number of passengers carried.

A very interesting fact that is worth to look at, are the curves of the United Kingdom and Spain alone, showed in Figure 1.3. Their shape is practically identical. This supports the idea that tourism is an important part of the increasing number of passengers carried, as people travel between these countries the most.

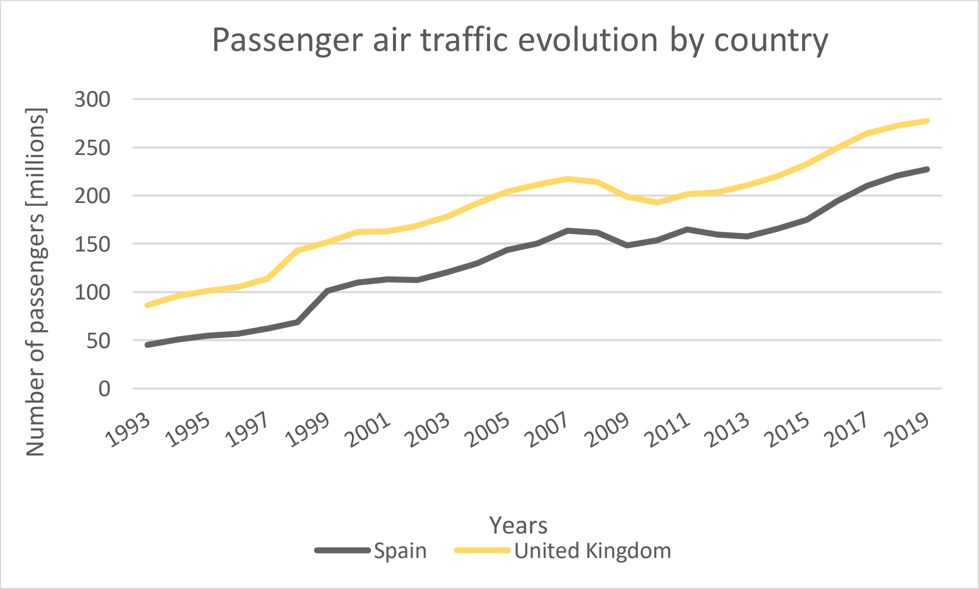


Figure 1.3 Passengers carried in United Kingdom and Spain

1.2. FREIGHT TRAFFIC EVOLUTION

Another factor for the evolution of air traffic as important as the passengers carried, is the evolution of the cargo and mail traffic.

Following the same structure as the one for the analysis of the passengers carried, Figure 1.4 shows the evolution of the freight transported in every European country. The behaviour of the graph is also lineal, but with a different slope. The one of the passengers is steeper than the one of freight.

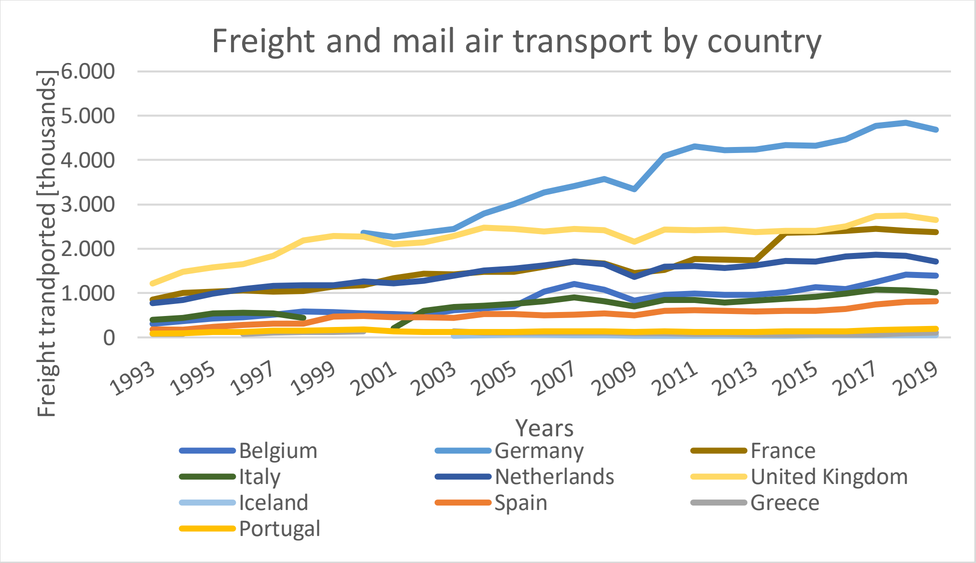


Figure 1.4 freight and mail air traffic evolution by country

Looking again at the five leading countries, it is important to notice that the leading countries differ from ones of the passengers. The United Kingdom, Germany and France stay in the ranking, but Spain and Italy have been replaced by The Netherlands and Belgium as Figure 1.5 shows.

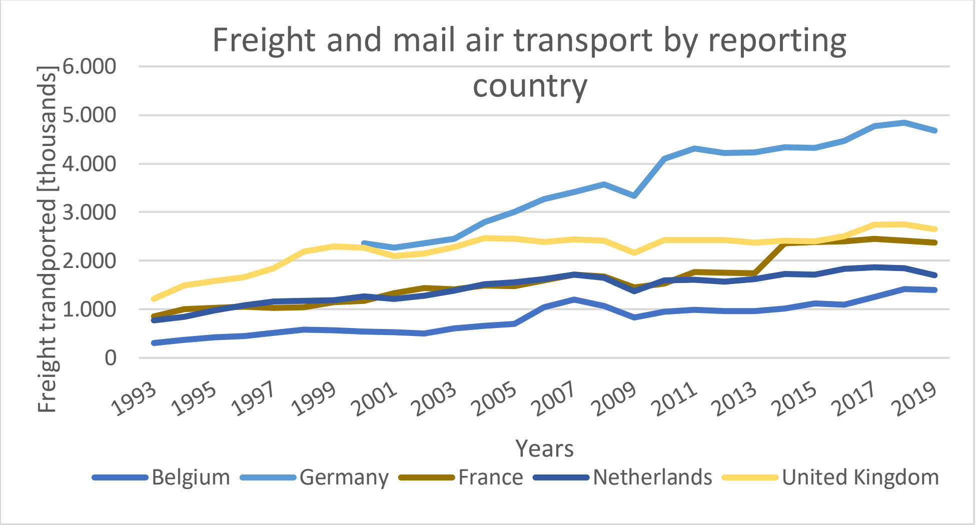


Figure 1.5 Five leading countries transporting freight and mail

Germany is leading the ranking for the transport of cargo and mail with a big difference. This is the result of their strong economy. The United Kingdom and France are respectively second and third.

The importance of the geographical location is a key factor for the transport of freight. That is the case for The Netherlands and Belgium. They are in a strategic position for transporting freight. The Netherlands has the biggest port in all of Europe, the port of Rotterdam, followed by Belgium with the second biggest, the port of Antwerp. Cargo and mail can be transported from anywhere in the world, and then it can be easily transported to the rest of Europe, either by sea or land.

It is important to recall the significance of the historical background in this case. Looking at the same period where there is a decrease of passengers carried, there is also a decrease of freight transport.

1.3. FUTURE EVOLUTION SCENARIOS

The evolution of air traffic during the past years, can help support long-term planning for aviation and take well-informed decisions. For that, EUROCONTROL Statistics and Forecast Service (STATFOR) developed the project "*The Challenges of Growth*" in 2017-2018. [3]

This report presents the forecast of annual numbers of instrument flight rules (IFR) movements in Europe up to 2040. Air traffic is in constant growth, but there are some factors and constraints that make the evolution volatile. The aspects to take into account are:

- Long-haul appearance
- New low-cost aircraft types and carriers
- Middle class growth in China
- Total network delay
- Alternatives to air transport
- Oil prices changes
- Climate changes

Furthermore, the assumption that the network will be constrained at airport level but not at airspace level is well studied.

Taking all of these into account, there are four possible scenarios:

- **Global Growth:** Globalization will increase and will lead to a strong global economic growth. Technology will be successful to mitigate the effects of sustainability challenges such as the environment or resource availability.

- **Regulation and Growth:** Moderate economic growth, with environmental and social regulations and economic demands to deal with the growing global sustainability concerns.

- **Fragmenting World:** Globalization will decrease and global tensions increase. This will rebound into more security threats, higher fuel prices, reduced trade and transport integration and knock-on effects of weaker economies.

- **Happy Localism:** Globalization will slightly decrease and Europe will look inwards and its fragility will increase. European economies will be exposed to shocks, pressure on costs will increase and stricter environmental constraints will take place.

Definitely, growth will not be uniform across Europe regardless the scenario. The states in Eastern Europe will grow quicker than the Western ones. The reason of such a clear statement is because the eastern European states are less developed than the western ones. Therefore, they have more chances to grow. Nevertheless, they growth will stay lower than the Western countries.

Figure 1.6 shows the evolution of the expected IFR movements in Europe up to 2040 with every possible scenario. Clearly a growth interval between 12%-84% is expected.

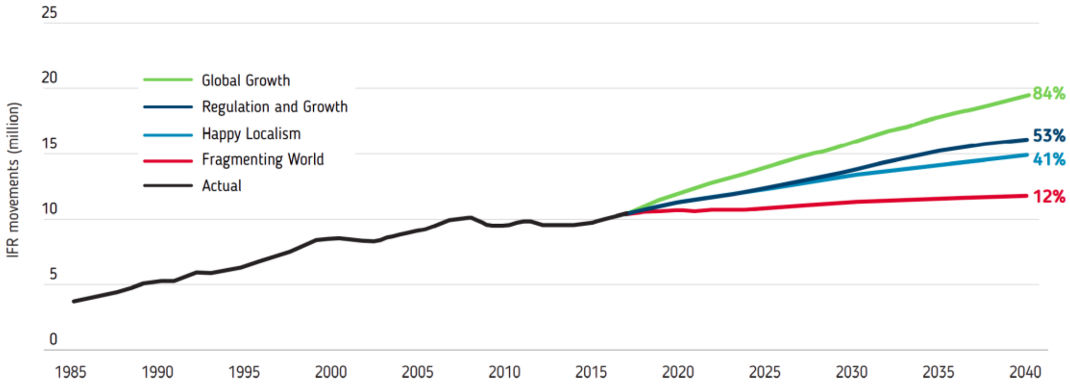


Figure 1.6 Expected IFR movements in Europe in the four scenarios by 2040 [15]

According to the situation of the past years, experts believed that the most likely scenario to happen was “Regulation and Growth”. But, no one could ever expect or predict a world pandemic as Covid-19 in 2020. This new scenario changes all the prediction made up until the moment. Precisely, the “Fragmenting World” scenario looks like the most realistic at the moment. But, it is very important to keep this predictions in mind because the future is very unpredictable.

1.4. IMPACT OF COVID-19

The reality of the situation is very far from all the predictions. The arrival of the Covid-19 virus resulted in a worldwide pandemic and impacted very hard on most countries in the world. For that, strong measurements as lockdowns and closing borders were implemented.

Since March 2019, Europe is involved in one of the biggest crises in history. The Schengen borders were close for external countries, and even the intra-Europe flow was restricted. On top, every country took its own restrictions. Figure 1.7 shows the traffic variation in Europe between 2019 and 2021 and a short prediction on what will happen in the second trimester of 2021. This figure shows that the impact of the pandemic it has been very strong and the air traffic has dropped immensely.

It is also important to recall the complexity and unknown of the situation. This can be seen in the difference of the top and bottom of figure 1.7. The top figure shows the actual traffic until November 2020, when the study was made, and the predictions until the moment. In April 2020, the first prediction was developed, but it was so optimistic that another one had to replace it. The second one, in September 2020 it got closer to reality.[4] But the situation is very volatile and it can change daily. For that, new predictions are constantly being studied.

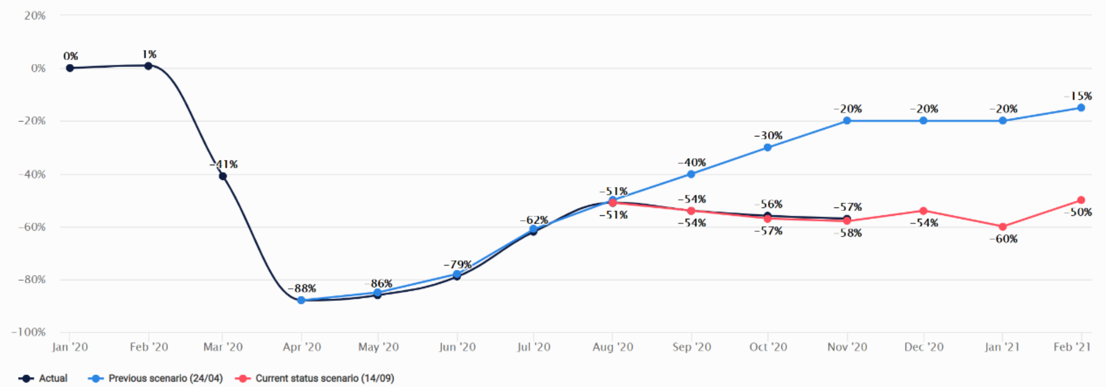


Figure 1.7a Evolution traffic scenario

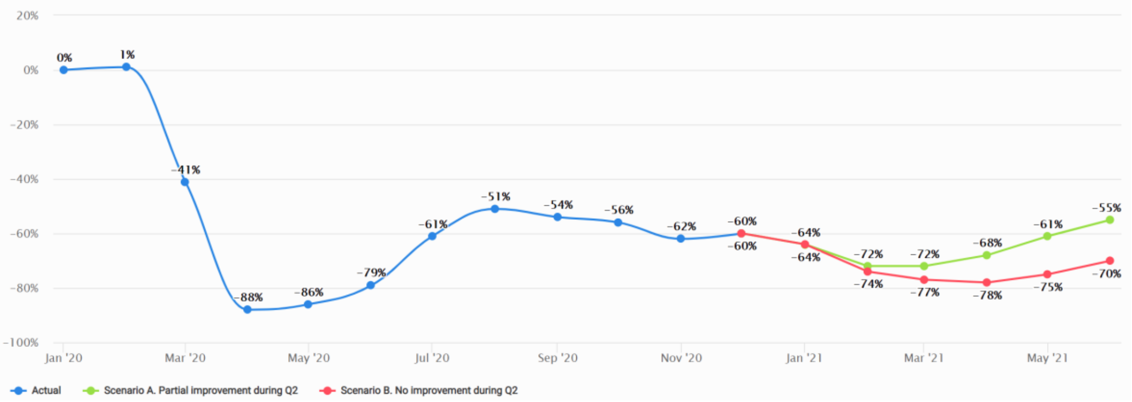


Figure 1.7b Evolution traffic scenario

EUROCONTROL published the latest STATFOR Forecast for the period 2020-2024.[5] This forecast shows the traffic outlook for the future. It takes into account the traffic trend and the economic growth. Also, it compares the situation with the evolution after other crises like 9/11 attack and the Great Financial crisis of 2008.

As this crisis has no precedents and the number of flights lost is greater than in the other crises, 3 scenarios are considered so far.

- **Scenario 1:** Considers that the vaccine will be effective and available for travellers or the pandemic will end by summer 2021. If this occurs, the recovery to 2019 levels will be in 2024.
- **Scenario 2:** Considers that the vaccine will be effective and available for travellers or the pandemic will end by summer 2022. If this occurs, the recovery to 2019 levels will be doubtfully in 2026.

- **Scenario 3:** Considers that the vaccine will not be effective. This will carry into low passenger confidence and drop into propensity to fly. Recovery to 2019 levels will be in 2029.

Figure 1.8 shows the evolution of the traffic according to the 3 scenarios and compares it with the traffic of 2019.

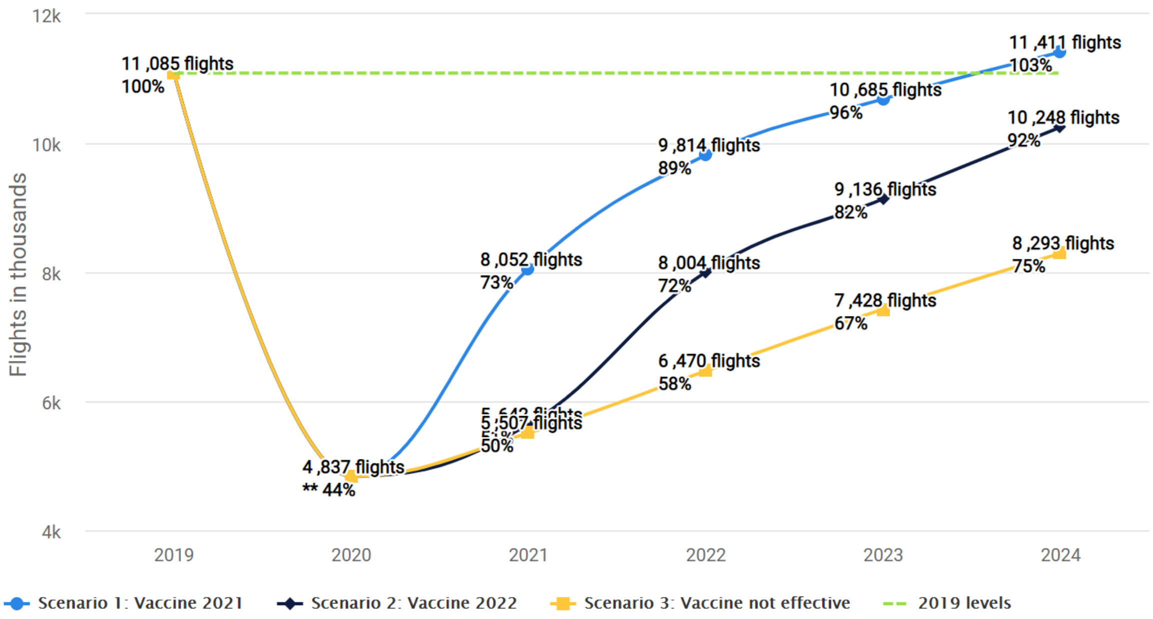


Figure 1.8 5-years forecast for Europe 2020-2024

CHAPTER 2. AIRCRAFT TYPE VS ROUTE

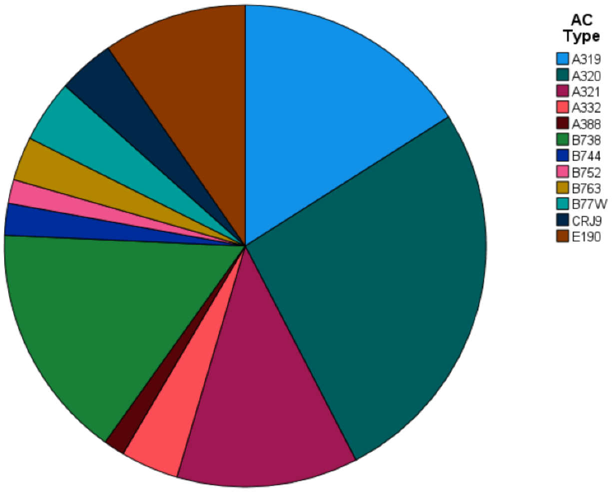
Knowing that air traffic is constantly growing, now the interest goes into the existing type of routes and aircrafts used for each one. *EUROCONTROL*, with the R&D data archive, provided a lot of data in order to make this study. [6] The data shows all the information of every flight for four different months a year between 2015 and 2019. As the big amount of data was difficult to analyse, the consideration of only using the data of one month was accepted. The chosen month is June 2015 as it would be representative enough because the period of the obtained data is not so long. Also, the program *IBM SPSS Statistics* has been used to do all the statistics results and graphs. [7]

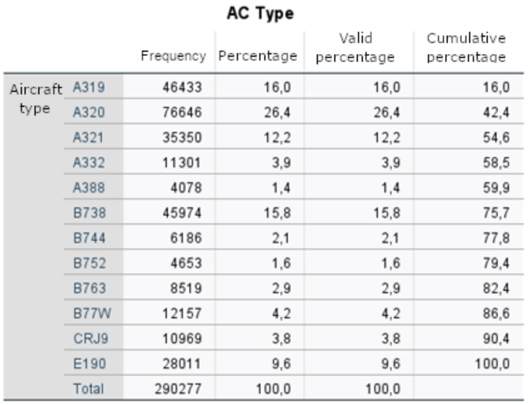
The objective of this chapter is to study the type of aircraft used and its relation with the routes and range travelled. For that, and following the same structure until the moment, the study will be divided into the transport of passengers and freight. Furthermore, a division between traditional and low-cost carriers will be performed in the study of passenger transport. The importance of this differentiation is due to the origin of the kind of business.

