Escola d'Enginyeria de Telecomunicació i Aeroespacial de Castelldefels

UNIVERSITAT POLITÈCNICA DE CATALUNYA

POLITECNICO DI TORINO

TRABAJO FINAL DE GRADO

TÍTULO DEL TFG: The international air cargo transport system: technological evolutions and perspectives in view of traffic trends, network management and energy issues

TITULACIÓN: Grado en Ingeniería de Aeronavegación

AUTOR: Inés Larrucea Osorio

DIRECTOR: Bruno Dalla Chiara

FECHA: 31 de octubre del 2019

Título: The international air cargo transport system: technological evolutions and perspectives in view of traffic trends, network management and energy issues

Autor: Inés Larrucea Osorio

Director: Bruno Dalla Chiara

Fecha: 31 de octubre del 2019

Resumen

La industria del transporte aéreo ha aumentado gradualmente su participación global del tráfico de pasajeros y carga, y esta tendencia se ha acelerado en los últimos cuarenta años.

En el pasado, el sector de carga aérea ofrecía servicios limitados, con una fuerte dependencia de varios intermediarios y una dependencia significativa de las operaciones de pasajeros aéreos. El sector se puede caracterizar ahora como sotisficado e innovador, que depende en gran medida de las nuevas tecnologías electrónicas y ofrece una amplia gama de productos de transporte y logística a través de operadores de carga especializados.

Este proyecto se ha desarrollado en dos fases. En primer lugar, se ha examinado el sector de carga aérea en términos de crecimiento, estructura y organización. Se ha analizado también las restricciones que se enfrenta los movimientos de la carga aérea y las posibles estrategias para acomodar su crecimiento en las perspectivas futuras.

En segundo lugar, se realizaron varias simluaciones de trenes y aviones de carga utilizando el software Advanced Emission Model (AEM), de Eurocontrol, para hacer una comparación del consumo de energía entre trenes de alta velocidad y aviones, ambos con carga.

Finalmente, la última parte del proyecto es analizar los resultados obtenidos de las simulaciones y llegar a una conclusión para determinar qué modo de transporte es el mejor para transportar mercancías en términos de tiempo, costo y consumo de energía.

Title: The international air cargo transport system: technological evolutions and perspectives in view of traffic trends, network management and energy issues.

Author: Inés Larrucea

Director: Bruno Dalla Chiara

Date: 31st of October 2019

Overview

Air transport industry has gradually increased its share of global passenger and freight traffic, and this trend has accelerated in the last forty years.

In the past, air-freight sector offered limited services, with heavy reliance on several intermediaries and a significant dependence on air passenger operations. The sector can now be characterized as a sophisticated, innovative one, relying heavily on new electronic technologies, offering a wide range of transport and logistical products through dedicated specialist freight operators.

This project has been developed in two phases. In the first place, it has been examined air freight sector in terms of its growth, structure and organization. It has been also analysed the constraints facing the air cargo movements and possible strategies for accommodating growth in air cargo in future prospects.

In the second place, a several simulations of freight aircraft and trains were carried out using the Advanced Emission Model (AEM) software, from Eurocontrol, in order to make a comparison of energy consumption between high speed trains and aircraft, both carrying freight.

Finally, the last part of the project is to analyse the results obtained from the simulations and make a conclusion to determine which mode of transport is the best to carry freight in terms of time, cost and energy consumption.

Acknowledgements

First of all, I want to say "Grazie mille a tutti che mi hanno aiutato nella mia tesi", because whitout them it could be more complicated and difficult.

Bruno Dalla Chiara with his patience, his knowledge and for all hours that he spent with me to explain all things that I didn't understand, professor Dario Pastrone for the information that he gave me about some aeronautical concepts and Nicola Coviello for his help in the freight train simulations.

GRAZIE DI CUORE A TUTTI.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The air freight transport has been an important progress engine in the last century and for the last years in the present and is becoming an important revenue source for airlines.

Two primary factors influence freight growth: economic conditions and rate levels. The outlook for both is positive for cargo. Moderate economic growth is expected to continue into the future, with only a minor slowdown in the short term. Cargo rates should also remain low as several factors serve to keep the lid on prices. The real potential for air cargo growth lies with air express and air freight. According to Boeing, it is expected that world air cargo will grow at a rate of 6.2 percent per year during the next 20 years. The North American market will grow at about 5 percent per year.

The purpose of this project is to analyse the air freight sector in terms of growth, structure and organization and make a comparison with rail freight transport in order to determine which is the best mode of transport to carry goods having the less energy consumption but optimizing time and cost.

The project has been developed in two phases. From chapter 1 to 6, it has been examined air freight sector in terms of its growth, structure and organization. It has been also analysed the constraints facing the air cargo movements and possible strategies for accommodating growth in air cargo in future prospects.
The second section, which belongs to chapter 7, a several simulations of freight aircraft and trains were carried out using the Advanced Emission Model (AEM) software, from Eurocontrol, in order to make a comparison of energy consumption between high speed trains and aircraft, both carrying freight.

SCOPE

Due to the fast growing of air freight transport during the last 40 years, it is necessary to describe which are the challenges that this industry is facing nowadays. In addition, it is important also to analyze rail cargo transport as it has become the most competitive transport mode for air freight due to its big development in the last years.

This study is focus on analyzing the specific energy consumption of air cargo transport and provide a comparison of it with the rail cargo transport.

The purpose of this project is to analyze in which areas the rail cargo transport is competing the most with the air cargo, in terms of time, cost, energy and network management.

1. CHAPTER 1- STATE OF THE ART

There are some researches on the competition between air cargo and road/rail cargo transport, energy consumption of trains and the management in the network of freight transport. Some relevant results are outlined hereafter.

Dalla Chiara (2017) quantified and compared the specific energy consumption of air transport and high-speed rail transport. In his study he discovered that small business jets, small regional turbofans and regional turboprops present a consumption comparable with the HST, but the gap between air transport and HST is reduced when the range is increased.

In that project he showed that for air transport, the specific consumption was decreasing while increasing the range due to the smaller effect of climb segment when the range is longer. On the contrary, for HST, the energy consumption per km is a weaker function of the range. Then, for a large ranges, the specific energy consumption of an aircraft may result to be lower than the one of a HST.

They analysed a short medium haul route in order to compare it with HST. The route was Milan-Naples, and it is a common route of both transport modes. They obtained the following results:

Milan-Naples route	Specific energy [Kw h/km]	Specific energy consumption [Kw h/pass km]
Aircraft	44,49	0,2694
HST	23,8	0,0415

Table 1.1: Specific energy consumption between aircraft and HST on the Milan-Naples route. Source: [Dalla Chiara, 2017]

As it can be seen in Table 1.1 the energy consumption of HST is appproximatey 50% of the specific energy for air transport.

Results here presented that HSTs are more convinient than air transport from a specific energy point of view, although for a longer routes the specific energy gap between HSR and air transport diminishes. Moreover, HSR requires expensive infrastructures that air transport does not require, and that of course means an additional energy consumption associated to them. And in terms of environmental aspects, they saw that the large use of HSR on routes up to 800km, or even up to 1000km, appeared to be a viable option that would allow a sustainable development of transport systems.

Woxenius (2007) described the different principles for the design of transport systems and applied them to intermodal freight transport. He saw that the network design that dominates more is direct link and it increases at the expense of consolidation networks. While direct trains offer simple and cost-efficient operations and a very good service on axes with large flows over long distances, consolidation is a prerequisite for competing with all-road transport on short distances.

Zhang (2002) provided a general discussion of different issues related to the air cargo liberalization from the international view. It was shown that air cargo carriers may have different scheduled routes than passanger carriers and thus require different traffic rights. It also was shown that separation of rights between air cargo and passengers in Asia will be undesirable as most of the passenger carriers have cargo business in their same fleets. Intermodal transportation was also discussed in this study.

Bowen (2012) studied the evolution of two of the most important air freight carriers: Federal Express and Unit Parcel Service. Their hubs in and outside the US were analyzed including various factors such us the support of ground transportation and competition with other airlines. The overall network of both cargo airlines were compared between them and between American Airlines and Southwest Airlines.

They used a common approach to summarizing a network, that is to treat it as a set of vertices (cities) and edges (routes) and then derive several graph theoretic measures. Data for all four airlines were drawn from the T-100 database.

Airline	Vertices, v	Edges, e	Beta index, e/v	Gamma index, $e/(½ v(v-1))$
FedEx Express	300	951	3.17	0.021
United Parcel Service Airlines	129	477	3.70	0.058
American Airlines	167	714	4.28	0.052
Southwest Airlines	73	968	13.26	0.368

Table 1.2: Basic network parameters for four airlines, 2010. Source: [Bowen, 2012]

The results (Table 1.2) indicate that FedEx and UPS are much more similar to American in their basic network structures than to Soutwest Airlines. In fact, both integrators have more highly centralized networks than even American, as indicated by low beta and for FedEx, for gamma indices. The beta index measures the number of edges per vertex and the gamma index indicates the ratio between the number of actual edges and the maximun possible given the number of vertices.

In this study it was also evaluated the patterns of accessibility in each network, that is the Shimbel index for every vertex or node. The accessibility of each vertex was then measured in terms of the minimun number of edges (links) required to connect it to every other vertex (airport) in the network:

$$A_j = \sum d_{ij}$$

Where d is the distance from airport i to airport j in edges.

Rank	FedEx Express		UPS Airlines		American Airlines		Southwest Airlines	
	Airport	A_j/i	Airport	A_j/i	Airport	A_j/i	Airport	A_j/i
1	Memphis	1.58	Louisville	1.30	Dallas-Ft. Worth	1.33	Las Vegas	1.18
2	Indianapolis	2.15	Rockford, IL	2.00	Miami	1.46	Chicago-Midway	1.27
3	Oakland	2.31	Ontario, CA	2.03	Chicago-O'Hare	1.59	Phoenix	1.37
4	Newark	2.37	Philadelphia	2.08	New York-JFK	1.74	Baltimore-Wash.	1.37
5	Seattle	2.44	Miami	2.10	Los Angeles	1.84	Denver	1.39
6	Portland, OR	2.46	Anchorage	2.11	San Juan, PR	1.92	Orlando	1.45
7	Anchorage	2.47	Columbia, SC	2.11	Boston	1.92	Tampa	1.55
8	Honolulu	2.49	Dallas-Ft. Worth	2.14	San Francisco	1.96	St. Louis	1.56
9	San Juan, PR	2.49	Newark	2.16	St. Louis	1.96	Nashville	1.58
10	Ontario, CA	2.49	Boeing Field, WA	2.17	London-Heathrow	1.96	Houston-Hobby	1.58

Table 1.3: Accesibility measures for top airports in four airline networks, 2010. Source: [Bowen, 2012]

As seen in Table 1.3, each city's value of Aj has been divided by number of cities (i) in their respective network. As expected, it was shown that the most accessible aiports in each network were the hubs. Also it was shown that for the integrator networks, the most heavily trafficked routes remain US domestic routes and are very heavily focused on each carrier's primary hub.

Kiso and Deljanin (2009) examined the air freight sector in terms of its structure, organization, its role in the supply chains, its constraints and future prospects.

They concluded that air freight is a significantly more expensive mode of carriage of goods than the other modes, and will be only used when the value per unit weight of shipments is relatively high and the speed of delivery is an important factor. But over shorter distances, air transport faces competition from surface modes. They also came to a conclusion that multimodal transport operations and greater integration of transport with other logistical services will dominate freight developments in the next two decades.

Schramm (2018) presented an overview of the recent development of Eurasian rail freight and evaluated its service quality in terms of transit times and transport costs compared to other transport modes in containerised supply chains between Europe and China.

In order to build a realistic and same scenario for all kind of transport modes, they used Shanghai and Hamburg as the origin and destination points.
In Table 1.4 there is a summary of the transport costs and average transit times of shipping an single FCL shipment of one FEU from Shanghai to Hamburg for four modes of transport on a terminal-terminal basis for 2017 compared to 2006.

Transport Mode	Year	Distance (km)	Transit Time (days)	Transport Cost (USD/FEU)	Cost/Distance (USD/km)	Transport Speed (km/day)
Rail	2017	11,249	16	6,350	0.56	703.1
Rail	2006	-	47	8,450	-	-
Sea	2017	20,053	32	2,410	0.12	626.7
Sea	2006	-	30	2,740	-	-
Air	2017	8,822	4	32,490	3.68	2,205.5
Air	2006	-	5	25,000	-	-
Sea/Air	2017	16,008	19	16,650	1.04	842.5
Sea/Air	2006	-	19	22,600	-	-

Table 1.4: Transport costs and transit times for different transport modes in 2006 and 2017. Source: [Schramm, 2018]

The results that they obtained in this study were that sea was and is still the cheapest option and air is very much higher than the other modes. Sea/air transport cost are around half of air, whereas Eurasian rail freight is about 80% less costly than air. In terms of transit time, they showed that air was the fastest transport solution from China to Europe and rail or sea/air were about half of the time than sea.

2. CHAPTER 2- HISTORY OF AIR CARGO

Air cargo has been one of the most successful businesses in the world today. Shipping by plane has not always been an option, it was not until the end of the World War I that such services were first offered in any significant way. Basically, due to the availavility of surplus airplanes and trained military pilots.

2.1. Europe

In Europe, civil aviation grew rapidly after the end of World War I, fueled primarily by demands from national postal services. The first only cargo flight, scheduled commercial air company began service between Paris and Lille in July 1919. The same aircraft that transported passengers during the day were used for mail and freight transport at night. Lufthansa, founded in 1926 in Germany, started dedicated air freight services in 1928. (Allaz, 2005)

In 1923 a government study in Great Britain concluded that a multitudinous of smaller companies were not economically suited to fulfill the national goal of linking all parts of the empire into one air transportation network. Many smaller airlines agreed to merge, forming Imperial Airways Limited. Imperial Airways soon operated in all corners of the British Empire, transporting mail and goods between London and destinations such as Cairo, Sydney, Delhi and Basra. In 1939, after the outbreak of World War II, Imperial Airways was nationalized and merged with British Airways Limited to form a new airline, British Overseas Airways Corporation (BOAC), a predecessor of today’s British Airways. (Rodrigue, 2016)

Due to range limitations, the first international air routes were composed of a series of refueling stages, as it can be seen in Figure 2.1. Crossing the comparatively calm and narrow South Atlantic was much easier than transiting the North Atlantic. Although the world's most powerful economies bracketed the North Atlantic, regular air services between the United States and Europe did not began until 1939 when Pan Am offered Boeing 314 flying boat services. (Rodrigue, 2016)

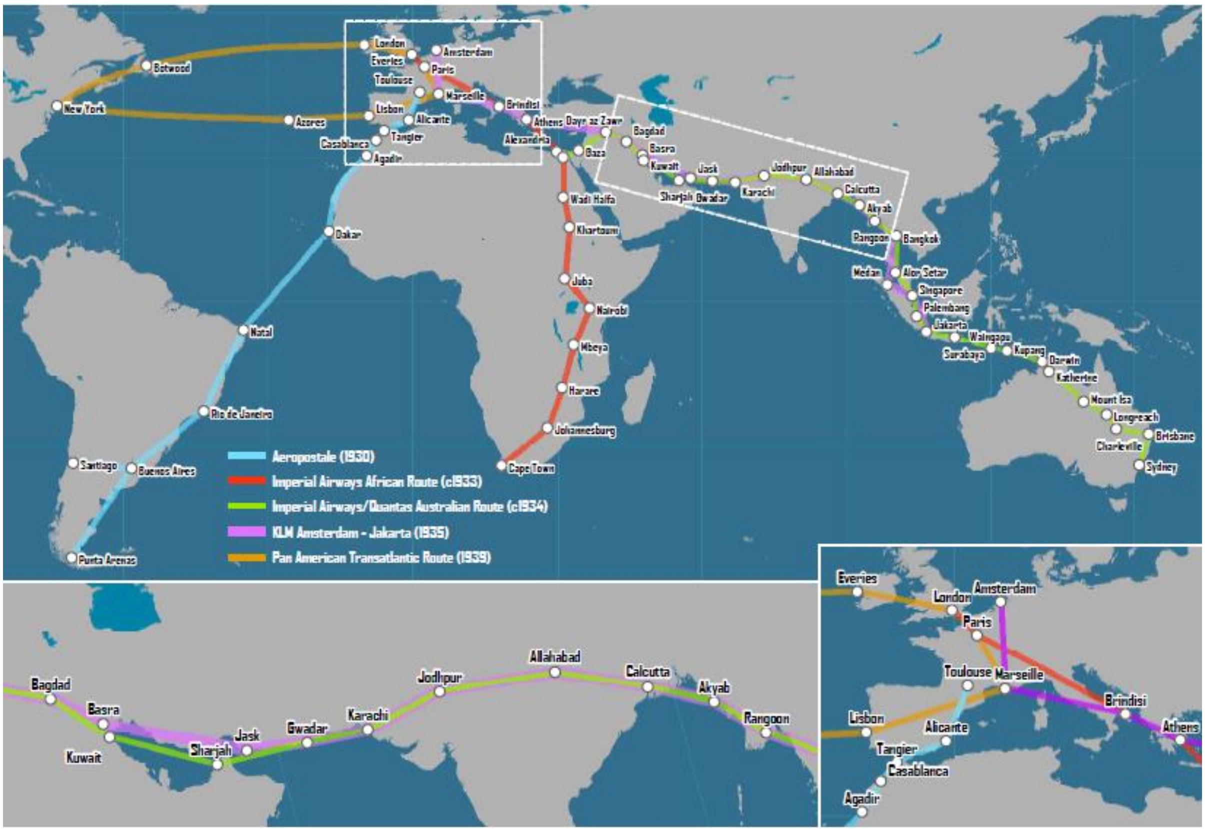

Figure 2.1:Intercontinental routes,1930s. Source: [Rodrigue, 2016]

Since the inauguration of the first commercial regular long-distance air services in the 1950s, many routes have been decreased their distances. One example of this is shown in the Figure 2.2.

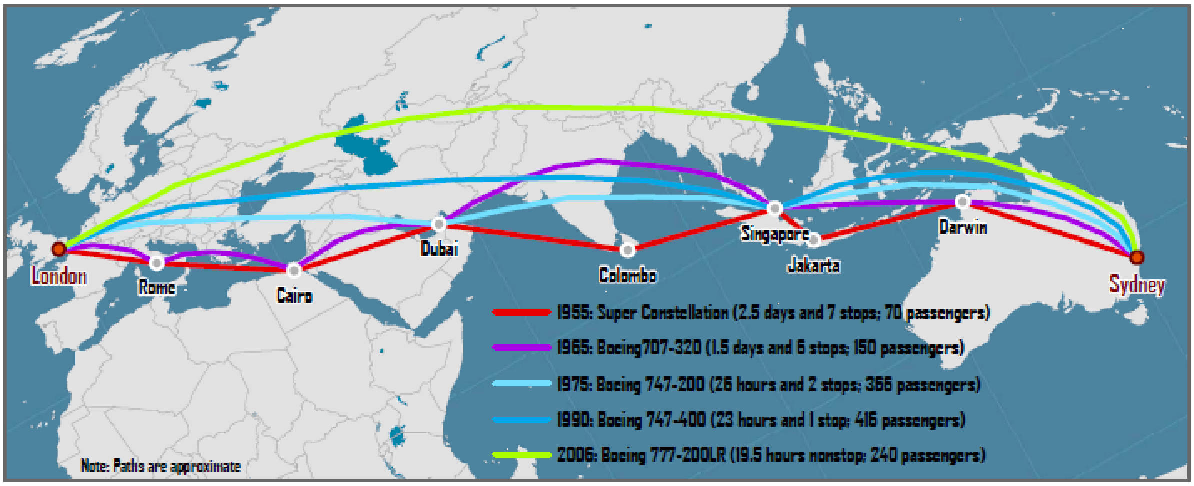

Figure 2.2: Shortest Air Route between London and Sydney, 1955 – 2006. Source: [Rodrigue, 2016]

When the route London-Sydney was serviced by a propeller plane (Super Constellation), the segment took two and a half days and 7 stops to be serviced (with an overnight stay in Cairo and Singapore), as it can be seen in the Figure 2.2, which belongs to the red line.
The introduction of the 747 in the 1970s reduced this route to 26 hours and two stops. A more fuel efficient and longer range 747-400 improved the route by 3 hours because only one stop was then required.
In 2006, for the first time, a direct flight became a possibility with a new generation of long range aircrafts such as the 777-200LR. However, this yet to be serviced route is at the extreme limit of serviceability as dominant winds would only make possible an east-west non-stop full load leg. Thus a “direct” flight between London and Sydney still involves a technical refueling stop in Singapore or Dubai. Considering technical limitations linked with the ratio speed/fuel consumption, it is unlikely that the travel time between London and Sydney will become lower than the current 19.5 hours direct flight. (Rodrigue, 2016)

2.2. United States

In the United States, the air freight transportation took place in 1910, when a department store shipped a bolt of silk by air from Dayton to Columbus, Ohio. The first dedicated air postal service operated by the US Army began in July 1918 with service between Washington DC, Philadelphia and New York City. In 1924, the US Postal Service inaugurated the first transcontinental postal service, connecting New York City to San Francisco. This trip took 34 hours and 45 minutes in one direction, and 32 hours and 21 minutes in the other. Similar case than in Europe, postal service was the foundation of air freight in the early years. Air mail service growth was very fast; in 1918, 713,240 mail pieces were transported; by 1927, the number reached to more than 22 million. (Allaz, 2005)

By 1921, a route spanning the United States had been forged. Due to the short range of the planes at that time, postal routes were composed of several stages, at most 375 km apart. Crossing the continent from New York to San Francisco involved 16 stopovers and took about 4 days, with some segments flown during the night (see Figure 2.3). (Rodrigue, 2016)

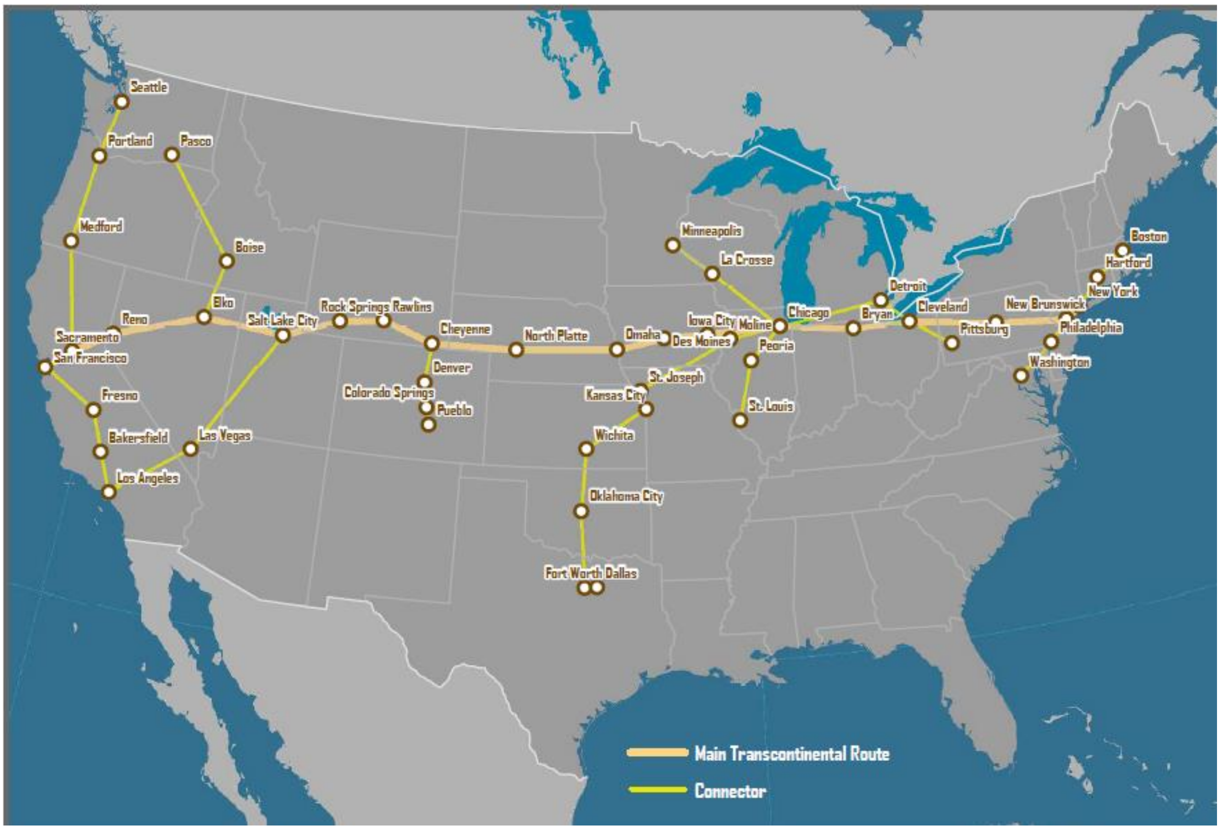

Figure 2.3: US Post Office Airmail Routes, 1921-26. Source: [Rodrigue, 2016]

The initial development of postal air routes was assumed by the US Postal Service, which acquired planes and took care of the setting of airfields and air operations. Once the service was established and demonstrated to be economically feasible, it was contracted to private operators. By 1927 the transport of airmail was entirely privatized. Some of these contractors would become the first commercial airlines. (Rodrigue, 2016)

Between 1926 and 1934 the aviation network in the United States changed dramatically. From a service almost exclusively used for the transport of mail, the air network system evolved into the largest passenger and cargo network in the world. The Air Commerce Act of 1926 is often cosidered the foundation for a continental air cargo system. This act established regulations concerning the licensure of pilots, standardized the rules for air traffic control, and specified the varying roles of airports in a national system. (Allaz, 2005)

By the start of World War II, the US air transport system was the largest in the world, handling more than half of all global passenger trips and just over one-third of mail traffic. On December 23 in 1940, United Airlines used a Douglas DC-4 aircraft to deliver mail between New York and Chicago for five months before cancelling the route. On March 14th of 1941, when Air Cargo, Inc., was formed by the “big four” airlines (United, American, TWA and Eastern), by the end of the war, many airlines begun their commercial air freight services. (Allaz, 2005)

By the late 1940s, the air freight service market was dominated by established passenger carriers. Through that period of time, it was made a debate between small operators and the governent’s Civil Aeronautics Board (CAB) on how to award contracts and set proper rates for freight transport. In August 1949, CAB gave permission for four all-freight airlines to operate: Slick, Flying Tiger, US Airlines and Airnews. The only airline that could surive with the competition of big airlines that had introduced all-freight services was Flying Tiger, mainly due to its business model, which had diversified its market share. (Allaz, 2005)

In the 1970s, a new airline revolutionized the air freight business. Fred Smith, now the chairman, CEO and president of FedEX, had the vision of an overnight delivery service. He was the first to present the option to offer the all-in one cargo transportation, that would eliminate the need to combine freight with passenger traffic, which slowed down the cargo delivery. He set up his headquarters in Memphis, Tennesse, and the Menphis International Airport became the hub for his exclusive freight air delivery service. One of the most important selling points was his guarenteed next-day delivery. This airline reported revenues of $1 billion in 1983 and now it is the largest overnight express delivery company in the United States. (Allaz, 2005)

2.3. World Air Freight Trends, 1970-2017

Figure 2.4 summarizes the historical trend of scheduled air freight activity in freight million ton-km since 1970 until 2016 in the world, separated per region of the world.

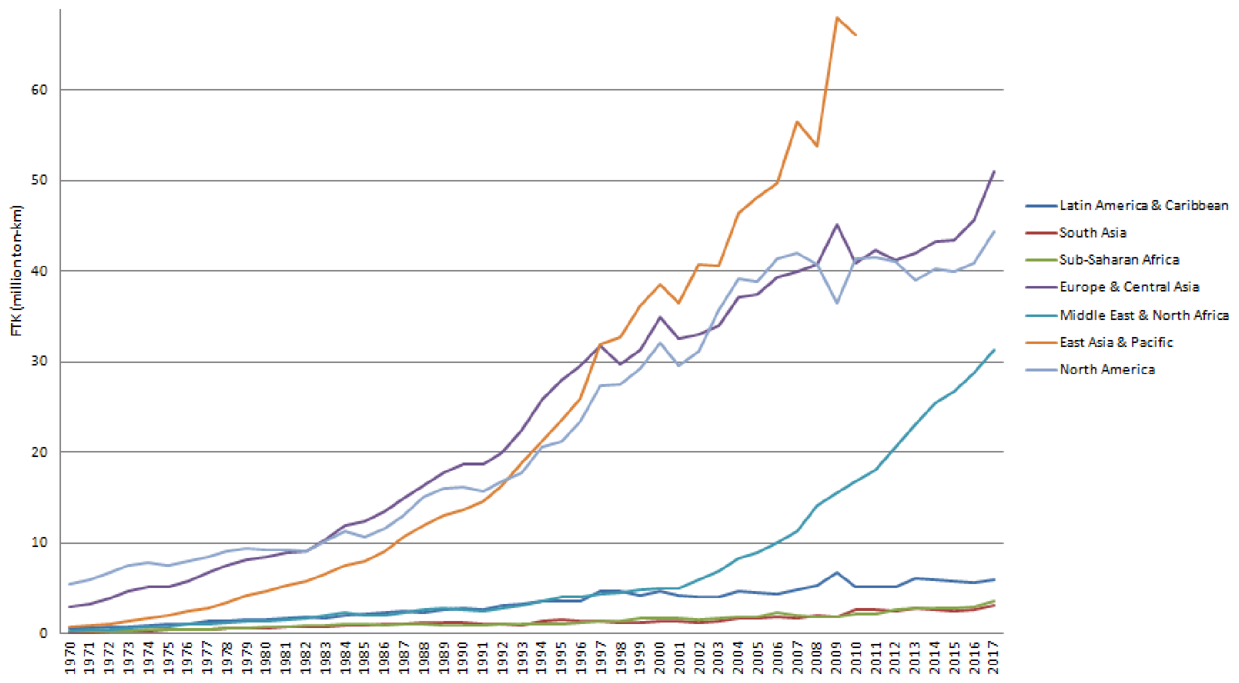

Figure 2.4: World Air freight traffic trend 1970-2017. Source: [ICAO, 2019]

2.4. Air Cargo Aircraft History

It was in the 1920's that the use of cargo aircraft became much more prevalent as it was needed for military purposes, including World War II. The planes were needed to transport troops as well as material in the fastest manner. During the war in 1939, cargo aircrafts with rear loading ramps were invented, which was a huge innovation for future cargo aircraft (in Table 2.1 it is indicated the name of the aircraft).

After the war era was over, several new custom-built cargo planes were introduced. Today, because of new safety and noise requirements, most cargo aircrafts can no longer be used for both cargo and passenger transportation. Some exceptions are the Boeing 747, Canadair CL-44, and the CASA CN-235 because of a special design that contains an unobstructed main deck to keep the cargo from crushing passengers in case of an accident.

Some important air freight aircraft in the history are shown chronollogically in the following Table 2.1.