The passengers transport has changed during all these years. The creation of the low-cost carriers and the evolution of the international market has been determining the way of travelling. Cargo has evolved due to the evolution of technology together with the deals between countries for the exchange of products, as for example the Schengen area.

Having these considerations into account, it is expected to find different outcomes, so it is important to analyse the routes and the kind of aircrafts used by these different markets.

Figure 2.1. shows the aircraft type used and a table of its usage frequency for traditional carriers, low-cost and cargo. In reality, there are more different types of aircraft used. But the study considers that planes with a usage frequency under 1% are not influenceable.

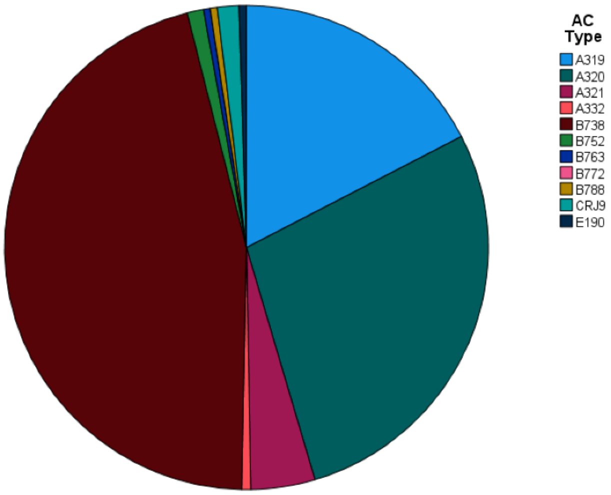


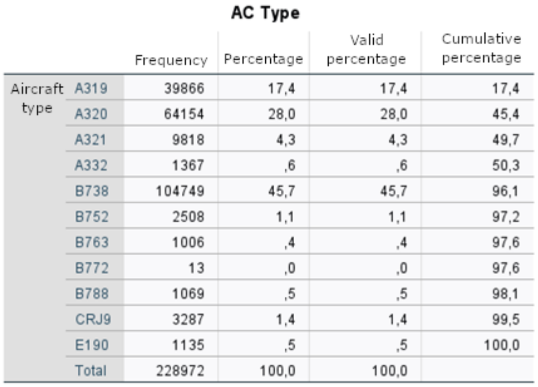


AC Type

		Frequency	Percentage	Valid percentage	Cumulative percentage
Aircraft type	A319	46433	16,0	16,0	16,0
	A320	76646	26,4	26,4	42,4
	A321	35350	12,2	12,2	54,6
	A332	11301	3,9	3,9	58,5
	A388	4078	1,4	1,4	59,9
	B738	45974	15,8	15,8	75,7
	B744	6186	2,1	2,1	77,8
	B752	4653	1,6	1,6	79,4
	B763	8519	2,9	2,9	82,4
	B77W	12157	4,2	4,2	86,6
	CRJ9	10969	3,8	3,8	90,4
	E190	28011	9,6	9,6	100,0
	Total	290277	100,0	100,0	

Figure 2.1a Aircraft type used for traditional carriers

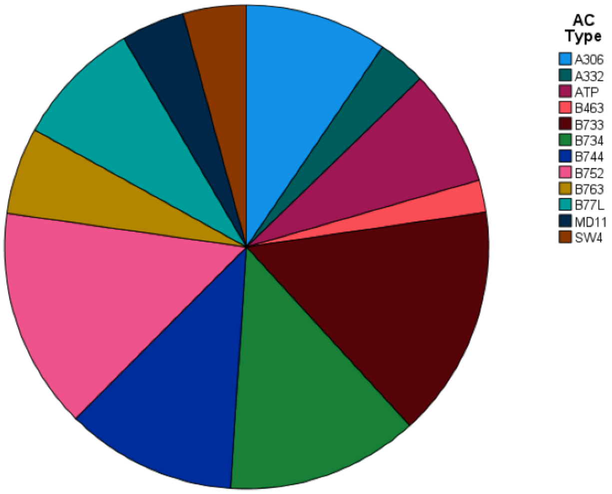


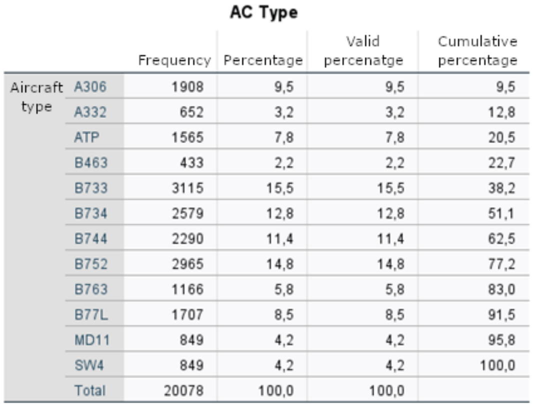


AC Type

		Frequency	Percentage	Valid percentage	Cumulative percentage
Aircraft type	A319	39866	17,4	17,4	17,4
	A320	64154	28,0	28,0	45,4
	A321	9818	4,3	4,3	49,7
	A332	1367	,6	,6	50,3
	B738	104749	45,7	45,7	96,1
	B752	2508	1,1	1,1	97,2
	B763	1006	,4	,4	97,6
	B772	13	,0	,0	97,6
	B788	1069	,5	,5	98,1
	CRJ9	3287	1,4	1,4	99,5
	E190	1135	,5	,5	100,0
	Total	228972	100,0	100,0	

Figure 2.1b Aircraft type used for low-cost carriers





AC Type

		Frequency	Percentage	Valid percenatge	Cumulative percentage
Aircraft type	A306	1908	9,5	9,5	9,5
	A332	652	3,2	3,2	12,8
	ATP	1565	7,8	7,8	20,5
	B463	433	2,2	2,2	22,7
	B733	3115	15,5	15,5	38,2
	B734	2579	12,8	12,8	51,1
	B744	2290	11,4	11,4	62,5
	B752	2965	14,8	14,8	77,2
	B763	1166	5,8	5,8	83,0
	B77L	1707	8,5	8,5	91,5
	MD11	849	4,2	4,2	95,8
	SW4	849	4,2	4,2	100,0
	Total	20078	100,0	100,0	

Figure 2.1c Aircraft type used for cargo

In the three markets, the utilization of narrow-body aircrafts prevails over the wide ones. This is not a surprise, as usually there are more short-haul flights than the long-haul ones and these are mainly operated by narrow-body aircraft whilst the long-haul flights are operated by wide-body aircrafts.

But what differs between these markets is the type of aircraft used and the percentage of usage of every type. Low-cost carriers mostly use narrow-body planes as they mainly have short-haul flights (except for a few airlines that operate both short- and long-haul), and they usually have the same kind of plane on their fleet. Traditional carriers operate both short- and long-haul flights and they have a diversity of aircrafts in their fleet.

For this, the percentage of usage of wide-body planes is higher than the one for low-cost carriers. The transport of cargo is either by short- and long-haul flights. This translates into a more equal percentage of plane usage.

Table 2.1. shows the usage percentage of wide- and narrow-body planes for the three different markets.

Table 2.1. Usage percentage of wide- and narrow-body planes

AIRCRAFT TYPE	LOW-COST CARRIERS	TRADITIONAL CARRIERS	CARGO
NARROW-BODY	98.4 %	85.4 %	61.5 %
WIDE-BODY	1.6 %	14.6 %	38.5 %

Figure 2.2 shows the aircraft type vs range on low-cost, traditional carriers, and cargo. A flight is considered long-haul if the distance travelled is higher than 2000 nm. So, this figure supports the analyses of the previous data obtained in this study.

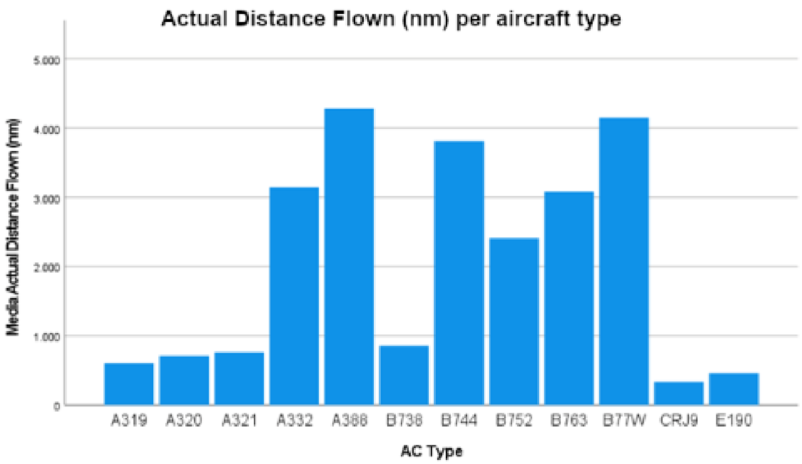


Figure 2.2a Aircraft type vs Range on Traditional carriers

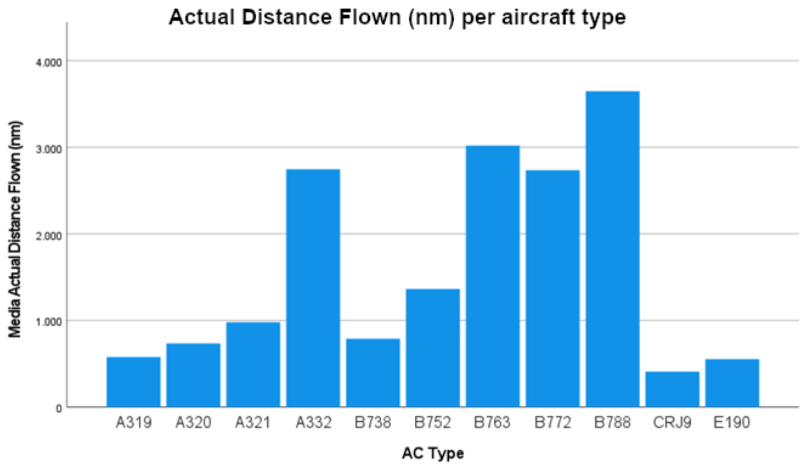


Figure 2.2b Aircraft type vs Range on Low-cost carriers

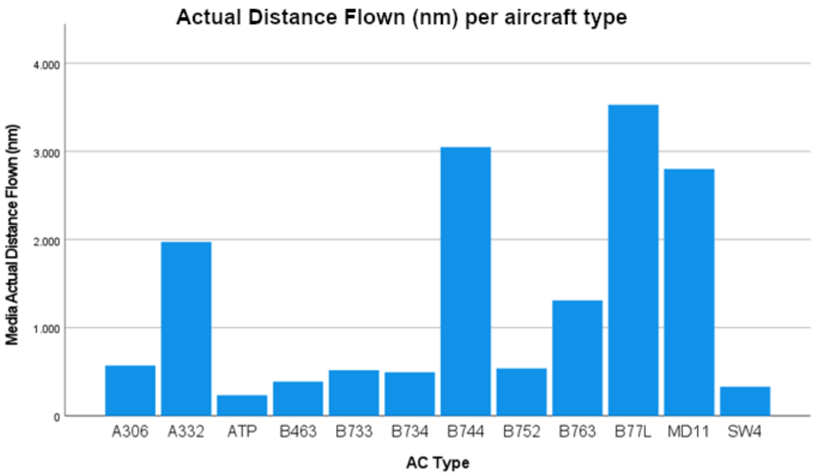


Figure 2.2c Aircraft type vs Range on Cargo

CHAPTER 3. CASE OF STUDY

At this point, the situation is clear. The amount of air traffic is increasing very fast. There are more short- than long-haul flights and the narrow-body aircraft are the most used. If the situation keeps developing this way, soon there will not be physical space to keep carrying all the programmed flights, and the delays will increase very fast.

Besides, some extra investigation has been done. It has been found that trips between two specific cities are flown many times a day with a narrow-body aircraft. But with all the capacity problems that have been mentioned before, it is easy to ask what would happen if instead of flying so many times with a narrow-body, that specific route would be flown less frequently but with a wide-body plane instead.

This would mean a less saturated system. The number of planes taking off and landing, which is the constraint for capacity, would be reduced. Less delays due to capacity purposes and more environment friendly with less contamination and of course, less consumption of fuel.

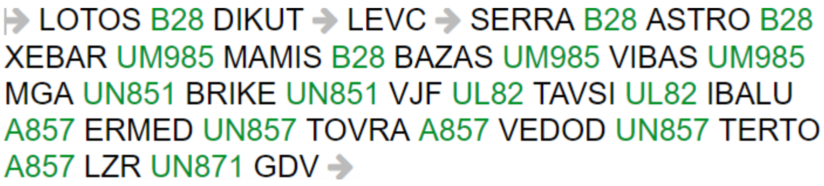
In fact, the aim of this project is to study all the factors that determine whether it is better to use several narrow-body or fewer wide-body planes. Therefore, the route between *Josep Tarradellas Barcelona-El Prat airport* (BCN) and *Gran Canaria airport* (LPA) has been chosen. Even though there are many pairs of cities where there are constant planes transferring passengers, this one is perfect for this study due its tourism purposes. Other cities need more connectivity as on top of being touristic, many businesses passengers are travelling and business meetings can happen all along the day. But, in a touristic destination, the hour of arrival or departure it is not a big factor to consider.

To make the study case, the aircrafts to compare will be an A320 and an A330, carrying 180 and 300 passengers, respectively. The assumptions to take into account are that the planes will be completely full, carrying 45% of men, 45% of women and 10% of children and every adult will take a bag in the hold. Also, the study will consist in the evaluation of the turn flight including the turn round times in *Josep Tarradellas Barcelona-El Prat airport* (BCN) and *Gran Canaria airport*.

The study case will be simplified as much as possible as the interest focuses on the comparison of the planes under the same circumstances. For that, no wind will be considered. It will be divided in different sections. First, the route will be stablished, then the weight and balance of both planes will be evaluated and finally the economic costs and environmental effects will be analysed.

3.1. ROUTE

The route will take place between *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport* (BCN-LPA), which corresponds to 1191 nm or 2205.73km. The plane will depart from BCN using the runway 25R and will be following the procedure of the SID to arrive to the point LOTOS5D. [8] Then, the next route will be performed:



LOTOS B28 DIKUT → LEVC → SERRA B28 ASTRO B28
XEBAR UM985 MAMIS B28 BAZAS UM985 VIBAS UM985
MGA UN851 BRIKE UN851 VJF UL82 TAVSI UL82 IBALU
A857 ERMED UN857 TOVRA A857 VEDOD UN857 TERTO
A857 LZR UN871 GDV →

Once the waypoint TERTO is reached, the approximation begins. The STAR TERTO7C procedure will be followed and the runway used to land will be 03L. [9] Figure 3.1 shows the route followed by the plane.

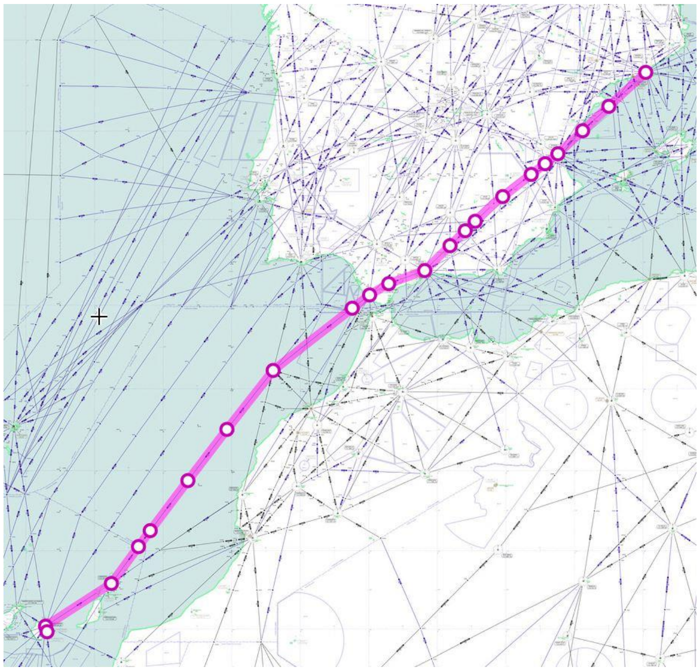


Figure 3.1 Route BCN-LPA [10]

In case of impossibility of landing in *Gran Canaria airport*, an alternate airport must be contemplated. In this case, *Tenerife Norte airport* has been chosen, being at a distance of 59 nm from *Gran Canaria airport*.

3.2. WEIGHT AND BALANCE

Following the steps mentioned before, the weight and balance of both planes will be calculated. This is very important as it has a direct effect on the stability and performance of the aircraft. Calculating all the weights and comparing them with the maximum weights given by the manufacturer is essential to assure that it is safe to fly in these conditions. Another very important factor is to know the needed fuel to reach the destination safely and the possible setbacks that can occur.

EASA normalized the mass of the passengers according to their gender to 88kg, 70kg and 35 kg for men, women and children. Also, there is a normalized weight for the bags in the hold to 11kg per suitcase. This information will help us calculate the payload of every plane. [11]

The Airbus Commercial Aircraft (ACAP) will be checked and the needed data will be collected. [12] Also, the consideration that the plane flies at FL350 in cruise from departure to destination and FL100 from destination to alternate will be taken into account.