	Aircraft	Specifications
From 1920 to 1940	Vickers Vernon	First dedicated troop transport aircraft in 1921 of the Royal Air Force
	Junkers Ju90	Innovation for future cargo aircraft as it introduced the rear loading ramp. First flight August 1937
From 1941 to 1950	Arado Ar232	First aircraft only dedicated to cargo (payload of 4500kg). It was designed and built during World War II. First flight June 1941.
	Douglas C-47 Skytrain	Reinforced fuselage floor and addition of a large cargo door (payload of 2700kg). It is actually in service with military operations. First flight December 1941
	Budd RB Conestoga	Twin-engine cargo aircraft designed for the USA during World War II (payolad of 4400kg). Firt flight October 1943.
	Fairchild C-82 Packet	It introduced a new feature for air cargo aircraft, that is the removale cargo area. It was used by the US Air Force during World War II. First flight September 1944.
	Fairchild C-123 Provider	It was built for the US Air Force (payload of 11000kg). The aircraft introduced the now common rear fuselage/upswept tail shaping to allow for a much larger rear loading ramp. First flight October 1949
From 1951 to 1960	Lockheed C-130 Hercules	It introduced the new turboprop engine (payload of 20400kg). It was originally designed as a troop, medical evacuation and cargo transport aircraft. First flight August 1954. It is the longest continously produced military aircraft at over 60 years.
From 1961 to 1970	Lockheed C-5 Galaxy	It is among the largest military aircraft in the world (payload of 130000kg). It was built for the US Air Force for a heavy intercontinental-range strategy. First flight June 1968
From 1971 to now	Antonov An-225 Mriya	It operates with six turbofan engines and is the heaviest aircraft ever built, with a MTOW of 640 tonnes. It also has the largest wingspan of any aircraft in operational service. First flight December 1988 and it has a max cargo hold of 1300m3
	Boeing 747F	It is the first wide-body aircraft produced. It has a cargo hold from 110 to 180m3, depending the variant (747-400, 747-800, etc). First flight February 1969
	Airbus A380F	This aircraft offers the largest payload capacity (payload of 84t), exceeded only by the Antonov An-225. First flight April 2005

Table 2.1: Important Cargo Aircraft in the history. Source: [Century of flight, 2019]

2.5. Stages in Air Network Development

Four major stages can summarize air network development through its history:

- **Stage 1 (initial development; connecting effect).** During the 1930s, basic linear services were established (see Figure 2.5). As the technical capabilities for those times were limited, especially in terms of range and capacity, intermediate stops were necessary. For instance, a flight across the Pacific required stops at Hawaii, Wake, Midway, Guam and the Philippines islands.
- **Stage 2 (By-passing effect).** During the 1940s and 1950s, the technical capabilities of aircrafts improved substantially, which enabled to by-pass several intermediate stops. Routes between major destinations still had a linear structure.
- **Stage 3 (Proximity effect).** Between 1960 and 1970, aircraft technology gave the possibility of operating longer distance routes, which improved the optimization of the network structure. From that time, the airports of large cities started to be a feeder service.
- **Stage 4 (Hubbing effect).** In the 1980s and 1990s, the existence lf large hubs handling the majority of air traffic was something very established in the air network, especially at the international level. Hub and spoke networks have the advantage of offering a larget market coverage with a smaller number of services.

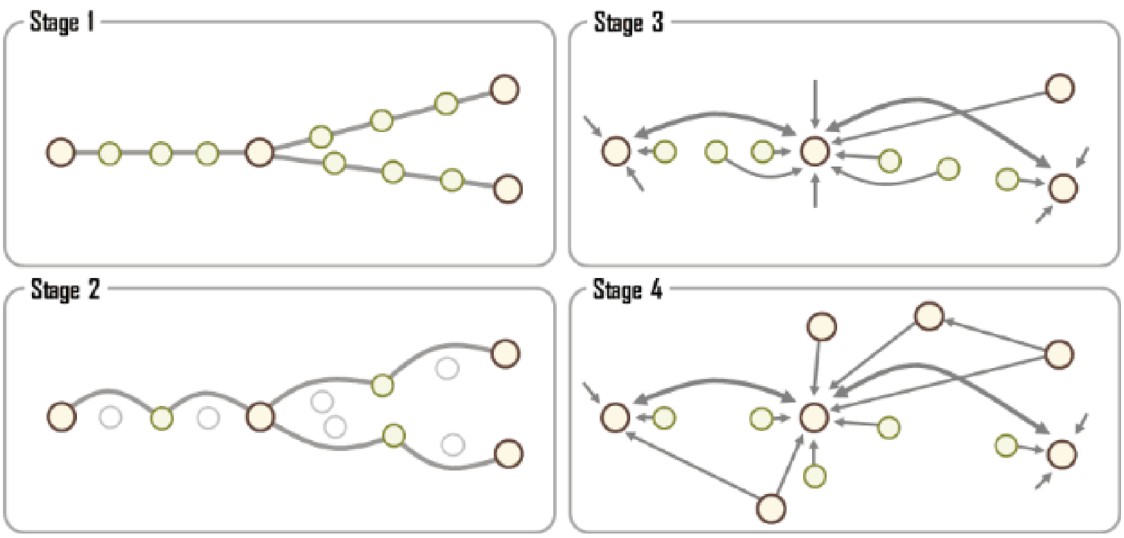

Figure 2.5: Stages in Air Network Development. Source: [Rodrigue, 2016]

The actual six principle designs for air transport network will be described further in section 3.1.6.

3. CHAPTER 3 - OVERVIEW AIR CARGO TRAFFIC

3.1. Global Traffic

3.1.1. Passenger and Air Freight Traffic

In Figure 3.1 it is shown the world scheduled air passenger traffic, measured with PKP, that is passenger per kilometres performed and the world scheduled air freight traffic expressed in freight tonne-kilometres performed (FTK), between the years 2003 and 2016.

International air freight traffic (including airmail), has grown at an average rate of 3.7 percent a year between 2003 and 2016. We can see that freight has a greater volatility traffic compared to passengers and surprinsingly, freight tonne-kms have grown at a slower rate than passengers over this period: 3.7 percent versus 5.9 percent for passengers. (ICAO, 2019)

In 2009, it was the worst demand decline in history for air freight and passenger demand as well. Freight demand was 9% lower than in 2008. (IATA, 2010).
Asia-Pacific carriers's freight volume remained 8% below 2008 peak levels and European carriers remained 20% below 2008 peak levels reflecting the glacial pace of economic recovery in Europe. (IATA, 2010).

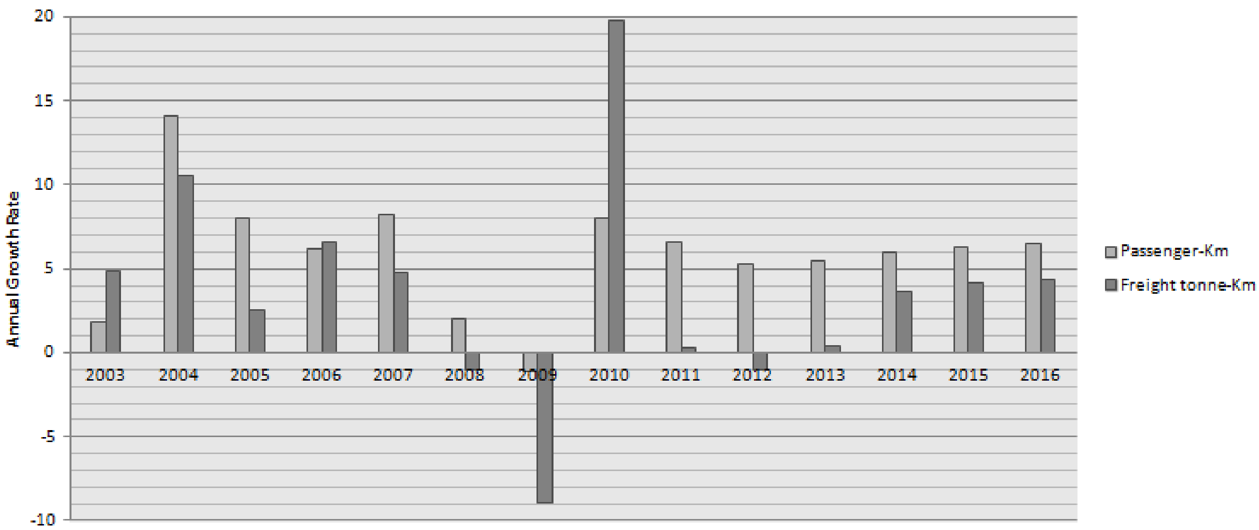

Figure 3.1: Passenger vs freight traffic trends, scheduled international services, 2003-2016. Source: [ICAO, 2019]

3.1.2. International Air Freight Route Traffic

Figure 3.2 gives a picture of world international freight traffic by trade lane in 2009. Flows which are close to zero have been omitted. Because this is international traffic the large market within the US has not been included and even trans-border flows within North America do not amount to much since most cargo is trucked.

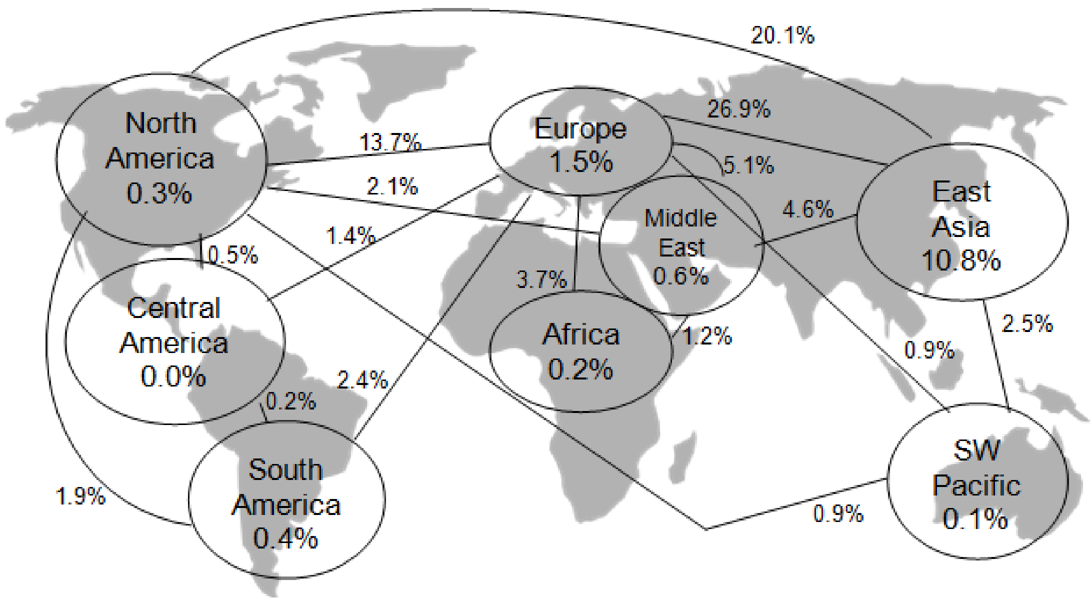

Figure 3.2: Distribution of world international freight tonne-km traffic by trade lane, 2009. Source: [Morrell, 2016]

In 2007, air cargo transport from Asia to North America were estimated to have 57 percent higher in terms of tonne-kms than imports from North America. This is obviously a problem for air cargo carriers, as it is not possible to achieve high load factors in return trips. For the case of air cargo from North America to Europe, in that year it was very similar to imports from Europe, but from Asia to Europe the aircargo flow was 74 percent larger than from Europe. In Intra-Europe, most of the aircargo transport were carried on trucks. (Morrell, 2016).

In Figure 3.3 it is indicated the most important goods categories transported by air freight in 2007 in the world. On a worldwide level, high-technical products represent the largest share. [Van de Voorde, 2010]

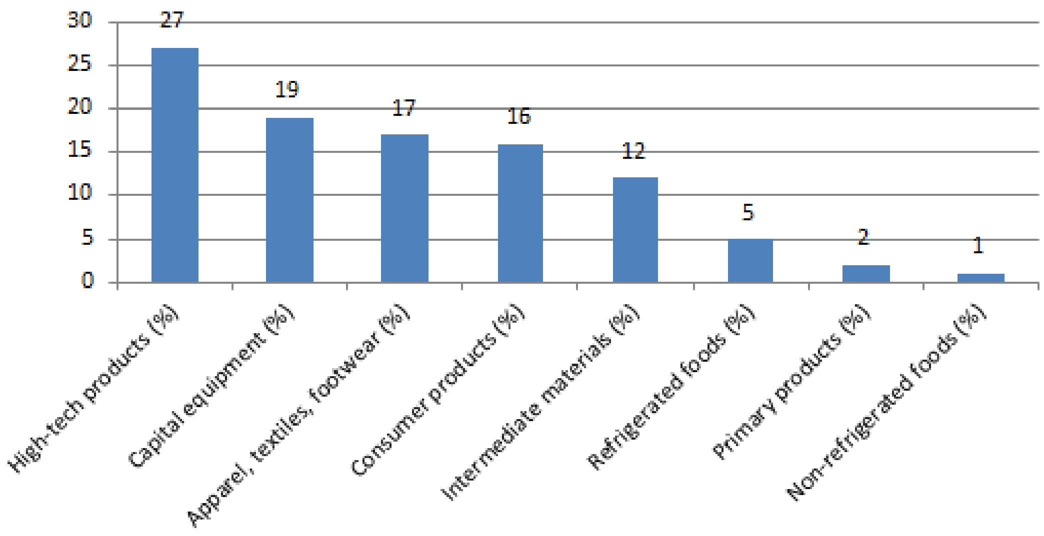

Figure 3.3: Commodity share of directional air freight markets in 2007 in the world. Source: [Van de Voorde, 2010]

Figure 3.4 represents the most important goods categories transported by air freight for different geographical markets in 2007. Capital equipment is the most important goods category in all the air exports from Europe.
The air exports from North America to Latin America are dominated by high-technical products. For its exports to Europe and Asia, high-technical products and capital equipment are the most important goods categories with only a small difference between them. For Asia's exports to Europe and North America, which are the largest air freight markets, manily consist of high-technical products. These are also dominant in the intra- Asian air cargo traffic. Finally, the market between Latin America and North America (LA-NA) is completely different from the other markets as it is largely dominated by refrigerated goods. [Van de Voorde, 2010]

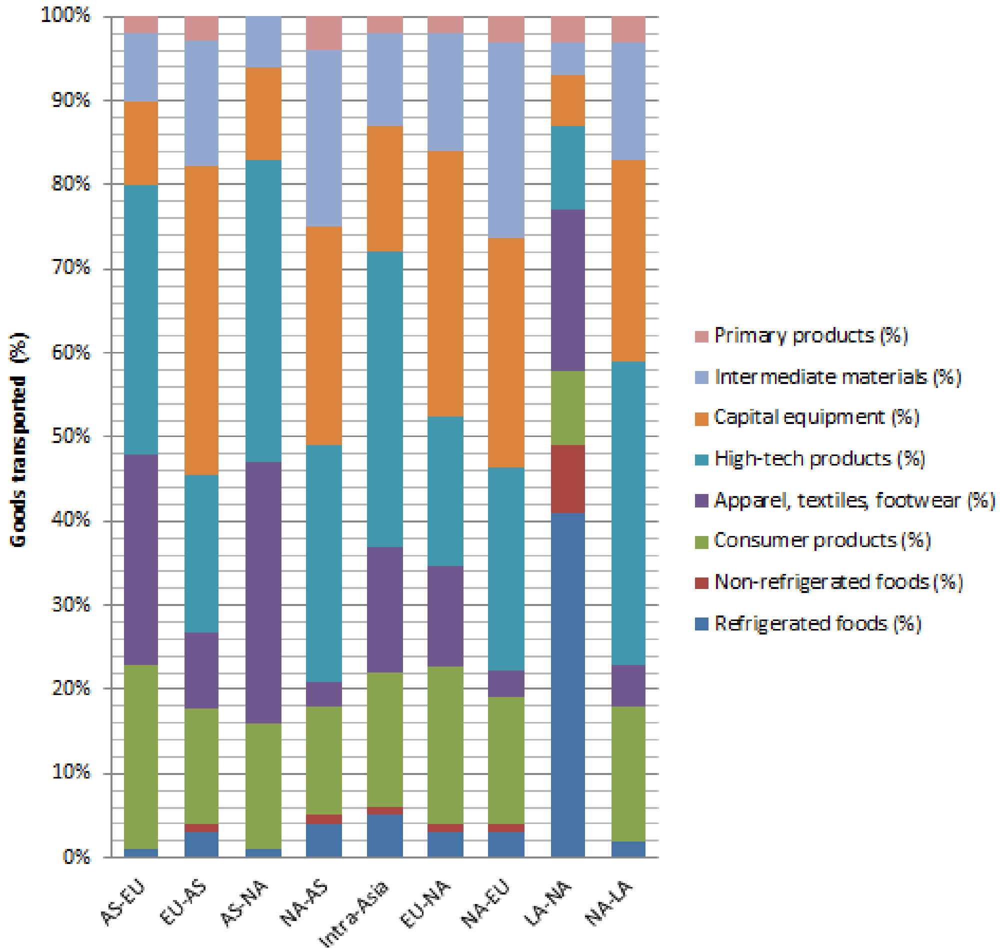

Figure 3.4: Most important goods categories transported by air freight for different markets in 2007. Source: [Van de Voorde, 2010]

Air cargo can be characterized according to the type of service required:

- **Emergency freight** includes time-critical shipments of spare parts and business and financial documents (where these cannot be transmitted electronically).
- **High-value freight** includes gold, jewelry, currency, artworks, electronic components and luxury vehicles. This type of freight is transported by air for security as well as speed.
- **Perishables** include fresh seafood, fruits and vegetables, pharmaceuticals and cut flowers.

In Figure 3.5 it is shown the distribution of air freight tonne-kms by region of registration airline during 2008, split into international and domestic operations. The Asian carriers take the largest share of international traffic. In the other hand, domestic markets are dominated by North America. In Europe, domestic markets are in high competence with road/rail transport. (Morrell, 2016)

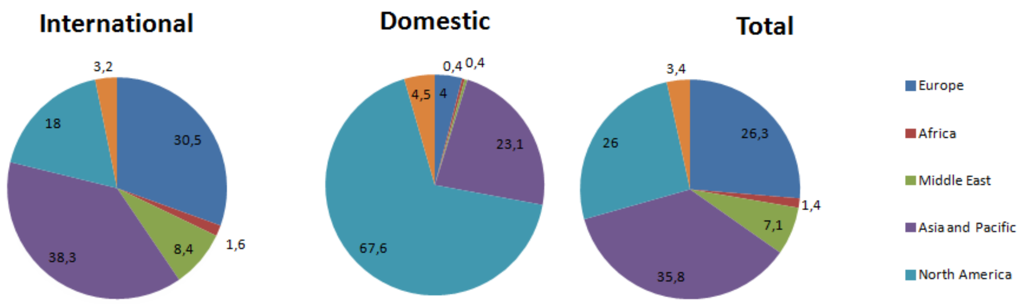

Figure 3.5: Distribution of FTK by region of registration airline, 2008. Source: [Morrell, 2016]

3.1.3. Type of Routes and Competing Modes

There are several important distinctions between passenger demand and shipper demands for air transport services. These distinctions mark a set of constraints and operating conditions on carriers depending on whether they are carrying cargo, passengers or both.

Freight comes in a large variety of shapes, density and sizes, and must be loaded onto and off aircraft by equipment and handlers. Large units may have to be carried in freighter-only aircraft.

The routing of cargo, including the number of stops or transfers it has to make, is not important to the shipper. What is really important is the lapsed time between pick-up and delivery. For passengers, however, their preference is typically for daytime, non-stop flights. Shippers' preferences are for night-time transport of goods, so that the delivery is early in the following morning. (Kiso and Deljnanin, 2009)

One of the most significant differences between passenger and freight air transport is that passenger typically travel on round-trip journeys, while cargo travels from a point of production to a point of consummation and it obviously leads to different network organization for freiht services compared with passenger services. For combination carriers, this can result in some difficulties, since freight demand does not coincide with the passenger demand for some principal destinations. (Kiso and Deljanin, 2009)

Regarding the air freight transport network, the most frequent routes are in general east-west, in basically the northern hemisphere, less north-south, and are almost non-existent east-west in the Southern hemisphere. (Bofinger, 2009)

Countries with high revenue in general have many cargo facilities and hubs and for normal reasons, much of the flow is dependent on better quality road access; items to be shipped need to somehow get to the airport.

Mixed modality, emerged even more strongly in the 1960s, when Air Canada developed a service that allowed coast-to-coat air transport increase the delivery efficiency of consumer goods manufactured in Japan: The goods arrived on the West Cost by sea, were transferred to aircraft flying them to the East Coast, and then either found their distribution there or were again, by sea, shipped to European consumer markets. (Bofinger, 2009)

Air cargo is generally competitive on long distance hauls with time-sensitive products, where other infrastructure, such as roads, do not exist. But on the other side, all air freight needs road transport to complete the supply chain from the airport to the user. Overall, air cargo is liberalizing more quickly than air passenger services, making the overall supply chain more efficient.

3.1.4. International Air Freight by type of Operators

Air freight providers are a mixed group of operators and they offer different types and different levels of logistics services.

There are three main categories of air freight operators (Kiso and Deljanin, 2009):

1) Line-haul operators
2) Integrate/Courier/express operators
3) Niche operators

Line-haul operators move freight from airport to airport, and rely on freight forwarders or consolidators to deal directly with customers. Line-haul operators can be:

- All- cargo operators: move only feight in dedicated freighter aircraft such as Cargolux (European Union) or Arrow Air (USA). All-cargo operators have the capability to move large volumes over long distances.

- Combination passenger and cargo operators: they use both dedicated freighter aircraft and passenger aircraft to move freight, such as Lufthansa (European Union) or United Airlines (USA). For the combination carriers, the cargo operations are mainly long-haul, with a large amount of freight being interlined onto shorter haul feeder services.

- Passenger operators: they use the passenger aircraft to move freight. Passenger operators tend to view cargo as by-product of passenger operations. They move cargo in the belly holds of passenger aircraft.

Integrate/Courier/express operators move consignments from door to door, with time-definite delivery services (e.g. UPS; Federal Express; TNT; DHL).

These integrated carriers operate multimodal networks, combining air services with extensive surface transport to meet customer demands.

Integrators offer a wide variety of services to make the shipments and they suplement the air services with an extensive ground network. In order for integrators to be able to offer door-to-door next day deliveries, they require night-time operations. In terms of aircraft requirements then, they need to operate quiet and reliable aircraft, with low utilization levels. These operators seek to purchase a combination of new aircraft, with high capital costs and better utilization on long-haul segments, with less expensive renovated second-hand aircraft for the medium-haul operations with lower utilizations.

Niche operators operate with specialized equipment and technology, in order to meet extraordinary requirements (e.g., Heavy lift from the Netherlands and Challenge Air Cargo from USA). These operators attract business through their capabilities for handling outside freight or special consignments, including line-haul to locations with poor infrastructure facilities. For chartered freight and niche operators, the discontinuous use of aircraft makes it financially preferable to acquire freighter aircraft on a second-hand basis.

Air freight industry was dominated until the mid-1980s by the line-haul carriers and from 1977, the integrators rapidly increased their market share and most recently in international air freight markets.

In Figure 3.6 it is shown the different ways of transporting air cargo that exist nowadays.

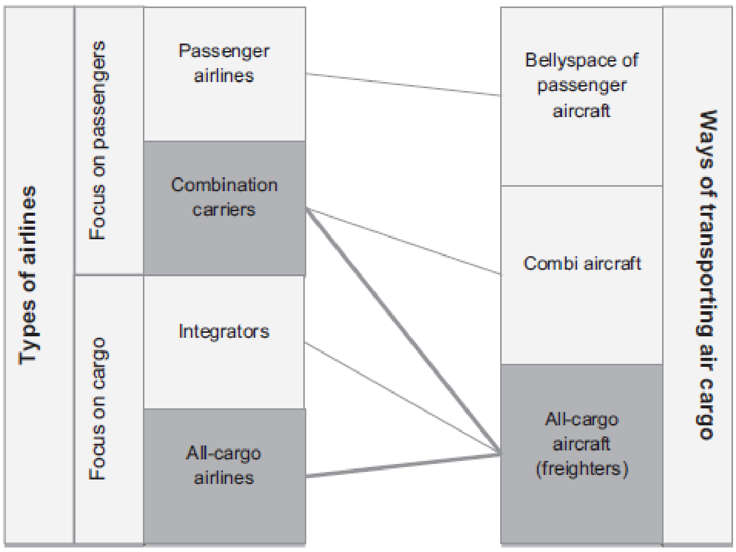

Figure 3.6: Ways of transporting air cargo. Source: [Kupfer, 2016]

In Table 3.1 it is shown the different type of carriers flying international air cargo in 2008. The largest part was carried on freighter aircraft operated by combination carriers (those airlines that offer both passenger and cargo services). The second place goes to the passenger flights of the same type of airline, most of it in the lower deck of aircraft. (Morrell, 2016)
A much smaller share of the world's international cargo traffic is carried by the integrators and specialist airlines that only operate freighter aircraft.

	Freight (tonne-kms (m))	**% total**
Freighter flights of combination carriers	74071	44,8%
Passenger flights of combination carriers	65364	39,5%
Integrators	13133	7,9%
Freighter-only airlines	12745	7,7%
Total international	165313	100,0%

Table 3.1: International air freight by type of carrier, 2008. Source: [Morrell, 2016]

The trend that is being followed nowadays is using the belly capacity for transport of freight in the passenger flights. As a consequence, over the last years, the additional cargo capacity from new aircraft relates more to passenger aircraft than to freighters. At world scale, as it can be seen in Table 3.1, in 2008, 39.5% of air cargo was shipped by belly. (Morrell, 2016)

Nevertheless, full freight aircraft still plays a major role. They still have a dominant position on routes between Asia and North-America and Europe.
Dedicated freighter services offer significant advantages to cargo operators. It offers:

- Predictable and reliable volumes
- Greater control over timing
- Ability to accommodate outsize cargo, hazardous materials and other types of cargo that cannot be shipped with passenger airplanes

3.1.5. Airport Traffic

The airports with largest cargo (international and domestic) transported in 2017 were most of them an Asian hub (see Table 3.2). Hong Kong leads the ranking with five million metric tonnes of cargo handled in 2017, a 9.4% increase over 2016. This airport is an Asian hub for DHL and main hub for Cathay Pacific.

Memphis, which is the main hub for FedEX and also a regional passenger hub for Nordwest Airlines, remained in second place with 4,3 million metric tonnes and Shanghai stayed in third with 3,8 million metric tonnes. (ACI, 2018).

RANK 2017	RANK 2016	AIRPORT CITY / COUNTRY / CODE	CARGO (000)	HUB Carriers
1	1	HONG KONG, HK (HKG)	5 049	DHL, Cathay Pacific
2	2	MEMPHIS TN, US (MEM)	4 336	FedEx
3	3	SHANGHAI, CN (PVG)	3 824	China Eastern, UPS, Great Wall
4	4	INCHEON, KR (ICN)	2 921	Korean Air, FedEx
5	6	ANCHORAGE AK, US (ANC)	2 713	FedEx, UPS, Northwest
6	5	DUBAI, AE (DXB)	2 654	Emirates
7	7	LOUISVILLE KY, US (SDF)	2 602	UPS
8	8	TOKYO, JP (NRT)	2 336	Japan Airlines
9	11	TAIPEI, Chinese Taipei (TPE)	2 269	China Airlines, Eva Airways
10	9	PARIS, FR (CDG)	2 195	Air France, FedEx, La Poste
11	10	FRANKFURT, DE (FRA)	2 194	Lufthansa, UPS
12	13	SINGAPORE, SG (SIN)	2 164	Singapore Airlines
13	14	LOS ANGELES CA, US (LAX)	2 158	Atlas Air
14	12	MIAMI FL, US (MIA)	2 071	South American Airways
15	15	BEIJING, CN (PEK)	2 029	Great Wall Airlines, Air China Cargo
16	16	DOHA, QA (DOH)	2 020	Qatar Airways
17	19	LONDON, GB (LHR)	1 794	British Airways, DHL, Virgin Atlantic
18	18	GUANGZHOU, CN (CAN)	1 780	FedEx
19	17	AMSTERDAM, NL (AMS)	1 778	KLM, AirBridge Cargo, Jade Cargo
20	20	CHICAGO IL, US (ORD)	1 721	United Airlines, American Airlines

Table 3.2: Top 20 Airport Ranking by Cargo in 2017 (Loaded and unloaded freight and mail in metric tonnes). Source: [ACI, 2018]

The largest international airports are all mainly combination carrier hubs, most operating a large fleet of freighters in addition to carrying cargo on their passenger flights.
Paris, Frankfurt, London and Amsterdam are the only four European airports in the top 20 in 2017, and all of them carry passengers in addition of cargo. (ACI, 2018)

Regarding the top freighter airlines during 2017, in the Figure 3.7 it is shown the top 15 cargo Airlines during that year.

FedEx extended its position as the world's busiest freight-parcel carrier in 2017, with 16,8bn FTKs (IATA, 2018).

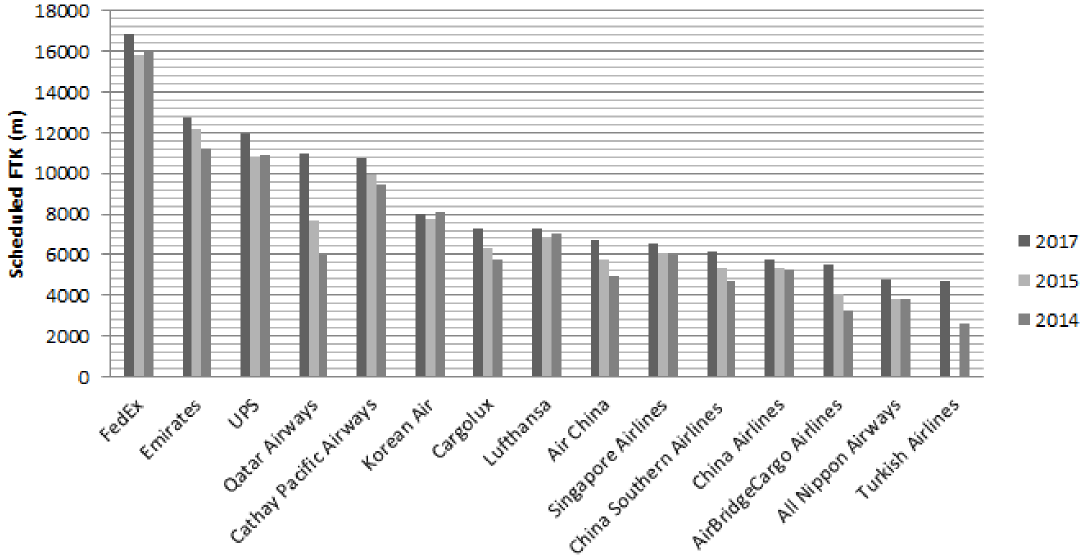

Figure 3.7: Top 15 Cargo Airlines in 2014-2017. Source: [IATA, 2018]

And below it is shown the operating fleet of this top 15 cargo airlines (Figure 3.8). FedEx is the air cargo operator with higher number of freighter aircraft, with a total number of 359 aircraft dedicated only to transport of freight. The rest of the airlines, except UPS and all-cargo carriers, have a higher proportion of combination aircraft. (Budd, Lucy and Andrew, 2014)

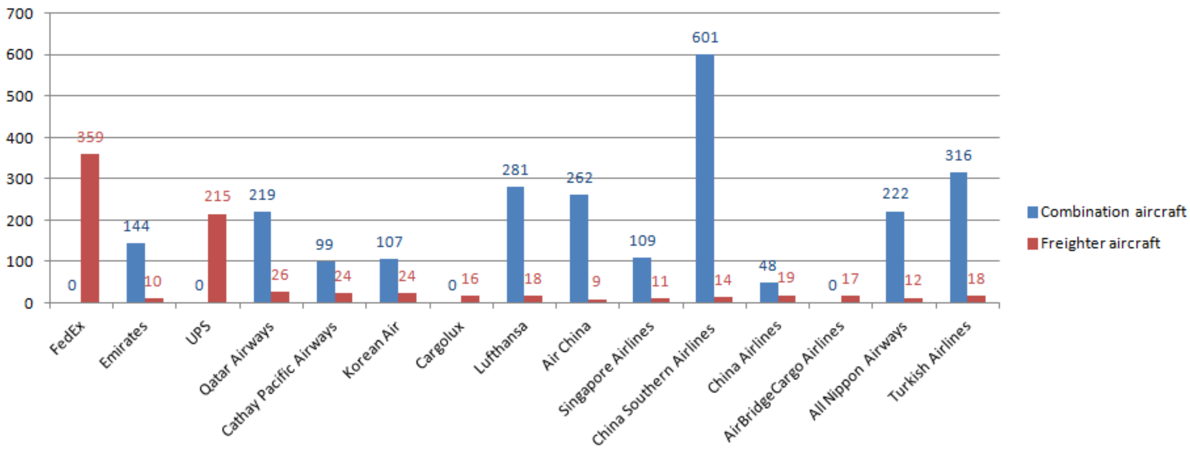

Figure 3.8: Operating fleet of top 15 Air Cargo carriers in 2017. Source: [Budd, Lucy and Andrew, 2014]

3.1.6. Transport Network Designs

When designing the air traffic network, the following factors are considered: (Woxenius, 2007)

- Geography
- Supply of infrastructure
- Transport demand
- Competion with other transport modes

In this section, six principles for the design of transport systems are described, including direct link, corridor, hub-and-spoke, connected hubs, static routes, and dynamic routes.