3.2.1. WEIGHT AND BALANCE A320

For the calculations of the weight and balance for the A320 the tables of annex 3 will be needed.

$$\text{Operational Empty weight (OEW)} = 40.500\ \text{kg}\ [12]$$

$$\begin{aligned}\text{Payload} = {} & \text{PAX num} * \%\ \text{males} * \text{standard male weight} + \text{PAX num} * \%\ \text{females} \\ & * \text{standard female weight} + \text{PAX num} * \%\ \text{children} \\ & * \text{standard children weight} + \text{PAX num} * \%\ \text{passengers with bags} \\ & * \text{standard bag weight} \\ & = 180 * 0.45 * 88 + 180 * 0.45 * 70 + 180 * 0.10 * 35 + 180 * 0.90 * 11 \\ & = 15.210\ \text{kg}\end{aligned}$$

$$\begin{aligned}\text{Zero Fuel Weight} = {} & \text{Operational Empty weight} + \text{payload} = 40.500 + 15.210 \\ & = 55.710\ \text{kg}\end{aligned}$$

$$\text{Block Fuel} = \text{Taxi fuel} + \text{Trip fuel} + \text{Holding fuel} + \text{Alternate fuel} + \text{Reserve fuel}$$

$$\text{Taxi fuel} = 120\ \text{kg (average quantity per 12 minutes of taxi)}[13]$$

$$\text{Holding fuel} = 1.063\ \text{kg}[13]$$

The calculation of the alternate fuel is not simply checking a table and directly getting the desired value. In this case there are some steps to follow and some calculations if interpolation is needed. First, the fuel weight to travel from *Gran Canaria airport* to *Tenerife Norte airport* must be found in the correct table, given the distance of 59 nm between them [13]. Then a fuel burn correction regarding the estimated landing weight at the alternate airport and a reference weight (50.000kg) must be calculated. Finally, this extra burnt fuel will be added to the fuel weight needed between the two airports.

$$\text{Alternate fuel (without considering the extra fuel burnt)} = 611 \text{ kg}$$

$$\begin{aligned}\text{Estimated landing weight at alternate(ELWalt)} &= \text{ Zero fuel weight} + \text{holding fuel} \\ &= 55.710 + 1.063 = 56.773 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Extra fuel burnt} &= (\text{ELWalt} - \text{Reference weight}) * \text{Fuel correction} \\ &= (56{,}773 - 50) * 4 = 27{,}09 \text{ kg}\end{aligned}$$

$$\text{Alternate fuel} = 611 + 27{,}09 = 638{,}09 \text{ kg}$$

Likewise, the trip weight will be calculated the same way as the alternate weight. But in this case, the pair of cities will be departure and destination (BCN-LPA).

$$\text{Trip fuel (without considering the extra fuel burnt)} = 6.237 \text{ kg}$$

$$\begin{aligned}&\text{Estimated landing weight at destination (ELWdest)} \\ &\quad = \text{Estimated landing weight at alternate} + \text{trip destination to alternate} \\ &\quad = 56.773 + 631{,}32 = 57.404 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Extra fuel burnt} &= (\text{ELWdest} - \text{Reference weight}) * \text{Fuel correction} \\ &= (57{,}404 - 50) * 47 = 348 \text{ kg}\end{aligned}$$

$$\text{Trip fuel} = 6.237 + 348 = 6.585 \text{ kg}$$

$$\text{Reserve fuel(5\% trip fuel)} = 6.585 * 0.05 = 329{,}25 \text{ kg}$$

$$\text{Block fuel} = 120 + 1.063 + 638{,}09 + 6.585 + 329{,}25 = 8.735 \text{ kg}$$

$$\begin{aligned}\text{Takeoff weight} &= \text{OEW} + \text{Payload} + \text{Block Fuel} - \text{Taxi fuel} \\ &= 40.500 + 15.210 + 8.735 - 120 = 64.325 \text{ kg}\end{aligned}$$

$$\text{Landing weight} = \text{Takeoff weight} - \text{Trip fuel} = 64.325 - 6.585 = 57.740 \text{ kg}$$

$$\begin{aligned}\text{Ramp weight} &= \text{OEW} + \text{Payload} + \text{Block Fuel} = 40.500 + 15.210 + 8.735 \\ &= 64.445 \text{ kg}\end{aligned}$$

Table 3.1. A320 Weights summary.

WEIGHTS	KG
OEW	40.500
PAYLOAD	15.210
BLOCK FUEL*	8.735
TAKE-OFF	64.325
LANDING	57.740
ZERO FUEL	55.710
RAMP FUEL	64.445

* BLOCK FUEL	KG
TAXI	120
TRIP	6.585
HOLDING	1.063
ALTERNATE	638,09
RESERVE	329,25
TOTAL	**8.735**

Next step, is to compare the maximum design weights with the ones obtained in this study and check if they are lower than the maximums.

Table 3.2. Comparison design weights. [12]

WEIGHTS	MAXIMUM	CURRENT
TAKE-OFF	70.000 kg	64.325 kg
LANDING	64.500 kg	57.740 kg
ZERO FUEL	60.500 kg	55.710 kg
RAMP FUEL	74.500 kg	64.445 kg

As table 3.2. shows, the calculated weights are never higher than the maximum design weights. Hence, flying in these conditions would be safe and it is possible to continue with the study.

3.2.2. WEIGHT AND BALANCE A330

The same procedure will be performed for the A330. This the tables needed will be found in annex 4.

$$\text{Operational Empty weight (OEW)} = 122.300 \text{ kg } [14]$$

$$\begin{aligned}\text{Payload} = {} & \text{PAX num} * \%\text{ males} * \text{standard male weight} + \text{PAX num} * \%\text{ females} \\ & * \text{standard female weight} + \text{PAX num} * \%\text{ children} \\ & * \text{standard children weight} + \text{PAX num} * \%\text{ passengers with bags} \\ & * \text{standard bag weight} \\ & = 300 * 0.45 * 88 + 300 * 0.45 * 70 + 300 * 0.10 * 35 + 300 * 0.90 * 11 \\ & = 25.350 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Zero Fuel Weight} &= \text{Operational Empty weight} + \text{payload} = 122.300 + 25.350\\ &= 147.650\ \text{kg}\end{aligned}$$

$$\text{Block Fuel} = \text{Taxi fuel} + \text{Trip fuel} + \text{Holding fuel} + \text{Alternate fuel} + \text{Reserve fuel}$$

$$\text{Taxi fuel} = 300\ \text{kg (average quantity per 12 minutes of taxi)}[15]$$

$\text{Holding fuel} = 1.100\ \text{kg}$[15]

For the calculation of the alternate fuel, the reference weight, also found in the table corresponds to 140.000 kg.

$$\text{Alternate fuel (without considering the extra fuel burnt)} = 1.674\ \text{kg}$$

$$\begin{aligned}\text{Estimated landing weight alternate(ELWalt)} &= \text{Zero fuel weight} + \text{holding fuel}\\ &= 147.650 + 1.100 = 148.750\ \text{kg}\end{aligned}$$

$$\begin{aligned}\text{Extra fuel burnt} &= (\text{ELWalt} - \text{Reference weight}) * \text{Fuel correction}\\ &= (148.750 - 140.000) * 2 = 17{,}5\ \text{kg}\end{aligned}$$

$$\text{Alternate fuel} = 1.674 + 17{,}5 = 1691{,}5\ \text{kg}$$

$$\text{Trip fuel (without considering the extra fuel burnt)} = 13.930\ \text{kg}$$

$$\begin{aligned}&\text{Estimated landing weight destination (ELWdest)}\\ &\qquad = \text{Estimated landing weight alternate} + \text{trip destination to alternate}\\ &\qquad = 148.750 + 13.930 = 162.680\ \text{kg}\end{aligned}$$

$$\begin{aligned}\text{Extra fuel burnt} &= (\text{ELWdest} - \text{Reference weight}) * \text{Fuel correction}\\ &= (162.680 - 140.000) * 43 = 975{,}24\ \text{kg}\end{aligned}$$

$$\text{Trip fuel} = 13.930 + 975{,}24 = 14.905\ \text{kg}$$

$$\text{Reserve fuel(5\% trip fuel)} = 14.905 * 0.05 = 745{,}26\ \text{kg}$$

$$\text{Block fuel} = 300 + 1.100 + 1.691{,}5 + 14.905 + 745{,}26 = 18.742\ \text{kg}$$

$$\begin{aligned}\text{Takeoff weight} &= \text{OEW} + \text{Payload} + \text{Block Fuel} - \text{Taxi weight}\\ &= 122.300 + 25.350 + 18.742 - 300 = 166.092\ \text{kg}\end{aligned}$$

$$\text{Landing weight} = \text{Takeoff weight} - \text{Trip fuel} = 166.092 - 14.905 = 151.187\ \text{kg}$$

$$\begin{aligned}\text{Ramp weight} &= \text{OEW} + \text{Payload} + \text{Block Fuel} = 122.300 + 25.350 + 18.742\\ &= 166.392\ \text{kg}\end{aligned}$$

Table 3.3. A330 Weights summary

WEIGHTS	KG
OEW	122.300
PAYLOAD	25.350
BLOCK FUEL*	18.742
TAKE-OFF	166.092
LANDING	151.187
ZERO FUEL	147.650
RAMP FUEL	166.392

*BLOCK FUEL	KG
TAXI	300
TRIP	14.905
HOLDING	1.100
ALTERNATE	1.691,5
RESERVE	745,26
TOTAL	**18.742**

Next step, is to compare the maximum design weights with the ones obtained in this study and check if they are lower than the maximums.

Table 3.4. Comparison design weights. [14]

WEIGHTS	MAXIMUM	CURRENT
TAKE-OFF	184.000 kg	166.092 kg
LANDING	174.000 kg	151.187 kg
ZERO FUEL	164.000 kg	147.650 kg
RAMP FUEL	184.900 kg	166.392 kg

The same as happened with the A320, the calculated weights for the A330 are never higher than the maximum design weights. Hence, flying in these conditions would be safe and it is possible to continue with the study.

3.3. AIRCRAFT RANGE

Another important aspect is to know the maximum range that the aircrafts would be able to achieve with the current payload and compare if this is bigger than the distance needed to travel, including the travel to the alternate airport. In that case it would be 1250 nm.

The Payload/ Range diagram is the one that gives that information by illustrating the trade-off relationship between the payload and the range of one single aircraft.

3.3.1. A320 RANGE

Figure 3.2. shows the Payload/Range diagram for the A320.

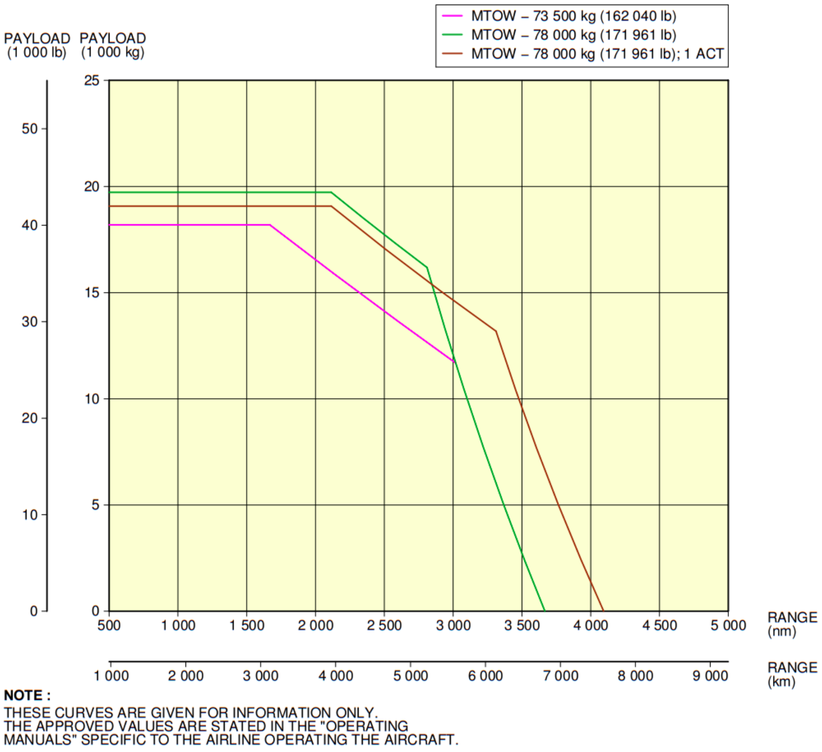
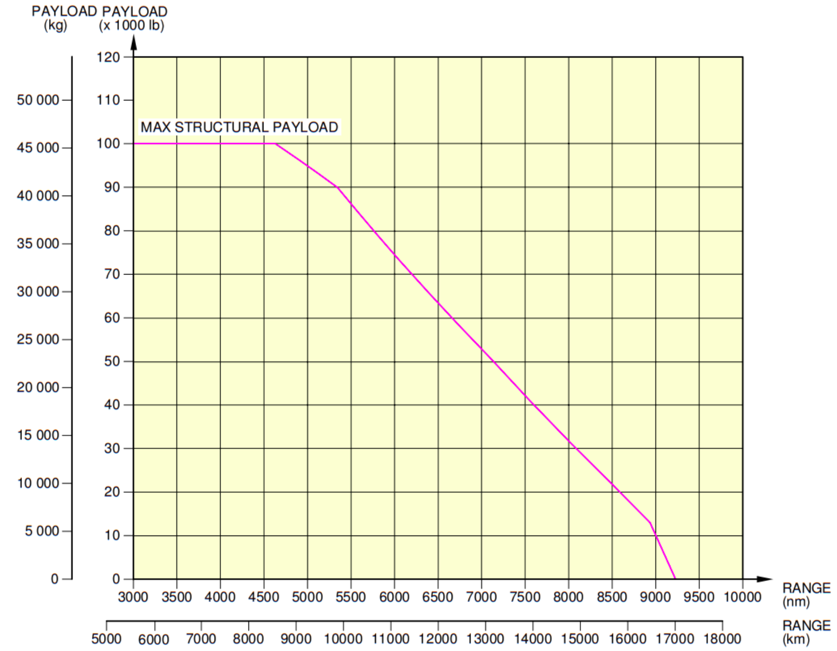


Figure 3.2. A320 Payload/Range diagram

In this diagram, the purple line is the one that has to be analyzed as it is the closest to the MTOW of this study. The payload is 15.210 kg as the previous section shows. The maximum range for the A320 in these conditions is approximately 2.300 nm, which is higher than the 1.250 nm needed for a safe flight.

3.3.2. A330 RANGE

To know the range of the A330 the Payload/Range diagram for this aircraft is shown in figure 3.3.



NOTE : THESE CURVES ARE GIVEN FOR INFORMATION ONLY
THE APPROVED VALUES ARE STATED IN THE "OPERATING MANUALS" SPECIFIC TO THE AIRLINE OPERATING THE AIRCRAFT.

MAX ZERO FUEL WEIGHT : 170 000 kg
MAX TAKE–OFF WEIGHT : 242 000 kg

Figure 3.3 A330 payload/range diagram

In this case the payload loaded in the plane is 25.350 kg and the maximum range is approximately 6.750 nm, which is also higher than the 1250 nm above mentioned.

3.3.3. RANGE COMPARISON

Figure 3.4. gives a better view of the range to achieve the journey BCN-LPA plus the alternate, the maximum range of the A320 and the maximum range of the A330.

Figure 3.4 Range for the study, A320 max range and A330 max range. [16]

The smaller one is the range of this study, the middle one is the maximum range of the A320 and the bigger one is the maximum of the A330. Any of the aircrafts would reach safely the destination.

On top, this figure shows the limitations of using an A320 for long range flights, their range is not big enough.

3.4. AIRPORT TAXES

The journey is travelled between two Spanish airports, which means that they are ruled by Spanish legislation. *AENA* is the society in charge of managing them. For that, some taxes, depending on the aircraft and the received services, must be paid to the airport manager, *AENA.* These taxes can be found in the *“Guia de tarifas de Aena 2020”* on its website. [17]

For the calculation of the taxes that should be paid for the A320 and the A330, the assumption of travelling inside the airports timetable, travelling only with passengers without special needs and the aircrafts will park at the tube will be considered.

3.4.1. LANDING TAXES

The use of the runways to land and the derived services for its use is one of the taxes to pay. The price is calculated accordingly to the maximum take-off weight of the aircraft and it can vary depending on the type of flight and the acoustic rating. Depending on the acoustic rating, a percentage to pay might be added to the tax.

Looking at figure 3.2, both the A320 and the A330 have a cumulative noise margin slightly over -10EPNdb and are categorized as Chapter 4.

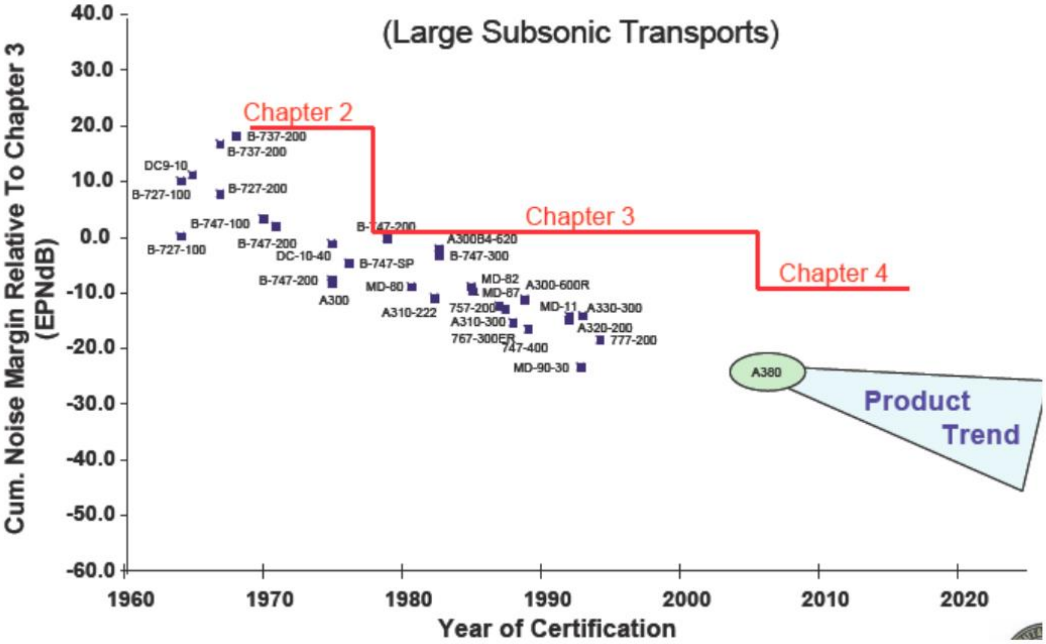


Figure 3.5 Aircraft cumulative noise margin

Knowing the chapter and looking at the table 3.5. the extra percentage to pay for these aircrafts is 0%.

Table 3.5. Extra percentage according to the chapter of the aircraft.

Acoustic classification	07:00-22:59 (local time)	23:00-06:59 (local time)
Chapter 1	70%	140%
Chapter 2	20%	40%
Chapter 3	0%	0%
Chapter 4	0%	0%

The last thing to consider is the type of flight and the airport where the landing is performed. For landing in Gran Canaria airport, the tax to pay is $6{,}910621 * \mathrm{MTOW}(\mathrm{tones})$ and in Josep Tarradellas Barcelona-El Prat airport is $7{,}285036 * \mathrm{MTOW}(\mathrm{tones})$. Table 3.6. shows the total price for every plane.

Table 3.6. Landing taxes.

AIRPORT	A320	A330
LPA	483,74 €	1.271,55 €
BCN	509,95 €	1.340,44 €

3.4.2. PASSENGERS AND SECURITY

The tax for passengers allows them the access to the needed airport facilities with the purpose to reach the aircraft.

The security tax is for the inspection and control of the passengers and their suitcases as well as all the equipment and facilities for surveillance services in all the airport.

The taxes are applied to every departure passenger and it might differ at different airport.

In *Gran Canaria airport* is 5,03€ per passenger and 2.87 per passenger security and in *Josep Tarradellas Barcelona-El Prat airport* 13,25€ and 3.38 respectively.

The tax to pay is calculated as follows:

A320

$$\text{Gran Canaria} \rightarrow (5{,}03 + 2{,}87) * 180 = \ 1.442€$$
$$\text{Barcelona} \rightarrow (13{,}25 + 3{,}38) * 180 = \ 2.993{,}40€$$

A330

$$\text{Gran Canaria} \rightarrow (5{,}03 + 2.87) * 300 = \ 2.370€$$
$$\text{Barcelona} \rightarrow (13{,}25 + 3{,}38) * 300 = \ 4.989€$$

Table 3.7. Passengers and security taxes.

AIRPORT	A320	A330
LPA	1.442 €	2.370 €
BCN	2.993,40 €	4.989 €

3.4.3. USAGE OF PARKING BRIDGE

Parking in a position and using (or not) the bridge to move passengers corresponds a tax. It is calculated according to the time that it is used. For an A320 the turn round time is of 44 minutes and for an A330 59 minutes. [12] [14]

Figure 3.3 shows the corresponding TRT for both aircrafts.

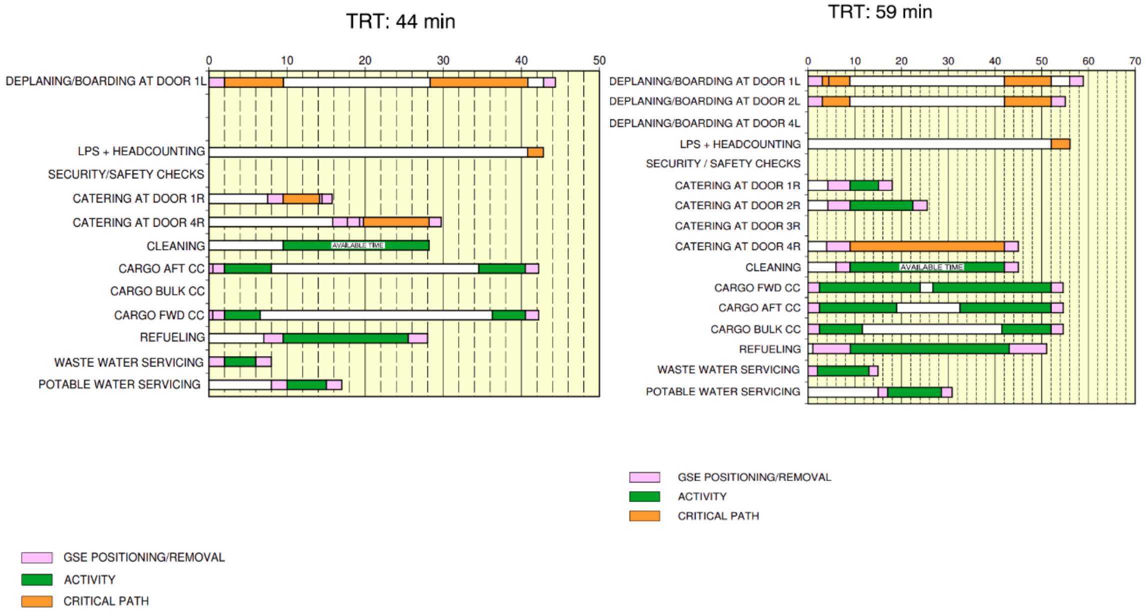


Figure 3.6. Turn Round Time A320 (left) and Turn Round Time A330 (right)

The tax is calculated following the equation:

$$\mathrm{P} = (\mathrm{p1} + \mathrm{p2} * \mathrm{Tm}) * \mathrm{Ft}$$

where:

P: Tax to pay.

p1: Amount time staying in the tube.

p2: Amount per weight and time staying in the tube.

Tm: maximum take-off weight in tones.

Ft: Time staying in the tube in periods of 15 minutes.

The same as happens with the other taxes, the amount depends on the airport. For *Gran Canaria airport* p1 corresponds to 20,473658€ and p2 to 0€. In *Josep Tarradellas Barcelona-El Prat airport is* 23,280197€ and 0€ for p1 and p2. This makes the calculations as follows:

A320

$$\text{Gran Canaria} \rightarrow (20{,}473658 + 0) * \frac{44}{15} = 60{,}05€$$

$$\text{Barcelona} \rightarrow (23{,}280197 + 0) * \frac{44}{15} = 68{,}29€$$

A330

$$\text{Gran Canaria} \rightarrow (20{,}473658 + 0) * \frac{59}{15} = 80{,}53€$$

$$\text{Barcelona} \rightarrow (23{,}280197 + 0) * \frac{59}{15} = 91{,}56€$$

Table 3.8. Usage of the parking bridge.

AIRPORT	A320	A330
LPA	60,05 €	80,53 €
BCN	68,29 €	91,56 €

3.4.4. FUEL SUPPLY

This tax is charged for the use of the airport facilities to transport and supply the fuel. Unlike the other taxes, this is the same amount regardless the airport. The price is 0,003771€/Liter

For the calculation of this tax, the weight and balance have to be checked, specifically the block fuel. Then, the kilos have to be converted to liters and the calculation can easily be made. An average density of kerosene of 810kg/m^3 has been chosen.

$$\text{A320 Block fuel(conversion kg to l)} = \frac{8.735}{810} * 1000 = 10.776{,}54\ \text{l}$$

$$\text{A320} \rightarrow 10.776{,}54 * 0{,}003771 = 40{,}64€$$

$$\text{A330 Block fuel(conversion kg to l)} = \frac{18.742}{810} * 1000 = 23.138{,}27\ \text{l}$$

$$\text{A330} \rightarrow 23.138{,}27 * 0{,}003771 = 87{,}25€$$

Table 3.9. Tax to supply fuel.

TAX	A320	A330
Fuel Supply	40,64 €	87,25 €

3.4.5. AIRCRAFT GROUND ASSISTANCE

This tax is divided into the different ground services that can be given to the aircraft and it is charged for the use of the airport facilities to achieve this purpose. Most of the services taxes remain the same for every airport except for the catering service, whose price varies accordingly to the departure airport. In this study, it is assumed that the aircrafts only need to be filled in *Josep Tarradellas Barcelona-El Prat airport* with food and beverages.

Additionally, the maximum take-off weight, divided into intervals, might also change the price of all the services taxes. The prices for the A320 and A330 are shown in table 3.10.

Table 3.10. Aircraft ground assistance taxes.

SERVICE	A320	A330
Baggage assistance	70,64 €	126,07 €
Runway operations assistance	22,44 €	40,25 €
Cleaning services	12,32 €	22,09 €
Line maintenance services	3,34 €	5,99 €
Catering service	20,22 €	36,27 €
Total	**128,96 €**	**230,67 €**

3.4.6. METEOROLOGICAL SERVICES

Tax because of the meteorological services given to the airlines by the airport manager. This tax is not linked to the airport, but to the aircraft weight. The price is obtained by the calculation of $0{,}181781 * \mathrm{TOW(tones)}$.

Table 3.11. Meteorology services tax.

TAX	A320	A330
Meteorological services	11,65 €	27,81 €

3.4.7. GROUND POWER SERVICE

The usage of the equipment and the airport facilities to supply electrical energy transformed in 400 hertz to the aircrafts is the last tax to consider. The MTOW (in intervals) and the time of use of this service are the aspects to calculate the price. Every aircraft is included in a different interval, so the amount to pay for the A320 is 6,920039€ and for the A330 is 13,50€ per 15 minutes of usage. Remembering the turn round time of the aircrafts, the calculations are the following:

$$\mathrm{A320} \rightarrow 6{,}920039 * \frac{44}{15} = 20{,}30€$$

$$\mathrm{A330} \rightarrow 13{,}5 * \frac{59}{15} = 53{,}10€$$

Table 3.12. 400Hz energy system service tax.

TAX	A320	A330
400Hz energy system service	20,30 €	53,10 €

3.4.8. OTHER SERVICES

There are other services, as checking desks, offices, machines and more that taxes are mandatory as well. But, for the aim of this project they can be neglected.

3.4.9. TOTAL TAXES PRICE

Once all the taxes are developed, it is possible to calculate the total taxes to pay to the airport manager if a plane wants to operate in their airports. Table 3.13. shows the total prices when the plane departs in J *Josep Tarradellas Barcelona-El Prat airport* and lands in *Gran Canaria airport*, the other way around and the total amount if the plane does both journeys.

Table 3.13. Total taxes prices.

JOURNEY	A320	A330
BCN->LPA	3.739,74 €	6.739,91 €
LPA->BCN	2.201,57 €	4.164,56 €
Total	**5.941,31 €**	**10.904,47 €**

3.5. ATC TAXES

As *AENA* is the agency who manages the airports in the Spanish territory, *ENAIRE* is the one who manages the air navigation services. Thus, is who charges the taxes, which are divided into En-route charges and Terminal navigation charges. *ENAIRE* launched the *"Guide to air navigation charges 2021"* where these taxes are explained and can be calculates. [18]

3.5.1. EN-ROUTE CHARGES

This tax is related to the use of the en-route air navigation facilities and services. The tax is calculated accordingly to the next equation:

$$r_i = t * N$$

where:

r_i: Total charge.

t: Spanish unit rate of the charge. This rate depends on the area of flying, differentiating between continental and Canary Island areas.

The flight of this study trespasses both areas. Therefore, it has been calculated the amount ok kilometres travelled in each area. This is 491nm continental area and 700 nm in the Canary Island one.

N: Number of service units. This number is related to the distance travelled and the MTOW.

The calculation is $N = \frac{\text{Great circle distance travelled (km)}}{100} * \frac{\text{MTOW(tons)}}{50} * 0.5$

The total calculation according to this study is:

$$A320 = 45{,}44 * \frac{491}{100} * \left(\frac{70}{50}\right)^{0.5} + 40 * \frac{700}{100} * \left(\frac{70}{50}\right)^{0.5} = 595{,}29€$$

$$A330 = 45{,}44 * \frac{491}{100} * \left(\frac{184}{50}\right)^{0.5} + 40 * \frac{700}{100} * \left(\frac{184}{50}\right)^{0.5} = 965{,}13€$$

Table 3.14. En-route charges.

TAX	A320	A330
En-route charges	595,29 €	965,13 €

3.5.2. TERMINAL NAVIGATION CHARGES

The terminal navigation charges is associated to the use of air navigation services to ensure the safety and orderly flow of movements at the approach and take-off.

The formula for the charge levied is:

$$R = \mathrm{t} * (\mathrm{P}/50)^{\mathrm{n}}$$

Where:

R: Total charge per operation.

t: Spanish unit rate of the charge. In this case, this rate depends on the departure airport and it is the same for *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport*.

P: Licensed MTOW of the aircraft.

n: Weighting coefficient. Always 0,7.

The total calculation in this case is:

$$\mathrm{A320} \rightarrow 20{,}01 * \left(\frac{70}{50}\right)^{0.5} = 25{,}32€$$

$$\mathrm{A330} \rightarrow 20{,}01 \left(\frac{184}{50}\right)^{0.5} = 49{,}81€$$

Table 3.15. Terminal Navigation charges.

TAX	A320	A330
Terminal navigation charges	25,32 €	49,81 €

3.5.3. TOTAL ATC CHARGES

The total ATC charges are simply the addition of the En-route charges and the Terminal navigation charges. This is for one leg of the journey. As in this study we want to do a comparison when the plane does both legs, the only thing we would need is having to apply these taxes 2 times. Table 3.16 shows the total ATC charges.

Table 3.16. Total ATC charges.

CHARGES	A320	A330
En-route	595,29 €	965,13 €
Terminal navigation	25,32 €	49,81 €
Total (1 leg)	620,61 €	1.014,94 €
Total	**1.241,22** €	**2.029,88** €

ENAIRE provides a document with all the related information and the prices needed to do all these calculations. These amounts are excluding taxes, so the real taxes to pay will be higher than the ones shown in this project. But once again, the focus of this project is to make a comparison of the two planes in the same conditions.

3.6. HANDLING COSTS

Until this moment, all the costs explained were for the payment of taxes derived of services. This section will talk about the costs of actual services on the plane.

When an aircraft is on ground it needs ground assistance. It either has to be prepared for departure or get unload if it just landed. These services are called handling, and they are usually done by external companies.

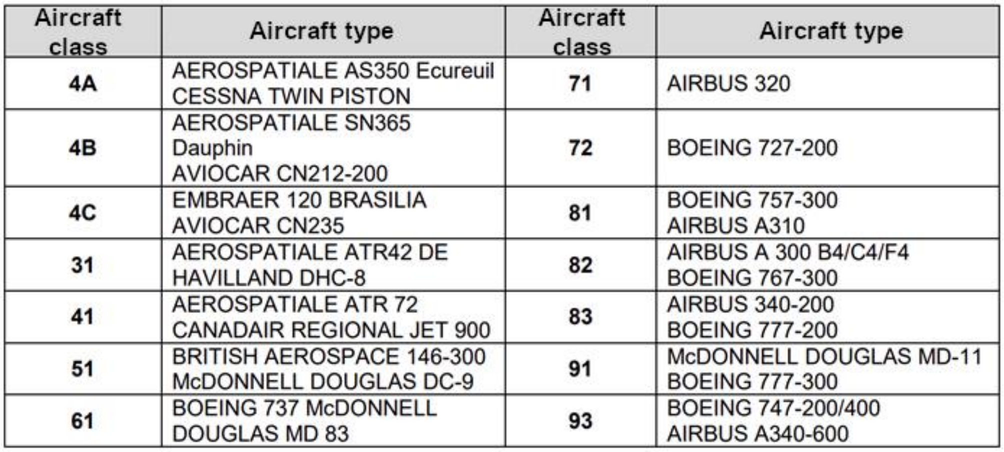
AENA, as the airport manager has to authorize these external companies to provide their services inside the airport facilities and also establishes a maximum rate that these companies can charge to offer their services. Although, under this maximum, the rate they charge is up to the company and the deals are different with every airline.

At *Josep Tarradellas Barcelona-El Prat* there are three authorized companies: *Iberia, Globalia* and *Swissport*. Instead, at *Gran Canaria airport* there are only two: *Iberia* and *Globalia*.

For this study, the handling services are considered to be carried by the same company in both airports and they charge the maximum rate price.

An aircraft classification is made to differentiate the handling prices. Table 3.17. shows the different aircraft classes with an example aircraft type. Then table 3.18. shows the maximum price for the handling services according to the aircraft class and the type of flight.

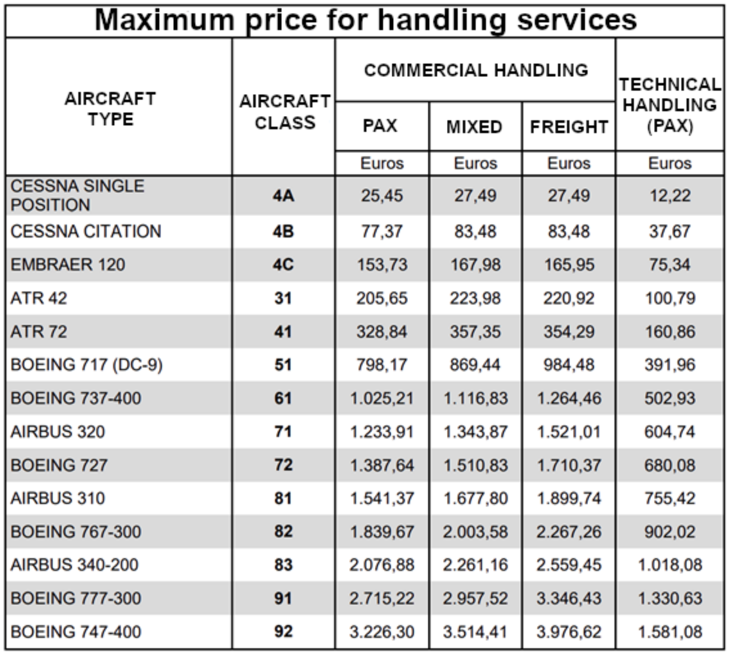
Table 3.17. Aircraft class with example of aircraft type.



Aircraft class	Aircraft type	Aircraft class	Aircraft type
4A	AEROSPATIALE AS350 Ecureuil CESSNA TWIN PISTON	**71**	AIRBUS 320
4B	AEROSPATIALE SN365 Dauphin AVIOCAR CN212-200	**72**	BOEING 727-200
4C	EMBRAER 120 BRASILIA AVIOCAR CN235	**81**	BOEING 757-300 AIRBUS A310
31	AEROSPATIALE ATR42 DE HAVILLAND DHC-8	**82**	AIRBUS A 300 B4/C4/F4 BOEING 767-300
41	AEROSPATIALE ATR 72 CANADAIR REGIONAL JET 900	**83**	AIRBUS 340-200 BOEING 777-200
51	BRITISH AEROSPACE 146-300 McDONNELL DOUGLAS DC-9	**91**	McDONNELL DOUGLAS MD-11 BOEING 777-300
61	BOEING 737 McDONNELL DOUGLAS MD 83	**93**	BOEING 747-200/400 AIRBUS A340-600

For the A320 there is no doubt that the aircraft class is 71, as it is explicitly shown in the table. The problem comes with the A330. This plane is in the aircraft class 82 for its resemblances with the aircraft examples of this class.

Table 3.18. Maximum price for handling services.



Maximum price for handling services

AIRCRAFT TYPE	AIRCRAFT CLASS	COMMERCIAL HANDLING			TECHNICAL HANDLING (PAX)
		PAX	MIXED	FREIGHT	
		Euros	Euros	Euros	Euros
CESSNA SINGLE POSITION	**4A**	25,45	27,49	27,49	12,22
CESSNA CITATION	**4B**	77,37	83,48	83,48	37,67
EMBRAER 120	**4C**	153,73	167,98	165,95	75,34
ATR 42	**31**	205,65	223,98	220,92	100,79
ATR 72	**41**	328,84	357,35	354,29	160,86
BOEING 717 (DC-9)	**51**	798,17	869,44	984,48	391,96
BOEING 737-400	**61**	1.025,21	1.116,83	1.264,46	502,93
AIRBUS 320	**71**	1.233,91	1.343,87	1.521,01	604,74
BOEING 727	**72**	1.387,64	1.510,83	1.710,37	680,08
AIRBUS 310	**81**	1.541,37	1.677,80	1.899,74	755,42
BOEING 767-300	**82**	1.839,67	2.003,58	2.267,26	902,02
AIRBUS 340-200	**83**	2.076,88	2.261,16	2.559,45	1.018,08
BOEING 777-300	**91**	2.715,22	2.957,52	3.346,43	1.330,63
BOEING 747-400	**92**	3.226,30	3.514,41	3.976,62	1.581,08

Table 3.19 shows the total cost for the handling of both planes. The prices have to be multiplied by two to have the costs in both *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport.*

Table 3.19. Total handling costs.