In Figure 3.9 it is shown the perspective of a transport system operator. A fixed example with ten nodes illustrates the different links used for a transport assignment from the origin (O) to the destination (D).

In the direct link alternative, transport is obviously direct from O to D, and there is no coordination between other O-D pairs, and no other nodes are involved.

The transport corridor is a design based on a hierarchically ordered nodes. In the example of below, O is a satellite node and D is a corridor node.

In the hub-and-spoke network, one node is designated the hub, and all transports call this node for transfer. Here the challenge is to coordinate a large number of interdependent transport services.

The connected hubs design is another hierarchical network in which local flows are collected at hubs that in turn are connected to other hubs in other regions.

With the static routes design, the transport operator designates a number of links to use on a regular basis. Here, several nodes are used as transfer points (hubs) along the route.

The final network design is called the dynamic routes, whic is the most flexibility network design. Links are designated depending on actual demand, and the transport operator can choose many different routes along the network, between O and D. Here, an optimization model is used.

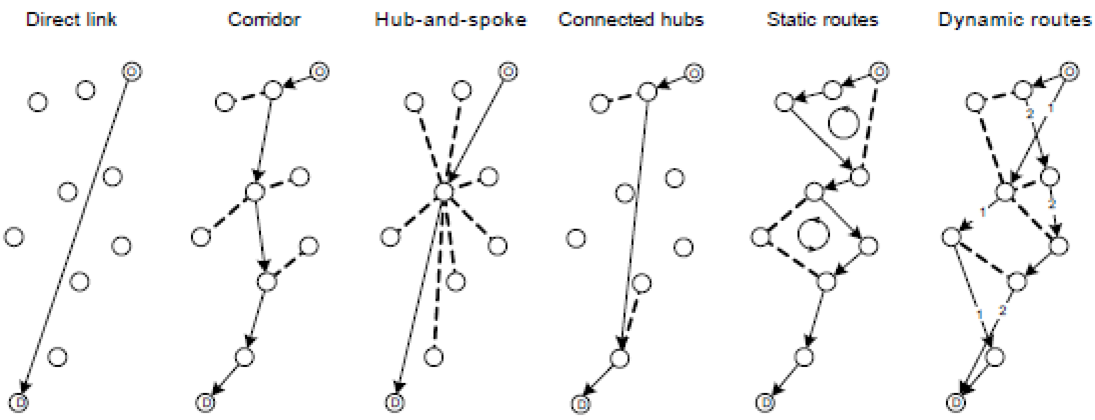

Figure 3.9: Six options for transport from an origin (O) to a destination (D) in a network of ten nodes. Source: [Woxenius, 2007]

3.2. World Air Cargo Traffic Growth Outlook

Two primary factors influence freight growth: economic conditions and rate levels. The outlook for both is positive for cargo. Air cargo has always been a good reflector of world trade and follows its trends. Moderate economic growth is expected to continue into the future and cargo rates should also remain low as several factors serve to keep the lid on prices. (Boeing, 2018)

World air cargo traffic is forecast to grow 4.2 percent per year in the next 20 years. In terms of RTK growth, air freight, including express traffic, is projected to grow at a rate of 4.3 percent per year while airmail will grow at a slower pace averaging 2 percent annual growth through 2037. Overall, world air cargo traffic will be more than double in the next 20 years, expanding from 256 billion RTKs in 2017 to 584 billion RTKs in 2037. (Boeing, 2018)

Asia will continue to lead the world in average annual air cargo growth, with domestic China and intra-East Asia markets expanding 6.3 percent and 5.8 percent per year, respectively. Middle East and Latin America markets connected to Europe will grow at approximately the world average. North America-Europe markets will grow below the world average (see Table 3.3). (Boeing, 2018)

REGION	**HISTORY 2007-2017 (%)**	**FORECAST 2018-2037 (%)**
World	2,6	4,2
East Asia-North America	1,2	4,7
Europe-East Asia	4,2	4,7
Intra-East Asia	3,8	5,8
Europe-North America	0	2,5
Intra-North America	2,3	2,3
Domestic China	5	6,3
Latin America-Europe	3	4

Latin America-North America	-0,3	4,1
Africa-Europe	-1	3,7
South Asia- Europe	2,4	4,2
Middle East-Europe	3,3	3,2
Intra-Europe	3,1	2,3

Table 3.3: Air Cargo Growth Rates in the world. Source: [Boeing, 2018]

3.3. Relation cost-time between Air, Rail and Sea Freight Transport

In this section, it will be analysed the relationship between cost and time for the three transport modes: air, rail and sea.

3.3.1. Cost of sea transport

In general terms, the cost associated to the maritime transport of goods in containers can be calculated analysing the cost items in the quotations made by the import and export companies (Dalla Chiara, 2012). The overall cost is the sum of the different cost items, the most significant of which is freightage, that is the amount established in the transport contract between the shipper and the carrier for the shipment of goods from a harbour to another one.

The main and most frequent additional items are:

- CUC (Chassis Usage Charge) that is the cost for the use of the company’s chassis
- CYC (Container Yard Charges) which corresponds to the expenses to unload the container to the arrival terminal
- OWC (On Wheel Charges) that is the transport of the container by trail or truck
- THC (Terminal Handling Charges): it is the expenses to load the container on board the ship at the harbour of origin
- ISPS (International Ship and Port Facility Security): it is the expenses incurred by the Carrier for security checks on the transported godos at the harbour, for instance the container scanning, inspection, etc.
- BUC (Bunker Contribution): it corresponds to the BAF (Bunker Adjustment Factor), that is the additional cost which is charged by the carriers when the cost of fuel increases.
- B/L (Bill of Lading): it is the document which describes the goods loaded to a ship.

- CAF (Currency Adjustment Factor): it is an additional cost in order to compensate the currency floating.
- SCS (Suez Canal Sur Charge) and PCS (Panama Canal Surcharge): they are the costs applied to the load for transit through these two canals.

The costs associated to the transport of containers (TEU) change according to different geographic areas. The Table 3.4 reports some indicative values of freightage, BAF and CAF for shipments whose origin/destination was an italian harbour.

Area geografica *Geographic area*	Import	Export	BAF	CAF
Estremo Oriente *Far East*	1.761	786	583	118
Cina *China*	1.609	537	565	118
Sud-Est Asiatico *South-East Asia*	1.688	816	571	133

Table 3.4: Freightage per TEU, BAF and CAF values, 2008. Source: [Dalla Chiara, 2012]

Finally, the resulting cost for maritime transport of one TEU, is approximately:

- 2000 to 2300 Euros Westwards
- 1500 to 1700 Euros Eastwards, because of the lower flows

3.3.2. Cost of rail transport

Here it is described the different cost items involved in the rail transport:

- Initial road haulage with related organisational costs
- Operations in the starting terminal
- Haulage through the railway connection
- Operations in the arrival terminal
- Final road haulage with related organisational costs
- Cost for the use of the Intermodal Transport Unit (ITU)
- Cost for the use of the rialway wagon for intermodal transport
- Organization and management costs of the railway operator

For railway traffic, we can assume a transit time of 15 days (according to Deutsche Bahn) on the course between Beijing and Hamburg. (Dalla Chiara, 2012)

3.3.3. Cost-time relation of the different modal alternatives

The indicative prices that have been considered for a freight transport equivalent in volume to one TEU from Beijing to Hamburg is approximately:

- 22000Euros by air
- 11000Euros by sea-air
- 3500Euros by railway
- 1850Euros by sea

Figure 3.10 indicates the time-cost relationship in the different transport modes of freight between Europe (Hamburg) and China (Beijing).

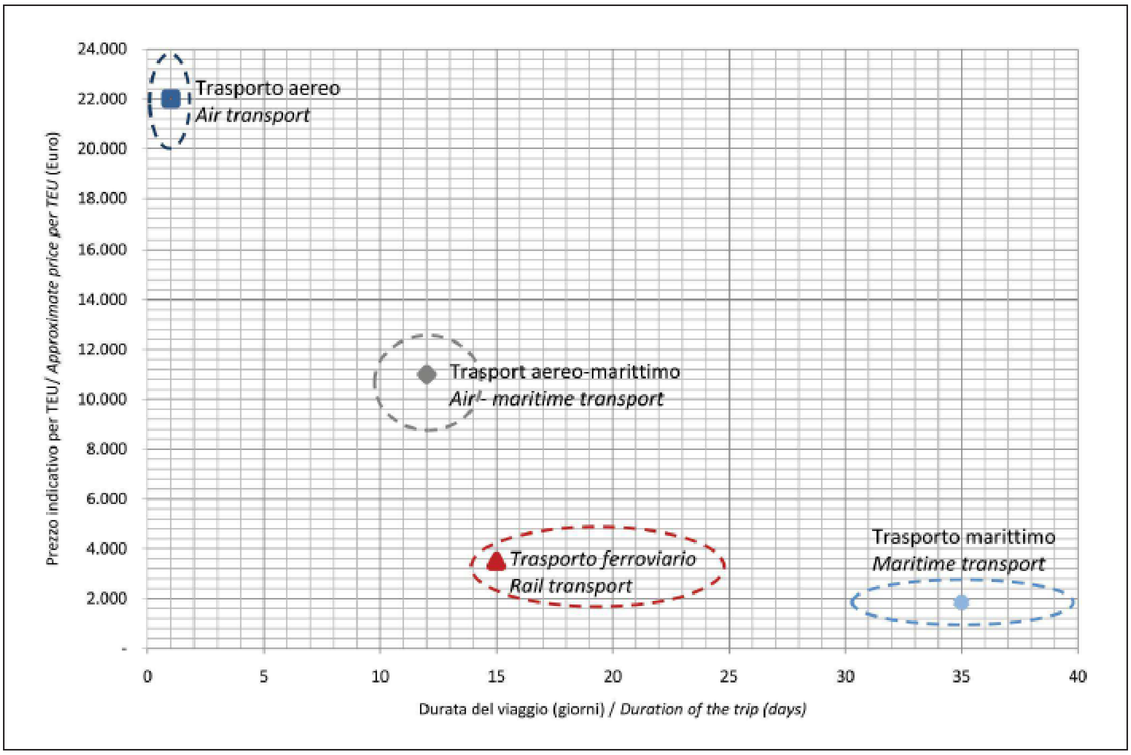

Figure 3.10: Time-cot relationship in the different modal alternatives between Europe and China. Source: [Dalla Chiara, 2012]

As it can be seen in Figure 3.10 sea is the cheapest option and air has a very much higher cost than the other transport modes. Sea/air transport cost are around half of air and rail transport costs even much less than air. In terms of transit time, they showed that air was the fastest transport solution from China to Europe and rail or sea/air were about half of the time than sea.

4. CHAPTER 4 - INFRASTRUCTURE, EQUIPMENT AND TECHNOLOGY

Air cargo infrastructure overall involves airports and their accessibility, in-flight navigation and communication systems, and the aircraft itself. In air transport, the infrastructure, especially regarding airports, is divided into air-side and land-side components. In general, with some exceptions, such as UPS' Lousville hub, the air side of infrastructure is very much the same as that for passenger transport overall. Aircraft fly using the same ground-based or satellite-based navigational systems as passenger airlines, but with somewhat with older aircraft.

4.1. Airports

Nearly all airports handle both cargo and passengers. There are relatively few pure cargo airports. For cargo operations, the airports can be categorized as hub and feeder airports, especially for international operations where the hub-and-spoke system continues to be the dominant operating model for scheduled flights, both passenger and cargo.

Larger aircraft are used on long-haul international routes, while smaller aircraft serve domestic origins and destinations. This system allows shipments between origin/destination pairs that could not support direct, point-to-point, service.

The hub airport is generally located in or near a major population center to have a significant amount of inbound and outbound baseload cargo. It provides a transshipment node not only for interlining between domestic and international carriers but also for connections between an airline's domestic and international services.

A larger hub airport may also act as regional gateway, for example:

- Hong Kong, which provides European and North American carriers with air and land access to China, as well as air access to other Asian destinations.

- Dubai, which provides connections between European and Asian services, also acts as a regional distribution center for Africa and the Middle East.

- Miami, Florida and Tocumen airport in Panama, which serve Latin American carriers connecting with North American and European carriers.

The hub and spoke system can also be intermodal providing a connection for sea-air services or for sea-road services. The latter involve RFS (Road Freight

Services) connections in which an international air movement is combined with a domestic road movement between the hub and feeder airport.

Airlines select an airport for major cargo operations based on the potential traffic. Little consideration is given to the physical characteristics of the airport other than the length of the runway and approach control. The landside facilities are less important because they can be adapted to meet the traffic. (Saghir, 2009)

The time required for cargo operations in an airport depends on four factors (Saghir, 2009):

- Customs clearance procedures
- Cargo inspection procedures
- The efficiency of cargo handlers
- Layout of storage facilities

Airports mostly consist of several parts and include: movement surfaces (runways, taxiways, and aprons), terminal buildings (passenger terminals and in many cases freight facilities), navigational aids and approaches to the airport that allows flying into the airport in less than optimal visibility and other weather conditions, air traffic control facilities, fuel facilities, security installations, and some form of road access.

Fuel facilities, air traffic control facilities, runways, and taxiways are generally shared with all traffic at the airport (passenger + cargo). The most minimal installation, however, for dedicated cargo flights is a dedicated cargo apron, allowing for the efficient loading and unloading of aircraft, with dedicated customs facilities close by for international cargo.

4.1.1. Airport Roles

In order to gain a better understanding of what drives air cargo operations to one particular airport versus another, it is important to differentiate the roles and uses of air cargo facilities, the operations they conduct and the markets they serve. The function of an air cargo facility can be divided into the following six distinct roles: (Maynard and Clawson, 2015)

- International gateways
- National cargo hubs
- Regional hubs
- O&D/local market stations
- Cargo airports
- Intercontinental hubs
- Alternate gateways

4.1.1.1. International gateways

The gateway works as a consolidation, distribution and processing point for international air cargo. As with the air cargo hub, much of the cargo moving through a gateway airport does not originate and is not destined for the gateway aiport's surrounding market area. (Maynard and Clawson, 2015)

Airpots in the United States that are considered international gateway airports include those serving Miami, New York (JFK), Los Angeles and Chicago.

4.1.1.2. National Cargo hubs

The hub is the backbone of an integrated express carrier since it provides connections to each market in the integrator's system. Each day of operation, flights from around the world arrive at the hub. Once at the hub, packages are unloaded, sorted for the appropiated destination market, and loaded onto the appropiated outbound aircraft.

The market area of an airport's cargo hub is typically located within a 3-hour driving radius of the airport. Typically, there are no cargo flights from the hub to airports within the radius since trucking is less expensive.

4.1.1.3. Regional hubs

Regional hubs serve the region in which they are located by performing the cargo sorting and distribution functions of that specific carrier's primary hub.

4.1.1.4. O&D/Local Market Stations

The criteria for a local market station, or direct air cargo service (O&D service to an airport's surrounding market area), generally coincide with population centers where there is a concentration of industry, commerce and transportation infrastructure. Often referred to as a "node" within a cargo carrier's network, the local market station is the simplest and most common type of air cargo facility.

These airports represent the spoke in a hub-and-spoke air carrier network. For airport-to-airport service providers, the local market station represents the origin or destination point for the cargo they are transporting.

4.1.1.5. Cargo Airports

Cargo airports are dedicated to the movement of air cargo and offer the advantage of uncongested airspace relative to airports with passenger airline service. Just as the lack of passenger service is an advantage to cargo carriers operating at these airports, it is also a disadvantage for forwarders and other customers since belly space for cargo parcels in unavailable. As a result, few examples of strictly cargo airports exist. Prior to closure in 2009, Airborne Airpark, located in Wilmington, Ohio, was the only true cargo airport as it was owned and operated by DHL.

4.1.1.6. Intercontinental hubs

An intercontinental hub connects two or three continents by air cargo and passenger aircraft and can be located in a relatively part of the world, away from dense populations.

These airports offer cargo hub capability as well as aircraft service centers for aircraft needing to refuel and change crews.

In Figure 4.1 it is shown a map of Europe with the air freight traffic of the major EU airports. As it can be seen, Frankfurt, Amsterdam, London Heathrow and Paris (CDG) are the leading hubs for freight transport in Europe. (IATA, 2017)

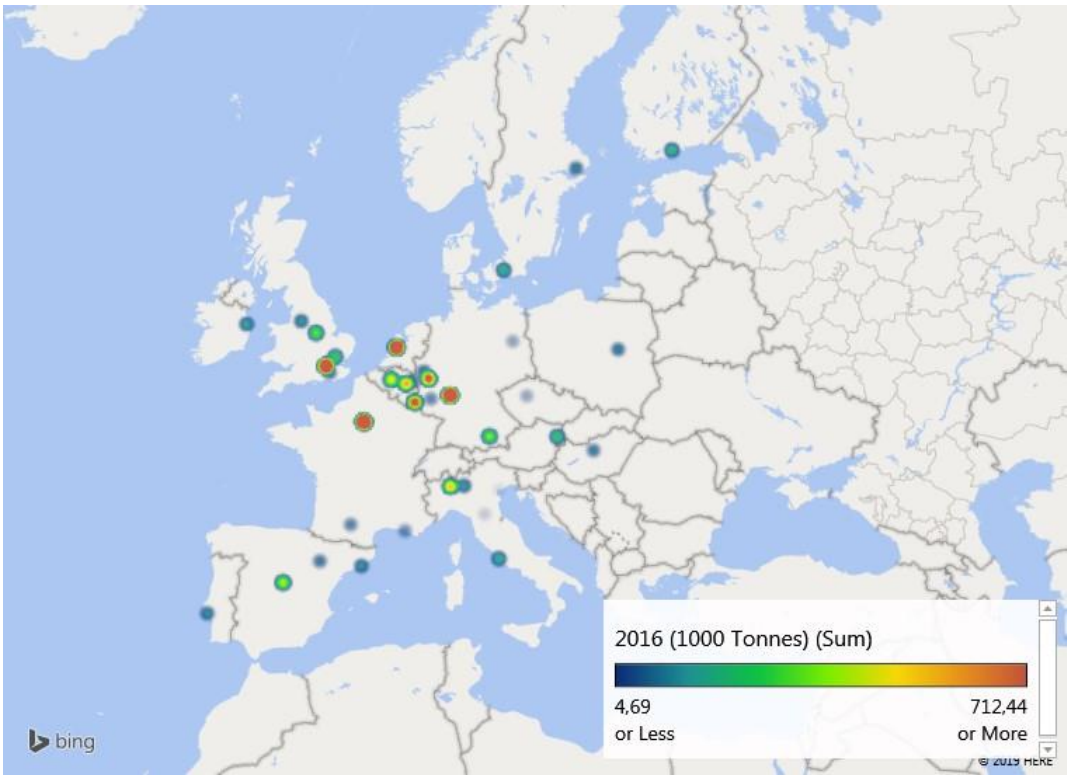

Figure 4.1: Air Freight Traffic at major EU airports, 2016. Source: [IATA, 2017]

4.1.1.7. Alternate Gateways

These airports either marketed themselves heavily to the air cargo industry during the industry's formative years (during the late 1980s and early 1990s), or they have locations in proximity to major distribution or production centers of time-sensitive commodities.

4.1.2. Cargo handling operations

Cargo handling operations at airports involve the preparation of cargo shipments, the loading and unloading of the aircraft and the transfer of cargo between the storage facilities and land transport.

For outbound cargo, the preparation includes building up of the air cargo pallets and containers, inspection and documentation. For inbound cargo, the preparation includes customs and other regulatory procedures.

Although air cargo ideally remains in the airport for a relatively short time, it is necessary to provide storage facilities. Bonded facilities are required for imports and international transshipment cargo. For perishable cargoes, it is necessary to provide cold rooms. For outbound cargo, it is necessary to provide X-ray scanners to inspect the cargo. The storage areas must be equipped with loading docks on the landside to allow for rapid movement of goods to and from trucks.

The airport determines who can provide ground handling, both ramp and warehouse services. National carriers are often given exclusive rights to provide these services, especially in smaller airports. Other carriers or cargo handlers are usually reluctant to become involved unless they have substantial traffic to justify the investment and/or are allowed to offer the service to other carriers who would provide sufficient volume.

The international third-party cargo handlers that exist nowadays are: Avia Partner, Cargo Center, Menzies Aviation, Rhesus Air Hadnling, Swissport and Worldwide Services.

4.2. Navigation Systems and Air Traffic Control

In general, navigational aids today consist of radio transmitters sending homing signals to aircrafts, identifying for the aircraft from exactly what direction it is approaching the sending station or airport, helping determine the proper angle for landing on the correct spot of the runway if approaching an airport. These instrument landing systems (ILSs) are the same used for passenger aircraft, and elements of these systems are slowly being supplanted by newer, satellite-based technologies.

Newer all-cargo aircraft will generally have the latest navigation and communications equipment on board, but older aircraft, as are often found in the air cargo industry, may still depend entirely on the older ground-based technologies.

In the U.S. UPS has been one of the pioneers in installing an aircraft monitoring system called ADS-B, using satellite technology. This system allows close tracking of aircraft, even on the ground, without radar technology, using data from the Global Positioning System, GPS, or any other navigation system e.g, GLONASS, INS (see Figure 4.2). The maximum range of the system is line-of-sight, this means typically 200 nautical miles (370 km), because of the Earth curvature. This new navigation system will improve not only safety, but the ability for more fuel-efficient operations.

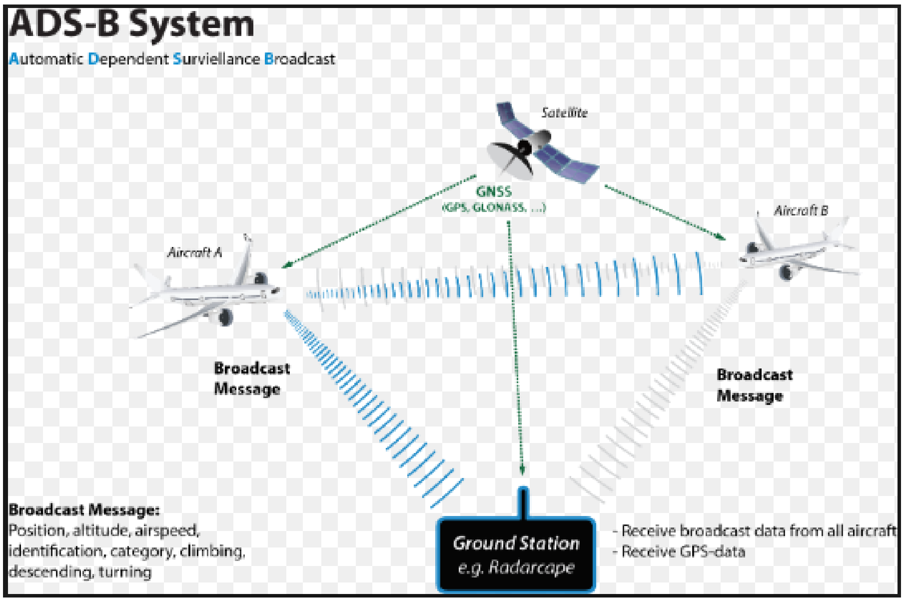

Figure 4.2: Outline of an ADS-B navigation system

4.3. Feighter Aircraft

The cost structure of operating cargo airliners is somewhat different than that of passenger jets. For example, as the Boeing 767 ages, it may become economically more costly to operate because of increased maintenance schedule needed for passenger service, and the much higher number of landing and take-off cycles over time than in cargo operations. At the same time, newer, more fuel-efficient aircraft enter the passenger market.

The older aircraft, then, become much more economical to operate as cargo aircraft. This is why one we can still find very old aircraft, such as the Boeing 727 and the DC10 (modified and upgraded to the designations MD-10 in some cases) fully operational in fleets such as FedEx Express. Charter operators can be found with fleets that go even further back in time, such as the four-engine DC-8. Though these aircraft may be much less fuel efficient, these aircraft are much less costly to acquire, and the overall flying time is much reduced, lowering the overall cost.

Aircraft can be grouped according to capacity as follows (Bofinger, 2009):

- **Below 30 tons**: small narrow-body aircraft used primarily by integrated carriers and national airlines operating in regional markets. This includes Boeing 727s, 737s, and DC-9s.
- **30-60 tons**: standard-bodied aircraft used primarily by integrated carriers and combination carriers in regional markets. This includes Boeing 757s and 767s, DC-8s and Airbus A300s used by combination carriers.
- **40-80 tons**: medium wide-body aircraft including DC-10s and MD-11s used by integrated and all-cargo airlines.
- **Above 80 tons**: Large wide-body aircraft including Boeing 747s and the forthcoming Airbus A380 freighter used by integrated and all-cargo airlines.

The specifed aircraft for air freight transport is shown below (Table 4.1).

Payload	Size	Typical Aircraft	Notes
Over 80 tonnes	Large wide-bodied	B747, B777, MD-11, A380, A350	
Between 40 and 80 tonnes	Medium wide-bodied (long-rage distances)	DC-10-30/40, MD 10 (modified DC 10), A330, A340 series, B747 combi, B767	
Between 30 and 60 tonnes	Standard-bodied (regional freighters)	B757, B767, older DC8, older B707, A300 series, A310 series, A321 series, A330 series	The DC 8 in general is too noisy to be flown in Europe without modifications to the engines (adding so-called “hush kits”), which unfortunately increase the fuel burn considerably. Often these aircraft are found in Africa, but their operators are limited by either noise or fuel consumption as to where they may practically operate.
Between 10 and 30 tonnes	Narrow-bodied (smaller distances)	Older B727, B737, DC9, Bae 146m TU204, A320P2F	Largest portion of the global freighter fleet
Less than 10 tonnes	Commuter-sized or General Aviation	ATR 42 & 72, Cessna Caravan, Beech 1900	
CIS Aircraft	Various, generally turboprop	Antonov AN225 (largest freighter in the world), AN25, AN32, AN12, AN124, Illushin II76-TD	Mostly former military design, includes some very large and unique aircraft used for special purposes
Older types of aircraft not found	Generally smaller in size	DC3 and DC6	

Table 4.1: Types of dedicated Cargo Aircraft in the Global Cargo Fleet. Source: [Heinrich, 2009]

The proportion of air freighters in each of these categories is shown in Figure 4.3

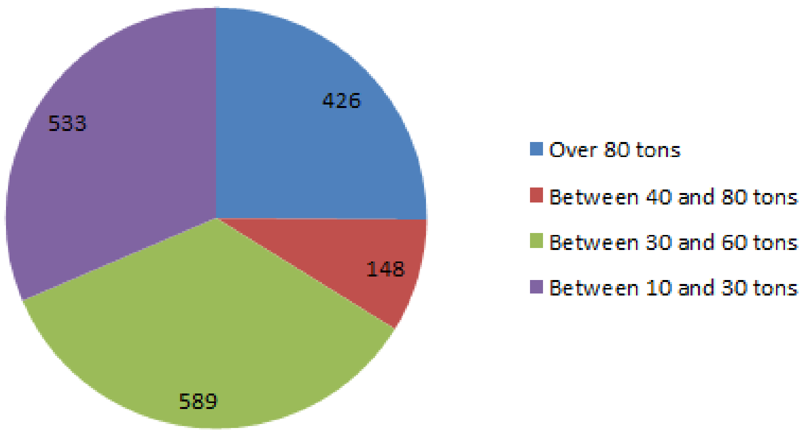

Figure 4.3: Distribution of freighter aircraft by capacity in 2009. Source: [Bofinger, 2009]

4.4. Unit Load Devices for Aircraft

Unit Load Devices (ULDs) can be either pallets or containers. A pallet is a wooden or metal base of varying size to which cargo is secured. An aircraft container is an enclosed unit with solid base, walls, door and roof that can fit various aircraft types and be handled by its equipment. (Morrell, 2016)

Before the introduction of wide-bodied aircraft, pallets were used for main deck freighters. With the advent of widebodied aircraft a large space needed to be filled in the lower decks of passenger flights and a quicker method of loading and unloading needed to be introduced. This led to the development of containers that were contoured to fit the shape of these holds. Containers were then also used on the main deck, and even on some narrow-bodied aircraft such as the A320.

There are two main systems of numbering or letters to identify the type of ULD. The IATA system of three letter codes was introduced in 1984, replacing the older system of LD followed by a number for lower deck ULDs and M followed by a number for main deck units. The IATA system replaced the widely used lower deck container LD3 with AKE.
The first letter denotes a certified structural container (i.e. can interface directly with an aircraft's loading and restraint system), the second the dimensions and the third its shape. An additional refinement is the use of the letter 'N' as the third letter to signify the presence of forklift slots in the base. This adds some weight and reduces volume but is more convenient for handling.

Special containers have also been developed for transporting horses and other livestock, and for items such as garments which can be hung on rails. Temperature controlled units are also available.

The major manufacturers of ULDs are SATCD, Driessen, Nordisk, Fylin, Amsafe and VRR.

Some of the integrators have developed their own containers to suit their aircraft and meet the tight transfer times at their hub airports. One example of an airline's ULDs is British Airways which uses LD3s for the lower decks of its B747, B777, B767 aircraft and main deck of B757 freighter aircraft, LD9s for the lower decks of its B747s, B777s and B767s, and LDlls either as pallets or containers for the lower decks of its B747s and B777s. Because the B767 has a slightly narrower cross-section, loading it with LD3s wastes some space. Hence one of the design requirements of the B767's replacement, the B787, was for it to use the LD3, LD6 and LDll family of ULDs to utilise fully the lower deck space.

4.4.1. ULD types

Below the different types of ULD for air freight.

ULD Type	External Volume	Internal Volume	Aircraft
LD-1	5,2m3	4,7m3	B747
LD-2	3,7m3	3,4m3	B767
LD-3	4,8m3	4,3m3	A300, A310, A330, A340, A380, B747, B767, B777, B787, DC-10, IL86/96, L1011, MD-11
LD-6	9,6m3	8,9m3	A300, A310, A330, A340, A380, B747, B767, B777, B787, DC-10, IL86/96, L1011, MD-11
LD-8	7,9m3	7,2m3	B767
LD-9	11,5m3	9,8m3	All wide-body aircraft except IL86/96
LD-11	7,7m3	7,2m3	A300, A310, A330, A340, A380, B747, B767, B777, B787, DC-10, IL86/96, L1011, MD-11
LD-26	14,2m3	12,7m3	All wide-body aircraft except B767, IL86/96
LD-29	15,6m3	13,9m3	B747
LD-39	16,9m3	15,8m3	B747
M-1	18,5m3	17,5m3	A330F, B747F, B767F, B777F, IL76, L100, MD11F
M-1H	23m3	21m3	B747F, B777F, IL76, L100

Table 4.2: ULD types. Source: [ULD, 2019]

4.4.2. Air Cargo Aircraft Capacities

In the following Table 4.3 it is shown the different capacities of the different air cargo aircrafts.

Aircraft	**Equip Avail**	**Vol for freight**	**Max weight**
Boeing 737-300		21.0m3	2,250 kg
Boeing 737-400		24.0m3	2,897 kg
Boeing 737-200	6LD7	70.0m3	19,500 kg
Boeing 767-300	4LD8/3LD7	63.0m3	16,500 kg
Boeing 777-200	4LD7/4LD3	61.0m3	21,000 kg
McDonnell Douglas MD-11 CF	26M1/6LD7/7LD3	543.1m3	82,000 kg
Airbus A330-300	6LD7 + 4LD3	86.0m3	13,500 kg
Airbus A330-300 (H)	6LD7 + 4LD3	86.0m3	21,000 kg
Boeing 747F (Freighter)	29M1/9LD7/2LD3	601.4m3	95,000 kg
Ilyushin IL-76		220 m3	101,000 lb
Antonov An-12		97 m3	44,092 lb.

Table 4.3: Air cargo Aircraft Capacities. Source: [Maynard and Clawson, 2015]

4.4.3. Payload-Range Capabilities

The role of aircraft performance analysis is to examine the capabilities and limitations of an aircraft in context to an operator's requirements. A carrier, for example, might be looking at aircraft optimized for particular routes in their network, or it might be more interested in the flexibility to operate an aircraft profitably across multiple routes. One of the most widely means used by airlines to compare the operating economics of an aircraft is by evaluating its payload-range performance, which can be illustrated graphically through the payload-range diagram (Figure 4.4, Figure 4.5 and Figure 4.6).

Payload-range analysis involves examining Maximum Take-off Weights (MTOW) and its various components to assess the aircraft's payload capability at different ranges, as well as range capability with different payloads. This multi-range versions of an aircraft type can help the airline better achieve both operational flexibility and cost advantages to particular parts of its network. Ideally, there should be a match between the stage lengths in the airline network and optimum payload-range of the aircraft employed.

B747-400F

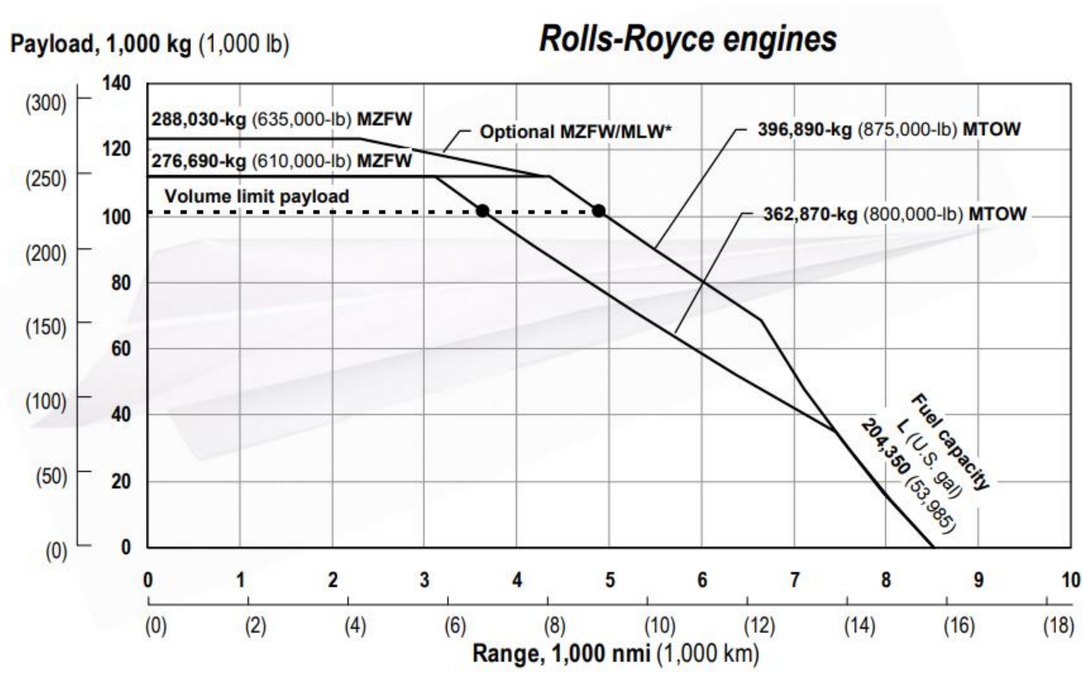

Figure 4.4: B747-400F Payload-Range Capability with Rolls-Royce engine. Source: [Boeing, 2010]

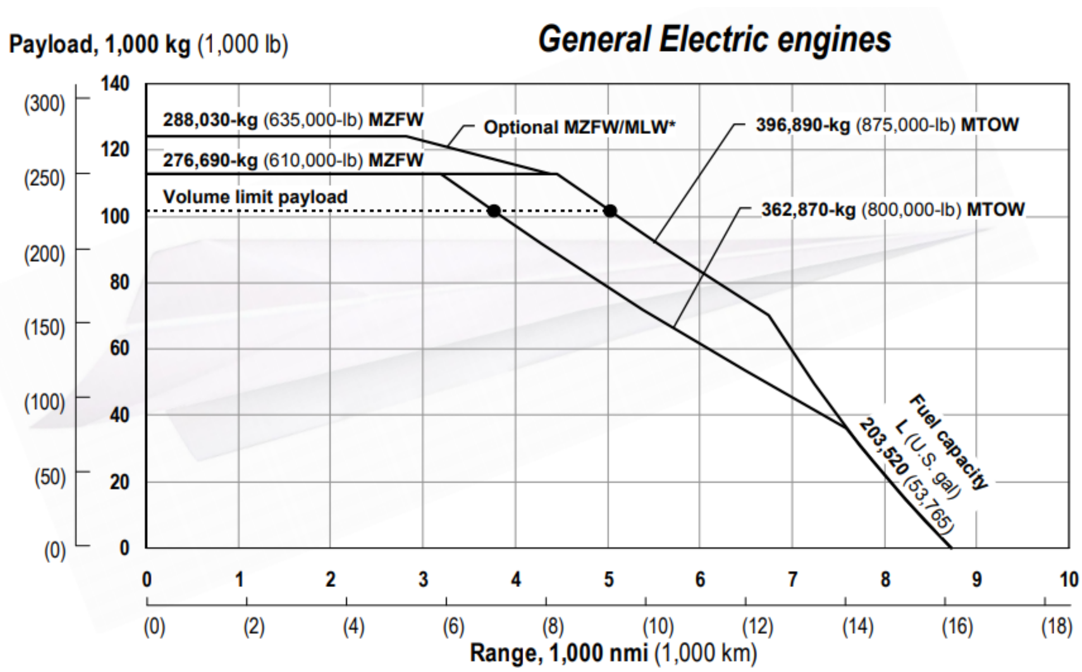

Figure 4.5: B747-400F Payload-Range Capability with General Electric engine. Source: [Boeing, 2010]

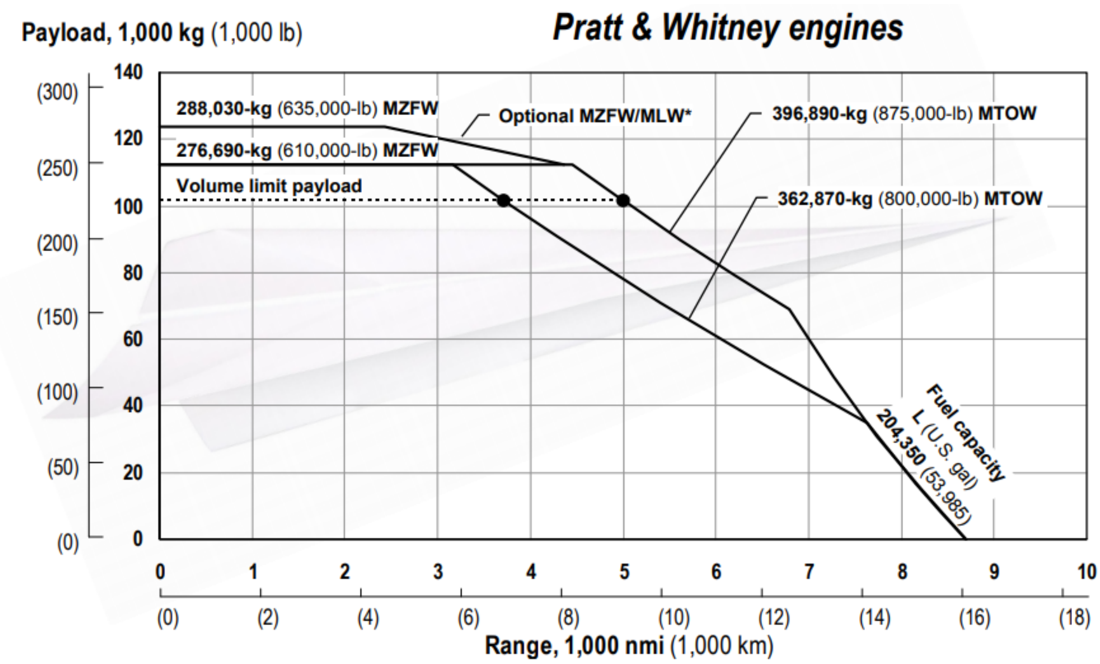

Figure 4.6: B747-400F Payload-Range Capability with Pratt & Whitney engine. Source: [Boeing, 2010]

In the first stage of the diagram the aircraft is at maximum payload with no fuel on-board. When the aircraft is carrying maximum payload, its capacity is limited by its MZFW (Maximum Zero Fuel Weight). If the manufacturer can increase this design weight then more payload can be carried. Alternatively, given the MZFW is a fixed value, whereas the OEW varies according with the airline's operating items, if the airline can lower the OEW then the aircraft is capable of carrying more payload.

In the second phase, payload is limited by MTOW. Payload is traded for fuel to reach greater range. The higher the MTOW, the more fuel or payload can be carried. The more fuel carried, the greater the range. This tends to be the region of greatest interest in terms of performance.

Finally, in the last phase of the diagram, paylod is limited by fuel. Only payload can be offloaded to make the aircraft lighter, thereby improving its range capability. This region is not good to operate because it requires large reductions in payload to achieve small increases in range. When the aircraft has not payload weight, it is theoretically at the Operator's Empty Weight (OEW), and range flown at this point is considered the maximum ferry-range.

The region inside of the boundary represents feasible combinations of payload and range missions and all these weight limits depend of course on the aircraft's engine.

5. CHAPTER 5 - AIR REGULATIONS

International air transport, unlike shipping, is governed by a bilateral agreement which restrict traffic rights to specified carriers.

By the time of the Second World War, international flights had grown to the point where a legal framework for their operation was thought essential. Safety and security reasons were considered to present sufficient risk to give rise to the need for international regulation, two factors that are not as important in ocean shipping. This emerged from the Chicago Conference of 1944 and its effect on air cargo flights is discussed in this chapter.

In order to operate cargo or passenger/cargo flights it is necessary an operator’s licence as well as the necessary traffic rights to pick up and set down cargo, which they will be described in the following sections of this chapter.

5.1. Licensing of Airlines

5.1.1. Tecnhical Regulation

The Chicago Conference resulted in the Chicago Convention of December 1944, agreed by 52 countries. This had 15 annexes that set standards and recommend practices (SARPs) for civil aviation covering both technical and commercial or economic aspects (Morrell, 2016).

The requirement for an air operator to hold an Operating Licence granted by the state in which it is based extends to virtually all carriage by air anywhere in the world of either passengers or cargo for remuneration, irrespective of whether the sale is made to the general public or to a charterer. Flights within the European Economic Area (EEA) are authorised by the European Council Market Access Regulation, which allows Operating Licence holders to operate on most routes in the EEA without needing a further license or permit from any state.

The granting of an Operating License depends on satisfying the authority that the airline: (Morrell, 2016)

- ✓ Has its principal place of business and company's registered office in this country
- ✓ Must be majority owned and effectively controlled by nationals of its country
- ✓ Has sufficient financial resources
- ✓ Has the necessary insurances to cover accidents involving passengers, cargo and third parties
- ✓ Has an Air Operator's Certificate

A US based air cargo operator would be regulated by the following:

- The US Department of Transportation (DOT), that deals with the economic aspects of air transport.
- The Federal Aviation Administration (FAA), which its main responsibility is air safety, including aircraft operating procedures, movement of hazardous materials, and it also records keeping standards and aircraft maintenance and the licensing of technical staff and ground facilities.
- Transportation Security Administration (TSA). It regulates various security aspects of air cargo transport. Its regulations cover staff, facilities and procedures.

5.1.2. Financial Fitness

The granting of air operator's licences, whether for passenger or cargo airlines, involves the assessment of the technical and financial fitness of the airline applying for the licence. The technical fitness is assessed to ensure that the airline operates safely in conformity with international standards. This would include the airworthiness of the aircraft that the airline intends to operate, the licensing of its personnel, provisions for maintenance, etc.

Financial fitness is required to make sure that the airline has sufficient captital at the outset to continue trading at least for the first year and in some cases for two years.

5.2. Regulation of International Air Services

In this section of the chapter 5 it is introduced the air transport liberalisation. This new concept was introduced by the US through their renegotiation of many of its key bilateral Air Services Agreements between (ASAs) 1977 and 1985.

ASAs are based on the principle of reciprocity, that is, an equal and fair exchange of rights between countries with different market size, different geographical location and different economic interests, and with airlines of different strength. They fix a set of rules to identify the airlines of the contracting parties with the rights to fly on each route, determine the capacity that can be provided by each of those designated airlines, and limit the capacity that can be offered by airlines from third countries (Zhang, Anming and Yimin, 2002). These were initially with European countries but their 'open skies' formula was subsequently applied both in Latin America and Asia.

5.2.1. Air Services Agreements

Air Services Agreements (ASAs) have generally been negotiated on a bilateral basis between two countries and are thus often called 'bilaterals'. These agreements usually cover the carriage of both passengers and cargo by air, including both passenger and freighter flights. Although a significant amount of air cargo is carried on passenger flights some countries have signed separate ASAs for all-cargo flights only.

All flights within the EU were gradually liberalized from the late 1980s. It had been hoped that the EU style liberalisation, described as an open aviation area, might be extended to include the US and perhaps Canada. However, little progress has so far been made, with major sticking points being the ownership and control clauses and a number of points including environmental issues.

In addition to the above, Australia and New Zealand have signed an open aviation area between their countries and more recent encouraging signs have come from two of the world's largest markets: India and China. India has recently signed a number of significantly liberalised agreements, and China is moving in a similar direction, although slowly.

Some of the statements that ASA includes is, that the airlines designated by each country should have a fair and equal opportunity to compete. Another statement covers the traffic rights permitted by route and in some cases frequency restrictions applied to the airlines of each country.

There are articles on designation of airlines and also safety and security. Customs duties and charges are also covered, and it is here that the uplift of fuel for international flights is given tax-free status. Pricing, airport fees and government subsidies are also addressed, as are the mechanisms for dealing with disputes and notice of termination of the agreement.

5.2.1.1. Air Traffic Rights

Air traffic rights for the carriage of freight and mail can be exercised both on passenger and freighter flights. Those related to passenger flights, which also carry cargo, depend on the carriage of passengers and the negotiations are mainly concerned with factors that are governed by passenger markets.

The number of third and fourth freedom routes has also been opened up, with the addition of some fifth freedoms (see Figure 5.1). Some airlines have been able to expand their hub airport in their country of registration by combining two sets of third/fourth freedoms to carry sixth freedom traffic. Examples of this were Singapore Airlines and more recently Emirates Airlines. Flying wide-body passenger aircraft they have also been able to carry significant amounts of cargo on these routes, mainly from Australasia to Europe.

Freedom	Air cargo examples
FIRST FREEDOM To overfly one country en-route to another	Lufthansa Cargo: Germany over Russia to China
SECOND FREEDOM To make a technical stop in another country	Lufthansa Cargo: Germany over Russia to China
THIRD FREEDOM To carry air traffic from the home country to another country	Lufthansa Cargo: air cargo from Germany to China
FOURTH FREEDOM To carry air traffic to the home country from another country	Lufthansa Cargo: air cargo from China to Germany
FIFTH FREEDOM To carry air traffic between two countries by an airline of a third country on route with origin / destination in its home country	Lufthansa Cargo: air cargo from Australia to China en route for Germany
SIXTH FREEDOM* To carry air traffic between two countries by an airline of a third country on two routes connecting in its home country	Cargolux: air cargo from North America to/from points in Africa via their Luxembourg base/hub
SEVENTH FREEDOM To carry air traffic between two countries by an airline of a third country on a route outside its home country	DHL's regional hub at Bahrain. Flights operated using B727, A300 and other smaller freighters based there to/from points in the region
EIGHTH FREEDOM OR CONSECUTIVE CABOTAGE To carry air traffic within a country by an airline of another country on a route with origin / destination in its home country	Cathay Pacific Cargo: air cargo from Atlanta to Dallas/Fort Worth (within USA) with flight continuing to Hong Kong
NINTH FREEDOM OR 'STAND-ALONE' CABOTAGE To carry air traffic entirely within an airline's home country	Tiger Airways Australia's traffic within Australia (no freighter airline examples)

Figure 5.1: Freedoms of the Air (Air Traffic Rights). Source: [Morrell, 2016]

Note: * The term 'sixth freedom' was coined to describe the combination of two sets of third and fourth rights, reflecting the reality of hub and spoke networks (it is not usually recognised in air services agreements).

Air cargo traffic rights are generally also granted under the same Air Services Agreement as passengers, and thus have benefited from the gradual opening up of rights that was evident for passengers. In a few cases (e.g. US/Japan) separate agreements were signed for all-cargo or freighter routes. These are often more liberal than their passenger counterparts, since they provide less of a threat to national or flag carriers that depend on passengers.

5.3. Future Air Cargo Liberalization

ICAO reported in their 2008 annual report to Council that 17 new 'open skies' agreements were concluded by 21 states, bringing the total to 153 agreements involving 96 states. These bilateral agreements provide for full-market access without restrictions on designations, route rights, capacity, frequencies, code-sharing and tariffs. (Morrell, 2016)

At the regional level, at least 13 liberalised agreements or arrangements were in operation, with another country joining MALIAT, and an agreement between nine countries in the Caribbean. The Association of SouthEast Asian Nations (ASEAN) also concluded the ASEAN Multilateral Agreement on Air Services and the ASEAN Multilateral Agreement on the Full Liberalization of Air Freight Services.

Airlines could typically react to liberalization through the following strategic responses: (IATA, 2019)

- <u>Expansion into new markets</u>. Liberalization can lead to greater competition in a firm’s main market, but can provide significant opportunities for firms to expand into new geographical markets too. However, if liberalization is not introduced at a similar step (e.g. EU energy markets) it may not provide a level playing field for firms to compete.
- <u>Diversification into new products</u>. In response to increased competition, some firms could look to offer a wider range of product choice (e.g. Indian media sector), helping to attract a wider customer base.
- <u>Specialization in niche products.</u> Liberalization can lead firms to concentrate on where their competitive strength lies, ensuring that a core customer base is retained and revenues are maximised among these clients (e.g. US banking).
- <u>Market exit.</u> Incumbents may be forced to exit some markets in response to competition, but new entrants could have also found that they are unable to gain a foothold in some markets when faced with efficient incumbent firms or a culturallydifferent customer base and are forced to exit (e.g. German TV sector).

5.3.1. Some issues related to Air Cargo Liberalization

Integrators, airlines and a number of general cargo handlers identified timeconsuming customs clearance procedures as a key constraint on development of freer and more efficient international trade.

Another aspect that is being an issue for air cargo liberalization is the inter-modal transportation system. Nearly all air cargo movements are inter-modal, since freight must move to and from airports via surface mode (usually truck). Infrastructure is needed to ease efficient freight movement through inter-modal terminals. This is especially so in the case of airports, since speed is the primary advantage of air cargo transportation. It is thus important to enhance cargo movement, facilitation, storage, and clearance facilities at all international airports to bring them with in line with international trade facilitation expectations, thereby encouraging trade growth by offering efficient cargo handling and processing facilities.

6. CHAPTER 6 - MOST IMPORTANT AIR FREIGHT CARRIERS STRUCTURE

6.1. FedEx

6.1.1. History

Fred Smith founded FedEx corp. As Federal Express in 1971, located in Little Rock, Arkansas.

The company is split into three main divisions: FedEx Express, FedEx Ground and FedEx Freight: (Morrell, 2016)

FedEx Express offers a wide range of shipping services for delivery of packages and freight. Overnight package services are backed by moneyback guarantees and extend to virtually the entire US population. FedEx Express offers three US overnight delivery services: FedEx First Overnight, FedEx Priority Overnight and FedEx Standard Overnight. FedEx Same Day service is available for urgent shipments up to 70 pounds (32 kg) to virtually any US destination. FedEx Express also offers express freight services backed by money-back guarantees to handle the needs of the time-definite global freight market. International express delivery with a money-back guarantee is available to more than 220 countries and territories, with a variety of time-definite services to meet distinct customer needs. FedEx Express also offers a comprehensive international freight service, backed by a money-back guarantee, real-time tracking and advanced customs clearance.

FedEx Ground operates a multiple hub-and-spoke sorting and distribution system consisting of 520 facilities, including 32 hubs, in the US and

Canada. FedEx Ground conducts its operations primarily with approximately 22,500 owner-operated vehicles and 31,500 companyowned trailers. It serves business and residential (home delivery) customers with guaranteed overnight services for packages of up to 150 pounds (68 kg) over sectors up to 400 miles or around 650 kilometres.

FedEx Freight Corporation provides a full range of L TL freight services through its FedEx Freight (regional LTL freight services), FedEx National LTL (long-haul LTL freight services) and FedEx Freight Canada businesses. These shipments move largely by truck within North America. The average weight of each LTL shipment in 2009 was 1,126 pounds or 51 kg, with a yield of $0.38 per kg. (Morrell, 2016)

Here it is shown the key FedEx highlights: (FedEx, 2019)

1971: Federal Express founded by Fred Smith
1973: Moved to Mempis International Airport
1978: Public listing of its shares on New York Stock Exchange
1981: Official opening of “superhub” at Memphis International Airport
1986: Hub opened at Newark International Airport
1988: Hubs opened at Oakland and Indianapolis
1989: Acquired Flying Tiger and opened Anchorage hub
1995: Opened an Asia and Pacific hub in Subic Bay International Airport
1997: Opened hub at Fort Worth Alliance Airport
1999: European hub started at Paris Charles de Gaulle Airport
2006: Acquired Flying-Cargo Hungary to support Eastern European expansion
2008: Started building new Central and Eastern European hub at Cologne Bonn Airport
2009: Closed Asia/Pacific hub at Subic Bay Philippines
2009: Opened new Asian hub at Guangzhou Baiyun International Airport in China; also announced start of Indian operations

It can be seen that the the first, and major, US hub at Memphis was followed by other US hubs and later European and Asian hubs.

FedEx reolcated to its current hub, Memphis, Tennessee, in 1973, beginning operations in April. Mainly it was chosen the most important hub for its central position in the US and the fact that there were few passenger flights, the weather was reasonably good and there was plenty of space for expansion (Morrell, 2016).

The European hub in Paris was partly chosen because their preferred UK option was restricted under the Air Services Agreement at that time. Paris is also more central for truck feed and lies next to a major auto route (highway) system connecting it to France and neighbouring countries. However, it has a smaller presence in Europe than in Asia (the reverse being the case for UPS).

Its Asian hub was moved in 2009 from Subic Bay in the Philippines to south China. This is now much closer to one of the major manufacturing bases in fast growing China, and it is also close to Hong Kong, whose airport is more congested and expensive. Additional major sorting and freight handling facilities are located at Narita Airport in Tokyo, for the Asian markets, London Stansted Airport in Europe and Toronto Airport for North America. The Miami Gateway Hub serves the South Florida, Latin American and Caribbean markets.

6.1.2. FedEx Express fleet

Aircraft type	Owned	Total	Payload (t)	Type of Route
Cessna 208B	244	244	1	US domestic
Airbus A300-600	68	68	39	US domestic
Boeing MD11	57	57	75	Long range routes, intercontinental routes
Airbus A310-200/300	3	3	28	US domestic
ATR 42-300/320	26	26	5	US domestic
Boeing B757-200	118	118	21	US domestic
ATR 72-202/212	21	21	7	US domestic
Boeing DC10	35	35	52	US domestic
Boeing 737-400	8	8	21	US domestic
Boeing 737-800	1	1	21	US domestic
Boeing 767-300	73	73	40	Long range routes, intercontinental routes
Boeing 777L	46	46	51	Long range routes, intercontinental routes
Total	700	581		

Table 6.1: FedEx air freight fleet, 2019. Source: [FedEx, 2019]

The large number of small aircraft with only around 1 tonne of payload has been an essential part of the integrator's strategy since its early days, in order to feed the major and regional hub airports from small airports within range (Morrell, 2016). This distinguishes them from UPS who rely on trucks, or DHL that operates more in international markets where ownership of aircraft by a foreign airline is difficult.

Table 6.2 shows the large number of departures with the small feeder aircraft that FedEx operates over an average sector of only 222 km (see Figure 6.1 to see the routes this aircraft operates in the US).

Almost all the aircraft except the MD-11Fs, Boeing B767-300 and Boeing B777L, are used on US domestic sectors, all at what would be regarded by combination carriers as very low average daily utilisation rates. This is because the aircraft are only used to feed the hubs and operate principally at nighttime. It works like this: The cargo is sorted at the Memphis facility overnight, loaded onto aircraft for delivery throughout the US, with departures in the early morning. The flights arrive at the destination airport and depart to the final destination on a distribution network of FedEx ground trucks by the late afternoon.

Aircraft type	Departures	Stage km	Hours/day
Cessna 208B	102481	222	1
Airbus A310	32049	1179	2,7
Airbus A300B4-600	45967	1373	4,2
B757-200F	748	1580	2,8
DC10-10F	43072	1588	4,9
DC10-30F	14074	1895	6,6
MD11F	40448	3809	9,7
Total	323093	12560	3,3

Table 6.2: FedEx Express Fleet Productivity, 2008. Source: [Morrell, 2016]

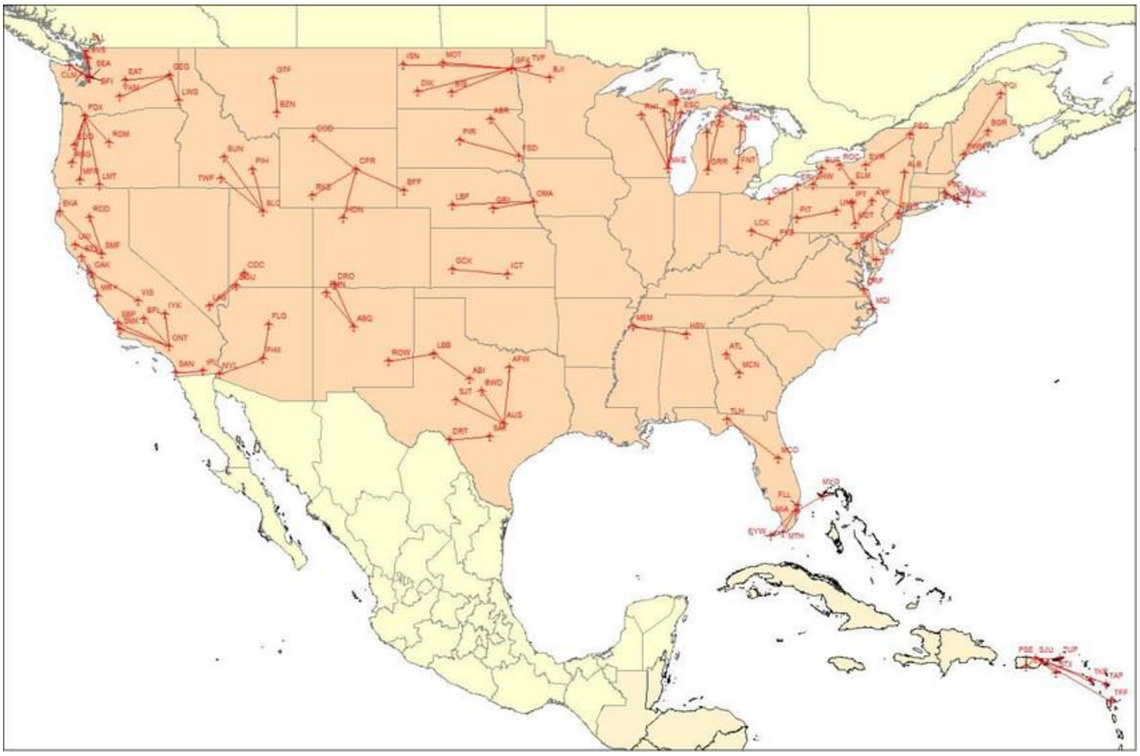

Figure 6.1: Fedex Cessna 208 services routes in the U.S. Source: [O'Kelly, 2014]

6.1.3. FedEx Express US Domestic Market

US connections from selected hubs are shown in Figure 6.2, Figure 6.3, Figure 6.4, Figure 6.5, Figure 6.6 and Figure 6.7. Memphis (MEM) is the primary hub and the other the top cities in terms of Indianapolis (IND), Oakland (OAK), Newark (EWR), Anchorage (ANC), Los Angeles (LAX) and Dallas-FortWorth (AFW). (O'Kelly, 2014)

Other cities not singled out here but which are important for particular regional interactions are Greensboro (with connections to a truck hub and also to Puerto Rico), Miami (an important gateway to the Caribbean), Seattle (connections to major west coast cities and Alaska), and Honolulu (onward connections to Guam and Australia).

Routes that do not involve Memphis as an origin or a destination focus on IND, OAK, LAX, EWR; the biggest cross-country flows are connecting east to west via IND and also some direct connections from EWR to west coast.