	A320	A330
Handling costs (per turn round)	1.233,91 €	1.839,67 €
Total	**2.467,82 €**	**3.679,34 €**

3.7. AIRCRAFT OPERATING COSTS

Aircraft operating costs are the costs that a plane produces for being used. The type of aircraft used it is a relevant factor. Therefore, this is the most important cost to study as it includes many elements concerning an aircraft. The operating costs are usually expressed in cost per block hour which state the cost per one hour.

They can be divided into fixed and variable costs depending on the origin of the expense. The variable costs can fluctuate and fixed costs show little or no change.

3.7.1. VARIABLE COSTS

The variable costs depend on the fares or taxes of specific services and they can affect directly to aircraft operators and indirectly to the users of air service. These costs include fuel and oil, maintenance and crew salaries.

3.7.1.1. Fuel and Oil costs

This is the cost of the fuel and oil loaded in the plane. The price is based on the price of the fuel at the given moment and the fuel consumption for a given operation. This cost changes when the price of the fuel changes, which is constantly.

3.7.1.2. Maintenance costs

In order to meet the safety requirements at the airline industry, maintenance costs are unavoidable. Maintenance can be scheduled or unscheduled. The last one is what it makes this cost variable.

It includes maintenance labor; airframe, engine and avionics parts; APU, propeller and Thrust reverse overhaul and dynamic components cost.

3.7.1.3. Crew costs

It includes the crew salaries, including pilot, co-pilot, flight engineers and stewardesses. It also includes the trainers and instructors, the personnel expenses and employees benefit, which are an extra on their wage.

3.7.2. FIXED COSTS

The fixed cost does not oscillate and in short-term, they are independent of a change of activity. They include depreciation, rentals, insurance and others.

3.7.2.1. Depreciation

It is assumed that aircrafts lose a fixed percentage of their original purchase price each year, which converts into a cost and it is a significant component for fixed costs.

3.7.2.2. Rentals

The rentals of hangars and other facilities in order to maintain the activity is also an important fixed cost.

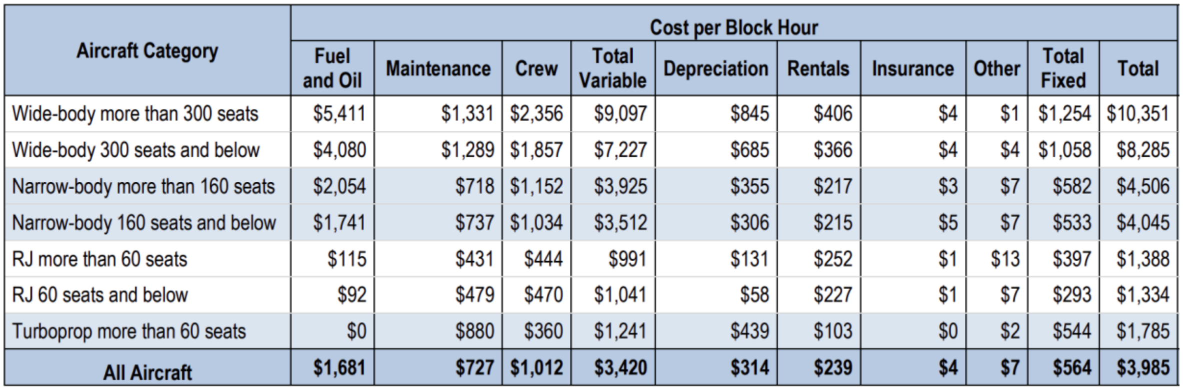
3.7.2.3. Insurance and others

The obligatory purchased insurances, sales costs, administration, accounts, general management and employment costs, among others are the rest of the fixed costs.

3.7.3. OPERATION COSTS CALCULATIONS

The operating costs of a plane depend on the air carrier who is using the aircraft, the fleet of the airline and the utilisation of the aircraft. Meaning that the operating costs are not equal for the same aircraft. The *Federal Aviation Administration* (FAA) released a document with standard values, which are the ones that will be used. [19] Once again, emphasizing the importance of the comparison in this project, these values are satisfactory. Table 3.20. shows in detail the variables and fixed costs per block hour of the different aircraft types.

Table 3.20. Aircraft type variable and fixed costs per block hour. [10]



Aircraft Category	Cost per Block Hour									
	Fuel and Oil	Maintenance	Crew	Total Variable	Depreciation	Rentals	Insurance	Other	Total Fixed	Total
Wide-body more than 300 seats	$5,411	$1,331	$2,356	$9,097	$845	$406	$4	$1	$1,254	$10,351
Wide-body 300 seats and below	$4,080	$1,289	$1,857	$7,227	$685	$366	$4	$4	$1,058	$8,285
Narrow-body more than 160 seats	$2,054	$718	$1,152	$3,925	$355	$217	$3	$7	$582	$4,506
Narrow-body 160 seats and below	$1,741	$737	$1,034	$3,512	$306	$215	$5	$7	$533	$4,045
RJ more than 60 seats	$115	$431	$444	$991	$131	$252	$1	$13	$397	$1,388
RJ 60 seats and below	$92	$479	$470	$1,041	$58	$227	$1	$7	$293	$1,334
Turboprop more than 60 seats	$0	$880	$360	$1,241	$439	$103	$0	$2	$544	$1,785
All Aircraft	**$1,681**	**$727**	**$1,012**	**$3,420**	**$314**	**$239**	**$4**	**$7**	**$564**	**$3,985**

A cost per block hour is the total cost that a plane produces in a one-hour block. The block time is the time that the airplane needs for its operation, starting with the taxi at the departure airport until the end of the taxi at the arrival airport.

Afterwards, the total block time for this study needs to be calculated. For the taxi time, 12 minutes average time is assumed either at *Josep Tarradellas Barcelona-El Prat airport* and at *Gran Canaria airport*. This means 12 minutes per 4 taxis is a total of 48 minutes in taxi. The total flying time can be extracted from the tables of the Flight Crew Operating Manual (FCOM). (Annex 3 and Annex 4)

The total block time for the A320 and A330 is the following:

$$\begin{aligned}\mathrm{A320} &\rightarrow \mathrm{taxi(BCN)} + \text{flying time} + \mathrm{taxi(LPA)} + \mathrm{taxi(LPA)} + \text{flying time} + \mathrm{taxi(BCN)} \\ &= 12 + 171 + 12 + 12 + 171 + 12 = 389\ \text{minutes} = 6\text{h } 29\ \text{min}\end{aligned}$$

$$\begin{aligned}\mathrm{A330} &\rightarrow \mathrm{taxi(BCN)} + \text{flying time} + \mathrm{taxi(LPA)} + \mathrm{taxi(LPA)} + \text{flying time} + \mathrm{taxi(BCN)} \\ &= 12 + 168 + 12 + 12 + 168 + 12 = 384\ \text{minutes} = 6\text{h } 24\ \text{min}\end{aligned}$$

Considering that the block times can be counted per period of times of 15 minutes, both aircrafts would need a block time of 6h and 30min. This means that the results in the table have to be multiplied by 6.5 in order to get the total operating costs. It is important to mention that the prices of the table are in dollars, so a conversion to euros will be needed first.

Table 3.21. shows the operation cost per block hour and the total operating costs of the A320 and A330 to perform the journey that is being studied.

Table 3.21. Total aircraft operating cost.

	A320	A330
Operating cost per block hour	3.696,29 €	6.796,23 €
Total aircraft operation cost	24.025,89 €	44.175,50 €

3.8. COST RESULTS

Once all the costs have been calculated, the results will be compiled. Table 3.22 shows a global overview of all the costs of a return flight from *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport*.

Table 3.22. Costs to perform a return flight BCN-LPA.

	A320	A330
AENA TAXES	5.941,74 €	10.904,47 €
ATC TAXES	1.241,22 €	2.029,88 €
HANDLING COSTS	2.467,82 €	3.679,34 €
OPERATING COSTS	24.025,89 €	44.175,50 €
TOTAL	**33.676,67 €**	**60.789,19 €**

The operating costs is the parameter that determines the total costs, as they are surprisingly higher than the rest. This is due to the fact that the operating costs include several costs related to the motion of the aircraft, meanwhile the others are taxes related or only indirect related to this motion.

The total price of performing the return flight and the big differences between planes is surprising.

Another way of interpreting these results is to observe the price per passenger. This number is obtained dividing the total cost by the number of passengers that every plane carries. As the total costs obtained are for a return flight, the passengers are counted two times.

$$\text{Price per passenger A320} = \frac{33.676{,}67}{360} = 93{,}55\,\frac{€}{\text{pax}}$$

$$\text{Price per passenger A330} = \frac{60.789{,}19}{600} = 101{,}32\,\frac{€}{\text{pax}}$$

Besides, there are two other interesting cases to know the price per passenger. The first one is the case where the price is higher for the A320 than for the A330. This happens when 27 seats of the A320s are empty, which corresponds to 8% of the total.

$$\text{Price per passenger A320(8\% empty seats)} = \frac{33.676{,}67}{332} = 101{,}43\,\frac{€}{\text{pax}}$$

The other one is when in both aircrafts are carried the same number of passengers, 300. This happens when the A330 is full and when in the A320s 60 seats, or 17% of the total are empty.

$$\text{Price per passenger A320(17\% empty seats)} = \frac{33.676{,}67}{300} = 112{,}26\,\frac{€}{\text{pax}}$$

3.9. ENVIRONMENTAL IMPACT

The last topic to be studied is the environmental impact of flying. Aircraft engines produce emissions and those are harmful for the environment.

Studies estimate that the total CO_2 aviation emissions are approximately 3% of the Global Greenhouse emissions, a very low percentage.

The Greenhouse gases extracted from airplanes are C02, H2O, sulphites, soot, and nitrogen oxide (NOx). The emission index for nitrogen oxide varies with altitude, Mach number, and fuel-flow rate, but it can be estimated with a fuel-flow-correlation model.

The aim of this project is not to calculate all these values, so they have been extracted from another study. [20] Table 3.23 shows a comparison of emission per passenger for a 1500 nm flight. The data extracted is a bit higher than the one it would be for this study, but once again the importance is to do the calculations for both planes under the same basis in order to be able to get a reliable comparison.

Table 3.23. Comparison of emission per passenger for the A320 and A330 over a 1.500 nm flight.

	A320	A330
PAX number	150	293
Fuel burnt	8.797 kg	18.749 kg
Emissions (kg/pax)		
$C0_2$	185	202
H_20	72,1	78,7
Sulphites	0,0117	0,0128
Soot	0,00235	0,00256
NO_x	0,785	1,08

The emission shown in table 3.23 are the kg per passenger. But the interest is in the total emission of the plane, which can be calculated for the specifications of the referenced study.

3.9.1. A320 emission

$$\begin{gathered}
\text{C02} = 185 * 150 = \ \ 27.750 \text{ kg} \\
\text{H20} = 72{,}1 * 150 = 10.815 \text{ kg} \\
\text{Sulphites} = 0{,}0117 * 150 = \ \ 1{,}775 \text{ kg} \\
\text{Soot} = 0{,}00235 * 150 = 0{,}3525 \text{ kg} \\
\text{NOx} \ = 0{,}785 * 150 = \ \ 117{,}75 \text{ kg}
\end{gathered}$$

3.9.2. A330 emission

$$
\begin{gathered}
\mathrm{C02} = 202 * 293 = \ 59.186\ \mathrm{kg} \\
\mathrm{H20} = 78{,}7 * 293 = 23.059{,}1\ \mathrm{kg} \\
\mathrm{Sulphites} = 0{,}0128 * 293 = \ 3{,}7504\ \mathrm{kg} \\
\mathrm{Soot} = 0{,}00256 * 293 = 0{,}75\ \mathrm{kg} \\
\mathrm{NOx} \ = 1{,}08 * 293 = \ 316{,}44\ \mathrm{kg}
\end{gathered}
$$

3.9.3. Emission comparison

After the different emission are calculated for both planes, table 3.24. shows the emission per a travel of 1500 nm of the A320, emission if the A320 would be used two times and emission of the A330.

Table 3.24. Comparison of aircraft total emission over a 1.500 nm flight.

	A320	**2xA320**	**A330**
$C0_2$	27.750 kg	55.500 kg	59.186 kg
H_20	10.815 kg	21.630 kg	23.059,10 kg
Sulfites	1,775 kg	3,55 kg	3,7504 kg
Soot	0,3525 kg	0,705 kg	0,75 kg
NO_x	117,75 kg	235,5 kg	316,44 kg

4. RESULTS

This section shows and comments on all the results of this study. Table 4.1 shows the total costs to operate a return flight from *Josep Tarradellas Barcelona-El Prat airport* and *Gran Canaria airport* with an A320 and an A330.

Table 4.1. Costs to perform a return flight BCN-LPA.

	A320	**A330**
TOTAL COSTS	33.676,67 €	60.789,19 €

From table 4.1. a big cost difference between operating an A320 and an A330 can be seen. This study considered that the planes fly completely full all the time, which means that the A320 transports 180 passengers and the A330 transports 300 passengers.

In these conditions, it is more profitable to use two times an A320 than one A330, as the relationship between economical cost and number of passengers transported is more efficient with the A320. The A330 can carry 66% more passengers than the A320 (300 passengers compared to 180), but the cost to use an A330 increases by 80%.

But the airplanes are not always full, and the occupancy rate is not always 100%. Then, the results change. In the case that two A320 and only one A330 are used, if the number of empty seats is equal or higher than 17% of the capacity of the A320, in other words, 60 seats are empty, then the option to use the A330 is better. Figure 4.1. shows a representation and a further explanation will be after.

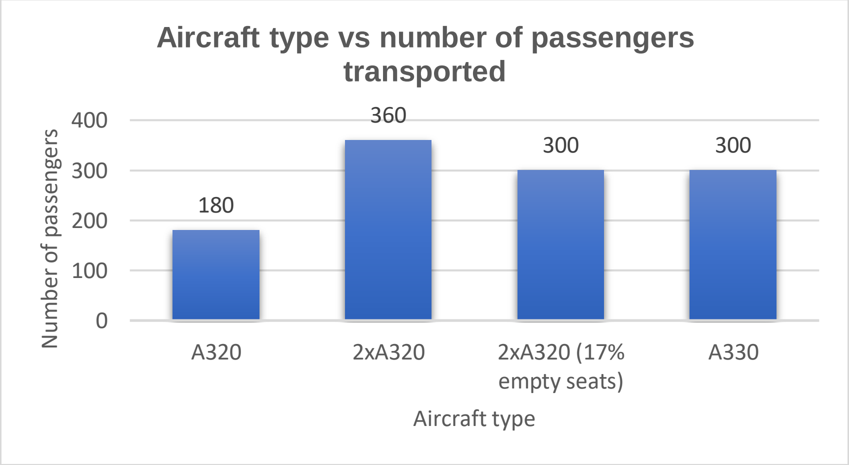


Figure 4.1 Aircraft type vs number of passengers transported

When 17% of the seats of the A320 are empty, the total number of passengers transported are 300, which is the maximum number of passengers that fit in just one A330. This would mean the possibility of unifying the two A320 into an A330 and the outcome is a reduction of costs for transporting the same number of passengers.
Another factor to consider is that the prices shown above might be modified when airlines get better deals with the airport managers or the external companies that give services. But in this project the maximum prices are the ones that have been used.

A different way of interpreting the results is to observe the price per passenger. Figure 4.2. show the total cost depending on the amount of empty seats.

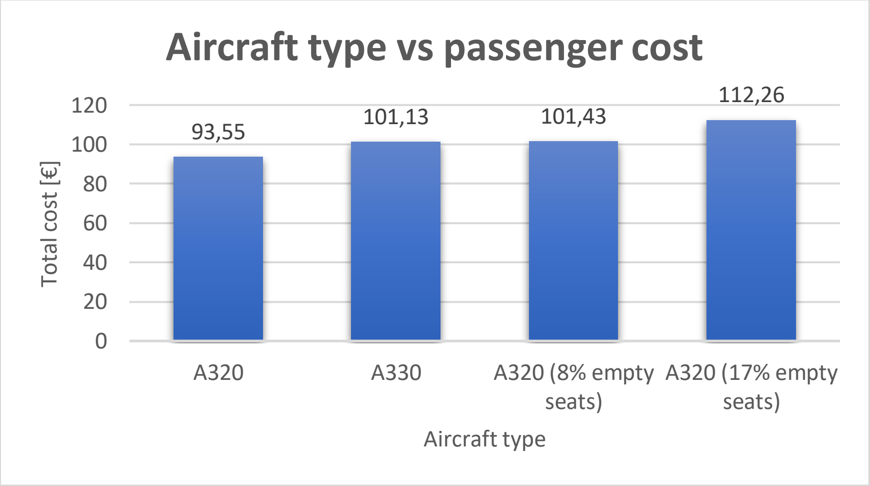


Figure 4.2. aircraft type vs passenger cost according to the empty seats

Following the same structure as before, if the planes occupancy rate is 100%, the cost per passenger for an A330 is higher than for the A320 and if 17% of the seats are empty, the situation reverts. But, the difference of using this way of interpretation is the point when the price per passenger for using the A320 becomes higher than for the A330. This occurs when 8% or 27 of the seats are empty. At this point, with two A320 the number of passengers transported would be 333, which would not fit in an A330. This is the trade-off point in what the decision to transport more passengers at a higher price and in two times or at a lower price and just in one time has to be decided.

Hence, the results depending on the number of empty seats, would be a good seasonal study for airlines to take into account when planning future flights. In summer, the occupancy of the planes is always higher than in winter.
Environmentally speaking, there is an impacting result. Figure 4.3. shows the emissions in kg per aircraft.

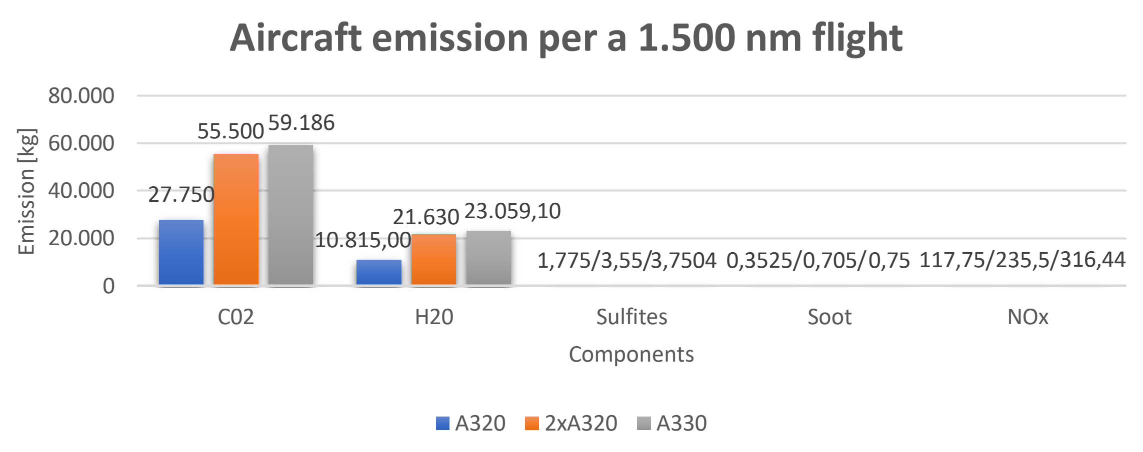


Figure 1.3. Aircraft emissions in kg per a 1.500 nm flight

Using an A320 contaminates less than an A330. But the surprising result is that using two A320 contaminates less than a single A330. So, for the environment is better to keep using narrow- above wide-body aircrafts.