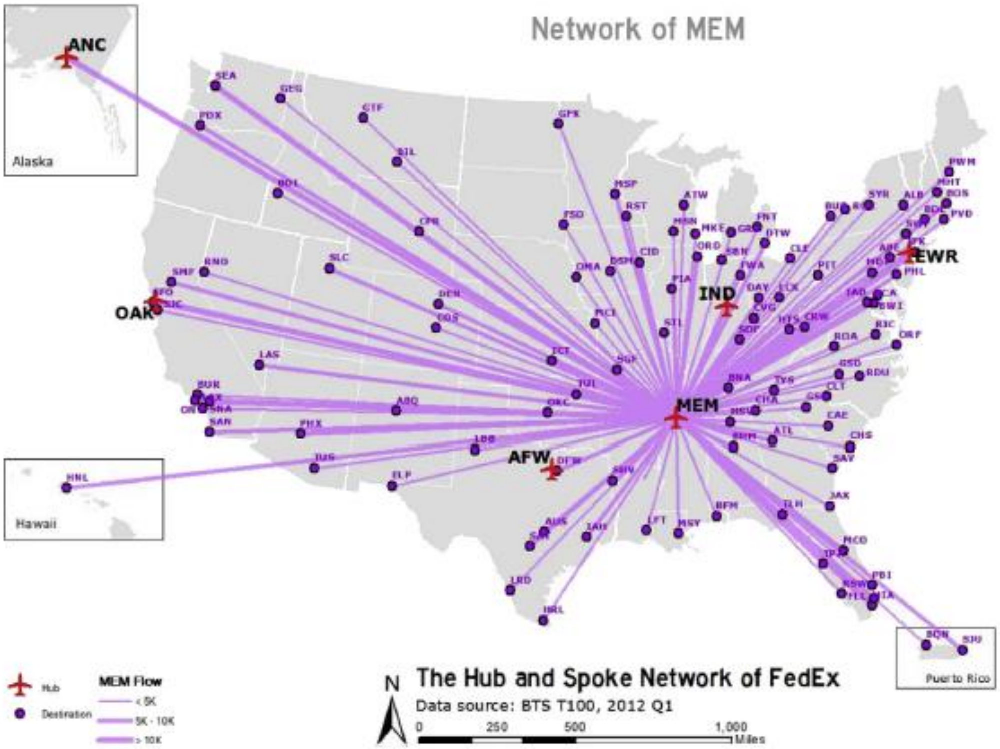

Figure 6.2: Memphis hub. Source: [O'Kelly, 2014]

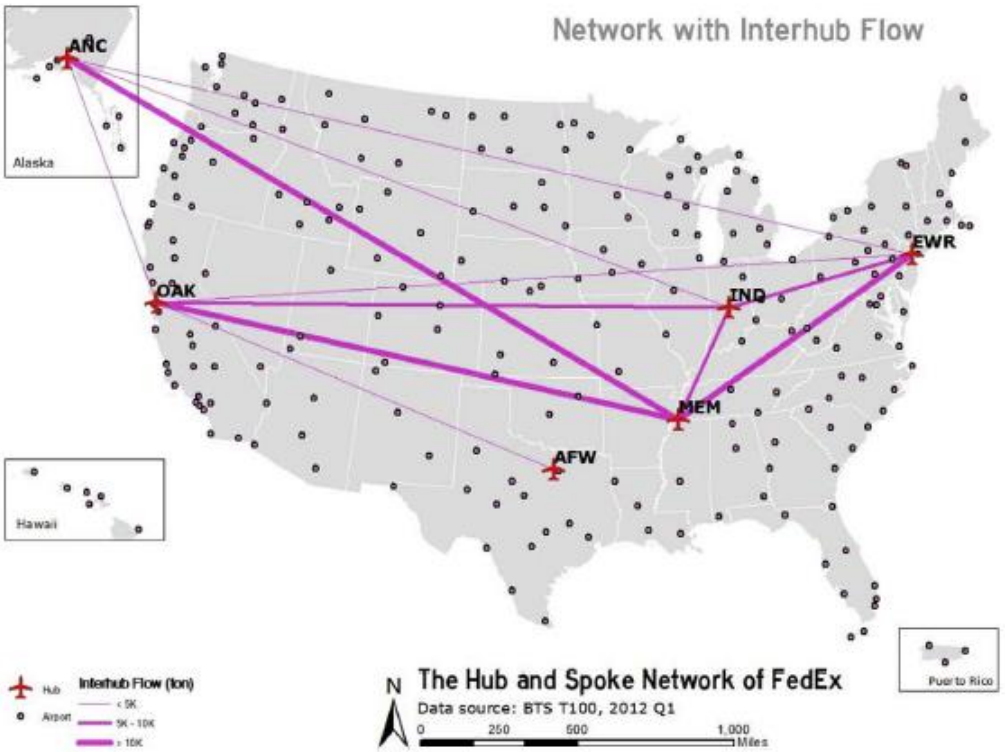

Fig. 2. Interhub flow.

Figure 6.3: Network with interhub flow. Source: [O'Kelly, 2014]

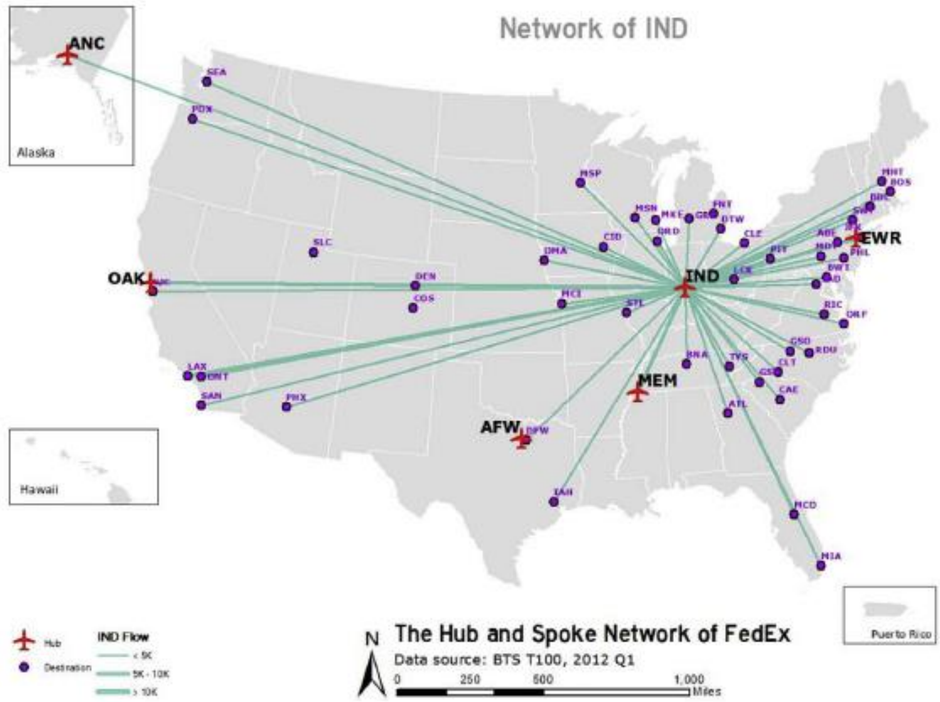

Figure 6.4: Indianapolis hub. Source: [O'Kelly, 2014]

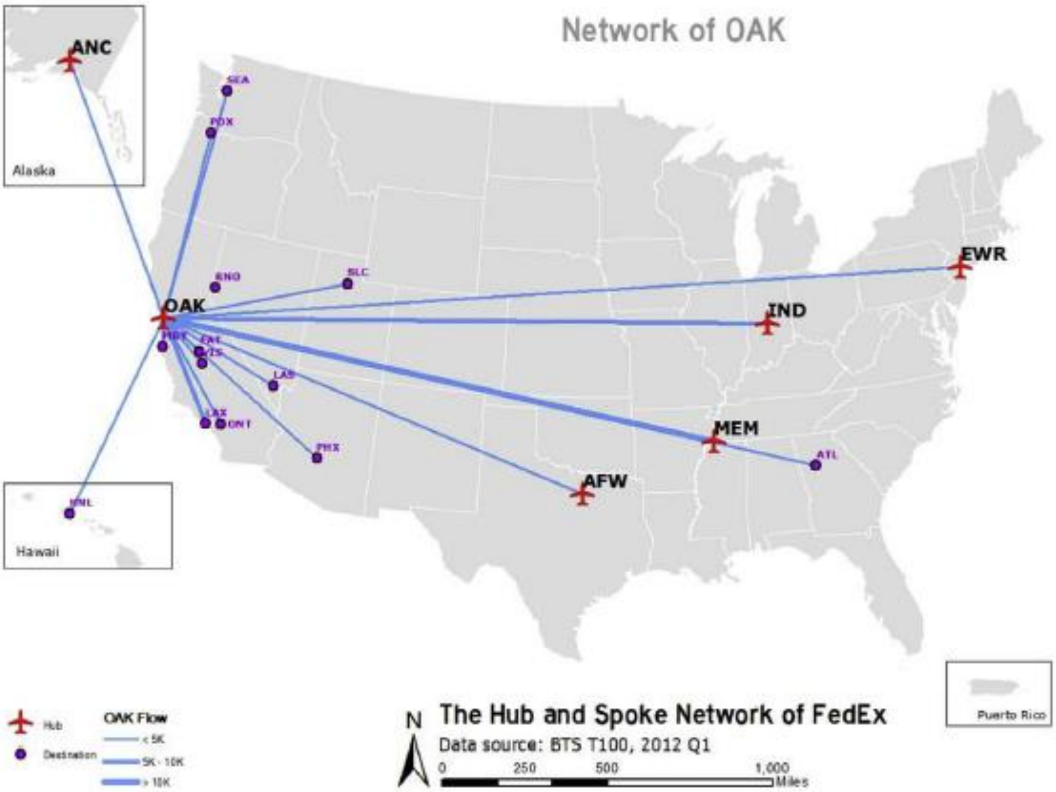

Fig. 4. Oakland hub.

Figure 6.5: Oakland hub. Source: [O'Kelly, 2014]

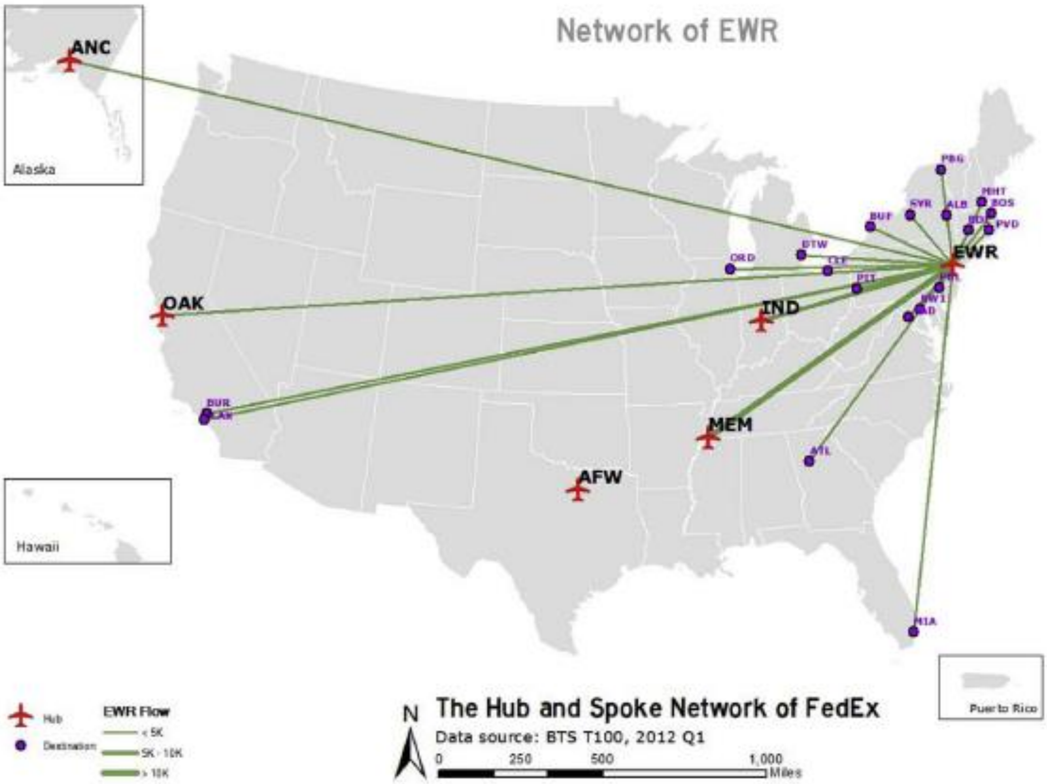

Figure 6.6: Newark hub. Source: [O'Kelly, 2014]

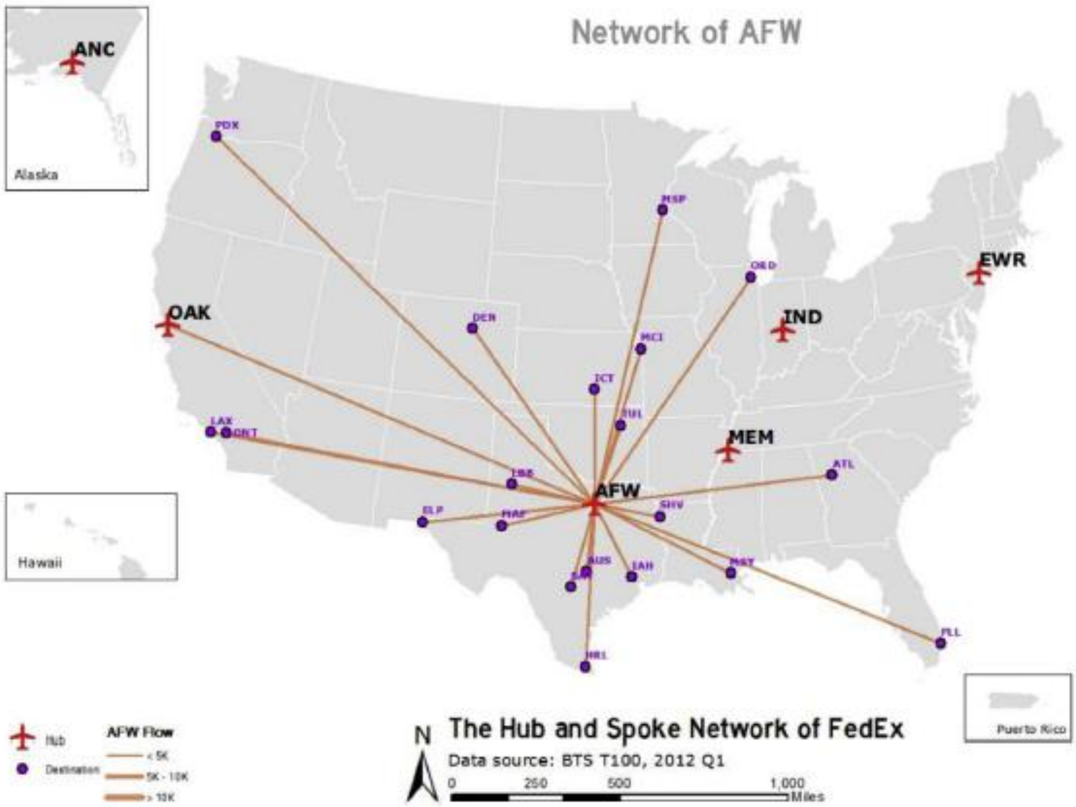

Figure 6.7: Dallas Fortworth hub. Source: [O'Kelly, 2014]

6.1.4. FedEx Express International Routes

Another way to examine the flow is to look at the FedEx US gateway to international (non-US) destinations. The largest flow from each base point (emphasized as the shaded number in each row in table 5.3) shows that although several hubs have interaction with multiple destinations there are some particularly large patterns: including massive flows to Alaska and the Pacific from EWR, MEM, OAK, and SEA. Anchorage has a major interaction with Japan/ Taiwan/Korea (J/T/K). And while the overall dominance of Memphis is evident, it is in fact the flows to Canadian cities which represent the largest volume of international flights. (O'Kelly, 2014)

Examining the largest number in each column, the chart emphasizes that MEM is the major source for each column with the exception of J/T/K with ANC airport and a close tie with MIA for South America.

DESTINATION	Canada	EU 1	EU 2	Mexico	Dubai	AK & Pac	J/T/K	Sth Am	Pt Rico	HK, De	Sydney	China	
KEWR	134	114	236		1	313							798
KGSO									254				254
KIND	408	171	203			259			238				1279
KLAX						262							262
KMEM	2110	602	408	999	208	1494	606	263	844				7534
KMIA				1				260	249				510
KOAK						726	154						880
KSEA	6					272							278
PANC						52	1556			167		170	1945
PHNL						209				8	301		518
	2658	887	847	1000	209	3587	2316	523	1585	175	301	170	14258

Table 6.3: FedEx hubs with international activity. Source: [O'Kelly, 2014]

Main hub of FedEx in Europe is Paris Charles de Gaulle, France. In the following Figure 6.8 it shows the different destinations that this integrator operates from its hub in Europe.

Figure 6.8: FedEx Routes to Europe. Source: [FedEx, 2019]

Asia is the fastest growing large air cargo market and this integrator has extensive intra-regional hub-and-spoke network there. FedEx provides overnight services among 22 cities and rapid onward connections to the US and Europe (see Figure 6.10). (Bowen, 2012)

Figure 6.9: FedEx Routes to Asia. Source: [FedEx, 2019]

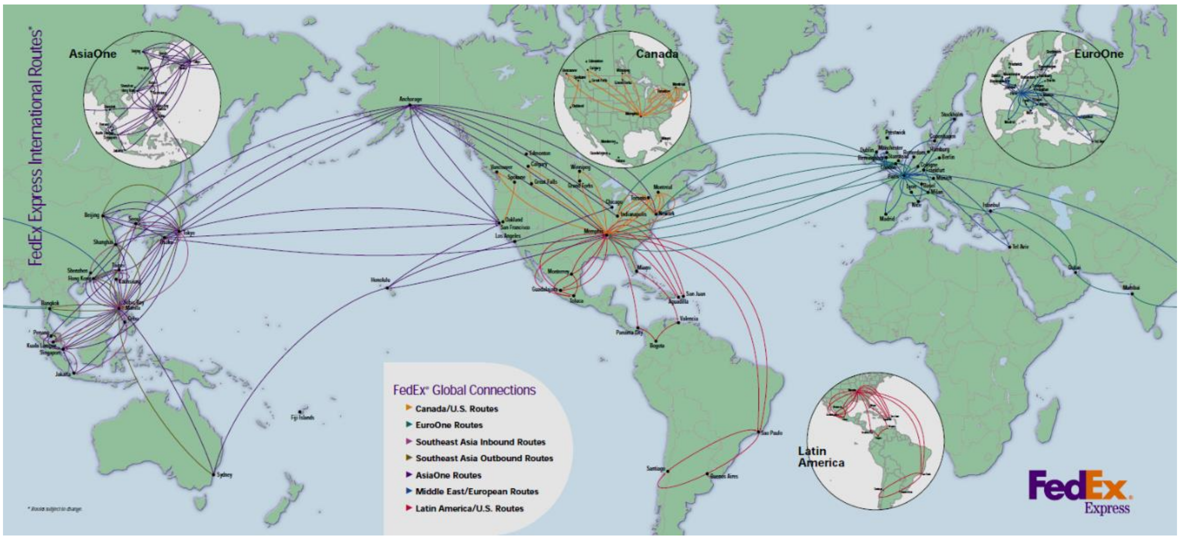

Figure 6.10: FedEx Iternational Routes. Source: [FedEx, 2019]

In January 2010, FedEx started nonstop Boeing 777-200 Long Range Freighter (777-200LF) service from Shanghai Pudong International Airport to its Memphis hub. Since then, the company has added regular nonstop 777-200LR services on a handful of direct lanes across the Pacific, the Atlantic, and Eurasia (see Figure 6.11). (Bowen, 2012)

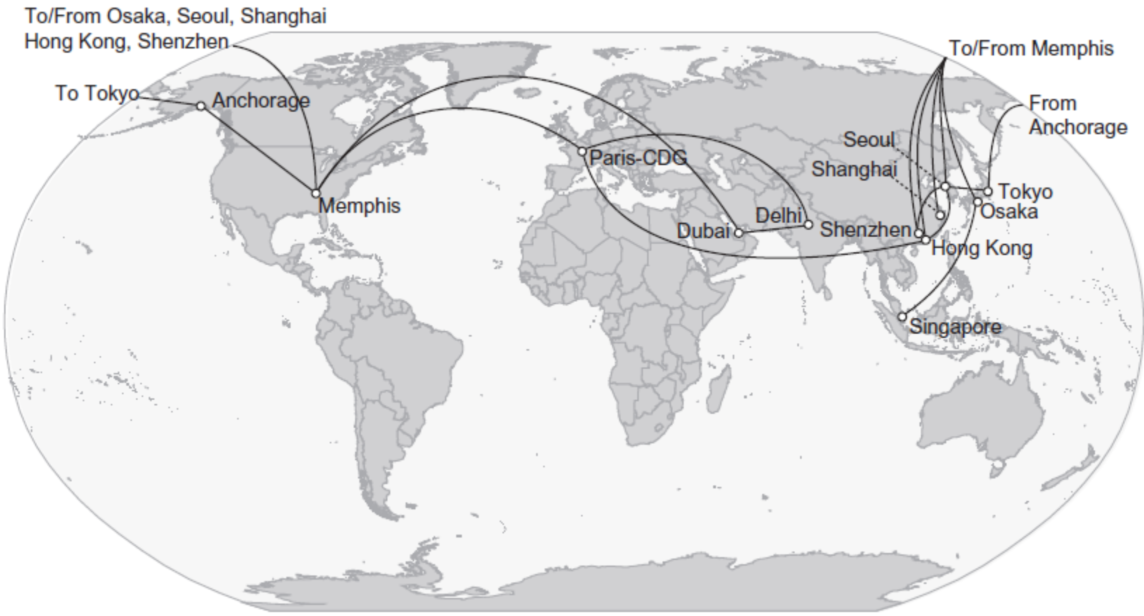

Figure 6.11: FedEx B777L direct lanes. Source: [Bowen, 2012]

In Figure 6.12 it is indicated all the hubs that most important integrators (Fedex and UPS) have nowadays in all the world.

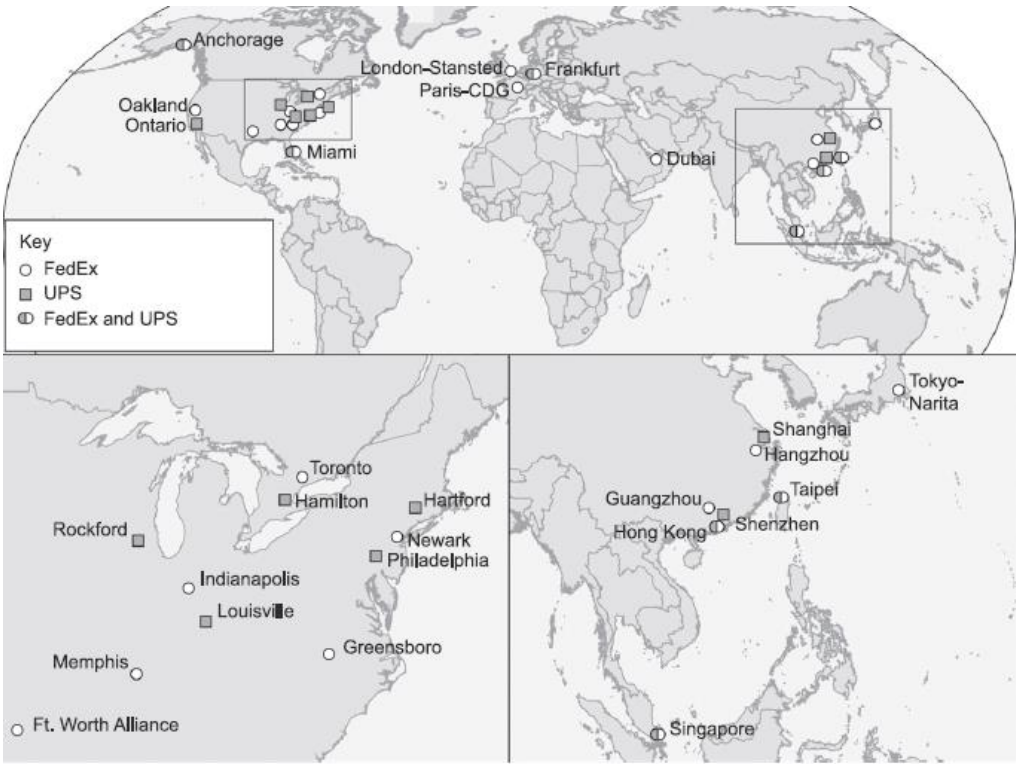

Figure 6.12: FedEx and UPS hubs around the world. Source: [Bowen, 2012]

6.2. UPS

6.2.1. History

United Parcel Service (UPS) was founded in Seattle, Washington in 1907 as a parcel transportation company utilizing truck routes along the US west coast. Even though UPS was founded with a focus on ground transportation, they pushed the frontier of air freight transportation.

In 1929, UPS became the first package delivery company to provide air service via privately operated airlines (UPS, 2019).

The company slowly expanded the air service so that by 1985, it was available in 49 states and six European countries. The success of FedEx and reduced capacity on scheduled passenger carriers forced UPS to adopt a much more aggressive strategy. Deregulation gave UPS the freedom to become the fastest expanding airline in US history to that time, with its fleet growing from a single aircraft in 1981 to 110 by 1989, including 7 747s. (Bowen, 2012)

The UPS's hub in Lousiville, Kentucky was established in 1982. International service was established in 1985 with European countries when a hub was established in Cologne, Germany. By 1990, UPS had established their Worldwide Express Service offering trade originating in 104 countries and destined for 175 countries (UPS, 2019).

The next significant move by UPS was the acquisition of the air freight company Challenge Air in 1999. Challenge Air had an established trade network between the US and Latin and South America, including 17 cities in 13 countries, all of which were turned over to UPS in the adquisition (Morrell, 2016).

6.2.2. UPS fleet

UPS Airlines has a fleet of 255 aircraft, as of May 2019. (UPS, 2019)
The airline does not own a short-haul aircraft (turboprop). If it needs such aircraft, they are chartered from companies that offer wetleases, such as Air Cargo Carriers and Ameriflight.

Aircraft	In Service	Orders	Payload (t)	Type of Route
Airbus A300-600RF	52		54,6	US domestic
Boeing 747-400BCF	2		107,8	Long range routes, intercontinental routes
Boeing 747-400F	11		113	Long range routes, intercontinental routes
Boeing 747-8F	14	17	138	Long range routes, intercontinental routes
Boeing 757-200PF	75		27	US domestic
Boeing 767-300ER/BCF	3		52	Long range routes, intercontinental routes
Boeing 767-300ERF	60	13	44	Long range routes, intercontinental routes
MD-11	38		75	US domestic
Total	255	30		

Table 6.4: UPS Fleet, 2019. Source: [UPS, 2019]

6.2.3. UPS US Domestic Market

Like FedEx, UPS has developed a multi-hub network within the US (see Figure 6.13).

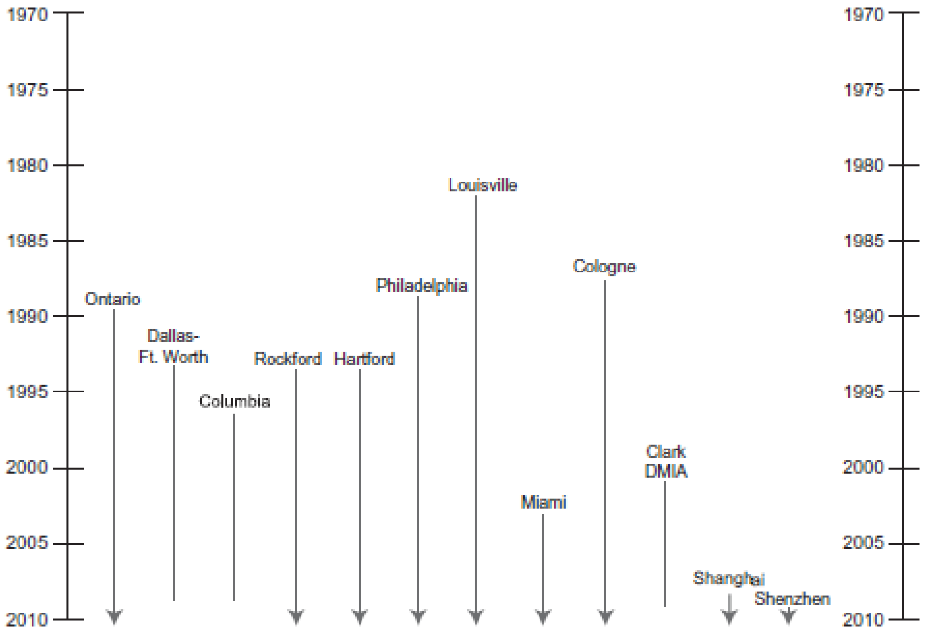

Figure 6.13: UPS major hub timeline. Source: [Bowen, 2012]

Using the traditional hub-and-spoke model, UPS Airlines operates through its central facility in Louisville, Kentucky. In addition, the company operates several facilities on a regional level across the United States:

Hub	Destinations
Lousville	More than 220 countries and territories around the world
Chicago	Massachussetts, Connecticut, Rhode island, New York, Maryland, Washington DC, Michigan, Minnesota, Texas, California, Arizona and Washington State
Philadelphia	Maine, New Hampshire, Vermont, New York, New Jersey, Massachusetts, Connecticut, Rhode Island, Pennsylvania, Maryland, Delaware, Washington DC, Virginia, West Virginia, South Carolina, Georgia, Illinois, Minnesota, Nevada and California
Ontario	California, Oregon, Washington State, Idaho, Nevada, Montana, Utah, Arizona, New Mexico, Colorado, Wyoming, Kansas and Nebraska along with Alaska and Hawaii.
Dallas/Forthworth	Texas, Loisiana, Mississippi, Arkansas, Oklahoma, New Mexico, Arizona, Nevada, California, Oregon, Hawaii, New York, Pennsylvania, Maryland, Delaware, Virginia and Washington DC

Table 6.5: Main US hubs with their domestic destinations. Source: [UPS, 2019]

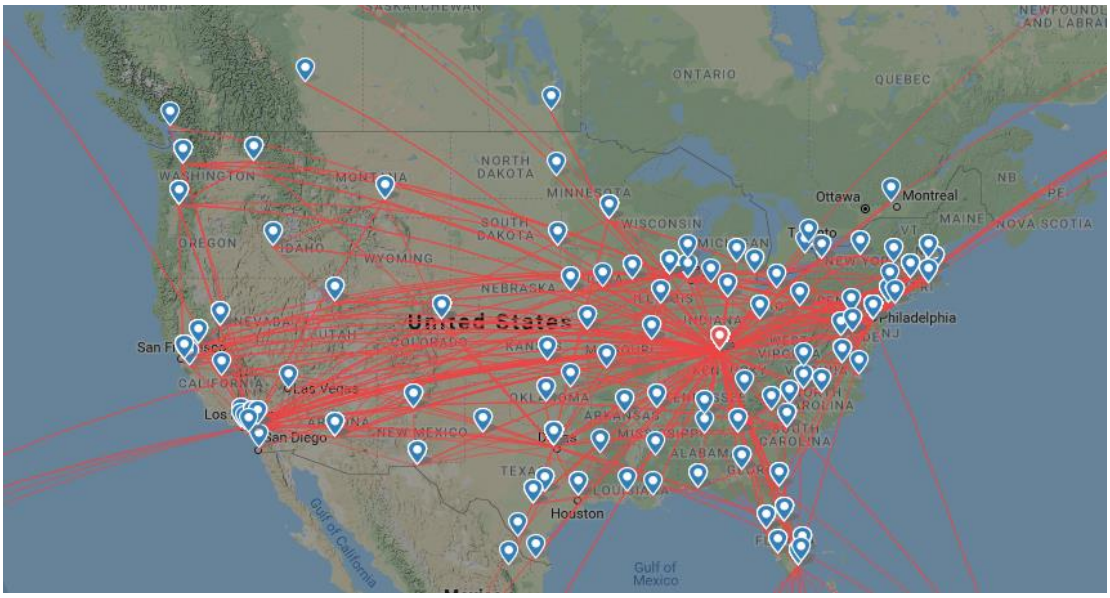

Figure 6.14: UPS US Domestic Routes. Source: [Flightradar24, 2019]

6.2.4. UPS International Routes

The 1980s saw UPS enter the international shipping market; the company established a presence in a growing number of countries and territories in the Americas, Eastern and Western Europe, the Middle East, Africa and the Pacific Rim. In 1985, UPS started international air service between the United States and six European countries. Then, in 1989, domestic air service was added in Germany.

Today, UPS operates an international small package and document network in more than 185 countries and territories, spanning both the Atlantic and Pacific oceans (see Figure 6.15). Main hub of UPS in Europe is Cologne, Germany. (UPS, 2019).

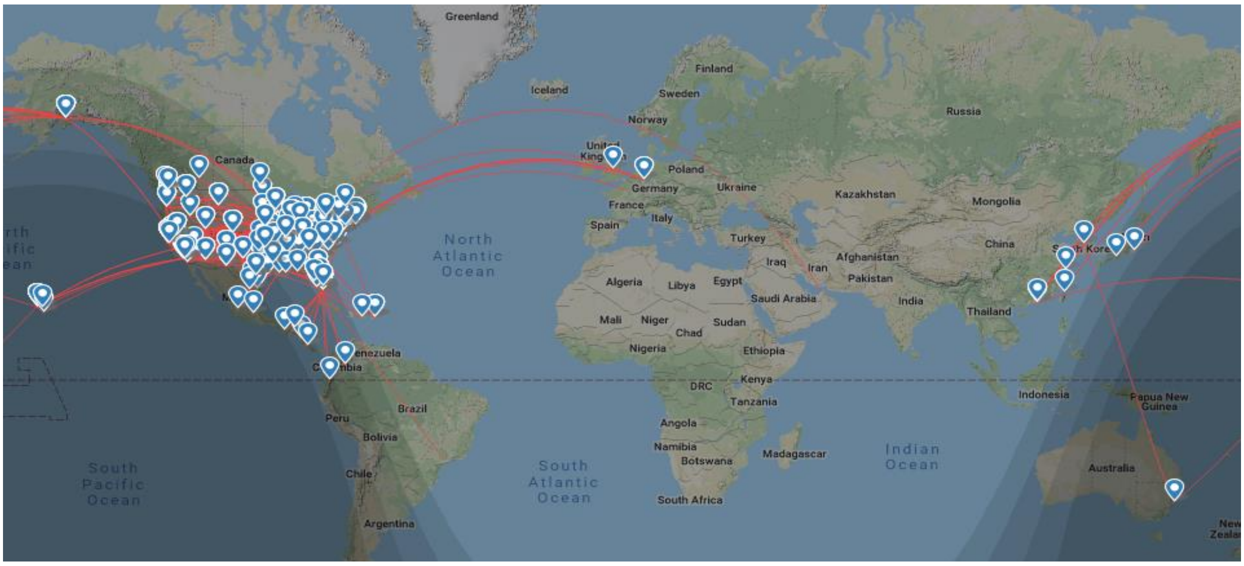

Figure 6.15: UPS International Routes. Source: [Flightradar24, 2019]

6.3. Emirates SkyCargo

Emirates SkyCargo is the air freight division of Emirates, which started operations in october 1985, the same year Emirates was formed.

6.3.1. Emirates SkyCargo fleet

As of April 2019, the Emirates SkyCargo fleet consists of the following aircraft:

Aircraft	In Service	Orders	Payload (t)	Type of Route
Boeing 777F	13		103	Long range routes, intercontinental routes

Table 6.6: Emirates SkyCargo fleet, 2019. Source: [Emirates SkyCargo, 2019]

In addition of those 13 deditaced freighter aircraft, Emirates has also a fleet of over 270 wide-bodied combination aircraft (passenger+cargo). (Emirates SkyCargo, 2019)

6.3.2. Emirates SkyCargo International Routes

Emirates SkyCargo operates dedicated freighter routes to 50 destinations and additionally has access to cargo capacity on further 100 Emirates passenger routes. In the following Figure 6.16 it is shown its route map.

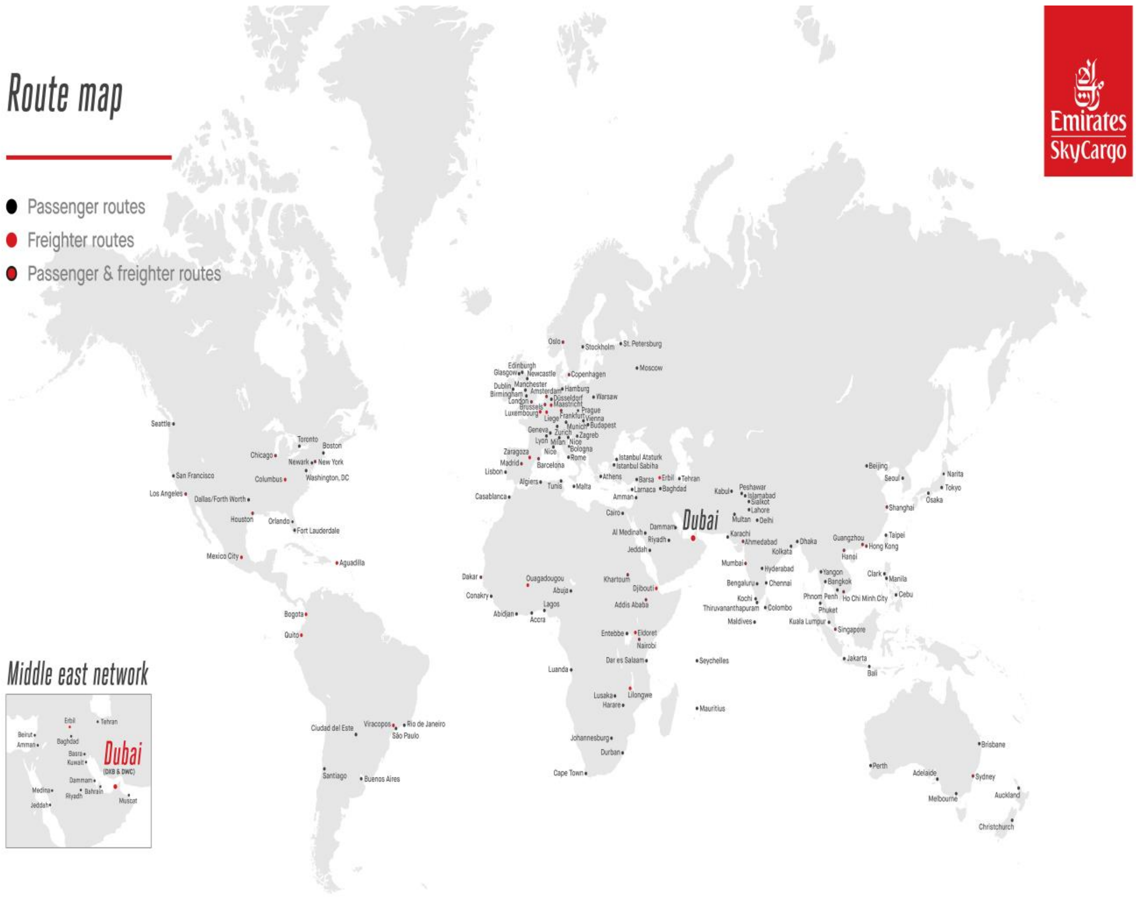

Figure 6.16: Emirates Cargo Global Distribution Network. Source: [Emirates SkyCargo, 2019]

6.4. Qatar Airways Cargo

Qatar Airways Cargo, the airline's freight branch, was the world's fourth largest international cargo carrier during 2014-2017(as it was shown in Figure 3.7). (IATA, 2018)

6.4.1. Qatar Airways Cargo fleet

Utilising a dedicated freighter fleet of two B747-8, 16 Boeing 777 and eight Airbus A330 freighters together with Qatar Airways' passenger fleet, this company delivers freight to more than 160 key business and leisure destinations globally on over 250 aircraft. (qrcargo, 2019)

Aircraft	In Service	Orders	Payload (t)	Type of Route
Boeing 777F	16	5	103	International routes
Airbus A330F	8		63	International routes
Boeing B747-800F	2		138	International routes
Total	26	5		

Table 6.7: Qatar Airways Cargo fleet, 2019. Source: [qrcargo, 2019]

6.4.2. Qatar Airways Cargo International Routes

Qatar Airways Cargo serves over 60 exclusive freighter destination wordwide via its Doha hub.

Figure 6.17: Qatar Airways Cargo Global Distribution Network. Source: [qrcargo, 2019]

6.5. Cargolux

Cargolux is a Luxembourgish cargo airline with its headquarters and hub at Luxembourg Airport. With a global network, it is one of the largest scheduled all-cargo airlines in Europe.

6.5.1. Cargolux fleet

The Cargolux fleet consists of the following freighter aircrafts. Both operates international routes.

Aircraft	In Service	Payload (t)	Type of Route
Boeing 747-400F	10	103	International routes
Boeing B747-800F	14	138	International routes
Total	24		

Table 6.8: Cargolux fleet, 2019. Source: [Flightradar24, 2019]

6.5.2. Cargolux all Routes

Figure 6.18: Cargolux Global Distribution Network. Source: [Flightradar24, 2019]

6.6. Amazon Air

Amazon Air, also known as Amazon Prime Air, is a cargo airline for Amazon's freight delivery service based in Hebron, Kentucky. It was founded on November 1st of 2015.

Amazon operates the delivery service using its own branded aircraft operated by Air Transport Internaional, ABX Air, Atas Air and Southern Air.

Its primary hub is located at the Cincinnati/Northern Kentucky Inernational Airport (CVG).

6.6.1. Amazon Air fleet

Three airlines operate for Amazon Air: ABX Air, Atlas Air and Air Transport International. They use Boeing 737 and Boeing 767 for operating the flights for Amazon Air.

Aircraft	In Service	Orders	Operator
Boeing 737-800BCF	3	2	Southern Air
Boeing 767-200BDSF	12		ABX Air/ Air Transport International
Boeing 767-300BDSF	27		Air Transport International/Atlas Air
Total	42	2	

Table 6.9: Amazon Air fleet, 2019. Source: [Flightradar24, 2019]

6.6.2. Amazon Air Routes

At the moment, Amazon Air only operates to US destinations, it only operates to US domestic routes.

Figure 6.19: Amazon Air Distribution Network. Source: [Flightradar24, 2019]

6.7. Freighter flights in Europe

In Figure 6.20 is shown a general view of the freighter flights that operate in Europe nowadays. The cargo airlines (the most important ones in Europe) that appears in the map are: AirBridgeCargo, Cargolux, FedEx and Lufthansa Cargo. As it can be seen in here, the most congested airports are the hubs (we could also see that in Figure 4.1), which are Frankfurt, Amsterdam, London Heathrow and Paris (CDG). (IATA, 2017)

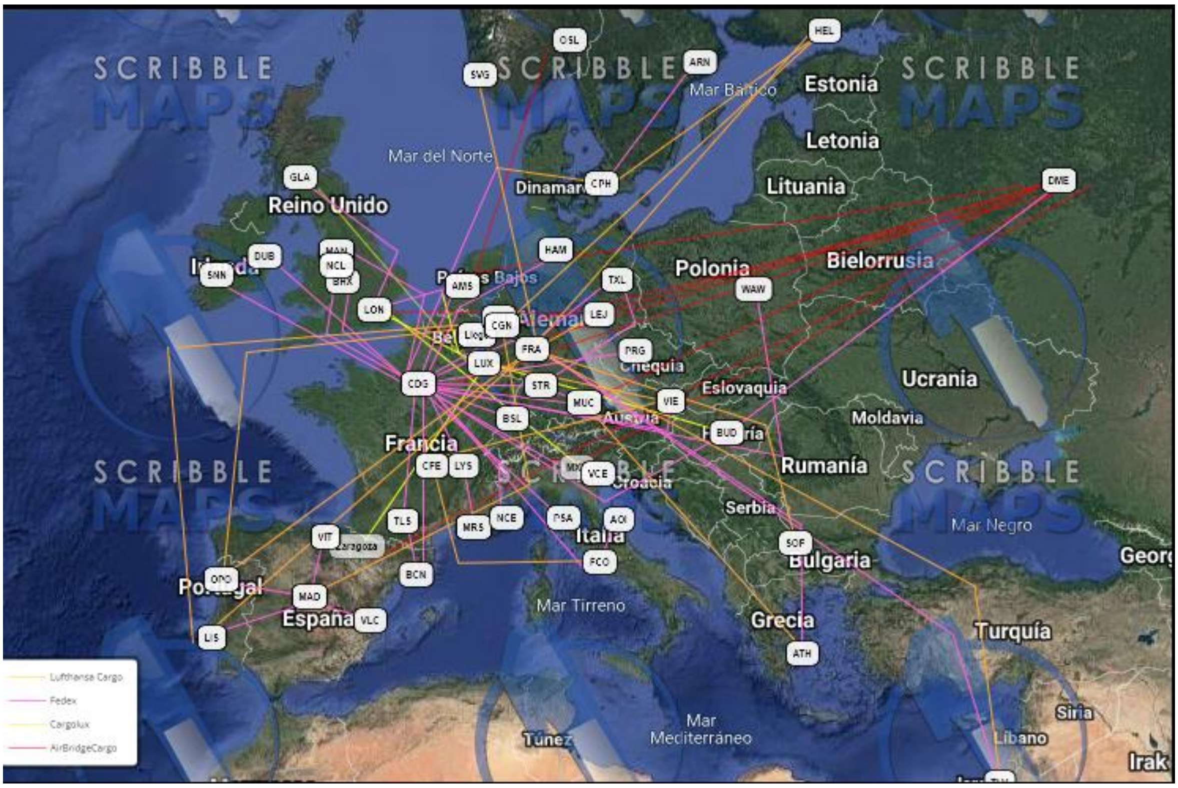

Figure 6.20: Scheduled cargo flights of four important air freight carriers in Europe, 2019. Source: [Flightradar24, 2019]

7. CHAPTER 7 – COMPARISON ENERGY CONSUMPTION BETWEEN HST AND AIR FREIGHT TRANSPORT

7.1. The energy consumption of High-Speed freight trains

In order to determine the energy consumption of a High-Speed freight Train, it will be analysed the energy consumption of the following route: Ventimiglia-San Giorgio di Nogaro, approximately 650km.

In the simulation, this route will be split in three sub-parts:

1. Ventimiglia – Genova (coastal line, neither mountain nor flat)
2. Genova – Tortona (mountain part)
3. Tortona – San Giorgio (flatlands)

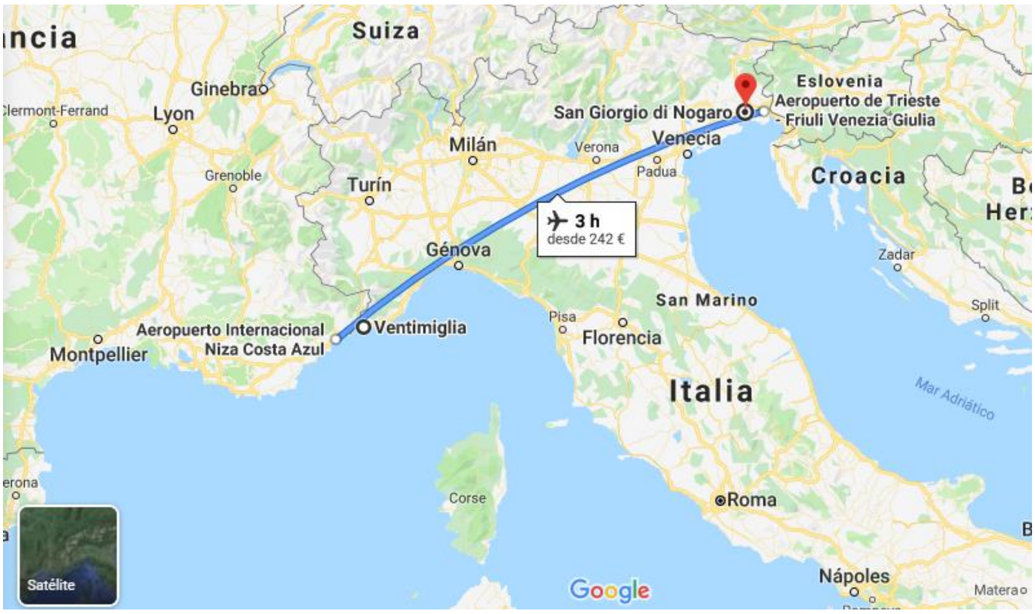

Figure 7.1: Route Ventimiglia-San Giorgio di Nogaro from google maps

7.2. The energy consumption of freight aircraft

The four forces acting on an aircraft in straight-and-level, unaccelerated flight are thrust, drag, lift and weight (see Figure 7.2). They are defined as follows: (Federal Aviation Administration, 2009).

- Thrust: the forward force produced by the powerplant/propeller or rotor. It opposes or overcomes the force of drag. As a general rule, it acts parallel to the longitudinal axis. However, this is not always the case.
- Drag: a rearward, retarding force caused by disruption of airflow by the wing, rotor, fuselage and other protruding objects. Drag opposes thrust and acts rearward parallel to the relative wind.
- Weight: the combined load of the aircraft itself, the crew, the fuel and the cargo or baggage. Weight pulls the aircraft downward because of the force of gravity. It opposes lift and acts vertically downward through the aircraft's center of gravity (CG).
- Lift: opposes the downward force of weight, is produced by the dynamic effect of the air acting on the airfoil and acts perpendicular to the flightpath through the center of lift.

In steady flight, the sum of these opposing forces is always zero. There can be no unbalanced forces in steady, straight flight bases upon Newton's Third Law, which states that for every action or force there is an equal, but opposite, reaction or force. This is true whether flying level or when climbing or descending.

In the force vectors of thrust, drag, lift and weight appear to be equal in value. It is true when the flight is in straight, level, unaccelerated state.

Figure 7.2: Relationship of forces acting on an airplane. Source: [Federal Aviation Administration, 2009]

In Table 7.1 it is shown the freight aircraft that it has been used in the simulations with their respective values of maximum payload (tonnes), range (km), type of cargo and engine used. B737-400 and A330F are characterized as light cargo aircraft with a short to medium range and its cargo can be transported together with passengers, in a commercial aircraft. For MD11 and B747-800F, they are inside the group of heavy cargo, and their range is from medium to long range. This classification will be taken into account later in the graphs in order to compare freight aircraft with freight trains.

Code	Aircraft type	Maximum payload (tonnes)	Type of Cargo	Range Max (km)	Engine
B737-400	Narrow-body jet airliner and Business jet	21	Small shipment transported in passenger plane	3850	CFM56-3C1
A330F	Medium- to long-range wide-body twin-engine jet airliner	63	Mid-sized cargo	5950	CF6-80E1A2
MD11	Three-engine medium to long range wide-body jet airliner	75	Heavy cargo	6652	CF6-80C2A3
B747-800F	Long range wide-body jet airliner	138	Heavy cargo	8130	CF6-80C2B2

Table 7.1: Aircraft used in the simulation with AEM

7.2.1. Theoretical calculation of energy consumption of freight aircraft

As the aircraft anlysed in this study have all a turbojet engine, all the equations and graphs will be related to turbojet engines.
In order to simplify the calculations, it will only be calculated the fuel consumption in the cruise.

In a turbojet engine, Newton's second and third laws govern the relationship between forces and motion. The output thrust is obtained as (Sadraey, 2012):

$$\boldsymbol{T} = \dot{\boldsymbol{m}}(\boldsymbol{V_e} - \boldsymbol{V_i}) + \boldsymbol{A_e}(\boldsymbol{P_e} - \boldsymbol{P_a}) \qquad \text{Equation 7.1}$$

where,

$\dot{m}$ represents the air mass flow rate into the engine,

V_e is the gas exit velocity from the nozzle,

V_i is the velocity of the incoming air to the inlet

A_e is the cross-sectional area of the engine nozzle exit

P_e is the static pressure of the gas exiting the nozzle

P_a is the ambient pressure at which the aircraft is flying

In order to know the cruise fuel consumption (kg) of a specific thrust (T) it is used the Breguet equation, that is a differential equation and relates the change of the aircraft weight to other aircraft parameters (Sadraey, 2012):

$$\frac{dx}{dW} = \frac{V}{SFC} \cdot \frac{C_L}{C_D} \cdot \frac{1}{W} \qquad \text{Equation 7.2}$$

Thus, integrating this equation and assuming a constant $\frac{C_L}{C_D}$, V and altitude, equation 7.2 yields:

$$\frac{W_{i-1}}{W_i} = \exp\left(\frac{x \cdot SFC}{V \cdot \frac{C_L}{C_D}}\right) \qquad \text{Equation 7.3}$$

Where W_{i-1} and W_i are the weights of the aircraft at the beginning and at the end of the cruise.

In the following Table 7.2 it is shown the different values of the engine parameters that are used for calculation of equation 7.3:

Engine	SFC (Cruise) [lb/lbf h]	Cruise speed [M]	Cruise altitude [ft]
CFM56-3C1	0,667	0,8	35000
CF6-80E1A2	0,345	0,82	41100
CF6-80C2A3	0,576	0,8	35000
CF6-80C2B2	0,576	0,8	35000

Table 7.2: Turbojet engines specifications. Source: [jet-engine.net, 2019]

The velocity in cruise (V) is calculated with relation of Mach number (see Table 7.2), using the following equation:

$$\boldsymbol{V = M \cdot a = M \cdot \sqrt{\gamma R T}} \qquad \text{Equation 7.4}$$

where,
a is the speed of sound [ft/s or m/s]
γ is the specific heat ratio, which is usually equal to 1.4
R is the specific gas constant, which equals 1716 ft-lb/slug/°R in English units and 287 J/kg/K in Metric units
T is the atmospheric temperature in degrees Rankine (°R) in English units and degrees Kelvin (K) in Metric units

Once it is obtained the mass of burned fuel it can be calculated the energy consumption and the specific energy consumption, using the fuel lower heating value:

$$\boldsymbol{Energy\ consumption = m_{fuel} \cdot LHV} \qquad \text{Equation 7.5}$$

Table 7.3 shows some basic data of aviation fuel useful for calculation of energy consumption.

Fuel	**Wide-cut**	**Kerosene**	**AV gas**
Specific weight	0,762 kg/l	0,810 kg/l	0,715 kg/l
Lower heating value	43,54 MJ/kg	43,28 MJ/kg	43,71 MJ/kg

Table 7.3: Characteristics of aviation fuels at 15ºC. Data are averages. Source: [Tooley, 2009]

7.3. Comparison between HST and freight aircraft

In this section of chapter 7 a comparison of specific energy consumption of HST and air freight transport is made.

In order to evaluate the specific energy consumption of different freight aircraft, a software of EUROCONTROL has been used in this thesis, which is called "Advanced Emission Model" (AEM). The needed inputs to obtain the different simulations of energy consumption are shown in the following Table 7.4. In annex C it is all the links of the input files used in order to run every simulation.

Softare	Inputs
AEM	Aircraft type
	Engine type
	4D trajectory
	Airport codes (Departure and Arrival)

Table 7.4: Required inputs to run the simulation in the software AEM

In Figure 7.3 it is shown the input parameters that were used for running the simulations and the output options (you can select which parameter you want or you don't want to have it in the output file).

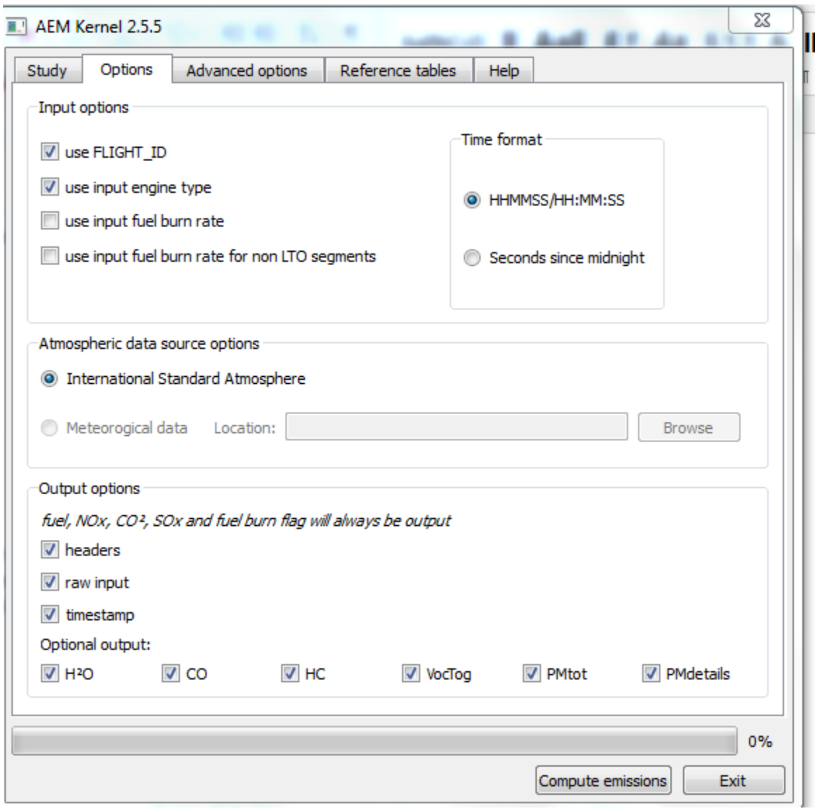

Figure 7.3: Screenshot of AEM Kernel 2.5.5 software

The output file can be generated per segment, flight or attitude (see Figure 7.4).

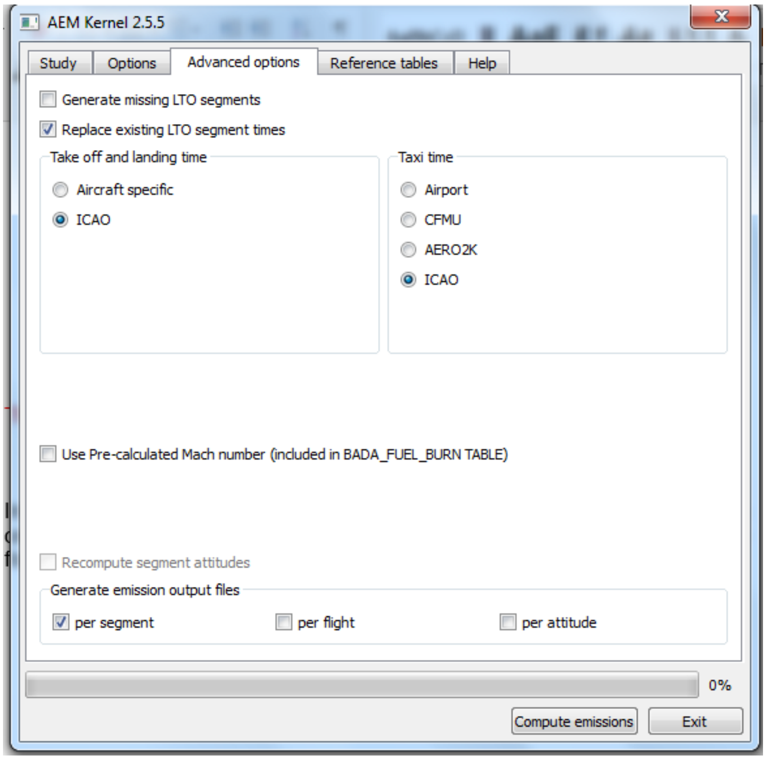

Figure 7.4: Screenshot of AEM Kernel 2.5.5 software

In Table 7.5 it is shown the air routes which have been used in the simulations in order to compare the energy consumption taking into account the route distance for the different freight aircrafts shown in Table 7.1. With help of flightradar it was possible to obtain the different latitude al altitude points for the different flight stages (climb, cruise, descent, etc). In annex B it is attached all the route files.

Route length (km)	Distance (NM)	Route
800	431	TRN-AMS
300	162	ALC-PMI
200	108	VLC-IBZ
150	81	ALC-IBZ

Table 7.5: Routes used in the simulations with AEM

7.3.1. Simulation Results

In Figure 7.5 is shown the specific consumption of freight aircraft (light and heavy aircraft) depending on the route distance, in km. As it can be seen in here, the specific consumption is smaller when the route length increases, for all freight aircraft.

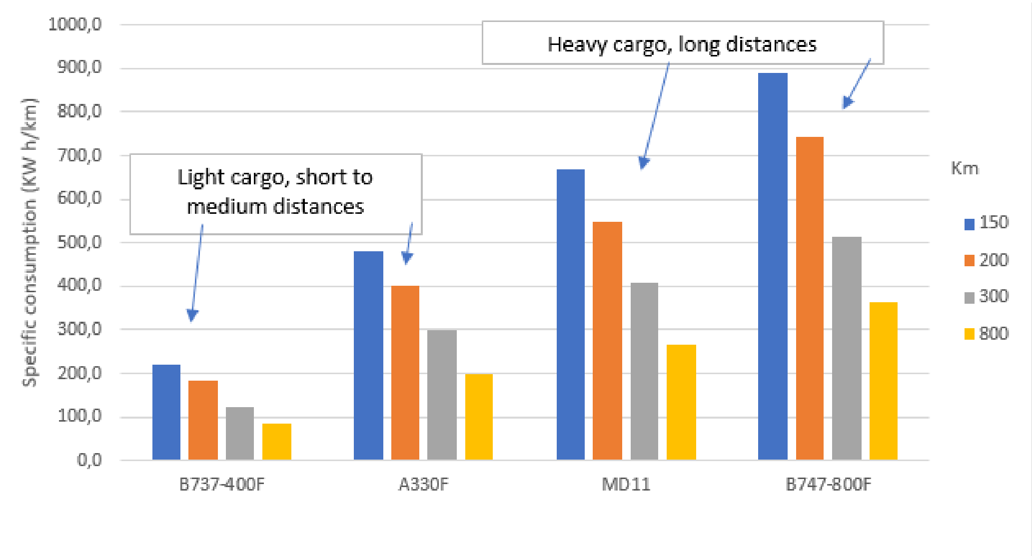

Figure 7.5: Specific consumption of freight aircraft depending on the route length

In Figure 7.6 is shown the specific energy consumption depending the route length. Now, the light aircrafts have the highest specific energy consumption, and this value increases as the distance is reduced.

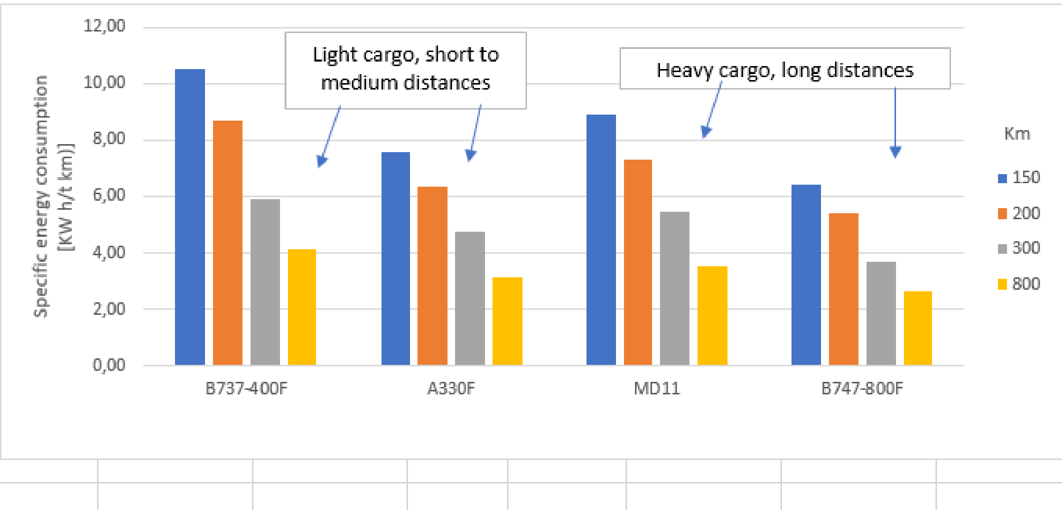

Figure 7.6: Specific energy consumption of freight aircraft depending on the route length

Another simulation that was made was the following: for a unique type of aircraft, which was the B737-400F aircraft and the engine 1CM007, it was compared the kg of burnt fuel for each flight stage, per each route length. The simulation result is shown in Figure 7.7. When the route length is bigger, the fuel consumption in cruise is higher as it is a longer stage. The climb belongs to the stage where the fuel consumption is higher (that is the same for all route lengths).