Lastly, another concept seems relevant to be mentioned. Nowadays, wide-body aircrafts are designed to fly long- instead of short-haul. Therefore, they are equipped and certified with the necessary instruments.

Perhaps, the possibility of adapting and manufacturing the wide-body aircraft for a short-haul travel, the so-called LASR (Large Aircraft for Short Range) could be the new way of operating. Removing the unnecessary instruments, like aid navigation to cross the Atlantic, and reducing the avionics of the plane removing extra wiring inside the plane, like the one used for the passenger's screens, would be some examples of this adjustment.

The outcome will affect the operational empty weight (OEW), which will be reduced. Therefore, the maximum take-off weight (MTOW) and the fuel consumption will be lower. Consequently, the operating costs and taxes, like landing taxes or meteorology taxes among others will be reduced. On top, the environmental impact would also be reduced.

Next step, knowing the new weights of the LASR aircraft, this study should be repeated to evaluate which option would be better.

5.CONCLUSIONS

The conclusions of this project can be divided basically into three general points. Economically, it is better to use narrow-body aircrafts above wide-body for short-haul flights if the planes are full. Instead, if the planes have a lower occupancy rate, then a wide-body aircraft is better.

Environmentally, using narrow-body aircrafts results the best option.

Finally, the idea of the LASR seems interesting as it could save costs and they could be better for the environment. But it also has negative aspects like the reduction of choices of schedule for the passengers. Although for touristic travels as the one studied in this project, the schedule choice would not have such impact and it would be a good way to start implementing this type of aircrafts.

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ANNEX:

ANNEX 1. AIR PASSENGER TRANSPORT BY REPORTING COUNTRY

TIME	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
European Union														
Belgium	10.028.692	11.235.430	12.505.217	13.354.702	15.923.010	18.481.800	20.002.289	21.594.842	18.594.842	13.558.962	15.095.879	17.468.503	17.813.943	19.154.673
Bulgaria														
Czechia										6.579.480	7.761.268	9.950.314	11.265.764	12.171.235
Denmark	270.791	606.937									361.945	21.006.048	22.173.770	22.967.560
Germany	58.845.059	64.555.531	84.943.369	87.901.604	93.978.791	104.533.962	112.191.393	120.691.010	118.186.356	114.383.253	121.181.405	135.909.864	146.102.479	154.090.077
Estonia												990.776	1.393.105	1.533.132
Ireland	5.554.914	8.101.297	9.781.040	9.915.730	12.373.093	13.274.833	15.235.311	16.685.717	17.316.121	18.235.186		20.851.353	24.254.298	27.558.133
Greece	17.317.040	20.123.470	19.313.135	17.709.200	18.611.962	24.103.793	27.593.971	30.725.465	29.725.465	28.725.465	28.165.427	30.314.835	31.572.652	33.580.794
Spain	45.274.592	50.552.232	55.025.894	57.052.551	62.173.233	68.767.908	101.326.370	109.971.151	112.936.603	112.237.754	120.238.878	129.771.378	143.679.871	150.599.291
France	40.715.189	44.131.762	44.652.838	48.976.296	79.333.292	84.621.906	90.729.435	96.366.913	94.390.723	96.533.114	96.295.691	103.042.925	107.964.706	113.189.378
Croatia														
Italy	23.680.153	26.780.183	44.852.540	48.358.178	53.430.518	35.052.392	35.452.392	35.852.392	40.289.030	65.227.580	73.917.022	80.805.830	87.906.438	95.914.382
Cyprus									6.539.766		6.077.403	6.421.198	6.782.521	6.714.102
Latvia												1.056.041	1.872.040	2.488.065
Lithuania											721.789	994.161	1.434.241	1.799.195
Luxembourg												1.509.069	1.538.152	1.597.404
Hungary										4.468.821	5.010.397	6.380.372	7.918.083	8.245.920
Malta									2.836.131	2.639.805	2.647.642	2.790.121	2.757.240	2.699.870
Netherlands	20.989.607	23.649.421	25.544.282	28.045.730	31.835.635	34.856.920	37.454.145	40.626.191	40.671.305	41.875.323	41.168.497	44.493.696	46.433.037	48.584.873
Austria										14.943.765	15.798.652	18.296.612	19.684.822	20.824.533
Poland												6.091.886	7.080.325	13.737.803
Portugal	8.206.870	10.581.802	11.299.367	11.478.794	12.143.767	13.694.126	14.972.855	19.572.269	17.310.534	17.383.237	17.739.078	18.423.155	20.274.653	22.028.195
Romania									2.360.467	2.414.809	2.717.516	3.192.620	3.493.783	4.900.134
Slovenia												1.046.162	1.217.167	1.327.333
Slovakia									414.356	497.007	625.861	1.080.945	1.519.452	2.124.447
Finland					6.441.657	9.983.372	9.796.432	10.721.453		10.295.754	10.516.364	11.785.244	12.348.113	13.443.365
Sweden	1.013.272											19.957.013	20.997.169	25.744.721
United Kingdom	86.372.686	95.858.948	100.971.029	104.921.402	114.155.365	142.897.783	151.467.129	162.339.818	163.041.375	168.756.893	177.905.268	192.282.712	204.022.904	211.230.640
Iceland											1.561.578	1.888.607	2.111.100	2.278.036
Norway										18.631.949	18.825.090	19.621.419	18.578.950	24.052.506
Switzerland	18.139.840	19.357.334	20.501.352	21.329.039	23.375.670	24.741.620	27.007.844	26.997.844	26.897.844	26.747.287	25.676.117	26.567.888	28.876.325	31.829.653

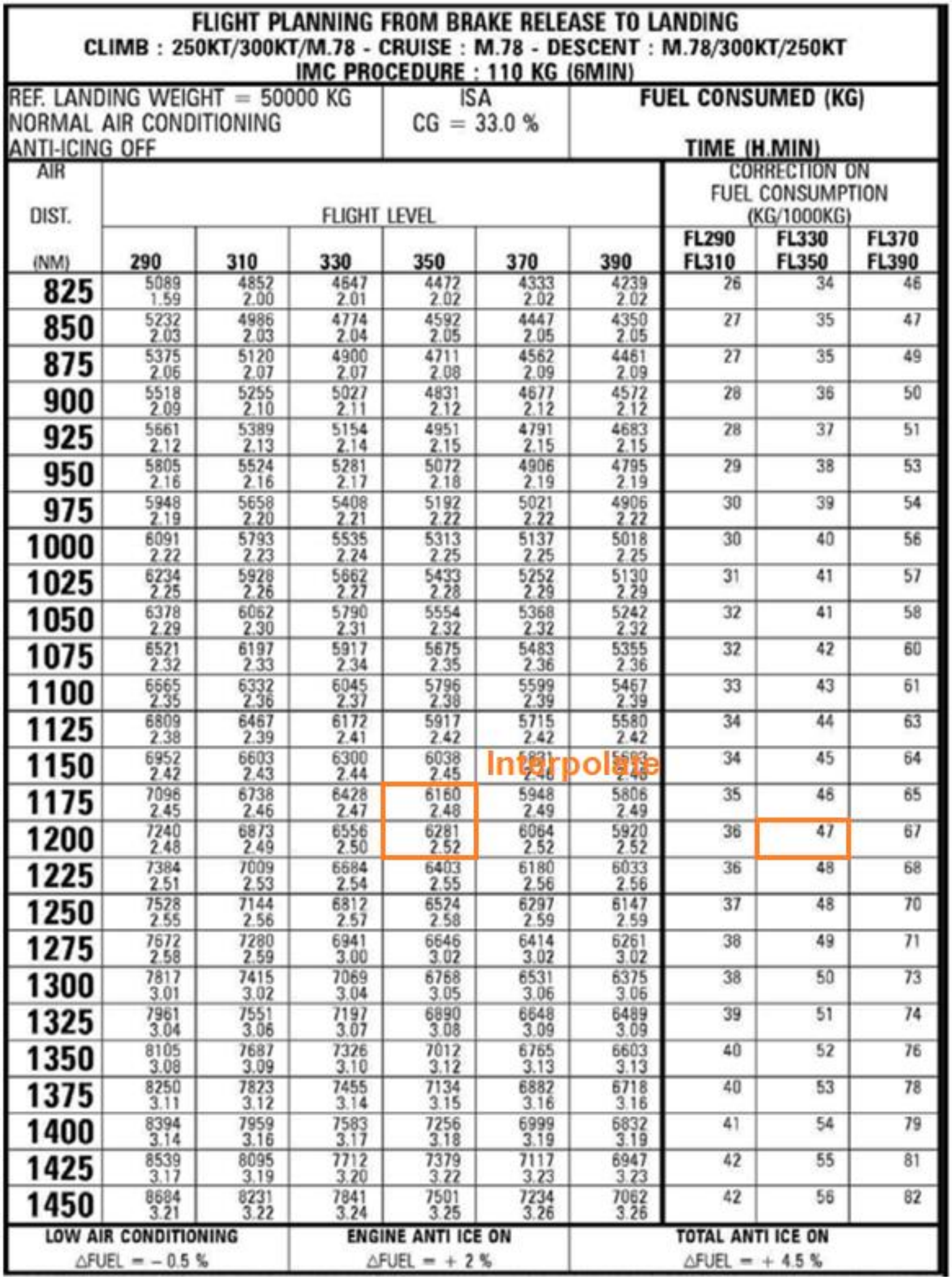
TIME	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
European Union	812.605.125	798.625.469	751.855.594	774.555.432	818.145.231	823.049.838	837.254.556	875.108.116	916.483.716	970.534.207	1.040.803.424	1.103.387.059	1.143.709.187
Belgium	20.805.455	21.983.683	21.316.690	22.697.764	25.102.695	25.919.515	26.389.927	28.776.258	30.958.841	30.115.832	33.260.493	34.506.309	35.385.188
Bulgaria	6.072.357	6.417.992	5.840.825	6.169.323	6.652.007	6.819.103	7.079.292	7.520.697	7.610.949	9.324.217	11.092.651	12.137.714	11.713.068
Czechia	13.098.141	13.429.149	12.367.467	12.242.386	12.650.532	11.742.352	11.891.812	12.079.873	12.672.004	13.672.362	16.245.554	17.838.221	18.832.696
Denmark	24.043.172	24.639.072	22.277.524	24.334.687	25.808.321	26.532.730	27.459.623	29.015.133	30.095.505	32.763.142	33.261.214	34.701.139	34.780.127
Germany	163.784.893	165.758.846	158.148.829	166.130.833	175.316.076	178.591.103	180.783.188	186.445.814	193.936.430	200.687.293	212.389.343	222.422.361	226.764.086
Estonia	1.722.505	1.804.430	1.341.294	1.381.062	1.907.569	2.202.427	1.958.565	2.019.806	2.160.978	2.214.989	2.635.145	2.995.528	3.258.003
Ireland	29.840.020	30.018.287	26.268.887	23.094.210	23.362.889	23.594.089	24.603.640	26.310.826	29.545.020	32.595.709	34.271.771	36.345.005	37.947.510
Greece	35.567.225	35.059.804	33.440.269	32.588.072	33.770.739	32.082.336	34.023.934	39.117.833	42.096.402	45.543.371	50.170.728	54.258.826	56.088.527
Spain	163.523.010	161.400.952	148.318.298	153.387.014	165.153.230	159.771.261	157.731.973	165.354.382	174.652.503	193.872.037	209.824.089	220.611.429	227.189.012
France	120.037.222	122.960.315	117.636.389	118.697.207	126.013.257	129.764.462	132.762.875	136.360.671	140.867.569	145.280.602	154.096.485	161.991.179	168.729.932
Croatia		4.504.677	4.335.208	4.677.414	4.989.236	5.422.632	5.722.447	6.140.797	6.571.698	7.475.463	8.843.053	9.731.294	10.623.239
Italy	106.294.258	105.216.903	101.823.772	109.064.953	116.226.667	116.029.388	115.279.105	121.164.587	127.665.221	134.477.781	144.306.325	153.352.444	160.665.682
Cyprus	7.004.315	7.218.084	6.729.787	6.948.288	7.190.387	7.328.300	7.011.437	7.328.546	7.590.787	8.961.817	10.238.913	10.927.101	11.261.410
Latvia	3.155.771	3.687.329	4.062.704	4.655.898	5.098.360	4.754.530	4.782.257	4.802.282	5.145.856	5.384.160	6.077.854	7.037.070	7.785.726
Lithuania	2.195.959	2.552.074	1.867.191	2.282.834	2.691.991	3.166.628	3.482.358	3.798.110	4.227.389	4.787.561	5.246.101	6.254.178	6.504.685
Luxembourg	1.634.465	1.713.217	1.535.261	1.613.696	1.836.780	1.893.991	2.169.327	2.433.966	2.651.751	2.984.242	3.554.730	3.988.804	4.365.569
Hungary	8.580.261	8.429.082	8.081.067	8.174.510	8.884.837	8.429.843	8.441.319	9.054.848	10.228.352	11.660.366	13.350.029	15.176.493	16.700.750
Malta	2.971.368	3.109.899	2.918.676	3.293.548	3.506.814	3.650.347	4.032.029	4.290.032	4.619.557	5.080.446	6.007.731	6.805.817	7.318.357
Netherlands	50.502.715	50.419.501	46.479.327	48.618.879	53.895.292	55.680.209	58.077.271	60.963.003	64.570.938	70.317.995	76.240.304	79.644.163	81.192.507
Austria	22.926.104	23.899.584	21.817.267	23.532.455	25.137.612	25.965.977	25.749.724	26.378.676	26.754.007	27.181.511	28.327.279	31.138.417	35.644.188
Poland	17.120.078	18.727.365	17.046.899	18.383.115	20.635.672	21.800.765	23.274.484	25.714.422	28.907.439	32.266.861	37.684.668	43.767.548	46.899.765
Portugal	24.326.238	25.182.901	24.116.313	25.735.500	27.579.707	28.186.254	29.694.146	32.560.621	36.005.814	40.930.044	47.673.057	51.018.598	55.007.894
Romania	6.908.599	8.031.267	7.984.057	8.848.949	9.687.456	9.674.226	10.016.933	10.907.487	12.580.711	15.153.719	17.934.774	19.809.642	21.546.204
Slovenia	1.504.446	1.648.977	1.423.391	1.382.341	1.358.792	1.167.877	1.265.766	1.307.128	1.436.003	1.404.152	1.682.133	1.810.567	1.719.039
Slovakia	2.232.411	2.596.334	1.948.361	1.881.844	1.808.187	1.563.197	1.557.149	1.671.290	1.943.656	2.158.261	2.402.651	2.794.094	2.839.787
Finland	14.464.575	14.850.682	13.828.812	14.220.636	16.374.398	16.458.815	16.565.391	17.171.931	17.479.246	18.099.954	20.054.947	22.173.530	23.287.929
Sweden	26.967.253	27.817.350	25.218.784	26.646.764	29.732.247	30.350.849	31.443.225	32.766.043	34.011.263	35.952.558	38.456.207	38.945.096	37.614.259
United Kingdom	217.291.360	213.890.470	198.533.970	192.887.734	201.536.753	203.067.015	210.468.980	220.022.122	232.270.437	248.868.873	264.629.454	272.190.155	277.432.380
Iceland	2.462.113	2.240.998	1.837.165	2.036.356	2.462.894	2.740.691	3.199.266	3.853.614	4.847.288	6.801.814	8.318.734	10.166.386	7.584.197
Norway	26.385.631	27.717.155	27.675.619	29.518.449	32.403.522	34.592.225	36.686.364	37.603.195	37.503.052	37.727.546	38.739.778	40.030.105	40.348.437
Switzerland	34.537.698	36.595.735	35.928.169	37.615.959	41.439.848	43.236.086	44.217.568	46.127.426	48.026.375	50.505.492	53.564.943	56.139.549	57.194.328

ANNEX 2. FREIGHT AND MAIL TRANSPORT BY REPORTING COUNTRY

TIME	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Belgium	306.183	374.816	426.233	449.534	518.009	585.342	565.342	545.342	525.342	499.431	606.504	660.431	694.523	1.037.357
Bulgaria														
Czechia										43.566	53.222	57.512	56.259	59.523
Denmark											417	7.928	7.826	7.615
Germany								2.364.760	2.269.152	2.362.153	2.447.061	2.788.200	3.006.462	3.269.209
Estonia												4.998	9.739	10.053
Ireland	50.019	42.703	60.910	42.420	76.338	58.685	71.943	77.258	69.480	41.236		62.163	89.356	132.062
Greece	80.625	82.230		72.660	106.214	125.898	126.635	134.563			137.045	114.809	107.822	109.951
Spain	179.395	174.350	243.885	280.846	308.885	309.241	463.436	478.953	454.004	450.065	439.991	520.503	526.125	504.763
France	852.609	1.005.530	1.034.330	1.057.784	1.025.039	1.042.203	1.147.485	1.170.979	1.329.957	1.436.392	1.416.967	1.486.743	1.477.634	1.594.180
Croatia														
Italy	402.501	438.104	534.703	554.113	535.304	445.529			206.773	593.104	683.863	710.593	754.302	810.446
Cyprus									32.294		31.816	37.190	39.232	44.858
Latvia												8.326	15.428	11.715
Lithuania											5.217	5.183	9.580	12.675
Luxembourg												616.583	624.803	633.747
Hungary										46.402	50.525	60.414	55.473	64.882
Malta										12.588	16.542	15.977	16.891	18.061
Netherlands	772.688	841.873	982.547	1.084.506	1.163.003	1.173.509	1.182.337	1.267.623	1.217.445	1.280.147	1.388.544	1.511.957	1.550.736	1.621.469
Austria										125.829	128.738	159.653	181.533	202.685
Poland												31.423	31.130	39.970
Portugal	86.478	93.663	122.086	125.870	145.870	155.870	165.870	177.908	133.417	128.829	123.546	123.309	129.526	136.332
Romania									15.624	16.488	15.835	19.339	17.980	20.738
Slovenia												4.983	4.549	6.593
Slovakia									4.676	6.557	12.847	8.197	4.058	5.376
Finland					92.459	102.639	96.016	101.423		89.107	89.693	123.493	119.569	128.838
Sweden	0											150.957	0	0
United Kingdom	1.215.474	1.485.910	1.584.054	1.657.409	1.846.581	2.183.408	2.290.898	2.274.057	2.094.067	2.145.288	2.285.602	2.471.242	2.450.979	2.390.502
Iceland											42.392	56.281	59.650	61.784
Norway										1.071	567	27	9.633	6.740
Switzerland	353.748	390.976	398.462	393.879	406.876	401.776	421.932			353.839	321.690	319.083	334.024	333.317