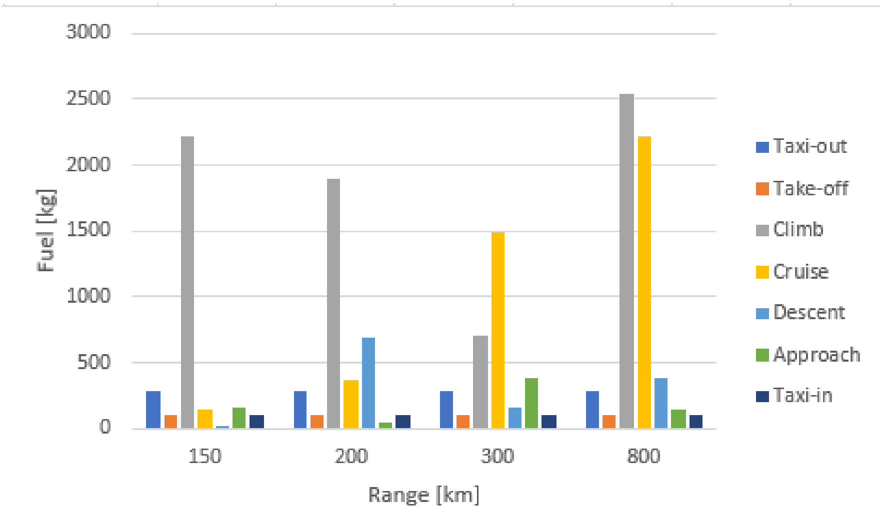

Figure 7.7: Fuel consumption division of B737-400F for different route lengths

In the Figure 7.8 it is made a comparison of specific energy consumption, in KWh/t·km, of both freight modes, train and aircraft. For doing this comparison it was simulated the energy consumption of the route Ventimiglia - San Giorgio di Nogaro, that is approximately 650 km, as explained in section 7.1.

.

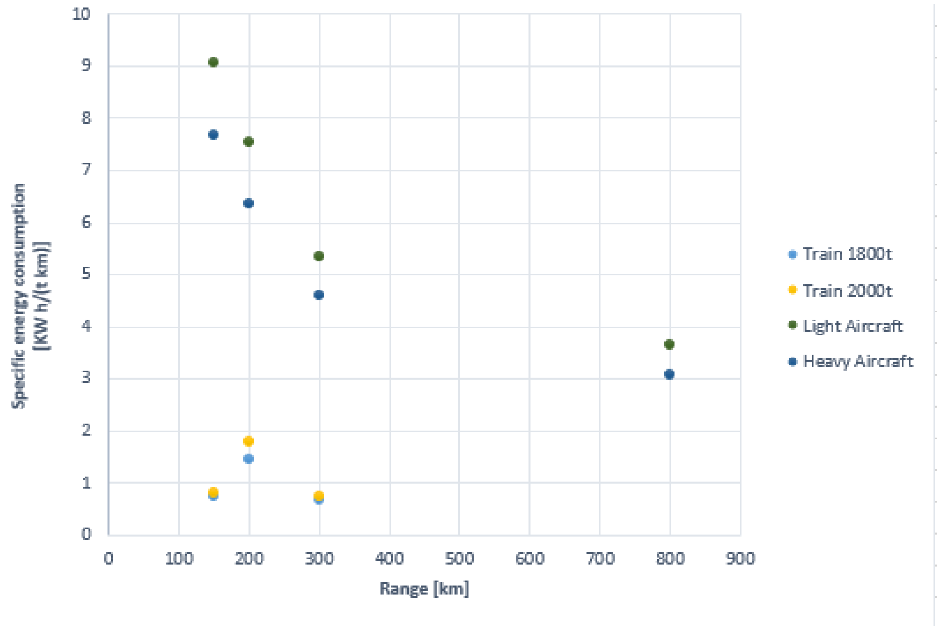

Figure 7.8: Comparison specific energy consumption freight train and freight aircraft

One aspect to take into account is that in the simulation of freight trains, the type of ground is quite important in order to estimate the energy consumption (the mountain section involves a higher consumption of energy than in a flat section). On the contrary, for air freight, the type of ground is not important at all.
As it is shown Figure 7.8, for longer distances, the specific energy consumption would be lower in air than in ground freight, if we are only referring to the mountain part.

In the following Figure 7.9, a comparison of travel times between freight train and freight aircraft is made. For doing this comparison, it was used the simulation route of freight train, Ventimiglia-San Giorgio (in Table 7.6 it is shown the route length for each route's section).
In terms of time, air freight is without any doubt the best way to carry freight, as it is much faster than train. For instance, in the route's section of 350 km, which is a flatland section, train is 6 times slower than aircraft (4h of travel time in train and 40min for aircraft).

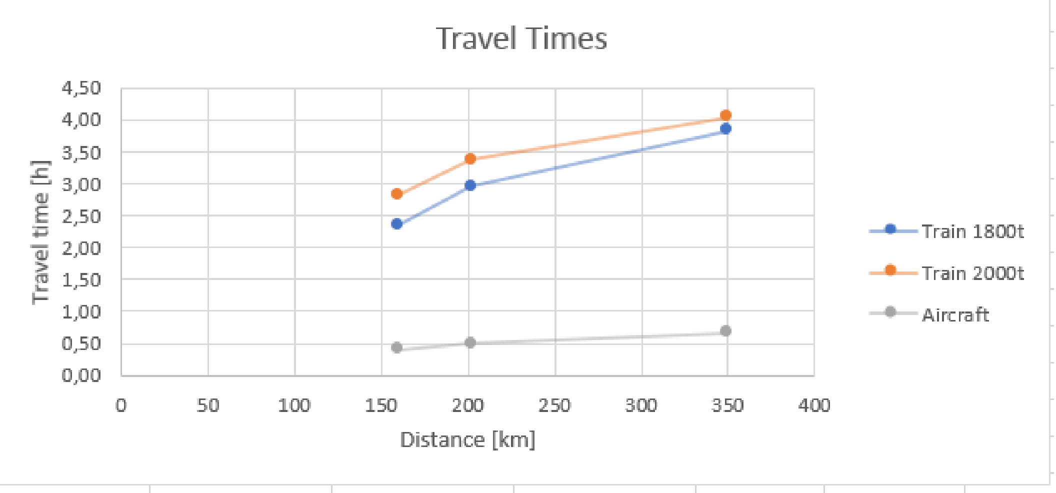

Figure 7.9: Comparison travel times freight train and aircraft

Route Length (km)	Route	Type of ground
160	Ventimiglia-Genova	Coastal line
202	Genova-Tortona	Mountain
350	Tortona-San Giorgio	Flatlands

Table 7.6: Distances used for comparison of travel times

CONCLUSIONS

Clearly, the air cargo volume has strongly linked to trade growth and its forecast is to grow 4.2 percent per year in the next twenty years. In terms of RTK growth, air freight, including express traffic, is projected to grow at a rate of 4.3 percent per year while airmail will grow at a slower pace averaging 2 percent anual growth through 2037.

The rapid development of connected technologies, including mobile devices in the past few decades has changed many aspects of consumers' lives, including their purchasing process. Consumers are often turning to e-commerce, which is online shopping, and that of course helps to increase the flow of air cargo. Overall, world air cargo traffic will be more than double in the next twenty years, expanding from 256 billion RTKs in 2017 to 584 billion RTKs in 2037, and Asia will continue to lead the world in average anual air cargo growth.

Future air cargo growth may, however, be constrained by the current international regulatory framework, so it is really important to liberalize the sector.

As seen in chapter 3.3, air freight is a significantly more expensive mode of carriage of goods than rail and maritime transport, and will be used when the speed of the delivery is an important factor.

The advantadges offered to the shippers through movement by air include speed, particularly over long distances, lower disk of damage than in train and ships, security, flexibility, accessibility to customers and good frequency for regular destinations. In addition, for integrators, the guaranteed delivery and the facility to track consigments gives customers additional advantadges.

Over shorter distances, air transport is not a good transport mode to carry freight, as the energy consumption is much higher than rail transport. As seen in the simulations, the specific energy comsumption for a distance of 300km, of a heavy aircraft (more than 70 tonnes of payload), is 6 times higher than a freight train of 2000 tonnes. But if the distance were longer, air transport would be a better option than rail transport.

In terms of time, definetly air freight transport is the fastest way to carry goods. As seen in Figure 7.9, which shows a comparison of travel times between freight train and freight aircraft, train is 6 times slower than aircraft (4h of travel time in train and 40min for aircraft) in the route Tortona-San Giorgio, that is 350km.

Talking about the cost, sea is the cheapest option and air has a very much higher cost than any other transport mode. As shown in Figure 3.10, sea/air transport cost are around half of air and rail transport costs even much less than air.

Finally, the emphasis on multimodal transport operations and on greater integration of transport with other logistical services will dominate freight developments in the next two decades. But that can be an issue for air cargo liberalization. Nearly all air cargo movements are inter-modal, since freight must move to and from airports via surface mode (usually truck). Infrastructure is needed to ease efficient freight movement through inter-modal terminals. This is especially so in the case of airports, since speed is the primary advantage of air cargo transportation. It is thus important to enhance cargo movement, facilitation, storage, and clearance facilities at all international airports to bring them with in line with international trade facilitation expectations, thereby encouraging trade growth by offering efficient cargo handling and processing facilities.

REFERENCES

[1] Chapman, Lee. "Transport and climate change: a review." *Journal of transport geography* 15.5 (2007): 354-367.

[2] Graham, Brian. *Geography and air transport*. John Wiley & Sons, 1995.

[3] Federici, M., S. Ulgiati, and Riccardo Basosi. "Air versus terrestrial transport modalities: An energy and environmental comparison." *Energy* 34.10 (2009): 1493-1503.

[4] Heinitz, Florian, Marcus Hirschberger, and Christian Werstat. "The role of road transport in scheduled air cargo networks." *Procedia-Social and Behavioral Sciences* 104 (2013): 1198-1207.

[5] Kupfer, Franziska, et al. "The origin–destination airport choice for all-cargo aircraft operations in Europe." *Transportation Research Part E: Logistics and Transportation Review* 87 (2016): 53-74.

[6] Bowen Jr, John T. "A spatial analysis of FedEx and UPS: hubs, spokes, and network structure." *Journal of Transport Geography* 24 (2012): 419-431.

[7] Morrell, Peter S. *Moving boxes by air: the economics of international air cargo*. Routledge, 2016.

[8] Feng, Bo, Yanzhi Li, and Zuo-Jun Max Shen. "Air cargo operations: Literature review and comparison with practices." *Transportation Research Part C: Emerging Technologies* 56 (2015): 263-280.

[10] Chao, Ching-Cheng. "Assessment of carbon emission costs for air cargo transportation." *Transportation Research Part D: Transport and Environment* 33 (2014): 186-195.

[11] Woxenius, Johan. "Generic framework for transport network designs: applications and treatment in intermodal freight transport literature." *Transport reviews* 27.6 (2007): 733-749.

[12] Zhang, Anming, and Yimin Zhang. "Issues on liberalization of air cargo services in international aviation." *Journal of Air Transport Management* 8.5 (2002): 275-287.

[13] Schramm, Hans-Joachim, and Sabrina Zhang. "Eurasian Rail Freight in the One Belt One Road Era." *30th Annual NOFOMA Conference: Relevant Logistics and Supply Chain Management Research*. Syddansk Universitet. Institut for Entreprenørskab og Relationsledelse, 2018.

[14] Rodrigue, Jean-Paul, Claude Comtois, and Brian Slack. *The geography of transport systems*. Routledge, 2016.

[15] Bofinger, Heinrich. "Freight Transport For Development Toolkit: Air Freight." *Department for International Development* (2009).

[16] Kiso, Fadila, and Abidin Deljanin. "Air Freight and Logistics Services." *Promet-Traffic&Transportation* 21.4 (2009): 291-298.

[17] Saghir, J., and B. Hoekman. "Air Freight: A Market Study with Implications for Landlocked Countries." *Washington, DC: The world bank group* (2009).

[18] Budd, Lucy, and Andrew R. Goetz. *The geographies of air transport*. Ashgate Publishing, Ltd., 2014.

[19] O'Kelly, Morton E. "Air freight hubs in the FedEx system: analysis of fuel use." *Journal of Air Transport Management* 36 (2014): 1-12.

[19] Allaz, Camille. *History of air cargo and airmail from the 18th century*. Google Consultant, 2005.

[20] Van de Voorde, Eddy, ed. *Critical issues in air transport economics and business*. Vol. 84. Routledge, 2010.
[24] Macário, Rosário, and Eddy Van de Voorde, eds. *Critical issues in air transport economics and business*. Routledge, 2010.

[25] Maynard, Mike and Clawson, Dave. *Guidebook for Air Cargo Facility Plannind and Development*. Sponsored by the Federal Aviation Administration. 2015

[26] Schramm, Hans-Joachim, and Sabrina Zhang. "Eurasian Rail Freight in the One Belt One Road Era." *The 30th NOFOMA Conference 2018*. Syddansk Universitet. Institut for Entreprenørskab og Relationsledelse, 2018.

[27] Dalla Chiara, Bruno, et al. "Comparative specific energy consumption between air transport and high-speed rail transport: A practical assessment." *Transportation Research Part D: Transport and Environment* 52 (2017): 227-243.

[28] Dalla Chiara, B., M. Pellicelli, and L. De Bonis. "The railway connections in the new Europe-Asia economic relationships/Le connessioni ferroviarie nelle nuove relazioni economiche Europa-Asia." *Ing. Ferrov* 67 (2012): 249-271.

[28] Federal Aviation Administration, and United States. Federal Aviation Administration. *Pilot's Handbook of Aeronautical Knowledge*. Skyhorse Publishing Inc., 2009.

[29] Tooley, Mike, et al. *Aerospace Engineering e-Mega Reference*. Butterworth-Heinemann, 2009.

[30] Sadraey, Mohammad H. *Aircraft design: A systems engineering approach*. John Wiley & Sons, 2012.

[20] The World Bank, 2019: Statistical data of air freight traffic between 1970 and 2017. Last accessed April, 2019. <https://data.worldbank.org/indicator/IS.AIR.GOOD.MT.K1?locations=US&name_desc=false>

[21] IATA: Annual Review 2018 report. Last accessed April, 2019. < https://www.iata.org/publications/Documents/iata-annual-review-2018.pdf>

[22] Boeing: World Air Cargo Forecast 2018-2037 report. Last accessed April, 2019. <http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/cargo-market-detail-wacf/download-report/assets/pdfs/2018_WACF.pdf>

[23] Airport Regions Conference (ARC): Air Cargo in Airports Regions report, 2016. Last accessed April, 2019. <https://airportregions.org/wp-content/uploads/Air-Cargo-in-Airport-Regions.pdf>

[28] ULDCARE: ULD types, 2019. Last accessed May, 2019. <https://www.uldcare.com/uld-tool-solutions/uld-types/#1471477848238-e095d776-30d6>

[30] World Class Shipping-New York, 2019: Air Cargo Capacities. Last accessed May, 2019. < http://www.worldclassshipping.com/aircraft.html>

[31] Century of Flight, 2019. “Airlines and Airliners”. Last accessed May, 2019. <http://www.century-of flight.net/new%20site/frames2/airliner%20profile_frame3.htm>

[32] Airports Council International (ACI). Airport Ranking by Cargo, 2017. Last accessed April, 2019. <https://aci.aero/news/2018/09/20/aci-world-publishes-annual-world-airport-traffic-report/>

[32] Boeing, 2010. Specifications of aircraft Boeing 747-400F. Last accessed June, 2019 <https://www.boeing.com/resources/boeingdotcom/company/about_bca/startup/pdf/freighters/747-400f.pdf>

[33] Fedex, 2019. History about FedEx. Last accessed June, 2019 <https://about.van.fedex.com/our-story/history-timeline/history/>

[34] UPS, 2019. History about UPS. Last accessed June, 2019 <https://www.ups.com/it/en/about/history.page>

[35] flightradar24, 2019. Information about fleet and routes of many airlines. Last accessed June, 2019 <https://www.flightradar24.com/data/airlines>

[36] Emirates SkyCargo, 2019. Air network of Emirates SkyCargo. Last accessed June, 2019
<https://www.skycargo.com/network/air/>

[37] Qatar Airways Cargo, 2019. Air network of Qatar Airways Cargo. Last accessed June, 2019
<http://www.qrcargo.com/qrcg>

[38] AirBridgeCargo, 2019. Air network of AirBridgeCargo. Last accessed June, 2019
<https://www.airbridgecargo.com/en/page/29/our-network>

[39] Lufthansa Cargo, 2019. Air network of Lufthansa Cargo. Last accessed June, 2019
<https://lufthansa-cargo.com/network/maps/stations>

[41] International Air Transport Association (IATA), 2010. Air freight statistics of 2009. Last accessed July, 2019.
<https://www.iata.org/pressroom/pr/Pages/2010-01-27-01.aspx>

[41] International Air Transport Association, IATA. Airline Liberalisation report. Last accessed June, 2019.
<https://www.iata.org/publications/economics/Reports/890000-airline-liberalisation-summary.pdf>

ANNEXES

Title: The international air cargo transport system: technological evolutions and perspectives in view of traffic trends, network management and energy issues.

Author: Inés Larrucea

Director: Bruno Dalla Chiara

Date: 31st of October 2019

ANNEX A. New Ideas for Freight Transportation

There are new ideas of rail transportation for freight, and may be up in the air.

Entrepreneurs and engineers have proposed a multistory flying tran that is pulled through the air by an electric-powered boom. Russian inventor Dahir Semenov says his flying train concept could carry up to 2000 passengers (or cargo) and travel at nearly twice the speed of China's Fuxing, the world's fastest bullet train. [41]

Figure 7.1: Draft of the flying train concept. Source: [41]

Another hybrid plane-train concept is being developed by AKKA Technologies, a European-based research and development company with operations worldwide. The company's Link & Fly concept features a tube-shaped passenger train that roll onto a runway, where it is attached to a pair of wings and then takes off to another airport. Upon landing, the wings are removed and the train continues to ground-based destinations. [41]

Figure 7.2: Akka's futuristic concept of hybid plane.train. Source: [41]

Meanwhile, in France, investors are funding development of a supersized blimp that can carry up to 60 tons of freight, and take off and land without requiring mooring pylons. The Flying Whale airship would be twice the size of a Boeing 747 jumbo jet with a rigid frame and pockets of helium for lift and small diesel or electric engines for power. The company plans to produce about 150 airships, with the first commercial flight slated for 2022.

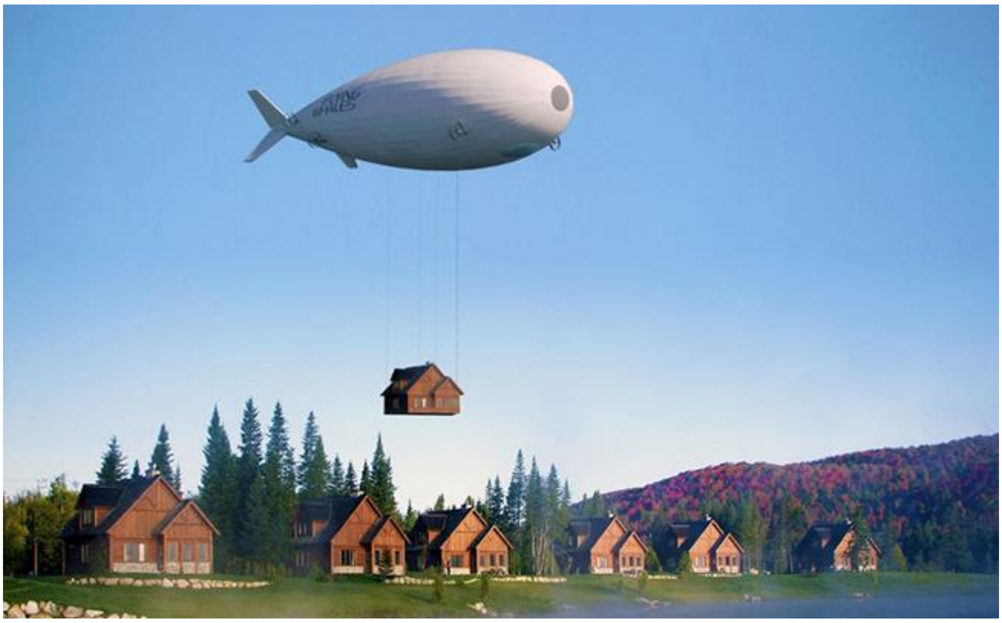

Figure 7.3: The Flying Whale airship concept. Source: [41]

And in China, researchers are working on super-high-speed trains and a version of Elon Musk's Hyperloop system that utilizes magnetic levitation to propel pods in tubes at speeds exceeding 600 mph.

ANNEX B. Route files from Flightradar

ALCIBZ - 150km

Timestamp	UTC	Callsign	Position	Altitude	Speed	Direction
1,57E+09	2019-08-16T05:17:44Z	VLG13NY	38.284687,-0.55741	0	0	271
1,57E+09	2019-08-16T05:20:49Z	VLG13NY	38.285122,-0.557512	0	23	329
1,57E+09	2019-08-16T05:20:57Z	VLG13NY	38.285282,-0.558004	0	26	286
1,57E+09	2019-08-16T05:21:04Z	VLG13NY	38.285339,-0.558467	0	28	281
1,57E+09	2019-08-16T05:21:13Z	VLG13NY	38.285458,-0.559168	0	31	281
1,57E+09	2019-08-16T05:21:25Z	VLG13NY	38.285412,-0.559974	0	28	247
1,57E+09	2019-08-16T05:21:35Z	VLG13NY	38.28495,-0.560215	0	26	191
1,57E+09	2019-08-16T05:21:42Z	VLG13NY	38.28463,-0.560288	0	29	191
1,57E+09	2019-08-16T05:21:58Z	VLG13NY	38.284424,-0.561515	0	15	281
1,57E+09	2019-08-16T05:22:36Z	VLG13NY	38.284851,-0.564617	0	32	281
1,57E+09	2019-08-16T05:22:48Z	VLG13NY	38.284992,-0.565602	0	15	281
1,57E+09	2019-08-16T05:22:56Z	VLG13NY	38.285099,-0.566366	0	16	281
1,57E+09	2019-08-16T05:23:07Z	VLG13NY	38.285259,-0.567534	0	18	281
1,57E+09	2019-08-16T05:23:20Z	VLG13NY	38.285477,-0.569039	0	20	281
1,57E+09	2019-08-16T05:23:35Z	VLG13NY	38.285763,-0.571011	0	23	281
1,57E+09	2019-08-16T05:23:43Z	VLG13NY	38.285923,-0.5722	0	24	281
1,57E+09	2019-08-16T05:25:54Z	VLG13NY	38.279526,-0.540609	600	166	101
1,57E+09	2019-08-16T05:26:06Z	VLG13NY	38.277786,-0.529272	1225	161	101
1,57E+09	2019-08-16T05:26:44Z	VLG13NY	38.277054,-0.486788	2075	220	68
1,57E+09	2019-08-16T05:26:54Z	VLG13NY	38.282776,-0.475042	2400	234	56
1,57E+09	2019-08-16T05:27:05Z	VLG13NY	38.289635,-0.462202	2800	249	55
1,57E+09	2019-08-16T05:27:11Z	VLG13NY	38.292801,-0.456291	3025	254	55
1,57E+09	2019-08-16T05:27:21Z	VLG13NY	38.299896,-0.442959	3550	262	55
1,57E+09	2019-08-16T05:27:31Z	VLG13NY	38.306854,-0.429986	3975	271	55
1,57E+09	2019-08-16T05:27:41Z	VLG13NY	38.314354,-0.415868	4500	280	55
1,57E+09	2019-08-16T05:27:52Z	VLG13NY	38.321384,-0.401897	5100	281	58
1,57E+09	2019-08-16T05:28:01Z	VLG13NY	38.327202,-0.386611	5600	286	65
1,57E+09	2019-08-16T05:28:11Z	VLG13NY	38.332321,-0.370729	6100	293	67
1,57E+09	2019-08-16T05:28:31Z	VLG13NY	38.342377,-0.338881	7250	296	67
1,57E+09	2019-08-16T05:28:42Z	VLG13NY	38.347961,-0.32135	7850	298	67
1,57E+09	2019-08-16T05:28:58Z	VLG13NY	38.35574,-0.296989	8775	296	68
1,57E+09	2019-08-16T05:29:12Z	VLG13NY	38.363617,-0.272087	9650	297	67
1,57E+09	2019-08-16T05:29:23Z	VLG13NY	38.36924,-0.255134	10175	299	67
1,57E+09	2019-08-16T05:29:38Z	VLG13NY	38.377617,-0.230414	10700	310	66
1,57E+09	2019-08-16T05:29:53Z	VLG13NY	38.386505,-0.204299	11000	328	66
1,57E+09	2019-08-16T05:30:09Z	VLG13NY	38.39621,-0.175255	11275	353	67
1,57E+09	2019-08-16T05:30:19Z	VLG13NY	38.402897,-0.155182	11450	365	66
1,57E+09	2019-08-16T05:30:33Z	VLG13NY	38.413322,-0.123657	11800	379	67

1,57E+09	2019-08-16T05:30:49Z	VLG13NY	38.423126,-0.0941	11975	371	67
1,57E+09	2019-08-16T05:31:03Z	VLG13NY	38.432922,-0.064575	12025	365	67
1,57E+09	2019-08-16T05:31:39Z	VLG13NY	38.457001,0.00824	12000	368	67
1,57E+09	2019-08-16T05:32:10Z	VLG13NY	38.476681,0.069763	12000	370	67
1,57E+09	2019-08-16T05:32:46Z	VLG13NY	38.499214,0.140259	12000	370	67
1,57E+09	2019-08-16T05:33:15Z	VLG13NY	38.518951,0.202148	12000	370	67
1,57E+09	2019-08-16T05:33:51Z	VLG13NY	38.541946,0.273865	12025	369	67
1,57E+09	2019-08-16T05:34:25Z	VLG13NY	38.563873,0.342651	12000	371	67
1,57E+09	2019-08-16T05:34:47Z	VLG13NY	38.577885,0.38678	12000	372	67
1,57E+09	2019-08-16T05:35:46Z	VLG13NY	38.611961,0.508667	11700	361	74
1,57E+09	2019-08-16T05:35:59Z	VLG13NY	38.617317,0.532898	11350	356	74
1,57E+09	2019-08-16T05:36:10Z	VLG13NY	38.622803,0.557556	11050	353	74
1,57E+09	2019-08-16T05:36:22Z	VLG13NY	38.628117,0.581482	10875	344	74
1,57E+09	2019-08-16T05:36:34Z	VLG13NY	38.633286,0.604666	10700	335	74
1,57E+09	2019-08-16T05:36:47Z	VLG13NY	38.638275,0.627176	10550	328	74
1,57E+09	2019-08-16T05:36:58Z	VLG13NY	38.643219,0.649447	10400	318	74
1,57E+09	2019-08-16T05:37:11Z	VLG13NY	38.647945,0.670959	10250	311	74
1,57E+09	2019-08-16T05:37:23Z	VLG13NY	38.652462,0.691772	10125	303	74
1,57E+09	2019-08-16T05:37:35Z	VLG13NY	38.656998,0.712678	9975	297	74
1,57E+09	2019-08-16T05:37:46Z	VLG13NY	38.661438,0.732919	9775	293	74
1,57E+09	2019-08-16T05:37:59Z	VLG13NY	38.665695,0.752623	9575	290	74
1,57E+09	2019-08-16T05:38:11Z	VLG13NY	38.670013,0.772278	9275	288	74
1,57E+09	2019-08-16T05:38:23Z	VLG13NY	38.67448,0.792786	8950	290	74
1,57E+09	2019-08-16T05:38:35Z	VLG13NY	38.678951,0.812988	8625	291	74
1,57E+09	2019-08-16T05:38:47Z	VLG13NY	38.683281,0.832825	8300	292	74
1,57E+09	2019-08-16T05:38:59Z	VLG13NY	38.687565,0.852722	7975	293	74
1,57E+09	2019-08-16T05:39:12Z	VLG13NY	38.692062,0.873294	7700	292	74
1,57E+09	2019-08-16T05:39:24Z	VLG13NY	38.696362,0.892944	7425	291	74
1,57E+09	2019-08-16T05:39:36Z	VLG13NY	38.700851,0.913716	7175	289	74
1,57E+09	2019-08-16T05:39:51Z	VLG13NY	38.706116,0.938077	6875	286	74
1,57E+09	2019-08-16T05:40:05Z	VLG13NY	38.710281,0.957397	6600	285	74
1,57E+09	2019-08-16T05:40:15Z	VLG13NY	38.714146,0.976257	6450	273	76
1,57E+09	2019-08-16T05:40:27Z	VLG13NY	38.717869,0.995178	6275	263	74
1,57E+09	2019-08-16T05:40:38Z	VLG13NY	38.722755,1.01178	6000	257	67
1,57E+09	2019-08-16T05:40:47Z	VLG13NY	38.726063,1.020874	5825	256	65
1,57E+09	2019-08-16T05:40:55Z	VLG13NY	38.730881,1.032894	5550	255	62
1,57E+09	2019-08-16T05:41:13Z	VLG13NY	38.740913,1.056641	5075	251	61
1,57E+09	2019-08-16T05:41:25Z	VLG13NY	38.74757,1.072449	4750	247	61
1,57E+09	2019-08-16T05:41:32Z	VLG13NY	38.750702,1.079944	4600	246	61
1,57E+09	2019-08-16T05:41:44Z	VLG13NY	38.757385,1.095886	4275	243	61
1,57E+09	2019-08-16T05:41:55Z	VLG13NY	38.763584,1.110657	4000	242	61
1,57E+09	2019-08-16T05:42:07Z	VLG13NY	38.769974,1.126039	3675	244	61
1,57E+09	2019-08-16T05:42:13Z	VLG13NY	38.773407,1.134338	3525	245	62
1,57E+09	2019-08-16T05:42:19Z	VLG13NY	38.776478,1.141602	3400	244	61
1,57E+09	2019-08-16T05:42:26Z	VLG13NY	38.779736,1.149475	3325	236	61
1,57E+09	2019-08-16T05:42:38Z	VLG13NY	38.785858,1.164193	3125	221	61