TIME	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Belgium	1.203.245	1.071.346	836.409	953.582	984.363	963.615	957.012	1.014.586	1.126.234	1.088.734	1.251.173	1.416.428	1.397.513
Bulgaria	18.728	19.533	17.450	21.110	21.879	18.529	19.575	23.073	31.520	32.977	34.807	29.867	28.749
Czechia	59.911	55.906	53.924	65.620	69.206	58.707	58.147	58.312	58.445	77.704	89.279	90.526	97.248
Denmark	7.492	254.105	158.767	150.271	155.662	166.283	148.980	208.590	210.570	200.133	235.937	242.068	244.997
Germany	3.418.349	3.568.563	3.341.222	4.099.072	4.309.649	4.218.208	4.231.474	4.336.163	4.325.665	4.467.022	4.773.359	4.842.716	4.684.553
Estonia	22.634	41.744	20.526	11.886	18.341	23.760	20.862	19.432	16.034	13.868	11.233	11.475	10.866
Ireland	132.754	126.855	112.049	122.266	113.409	126.834	127.423	138.203	148.714	145.769	163.123	156.265	144.141
Greece	107.198	112.225	97.797	88.564	81.355	72.192	67.262	60.324	62.332	69.949	69.074	96.889	105.403
Spain	510.579	539.803	502.585	592.336	611.974	593.523	580.847	593.902	594.393	639.237	742.443	806.518	815.612
France	1.708.761	1.672.284	1.450.562	1.525.970	1.765.733	1.753.085	1.741.021	2.361.510	2.380.931	2.401.593	2.450.326	2.407.878	2.377.384
Croatia		8.582	8.724	7.443	7.228	6.961	6.857	6.908	7.189	7.691	9.510	11.934	10.846
Italy	906.680	814.995	705.883	838.724	846.551	790.493	826.981	876.495	916.755	991.688	1.077.874	1.066.221	1.024.033
Cyprus	42.024	42.796	38.636	37.265	29.480	27.581	28.328	28.095	27.626	28.430	30.880	32.186	32.360
Latvia	7.197	6.884	8.646	11.268	11.571	31.460	52.473	31.439	16.809	17.922	21.204	24.628	25.866
Lithuania	12.804	9.049	6.465	9.762	10.011	14.342	15.857	13.210	14.904	14.245	15.064	16.779	17.211
Luxembourg	702.760	788.218	627.261	705.829	666.011	615.286	673.380	707.150	736.880	801.058	892.660	895.004	853.030
Hungary	67.591	62.544	54.138	65.305	68.860	61.902	64.166	61.970	65.783	77.535	87.277	101.411	95.590
Malta	17.990	18.222	17.496	16.882	16.204	16.493	16.028	15.602	16.405	15.690	16.194	17.677	12.210
Netherlands	1.709.271	1.648.522	1.371.235	1.600.381	1.614.895	1.563.500	1.620.038	1.727.455	1.712.031	1.831.792	1.865.106	1.840.419	1.703.556
Austria	206.643	206.221	202.642	236.633	219.448	197.543	196.459	217.785	216.621	223.421	227.643	237.701	228.223
Poland	44.730	58.148	53.510	61.238	68.485	74.831	77.560	84.386	92.690	107.880	121.303	134.673	143.482
Portugal	130.827	136.364	125.501	137.131	121.465	117.645	126.612	134.982	133.416	136.578	164.732	173.493	194.214
Romania	19.229	24.431	23.482	24.512	26.156	28.523	30.605	31.113	33.399	37.456	41.692	45.310	44.217
Slovenia	12.515	8.180	5.584	6.071	6.877	7.572	7.969	8.563	8.891	8.970	12.025	12.337	11.358
Slovakia	2.282	7.432	12.231	17.835	20.542	20.893	20.588	18.498	21.216	23.028	27.188	24.565	20.525
Finland	146.134	147.822	126.900	165.254	179.216	195.631	192.512	190.586	182.089	186.471	188.722	196.810	225.242
Sweden	0	205.760	161.179	186.263	164.618	141.365	130.405	141.887	146.287	147.214	159.130	158.632	47.959
United Kingdom	2.443.483	2.411.463	2.156.206	2.429.026	2.419.718	2.428.375	2.369.879	2.406.673	2.405.225	2.511.011	2.738.784	2.748.539	2.650.232
Iceland	46.904	54.739	38.776	35.234	37.558	40.030	41.491	41.908	44.664	48.459	52.870	56.889	55.100
Norway	3.324	3.516	51.357	49.414	65.742	78.420	106.722	116.390	127.698	127.745	169.295	174.840	187.379
Switzerland	354.623	347.979	315.695	375.176	390.335	398.715	400.028	407.704	401.925	428.495	486.164	493.202	459.877

ANNEX 3. A320 WEIGHT AND BALANCE CALCULATION TABLES



FLIGHT PLANNING FROM BRAKE RELEASE TO LANDING
CLIMB : 250KT/300KT/M.78 - CRUISE : M.78 - DESCENT : M.78/300KT/250KT
IMC PROCEDURE : 110 KG (6MIN)

REF. LANDING WEIGHT = 50000 KG
NORMAL AIR CONDITIONING
ANTI-ICING OFF

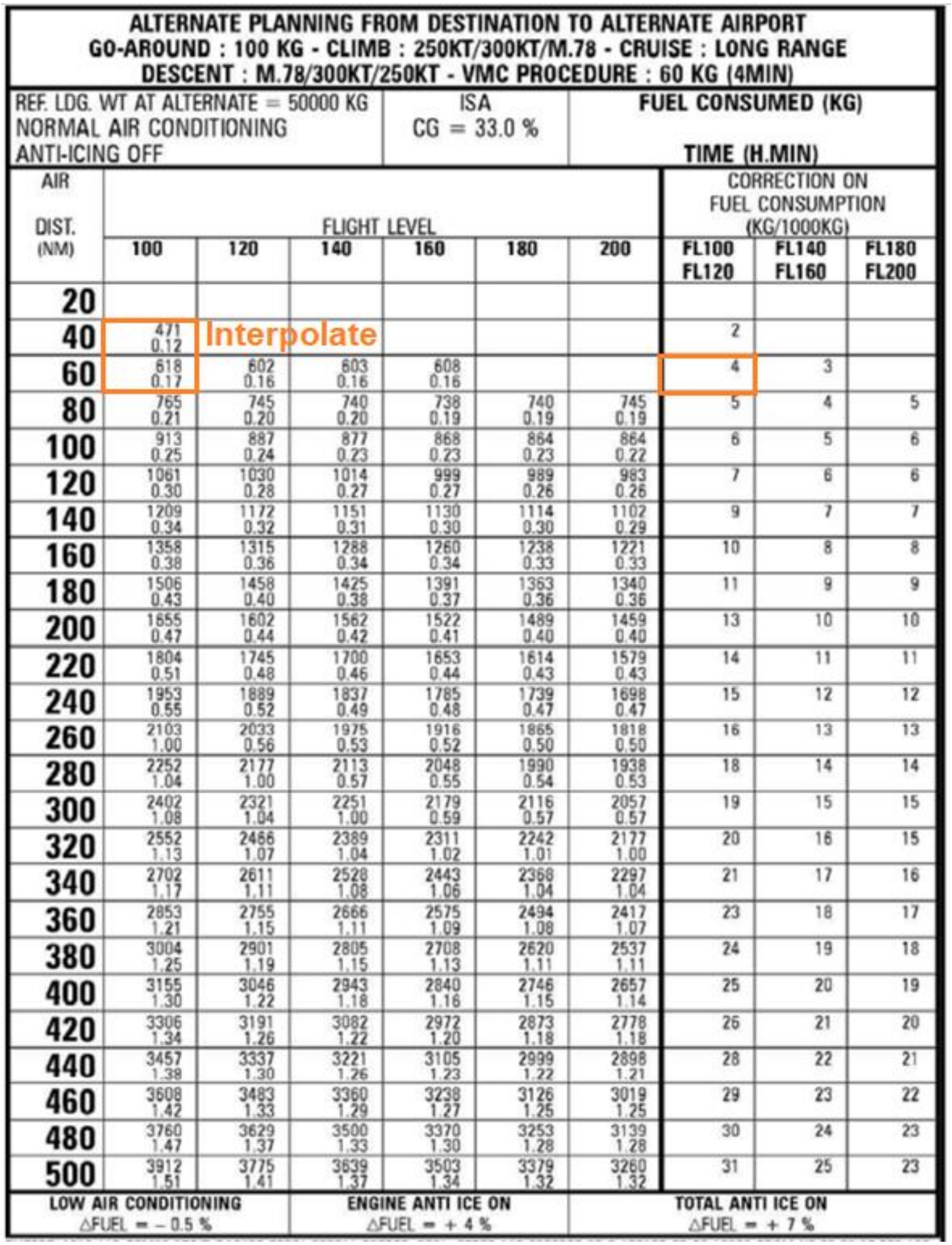
ISA
CG = 33.0 %

FUEL CONSUMED (KG)
TIME (H.MIN)

Interpolate

AIR DIST. (NM)	FLIGHT LEVEL						CORRECTION ON FUEL CONSUMPTION (KG/1000KG)		
	290	**310**	**330**	**350**	**370**	**390**	**FL290 FL310**	**FL330 FL350**	**FL370 FL390**
825	5089 1.59	4852 2.00	4647 2.01	4472 2.02	4333 2.02	4239 2.02	26	34	46
850	5232 2.03	4986 2.03	4774 2.04	4592 2.05	4447 2.05	4350 2.05	27	35	47
875	5375 2.06	5120 2.07	4900 2.07	4711 2.08	4562 2.09	4461 2.09	27	35	49
900	5518 2.09	5255 2.10	5027 2.11	4831 2.12	4677 2.12	4572 2.12	28	36	50
925	5661 2.12	5389 2.13	5154 2.14	4951 2.15	4791 2.15	4683 2.15	28	37	51
950	5805 2.16	5524 2.16	5281 2.17	5072 2.18	4906 2.19	4795 2.19	29	38	53
975	5948 2.19	5658 2.20	5408 2.21	5192 2.22	5021 2.22	4906 2.22	30	39	54
1000	6091 2.22	5793 2.23	5535 2.24	5313 2.25	5137 2.25	5018 2.25	30	40	56
1025	6234 2.25	5928 2.26	5662 2.27	5433 2.28	5252 2.29	5130 2.29	31	41	57
1050	6378 2.29	6062 2.30	5790 2.31	5554 2.32	5368 2.32	5242 2.32	32	41	58
1075	6521 2.32	6197 2.33	5917 2.34	5675 2.35	5483 2.36	5355 2.36	32	42	60
1100	6665 2.35	6332 2.36	6045 2.37	5796 2.38	5599 2.39	5467 2.39	33	43	61
1125	6809 2.38	6467 2.39	6172 2.41	5917 2.42	5715 2.42	5580 2.42	34	44	63
1150	6952 2.42	6603 2.43	6300 2.44	6038 2.45	[illegible]	[illegible]	34	45	64
1175	7096 2.45	6738 2.46	6428 2.47	6160 2.48	5948 2.49	5806 2.49	35	46	65
1200	7240 2.48	6873 2.49	6556 2.50	6281 2.52	6064 2.52	5920 2.52	36	47	67
1225	7384 2.51	7009 2.53	6684 2.54	6403 2.55	6180 2.56	6033 2.56	36	48	68
1250	7528 2.55	7144 2.56	6812 2.57	6524 2.58	6297 2.59	6147 2.59	37	48	70
1275	7672 2.58	7280 2.59	6941 3.00	6646 3.02	6414 3.02	6261 3.02	38	49	71
1300	7817 3.01	7415 3.02	7069 3.04	6768 3.05	6531 3.06	6375 3.06	38	50	73
1325	7961 3.04	7551 3.06	7197 3.07	6890 3.08	6648 3.09	6489 3.09	39	51	74
1350	8105 3.08	7687 3.09	7326 3.10	7012 3.12	6765 3.13	6603 3.13	40	52	76
1375	8250 3.11	7823 3.12	7455 3.14	7134 3.15	6882 3.16	6718 3.16	40	53	78
1400	8394 3.14	7959 3.16	7583 3.17	7256 3.18	6999 3.19	6832 3.19	41	54	79
1425	8539 3.17	8095 3.19	7712 3.20	7379 3.22	7117 3.23	6947 3.23	42	55	81
1450	8684 3.21	8231 3.22	7841 3.24	7501 3.25	7234 3.26	7062 3.26	42	56	82

LOW AIR CONDITIONING	**ENGINE ANTI ICE ON**	**TOTAL ANTI ICE ON**
ΔFUEL = – 0.5 %	ΔFUEL = + 2 %	ΔFUEL = + 4.5 %



ALTERNATE PLANNING FROM DESTINATION TO ALTERNATE AIRPORT
GO-AROUND : 100 KG - CLIMB : 250KT/300KT/M.78 - CRUISE : LONG RANGE
DESCENT : M.78/300KT/250KT - VMC PROCEDURE : 60 KG (4MIN)

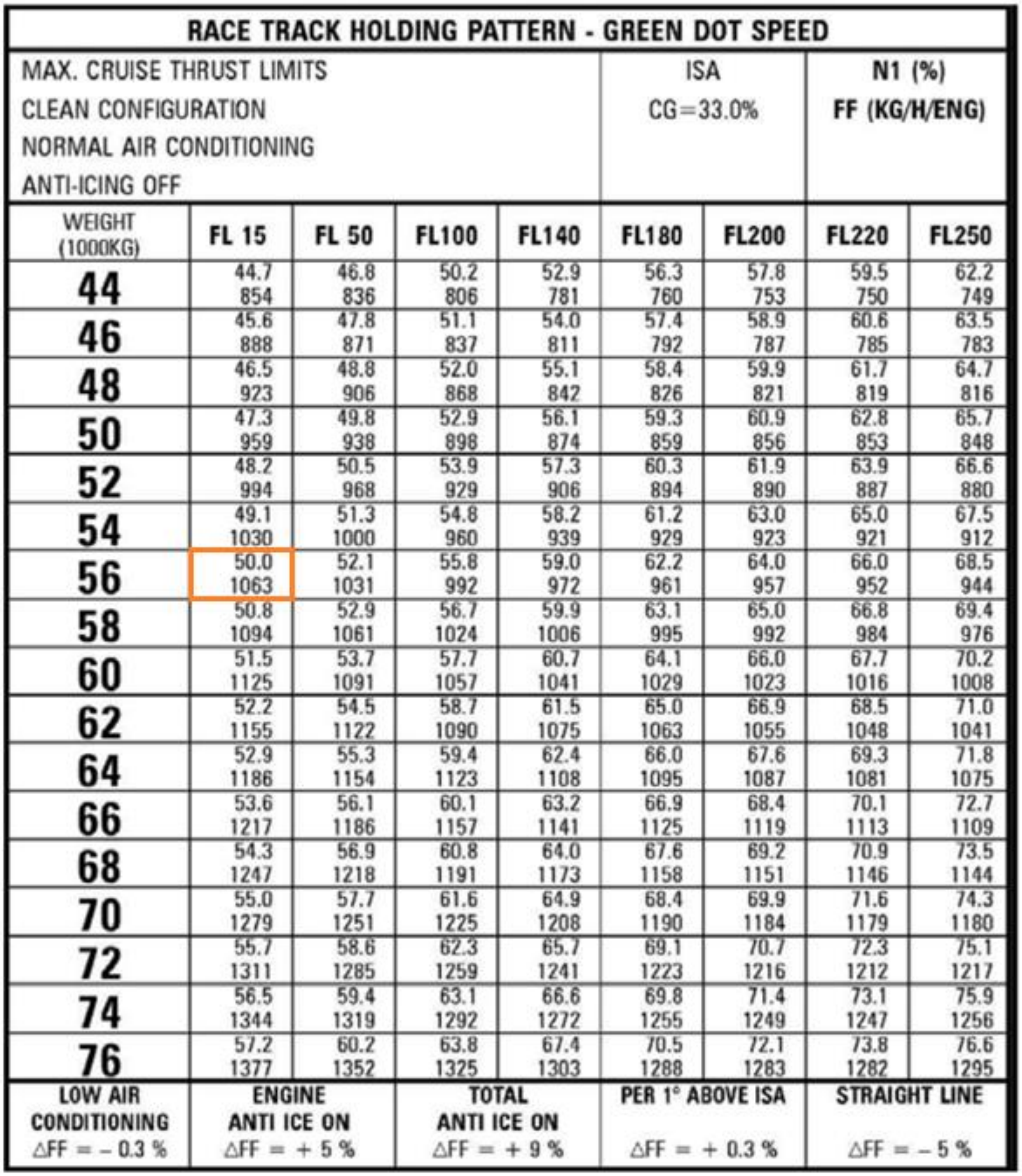
REF. LDG. WT AT ALTERNATE = 50000 KG
NORMAL AIR CONDITIONING
ANTI-ICING OFF

ISA
CG = 33.0 %

FUEL CONSUMED (KG)
TIME (H.MIN)

AIR DIST. (NM)	FLIGHT LEVEL 100	120	140	160	180	200	CORRECTION ON FUEL CONSUMPTION (KG/1000KG) FL100 FL120	FL140 FL160	FL180 FL200
20									
40	471 0.12						2		
60	618 0.17	602 0.16	603 0.16	608 0.16			4	3	
80	765 0.21	745 0.20	740 0.20	738 0.19	740 0.19	745 0.19	5	4	5
100	913 0.25	887 0.24	877 0.23	868 0.23	864 0.23	864 0.22	6	5	6
120	1061 0.30	1030 0.28	1014 0.27	999 0.27	989 0.26	983 0.26	7	6	6
140	1209 0.34	1172 0.32	1151 0.31	1130 0.30	1114 0.30	1102 0.29	9	7	7
160	1358 0.38	1315 0.36	1288 0.34	1260 0.34	1238 0.33	1221 0.33	10	8	8
180	1506 0.43	1458 0.40	1425 0.38	1391 0.37	1363 0.36	1340 0.36	11	9	9
200	1655 0.47	1602 0.44	1562 0.42	1522 0.41	1489 0.40	1459 0.40	13	10	10
220	1804 0.51	1745 0.48	1700 0.46	1653 0.44	1614 0.43	1579 0.43	14	11	11
240	1953 0.55	1889 0.52	1837 0.49	1785 0.48	1739 0.47	1698 0.47	15	12	12
260	2103 1.00	2033 0.56	1975 0.53	1916 0.52	1865 0.50	1818 0.50	16	13	13
280	2252 1.04	2177 1.00	2113 0.57	2048 0.55	1990 0.54	1938 0.53	18	14	14
300	2402 1.08	2321 1.04	2251 1.00	2179 0.59	2116 0.57	2057 0.57	19	15	15
320	2552 1.13	2466 1.07	2389 1.04	2311 1.02	2242 1.01	2177 1.00	20	16	15
340	2702 1.17	2611 1.11	2528 1.08	2443 1.06	2368 1.04	2297 1.04	21	17	16
360	2853 1.21	2755 1.15	2666 1.11	2575 1.09	2494 1.08	2417 1.07	23	18	17
380	3004 1.25	2901 1.19	2805 1.15	2708 1.13	2620 1.11	2537 1.11	24	19	18
400	3155 1.30	3046 1.22	2943 1.18	2840 1.16	2746 1.15	2657 1.14	25	20	19
420	3306 1.34	3191 1.26	3082 1.22	2972 1.20	2873 1.18	2778 1.18	26	21	20
440	3457 1.38	3337 1.30	3221 1.26	3105 1.23	2999 1.22	2898 1.21	28	22	21
460	3608 1.42	3483 1.33	3360 1.29	3238 1.27	3126 1.25	3019 1.25	29	23	22
480	3760 1.47	3629 1.37	3500 1.33	3370 1.30	3253 1.28	3139 1.28	30	24	23
500	3912 1.51	3775 1.41	3639 1.37	3503 1.34	3379 1.32	3260 1.32	31	25	23

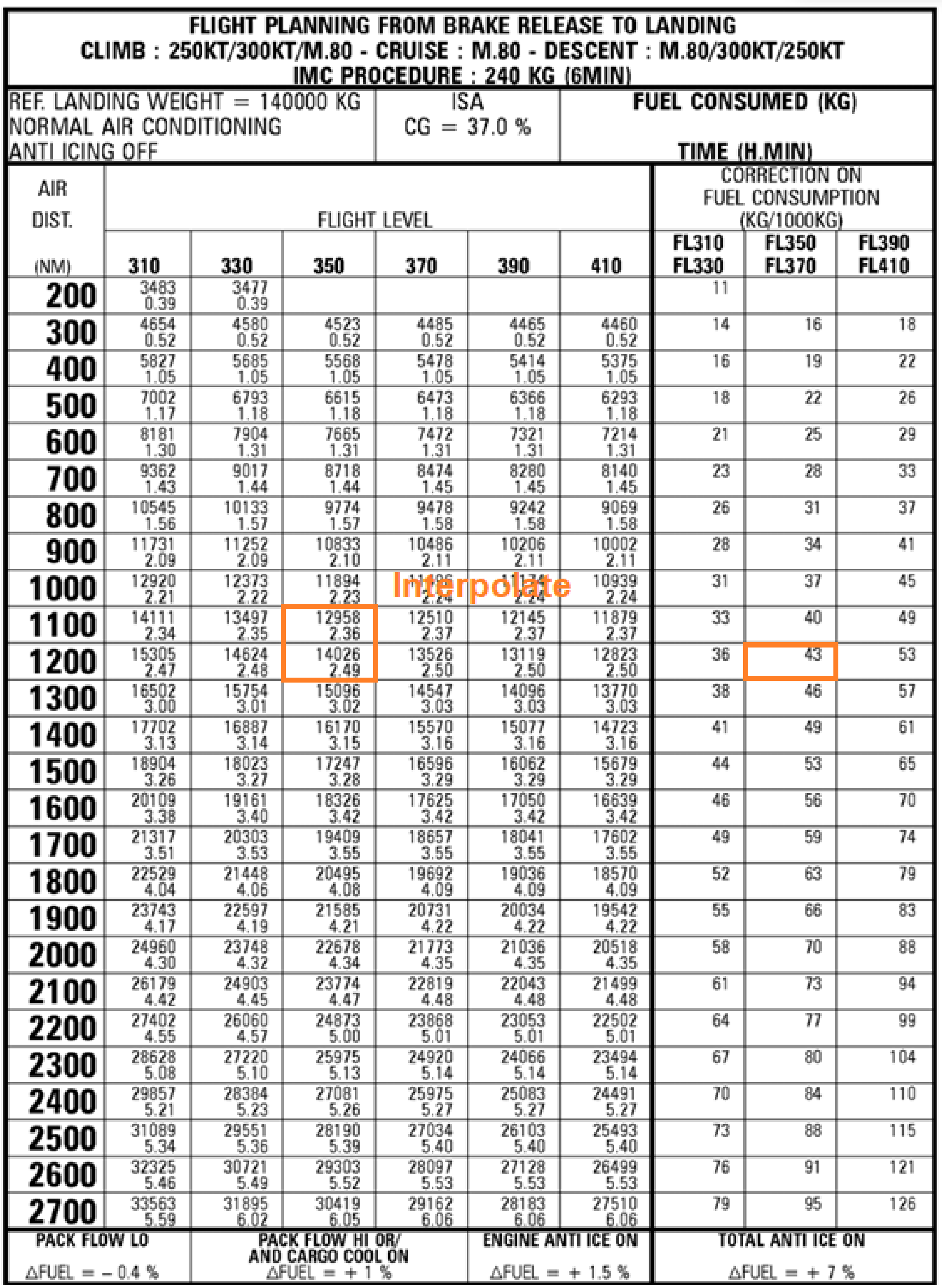
LOW AIR CONDITIONING	**ENGINE ANTI ICE ON**	**TOTAL ANTI ICE ON**
ΔFUEL = – 0.5 %	ΔFUEL = + 4 %	ΔFUEL = + 7 %



RACE TRACK HOLDING PATTERN - GREEN DOT SPEED

MAX. CRUISE THRUST LIMITS CLEAN CONFIGURATION NORMAL AIR CONDITIONING ANTI-ICING OFF					ISA CG=33.0%		N1 (%) FF (KG/H/ENG)	
WEIGHT (1000KG)	FL 15	FL 50	FL100	FL140	FL180	FL200	FL220	FL250
44	44.7 854	46.8 836	50.2 806	52.9 781	56.3 760	57.8 753	59.5 750	62.2 749
46	45.6 888	47.8 871	51.1 837	54.0 811	57.4 792	58.9 787	60.6 785	63.5 783
48	46.5 923	48.8 906	52.0 868	55.1 842	58.4 826	59.9 821	61.7 819	64.7 816
50	47.3 959	49.8 938	52.9 898	56.1 874	59.3 859	60.9 856	62.8 853	65.7 848
52	48.2 994	50.5 968	53.9 929	57.3 906	60.3 894	61.9 890	63.9 887	66.6 880
54	49.1 1030	51.3 1000	54.8 960	58.2 939	61.2 929	63.0 923	65.0 921	67.5 912
56	50.0 1063	52.1 1031	55.8 992	59.0 972	62.2 961	64.0 957	66.0 952	68.5 944
58	50.8 1094	52.9 1061	56.7 1024	59.9 1006	63.1 995	65.0 992	66.8 984	69.4 976
60	51.5 1125	53.7 1091	57.7 1057	60.7 1041	64.1 1029	66.0 1023	67.7 1016	70.2 1008
62	52.2 1155	54.5 1122	58.7 1090	61.5 1075	65.0 1063	66.9 1055	68.5 1048	71.0 1041
64	52.9 1186	55.3 1154	59.4 1123	62.4 1108	66.0 1095	67.6 1087	69.3 1081	71.8 1075
66	53.6 1217	56.1 1186	60.1 1157	63.2 1141	66.9 1125	68.4 1119	70.1 1113	72.7 1109
68	54.3 1247	56.9 1218	60.8 1191	64.0 1173	67.6 1158	69.2 1151	70.9 1146	73.5 1144
70	55.0 1279	57.7 1251	61.6 1225	64.9 1208	68.4 1190	69.9 1184	71.6 1179	74.3 1180
72	55.7 1311	58.6 1285	62.3 1259	65.7 1241	69.1 1223	70.7 1216	72.3 1212	75.1 1217
74	56.5 1344	59.4 1319	63.1 1292	66.6 1272	69.8 1255	71.4 1249	73.1 1247	75.9 1256
76	57.2 1377	60.2 1352	63.8 1325	67.4 1303	70.5 1288	72.1 1283	73.8 1282	76.6 1295
LOW AIR CONDITIONING ΔFF = – 0.3 %	**ENGINE ANTI ICE ON** ΔFF = + 5 %		**TOTAL ANTI ICE ON** ΔFF = + 9 %		**PER 1° ABOVE ISA** ΔFF = + 0.3 %		**STRAIGHT LINE** ΔFF = – 5 %	

ANNEX 4. A330 WEIGHT AND BALANCE CALCULATION TABLES



FLIGHT PLANNING FROM BRAKE RELEASE TO LANDING
CLIMB : 250KT/300KT/M.80 - CRUISE : M.80 - DESCENT : M.80/300KT/250KT
IMC PROCEDURE : 240 KG (6MIN)

REF. LANDING WEIGHT = 140000 KG
NORMAL AIR CONDITIONING
ANTI ICING OFF

ISA
CG = 37.0 %

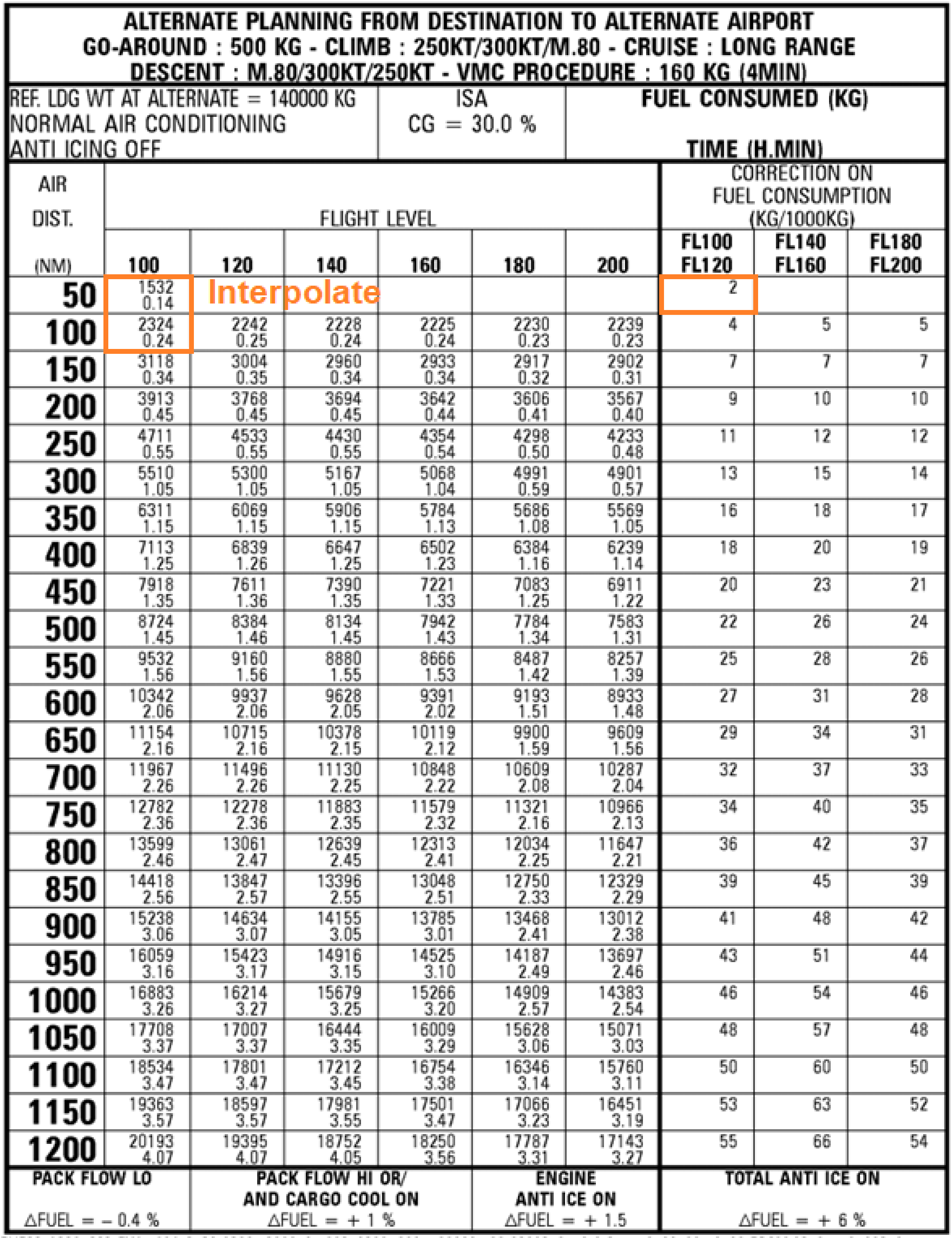
FUEL CONSUMED (KG)

TIME (H.MIN)

AIR DIST. (NM)	FLIGHT LEVEL						CORRECTION ON FUEL CONSUMPTION (KG/1000KG)		
	310	**330**	**350**	**370**	**390**	**410**	**FL310 FL330**	**FL350 FL370**	**FL390 FL410**
200	3483 0.39	3477 0.39					11		
300	4654 0.52	4580 0.52	4523 0.52	4485 0.52	4465 0.52	4460 0.52	14	16	18
400	5827 1.05	5685 1.05	5568 1.05	5478 1.05	5414 1.05	5375 1.05	16	19	22
500	7002 1.17	6793 1.18	6615 1.18	6473 1.18	6366 1.18	6293 1.18	18	22	26
600	8181 1.30	7904 1.31	7665 1.31	7472 1.31	7321 1.31	7214 1.31	21	25	29
700	9362 1.43	9017 1.44	8718 1.44	8474 1.45	8280 1.45	8140 1.45	23	28	33
800	10545 1.56	10133 1.57	9774 1.57	9478 1.58	9242 1.58	9069 1.58	26	31	37
900	11731 2.09	11252 2.09	10833 2.10	10486 2.11	10206 2.11	10002 2.11	28	34	41
1000	12920 2.21	12373 2.22	11894 2.23	[illegible] 2.24	[illegible] 2.24	10939 2.24	31	37	45
1100	14111 2.34	13497 2.35	12958 2.36	12510 2.37	12145 2.37	11879 2.37	33	40	49
1200	15305 2.47	14624 2.48	14026 2.49	13526 2.50	13119 2.50	12823 2.50	36	43	53
1300	16502 3.00	15754 3.01	15096 3.02	14547 3.03	14096 3.03	13770 3.03	38	46	57
1400	17702 3.13	16887 3.14	16170 3.15	15570 3.16	15077 3.16	14723 3.16	41	49	61
1500	18904 3.26	18023 3.27	17247 3.28	16596 3.29	16062 3.29	15679 3.29	44	53	65
1600	20109 3.38	19161 3.40	18326 3.42	17625 3.42	17050 3.42	16639 3.42	46	56	70
1700	21317 3.51	20303 3.53	19409 3.55	18657 3.55	18041 3.55	17602 3.55	49	59	74
1800	22529 4.04	21448 4.06	20495 4.08	19692 4.09	19036 4.09	18570 4.09	52	63	79
1900	23743 4.17	22597 4.19	21585 4.21	20731 4.22	20034 4.22	19542 4.22	55	66	83
2000	24960 4.30	23748 4.32	22678 4.34	21773 4.35	21036 4.35	20518 4.35	58	70	88
2100	26179 4.42	24903 4.45	23774 4.47	22819 4.48	22043 4.48	21499 4.48	61	73	94
2200	27402 4.55	26060 4.57	24873 5.00	23868 5.01	23053 5.01	22502 5.01	64	77	99
2300	28628 5.08	27220 5.10	25975 5.13	24920 5.14	24066 5.14	23494 5.14	67	80	104
2400	29857 5.21	28384 5.23	27081 5.26	25975 5.27	25083 5.27	24491 5.27	70	84	110
2500	31089 5.34	29551 5.36	28190 5.39	27034 5.40	26103 5.40	25493 5.40	73	88	115
2600	32325 5.46	30721 5.49	29303 5.52	28097 5.53	27128 5.53	26499 5.53	76	91	121
2700	33563 5.59	31895 6.02	30419 6.05	29162 6.06	28183 6.06	27510 6.06	79	95	126

PACK FLOW LO	PACK FLOW HI OR/ AND CARGO COOL ON	ENGINE ANTI ICE ON	TOTAL ANTI ICE ON
ΔFUEL = – 0.4 %	ΔFUEL = + 1 %	ΔFUEL = + 1.5 %	ΔFUEL = + 7 %

Interpolate



ALTERNATE PLANNING FROM DESTINATION TO ALTERNATE AIRPORT
GO-AROUND : 500 KG - CLIMB : 250KT/300KT/M.80 - CRUISE : LONG RANGE
DESCENT : M.80/300KT/250KT - VMC PROCEDURE : 160 KG (4MIN)

REF. LDG WT AT ALTERNATE = 140000 KG NORMAL AIR CONDITIONING ANTI ICING OFF	ISA CG = 30.0 %	**FUEL CONSUMED (KG)** **TIME (H.MIN)**

AIR DIST. (NM)	FLIGHT LEVEL 100	120	140	160	180	200	CORRECTION ON FUEL CONSUMPTION (KG/1000KG) **FL100 FL120**	**FL140 FL160**	**FL180 FL200**
50	1532 0.14	Interpolate					2		
100	2324 0.24	2242 0.25	2228 0.24	2225 0.24	2230 0.23	2239 0.23	4	5	5
150	3118 0.34	3004 0.35	2960 0.34	2933 0.34	2917 0.32	2902 0.31	7	7	7
200	3913 0.45	3768 0.45	3694 0.45	3642 0.44	3606 0.41	3567 0.40	9	10	10
250	4711 0.55	4533 0.55	4430 0.55	4354 0.54	4298 0.50	4233 0.48	11	12	12
300	5510 1.05	5300 1.05	5167 1.05	5068 1.04	4991 0.59	4901 0.57	13	15	14
350	6311 1.15	6069 1.15	5906 1.15	5784 1.13	5686 1.08	5569 1.05	16	18	17
400	7113 1.25	6839 1.26	6647 1.25	6502 1.23	6384 1.16	6239 1.14	18	20	19
450	7918 1.35	7611 1.36	7390 1.35	7221 1.33	7083 1.25	6911 1.22	20	23	21
500	8724 1.45	8384 1.46	8134 1.45	7942 1.43	7784 1.34	7583 1.31	22	26	24
550	9532 1.56	9160 1.56	8880 1.55	8666 1.53	8487 1.42	8257 1.39	25	28	26
600	10342 2.06	9937 2.06	9628 2.05	9391 2.02	9193 1.51	8933 1.48	27	31	28
650	11154 2.16	10715 2.16	10378 2.15	10119 2.12	9900 1.59	9609 1.56	29	34	31
700	11967 2.26	11496 2.26	11130 2.25	10848 2.22	10609 2.08	10287 2.04	32	37	33
750	12782 2.36	12278 2.36	11883 2.35	11579 2.32	11321 2.16	10966 2.13	34	40	35
800	13599 2.46	13061 2.47	12639 2.45	12313 2.41	12034 2.25	11647 2.21	36	42	37
850	14418 2.56	13847 2.57	13396 2.55	13048 2.51	12750 2.33	12329 2.29	39	45	39
900	15238 3.06	14634 3.07	14155 3.05	13785 3.01	13468 2.41	13012 2.38	41	48	42
950	16059 3.16	15423 3.17	14916 3.15	14525 3.10	14187 2.49	13697 2.46	43	51	44
1000	16883 3.26	16214 3.27	15679 3.25	15266 3.20	14909 2.57	14383 2.54	46	54	46
1050	17708 3.37	17007 3.37	16444 3.35	16009 3.29	15628 3.06	15071 3.03	48	57	48
1100	18534 3.47	17801 3.47	17212 3.45	16754 3.38	16346 3.14	15760 3.11	50	60	50
1150	19363 3.57	18597 3.57	17981 3.55	17501 3.47	17066 3.23	16451 3.19	53	63	52
1200	20193 4.07	19395 4.07	18752 4.05	18250 3.56	17787 3.31	17143 3.27	55	66	54

PACK FLOW LO ΔFUEL = – 0.4 %	**PACK FLOW HI OR/ AND CARGO COOL ON** ΔFUEL = + 1 %	**ENGINE ANTI ICE ON** ΔFUEL = + 1.5	**TOTAL ANTI ICE ON** ΔFUEL = + 6 %