1,57E+09	2019-08-16T05:42:44Z	VLG13NY	38.788742,1.17094	3025	216	61
1,57E+09	2019-08-16T05:42:54Z	VLG13NY	38.794262,1.184265	2800	209	62
1,57E+09	2019-08-16T05:43:00Z	VLG13NY	38.796936,1.190703	2725	204	61
1,57E+09	2019-08-16T05:43:08Z	VLG13NY	38.799522,1.196899	2600	198	61
1,57E+09	2019-08-16T05:43:20Z	VLG13NY	38.804688,1.209229	2375	191	61
1,57E+09	2019-08-16T05:43:33Z	VLG13NY	38.80957,1.220915	2150	183	62
1,57E+09	2019-08-16T05:43:40Z	VLG13NY	38.811905,1.226468	2075	178	62
1,57E+09	2019-08-16T05:43:50Z	VLG13NY	38.816391,1.237275	1950	166	62
1,57E+09	2019-08-16T05:43:56Z	VLG13NY	38.818588,1.24253	1850	162	62
1,57E+09	2019-08-16T05:44:02Z	VLG13NY	38.820602,1.247366	1750	157	62
1,57E+09	2019-08-16T05:44:14Z	VLG13NY	38.824402,1.256502	1600	146	61
1,57E+09	2019-08-16T05:44:36Z	VLG13NY	38.831223,1.272921	1325	134	62
1,57E+09	2019-08-16T05:44:46Z	VLG13NY	38.83411,1.279846	1225	133	62
1,57E+09	2019-08-16T05:45:14Z	VLG13NY	38.842117,1.299011	900	133	62
1,57E+09	2019-08-16T05:45:26Z	VLG13NY	38.845596,1.307492	750	131	62
1,57E+09	2019-08-16T05:45:38Z	VLG13NY	38.848911,1.31543	625	131	61
1,57E+09	2019-08-16T05:45:44Z	VLG13NY	38.850727,1.319946	550	130	62
1,57E+09	2019-08-16T05:45:50Z	VLG13NY	38.85228,1.323673	500	130	61
1,57E+09	2019-08-16T05:46:01Z	VLG13NY	38.855713,1.331854	375	131	61
1,57E+09	2019-08-16T05:46:07Z	VLG13NY	38.857246,1.33551	300	132	62

VLCIBZ - 200km

Timestamp	UTC	Callsign	Position	Altitude	Speed	Direction
1,57E+09	2019-08-16T09:11:42Z	RYR7216	39.489864,-0.474233	0	13	30
1,57E+09	2019-08-16T09:15:15Z	RYR7216	39.489349,-0.474606	0	0	210
1,57E+09	2019-08-16T09:16:15Z	RYR7216	39.490585,-0.476368	0	33	292
1,57E+09	2019-08-16T09:16:25Z	RYR7216	39.490692,-0.47728	0	34	275
1,57E+09	2019-08-16T09:17:13Z	RYR7216	39.49165,-0.480377	0	24	295
1,57E+09	2019-08-16T09:17:25Z	RYR7216	39.491776,-0.48114	0	25	253
1,57E+09	2019-08-16T09:17:35Z	RYR7216	39.491451,-0.481598	0	24	239
1,57E+09	2019-08-16T09:18:27Z	RYR7216	39.493057,-0.486205	0	24	295
1,57E+09	2019-08-16T09:18:44Z	RYR7216	39.493973,-0.488593	0	27	295
1,57E+09	2019-08-16T09:18:50Z	RYR7216	39.494289,-0.489426	0	26	295
1,57E+09	2019-08-16T09:18:56Z	RYR7216	39.494617,-0.490295	0	24	295
1,57E+09	2019-08-16T09:19:16Z	RYR7216	39.495564,-0.492788	0	21	295
1,57E+09	2019-08-16T09:19:25Z	RYR7216	39.49593,-0.493668	0	19	295
1,57E+09	2019-08-16T09:19:55Z	RYR7216	39.497047,-0.496613	0	16	295
1,57E+09	2019-08-16T09:20:10Z	RYR7216	39.49752,-0.497833	0	34	295
1,57E+09	2019-08-16T09:20:17Z	RYR7216	39.497746,-0.498413	0	32	295
1,57E+09	2019-08-16T09:20:24Z	RYR7216	39.497932,-0.498932	0	31	295
1,57E+09	2019-08-16T09:20:31Z	RYR7216	39.498013,-0.499374	0	29	267
1,57E+09	2019-08-16T09:20:41Z	RYR7216	39.497677,-0.499725	0	26	208
1,57E+09	2019-08-16T09:20:49Z	RYR7216	39.497246,-0.5	0	25	205
1,57E+09	2019-08-16T09:20:57Z	RYR7216	39.496902,-0.500236	0	25	208

1,57E+09	2019-08-16T09:21:04Z	RYR7216	39.496651,-0.500415	0	21	208
1,57E+09	2019-08-16T09:21:14Z	RYR7216	39.496445,-0.5004	0	12	149
1,57E+09	2019-08-16T09:22:42Z	RYR7216	39.496292,-0.499908	0	18	115
1,57E+09	2019-08-16T09:22:49Z	RYR7216	39.495781,-0.498581	0	48	118
1,57E+09	2019-08-16T09:23:18Z	RYR7216	39.488449,-0.47937	100	163	116
1,57E+09	2019-08-16T09:23:25Z	RYR7216	39.486511,-0.474263	325	166	116
1,57E+09	2019-08-16T09:23:31Z	RYR7216	39.484451,-0.46883	575	165	116
1,57E+09	2019-08-16T09:23:37Z	RYR7216	39.482483,-0.463635	850	165	116
1,57E+09	2019-08-16T09:23:43Z	RYR7216	39.480534,-0.458435	1125	162	115
1,57E+09	2019-08-16T09:23:50Z	RYR7216	39.478439,-0.453064	1400	163	116
1,57E+09	2019-08-16T09:24:02Z	RYR7216	39.474064,-0.442078	1725	175	116
1,57E+09	2019-08-16T09:24:11Z	RYR7216	39.469921,-0.433838	1850	190	128
1,57E+09	2019-08-16T09:24:18Z	RYR7216	39.465775,-0.429303	1950	198	144
1,57E+09	2019-08-16T09:24:25Z	RYR7216	39.458561,-0.424072	2150	205	151
1,57E+09	2019-08-16T09:24:32Z	RYR7216	39.4533,-0.419861	2250	214	147
1,57E+09	2019-08-16T09:24:40Z	RYR7216	39.447052,-0.411987	2425	223	127
1,57E+09	2019-08-16T09:24:46Z	RYR7216	39.443573,-0.404602	2700	223	119
1,57E+09	2019-08-16T09:24:52Z	RYR7216	39.440685,-0.39801	2975	225	120
1,57E+09	2019-08-16T09:24:58Z	RYR7216	39.437054,-0.390625	3350	225	122
1,57E+09	2019-08-16T09:25:06Z	RYR7216	39.432678,-0.382253	3775	226	124
1,57E+09	2019-08-16T09:25:14Z	RYR7216	39.428879,-0.375147	4000	234	124
1,57E+09	2019-08-16T09:25:25Z	RYR7216	39.420109,-0.359253	4275	261	125
1,57E+09	2019-08-16T09:25:32Z	RYR7216	39.415501,-0.35083	4525	269	125
1,57E+09	2019-08-16T09:25:43Z	RYR7216	39.406982,-0.335022	5075	276	124
1,57E+09	2019-08-16T09:25:53Z	RYR7216	39.399719,-0.320618	5600	281	121
1,57E+09	2019-08-16T09:26:09Z	RYR7216	39.39106,-0.299988	6200	291	117
1,57E+09	2019-08-16T09:26:19Z	RYR7216	39.383751,-0.281799	6825	294	117
1,57E+09	2019-08-16T09:26:31Z	RYR7216	39.375839,-0.26239	7500	297	117
1,57E+09	2019-08-16T09:26:44Z	RYR7216	39.368015,-0.243347	8175	298	117
1,57E+09	2019-08-16T09:26:57Z	RYR7216	39.360123,-0.224026	8850	299	117
1,57E+09	2019-08-16T09:27:08Z	RYR7216	39.352421,-0.2052	9525	301	117
1,57E+09	2019-08-16T09:27:20Z	RYR7216	39.344555,-0.185974	10175	303	117
1,57E+09	2019-08-16T09:27:32Z	RYR7216	39.336411,-0.166228	10625	314	117
1,57E+09	2019-08-16T09:27:44Z	RYR7216	39.328217,-0.146226	10825	331	118
1,57E+09	2019-08-16T09:27:55Z	RYR7216	39.319183,-0.124573	11100	350	118
1,57E+09	2019-08-16T09:28:07Z	RYR7216	39.309723,-0.101743	11625	356	118
1,57E+09	2019-08-16T09:28:19Z	RYR7216	39.300423,-0.079285	12250	359	118
1,57E+09	2019-08-16T09:28:53Z	RYR7216	39.274475,-0.016897	14175	353	118
1,57E+09	2019-08-16T09:29:27Z	RYR7216	39.248936,0.044312	15100	365	118
1,57E+09	2019-08-16T09:30:00Z	RYR7216	39.221741,0.109147	15650	374	118
1,57E+09	2019-08-16T09:30:32Z	RYR7216	39.194283,0.174744	15975	370	118
1,57E+09	2019-08-16T09:31:02Z	RYR7216	39.170746,0.230892	16000	355	118
1,57E+09	2019-08-16T09:31:34Z	RYR7216	39.144745,0.29269	16000	352	118
1,57E+09	2019-08-16T09:32:08Z	RYR7216	39.119202,0.353473	16000	350	118
1,57E+09	2019-08-16T09:32:40Z	RYR7216	39.09407,0.412943	15825	350	118
1,57E+09	2019-08-16T09:33:14Z	RYR7216	39.068024,0.476174	14125	372	114

1,57E+09	2019-08-16T09:33:26Z	RYR7216	39.060745,0.500774	13650	372	108
1,57E+09	2019-08-16T09:33:33Z	RYR7216	39.057587,0.51373	13325	373	107
1,57E+09	2019-08-16T09:33:56Z	RYR7216	39.040466,0.564482	11825	387	118
1,57E+09	2019-08-16T09:34:02Z	RYR7216	39.035843,0.574991	11475	389	119
1,57E+09	2019-08-16T09:34:08Z	RYR7216	39.030533,0.586992	11075	394	119
1,57E+09	2019-08-16T09:34:21Z	RYR7216	39.018829,0.613647	10375	399	119
1,57E+09	2019-08-16T09:34:31Z	RYR7216	39.009007,0.636108	10100	392	119
1,57E+09	2019-08-16T09:34:44Z	RYR7216	38.998581,0.660135	9600	384	118
1,57E+09	2019-08-16T09:34:56Z	RYR7216	38.987591,0.685669	8975	378	118
1,57E+09	2019-08-16T09:35:11Z	RYR7216	38.974915,0.714768	8175	374	119
1,57E+09	2019-08-16T09:35:22Z	RYR7216	38.964737,0.737915	7575	375	119
1,57E+09	2019-08-16T09:35:35Z	RYR7216	38.954029,0.761597	7300	368	120
1,57E+09	2019-08-16T09:36:03Z	RYR7216	38.931358,0.811768	7025	340	120
1,57E+09	2019-08-16T09:36:15Z	RYR7216	38.922699,0.831177	6925	330	119
1,57E+09	2019-08-16T09:36:29Z	RYR7216	38.913208,0.852575	6800	320	119
1,57E+09	2019-08-16T09:36:39Z	RYR7216	38.904823,0.871704	6675	311	119
1,57E+09	2019-08-16T09:36:51Z	RYR7216	38.896488,0.890808	6450	305	119
1,57E+09	2019-08-16T09:37:04Z	RYR7216	38.888168,0.909835	6250	301	119
1,57E+09	2019-08-16T09:37:16Z	RYR7216	38.879963,0.928711	5950	297	119
1,57E+09	2019-08-16T09:37:27Z	RYR7216	38.873703,0.943152	5725	294	118
1,57E+09	2019-08-16T09:37:42Z	RYR7216	38.862507,0.96875	5400	290	119
1,57E+09	2019-08-16T09:37:54Z	RYR7216	38.854874,0.986206	5300	272	119
1,57E+09	2019-08-16T09:38:06Z	RYR7216	38.847565,1.002383	5200	265	120
1,57E+09	2019-08-16T09:38:18Z	RYR7216	38.839882,1.019165	5100	258	120
1,57E+09	2019-08-16T09:38:30Z	RYR7216	38.833179,1.033936	5000	251	120
1,57E+09	2019-08-16T09:38:43Z	RYR7216	38.826057,1.049805	4900	245	119
1,57E+09	2019-08-16T09:38:49Z	RYR7216	38.822563,1.057678	4825	242	119
1,57E+09	2019-08-16T09:38:56Z	RYR7216	38.818562,1.066711	4675	242	119
1,57E+09	2019-08-16T09:39:31Z	RYR7216	38.799614,1.10968	4075	240	119
1,57E+09	2019-08-16T09:39:37Z	RYR7216	38.796215,1.11731	4000	236	119
1,57E+09	2019-08-16T09:39:49Z	RYR7216	38.789749,1.132129	3700	234	118
1,57E+09	2019-08-16T09:39:55Z	RYR7216	38.786953,1.139221	3550	233	116
1,57E+09	2019-08-16T09:40:04Z	RYR7216	38.784668,1.151833	3325	232	100
1,57E+09	2019-08-16T09:40:23Z	RYR7216	38.790024,1.174316	2975	228	62
1,57E+09	2019-08-16T09:40:37Z	RYR7216	38.798035,1.192435	2600	221	61
1,57E+09	2019-08-16T09:40:45Z	RYR7216	38.801559,1.200973	2475	217	62
1,57E+09	2019-08-16T09:40:58Z	RYR7216	38.807419,1.215482	2250	207	62

ALCPMI - 300km

Timestamp	UTC	Callsign	Position	Altitude	Speed	Direction
1,57E+09	2019-08-16T06:56:50Z	AEA4025	38.357788,-0.286898	6575	177	68
1,57E+09	2019-08-16T06:58:48Z	AEA4025	38.391346,-0.187096	8400	174	63
1,57E+09	2019-08-16T06:59:02Z	AEA4025	38.391853,-0.184379	8599	144	193
1,57E+09	2019-08-16T06:59:30Z	AEA4025	38.405613,-0.172659	9025	225	84

1,57E+09	2019-08-16T06:59:43Z	AEA4025	38.411598,-0.145252	9275	228	74
1,57E+09	2019-08-16T06:59:54Z	AEA4025	38.415085,-0.129702	9412	246	75
1,57E+09	2019-08-16T07:00:03Z	AEA4025	38.425278,-0.120378	9500	283	17
1,57E+09	2019-08-16T07:00:17Z	AEA4025	38.426491,-0.109905	9605	253	72
1,57E+09	2019-08-16T07:00:32Z	AEA4025	38.429749,-0.089732	9817	229	80
1,57E+09	2019-08-16T07:00:44Z	AEA4025	38.433277,-0.07038	10050	212	76
1,57E+09	2019-08-16T07:00:54Z	AEA4025	38.434864,-0.062299	10124	207	75
1,57E+09	2019-08-16T07:01:08Z	AEA4025	38.438145,-0.048678	10274	204	72
1,57E+09	2019-08-16T07:01:24Z	AEA4025	38.442207,-0.034034	10400	204	72
1,57E+09	2019-08-16T07:01:39Z	AEA4025	38.451534,-0.006735	10700	206	58
1,57E+09	2019-08-16T07:01:48Z	AEA4025	38.453941,0.001324	10814	203	66
1,57E+09	2019-08-16T07:02:04Z	AEA4025	38.459351,0.019906	11045	204	69
1,57E+09	2019-08-16T07:02:19Z	AEA4025	38.464527,0.036187	11250	201	67
1,57E+09	2019-08-16T07:02:28Z	AEA4025	38.467781,0.046533	11375	200	67
1,57E+09	2019-08-16T07:02:44Z	AEA4025	38.473103,0.063716	11598	204	67
1,57E+09	2019-08-16T07:02:56Z	AEA4025	38.477188,0.07789	11727	211	68
1,57E+09	2019-08-16T07:03:02Z	AEA4025	38.482399,0.087444	11854	218	58
1,57E+09	2019-08-16T07:03:10Z	AEA4025	38.502132,0.091166	12000	334	20
1,57E+09	2019-08-16T07:03:31Z	AEA4025	38.501633,0.113116	12250	234	88
1,57E+09	2019-08-16T07:03:39Z	AEA4025	38.502178,0.124059	12324	224	86
1,57E+09	2019-08-16T07:04:10Z	AEA4025	38.507885,0.163226	12718	210	77
1,57E+09	2019-08-16T07:04:46Z	AEA4025	38.518841,0.203601	13091	201	67
1,57E+09	2019-08-16T07:05:20Z	AEA4025	38.530365,0.240828	13425	212	67
1,57E+09	2019-08-16T07:05:50Z	AEA4025	38.542507,0.279152	13786	214	67
1,57E+09	2019-08-16T07:06:26Z	AEA4025	38.555481,0.324466	14150	213	65
1,57E+09	2019-08-16T07:06:36Z	AEA4025	38.558758,0.333698	14228	211	65
1,57E+09	2019-08-16T07:07:06Z	AEA4025	38.572197,0.369166	14456	212	63
1,57E+09	2019-08-16T07:07:38Z	AEA4025	38.584545,0.407676	14699	217	68
1,57E+09	2019-08-16T07:08:10Z	AEA4025	38.596821,0.447043	15000	218	67
1,57E+09	2019-08-16T07:08:44Z	AEA4025	38.609386,0.486174	15337	218	64
1,57E+09	2019-08-16T07:09:19Z	AEA4025	38.622303,0.525748	15600	224	66
1,57E+09	2019-08-16T07:09:56Z	AEA4025	38.637146,0.571798	15975	228	67
1,57E+09	2019-08-16T07:10:28Z	AEA4025	38.650143,0.619978	16050	247	74
1,57E+09	2019-08-16T07:11:00Z	AEA4025	38.658123,0.646125	16049	247	74
1,57E+09	2019-08-16T07:11:40Z	AEA4025	38.672508,0.69405	16050	247	74
1,57E+09	2019-08-16T07:12:11Z	AEA4025	38.68354,0.764556	16049	247	74
1,57E+09	2019-08-16T07:12:44Z	AEA4025	38.68795,0.815848	16050	272	84
1,57E+09	2019-08-16T07:13:16Z	AEA4025	38.692474,0.866631	16049	271	82
1,57E+09	2019-08-16T07:13:48Z	AEA4025	38.694679,0.917105	16050	290	83
1,57E+09	2019-08-16T07:14:24Z	AEA4025	38.698353,0.955265	16050	282	82
1,57E+09	2019-08-16T07:15:02Z	AEA4025	38.708176,1.046191	16050	277	81
1,57E+09	2019-08-16T07:15:36Z	AEA4025	38.712898,1.088882	16049	266	80
1,57E+09	2019-08-16T07:16:07Z	AEA4025	38.719669,1.144465	16050	267	79
1,57E+09	2019-08-16T07:16:38Z	AEA4025	38.725727,1.193073	16050	261	79
1,57E+09	2019-08-16T07:17:20Z	AEA4025	38.731251,1.243827	16050	272	81
1,57E+09	2019-08-16T07:17:50Z	AEA4025	38.737919,1.307891	16049	271	82

1,57E+09	2019-08-16T07:18:32Z	AEA4025	38.743713,1.360111	16050	270	81
1,57E+09	2019-08-16T07:19:08Z	AEA4025	38.750504,1.432547	16050	274	81
1,57E+09	2019-08-16T07:19:42Z	AEA4025	38.757286,1.490321	16050	272	82
1,57E+09	2019-08-16T07:20:14Z	AEA4025	38.762142,1.541739	16050	272	82
1,57E+09	2019-08-16T07:20:48Z	AEA4025	38.7654,1.590434	16050	281	81
1,57E+09	2019-08-16T07:21:16Z	AEA4025	38.771275,1.639754	16050	267	80
1,57E+09	2019-08-16T07:21:51Z	AEA4025	38.778332,1.695427	16050	264	80
1,57E+09	2019-08-16T07:22:23Z	AEA4025	38.783421,1.745047	16049	268	81
1,57E+09	2019-08-16T07:22:54Z	AEA4025	38.788925,1.79669	16050	268	81
1,57E+09	2019-08-16T07:23:27Z	AEA4025	38.793335,1.848295	16050	272	85
1,57E+09	2019-08-16T07:24:00Z	AEA4025	38.797684,1.899016	16050	278	85
1,57E+09	2019-08-16T07:24:27Z	AEA4025	38.805832,1.943995	16024	268	70
1,57E+09	2019-08-16T07:24:34Z	AEA4025	38.810181,1.9544	16024	264	67
1,57E+09	2019-08-16T07:24:44Z	AEA4025	38.81517,1.964567	16042	262	61
1,57E+09	2019-08-16T07:24:51Z	AEA4025	38.82148,1.97545	16050	261	57
1,57E+09	2019-08-16T07:24:58Z	AEA4025	38.82658,1.985548	16049	272	57
1,57E+09	2019-08-16T07:25:26Z	AEA4025	38.849697,2.021305	16049	271	42
1,57E+09	2019-08-16T07:25:38Z	AEA4025	38.859989,2.036575	16050	271	42
1,57E+09	2019-08-16T07:25:46Z	AEA4025	38.86718,2.043625	16050	270	38
1,57E+09	2019-08-16T07:26:23Z	AEA4025	38.897366,2.083791	16050	264	46
1,57E+09	2019-08-16T07:26:54Z	AEA4025	38.924107,2.122959	16050	260	47
1,57E+09	2019-08-16T07:27:27Z	AEA4025	38.947693,2.162414	16049	264	51
1,57E+09	2019-08-16T07:28:00Z	AEA4025	38.970642,2.200384	16050	260	52
1,57E+09	2019-08-16T07:28:19Z	AEA4025	39.000214,2.221251	16049	401	19
1,57E+09	2019-08-16T07:28:47Z	AEA4025	39.013676,2.254356	16050	340	52
1,57E+09	2019-08-16T07:29:27Z	AEA4025	39.038651,2.312058	16050	265	59
1,57E+09	2019-08-16T07:30:00Z	AEA4025	39.059933,2.351386	16050	260	53
1,57E+09	2019-08-16T07:30:34Z	AEA4025	39.086494,2.39766	15775	266	50
1,57E+09	2019-08-16T07:31:04Z	AEA4025	39.108124,2.434877	15450	267	53
1,57E+09	2019-08-16T07:31:38Z	AEA4025	39.138676,2.481501	15038	289	46
1,57E+09	2019-08-16T07:31:54Z	AEA4025	39.154835,2.499791	14867	293	40
1,57E+09	2019-08-16T07:32:00Z	AEA4025	39.160252,2.505645	14800	293	40
1,57E+09	2019-08-16T07:32:10Z	AEA4025	39.172897,2.517287	14665	294	35
1,57E+09	2019-08-16T07:32:50Z	AEA4025	39.214848,2.551325	14249	301	31
1,57E+09	2019-08-16T07:33:26Z	AEA4025	39.262737,2.591045	13638	303	32
1,57E+09	2019-08-16T07:33:54Z	AEA4025	39.295265,2.620832	13156	303	34
1,57E+09	2019-08-16T07:34:28Z	AEA4025	39.358185,2.676455	12624	229	41
1,57E+09	2019-08-16T07:34:39Z	AEA4025	39.384716,2.674418	12437	189	84
1,57E+09	2019-08-16T07:34:46Z	AEA4025	39.385719,2.68141	12300	169	80
1,57E+09	2019-08-16T07:34:52Z	AEA4025	39.386143,2.684597	12230	169	80
1,57E+09	2019-08-16T07:35:04Z	AEA4025	39.388016,2.69488	12027	158	72
1,57E+09	2019-08-16T07:35:11Z	AEA4025	39.390495,2.701605	11899	162	66
1,57E+09	2019-08-16T07:35:18Z	AEA4025	39.394764,2.709563	11770	177	57
1,57E+09	2019-08-16T07:35:30Z	AEA4025	39.402508,2.72199	11566	190	52
1,57E+09	2019-08-16T07:35:36Z	AEA4025	39.4053,2.726095	11502	202	49
1,57E+09	2019-08-16T07:35:44Z	AEA4025	39.411907,2.734247	11352	217	44

1,57E+09	2019-08-16T07:35:50Z	AEA4025	39.41795,2.742329	11227	226	44
1,57E+09	2019-08-16T07:35:58Z	AEA4025	39.424934,2.750513	11091	239	42
1,57E+09	2019-08-16T07:36:11Z	AEA4025	39.436657,2.764935	10876	251	42
1,57E+09	2019-08-16T07:36:23Z	AEA4025	39.446835,2.780541	10630	271	48
1,57E+09	2019-08-16T07:36:31Z	AEA4025	39.452835,2.791786	10434	278	53
1,57E+09	2019-08-16T07:36:39Z	AEA4025	39.457939,2.803214	10250	282	57
1,57E+09	2019-08-16T07:36:46Z	AEA4025	39.463081,2.81651	10034	285	61
1,57E+09	2019-08-16T07:36:54Z	AEA4025	39.465073,2.822068	9953	285	61
1,57E+09	2019-08-16T07:37:04Z	AEA4025	39.472263,2.841482	9646	294	64
1,57E+09	2019-08-16T07:37:15Z	AEA4025	39.478916,2.861718	9311	292	65
1,57E+09	2019-08-16T07:37:27Z	AEA4025	39.484543,2.8799	9031	290	67
1,57E+09	2019-08-16T07:37:39Z	AEA4025	39.491787,2.898679	8738	290	63
1,57E+09	2019-08-16T07:37:50Z	AEA4025	39.498383,2.917338	8441	290	64
1,57E+09	2019-08-16T07:38:07Z	AEA4025	39.507954,2.941058	8050	286	60
1,57E+09	2019-08-16T07:38:21Z	AEA4025	39.51321,2.952304	7850	283	58
1,57E+09	2019-08-16T07:38:42Z	AEA4025	39.523788,2.974815	7450	272	56
1,57E+09	2019-08-16T07:39:08Z	AEA4025	39.532761,3.007719	6924	272	56
1,57E+09	2019-08-16T07:39:56Z	AEA4025	39.547401,3.03576	6400	272	56
1,57E+09	2019-08-16T07:40:22Z	AEA4025	39.595722,3.112731	5850	272	56
1,57E+09	2019-08-16T07:40:32Z	AEA4025	39.600021,3.116689	5849	227	40
1,57E+09	2019-08-16T07:40:42Z	AEA4025	39.604809,3.123901	5875	212	46
1,57E+09	2019-08-16T07:41:17Z	AEA4025	39.62336,3.156012	5875	198	52
1,57E+09	2019-08-16T07:41:34Z	AEA4025	39.635448,3.178415	5874	198	54
1,57E+09	2019-08-16T07:41:59Z	AEA4025	39.63702,3.181617	5875	198	54
1,57E+09	2019-08-16T07:42:10Z	AEA4025	39.651455,3.206293	5675	198	54
1,57E+09	2019-08-16T07:42:22Z	AEA4025	39.666473,3.214545	5250	198	281
1,57E+09	2019-08-16T07:42:35Z	AEA4025	39.676888,3.213544	4925	190	71
1,57E+09	2019-08-16T07:46:16Z	AEA4025	39.68359,3.211251	4740	190	275
1,57E+09	2019-08-16T07:47:19Z	AEA4025	39.661648,2.973652	2875	190	275
1,57E+09	2019-08-16T07:47:40Z	AEA4025	39.641743,2.913657	2175	190	275

TRNAMS - 800km

Timestamp	UTC	Callsign	Position	Altitude	Speed	Direction
1,57E+09	2019-08-14T04:26:49Z	KLM20R	45.193325,7.645814	0	9	258
1,57E+09	2019-08-14T04:27:08Z	KLM20R	45.193356,7.646132	0	9	264
1,57E+09	2019-08-14T04:27:29Z	KLM20R	45.193405,7.646468	0	9	247
1,57E+09	2019-08-14T04:27:49Z	KLM20R	45.19352,7.646697	0	2	213
1,57E+09	2019-08-14T04:28:13Z	KLM20R	45.193726,7.646752	0	2	182
1,57E+09	2019-08-14T04:30:31Z	KLM20R	45.193405,7.646746	0	19	182
1,57E+09	2019-08-14T04:30:45Z	KLM20R	45.192703,7.646685	0	30	182
1,57E+09	2019-08-14T04:30:56Z	KLM20R	45.191895,7.646632	0	16	182
1,57E+09	2019-08-14T04:31:11Z	KLM20R	45.19062,7.646551	0	19	182
1,57E+09	2019-08-14T04:31:21Z	KLM20R	45.189812,7.646501	0	20	182
1,57E+09	2019-08-14T04:31:29Z	KLM20R	45.188946,7.646451	0	20	182

1,57E+09	2019-08-14T04:31:42Z	KLM20R	45.18782,7.646386	0	18	182
1,57E+09	2019-08-14T04:31:52Z	KLM20R	45.187023,7.646334	0	32	182
1,57E+09	2019-08-14T04:32:02Z	KLM20R	45.186493,7.646501	0	26	146
1,57E+09	2019-08-14T04:32:13Z	KLM20R	45.186195,7.647155	0	31	106
1,57E+09	2019-08-14T04:32:23Z	KLM20R	45.18623,7.648037	0	30	75
1,57E+09	2019-08-14T04:32:32Z	KLM20R	45.186401,7.648643	0	17	59
1,57E+09	2019-08-14T04:32:58Z	KLM20R	45.186859,7.648757	0	23	2
1,57E+09	2019-08-14T04:33:04Z	KLM20R	45.187981,7.648839	0	54	2
1,57E+09	2019-08-14T04:33:17Z	KLM20R	45.193176,7.649166	925	110	2
1,57E+09	2019-08-14T04:33:28Z	KLM20R	45.199814,7.649623	950	147	2
1,57E+09	2019-08-14T04:33:39Z	KLM20R	45.207344,7.650102	1125	161	2
1,57E+09	2019-08-14T04:33:49Z	KLM20R	45.214828,7.650735	1600	157	3
1,57E+09	2019-08-14T04:33:57Z	KLM20R	45.220844,7.650973	1900	162	1
1,57E+09	2019-08-14T04:34:06Z	KLM20R	45.228104,7.650735	2175	170	358
1,57E+09	2019-08-14T04:34:34Z	KLM20R	45.252827,7.652178	2675	215	3
1,57E+09	2019-08-14T04:34:44Z	KLM20R	45.262711,7.65322	2950	224	7
1,57E+09	2019-08-14T04:34:54Z	KLM20R	45.272751,7.657537	3450	221	23
1,57E+09	2019-08-14T04:35:04Z	KLM20R	45.281128,7.666715	3975	220	49
1,57E+09	2019-08-14T04:35:14Z	KLM20R	45.285828,7.679116	4450	220	71
1,57E+09	2019-08-14T04:35:24Z	KLM20R	45.287155,7.693961	5025	221	92
1,57E+09	2019-08-14T04:35:33Z	KLM20R	45.285187,7.706582	5550	224	110
1,57E+09	2019-08-14T04:35:44Z	KLM20R	45.279007,7.719988	6025	230	132
1,57E+09	2019-08-14T04:35:55Z	KLM20R	45.270283,7.730222	6625	230	142
1,57E+09	2019-08-14T04:36:04Z	KLM20R	45.262482,7.738233	7125	232	144
1,57E+09	2019-08-14T04:36:10Z	KLM20R	45.257263,7.743596	7450	232	144
1,57E+09	2019-08-14T04:36:24Z	KLM20R	45.244583,7.756609	8200	237	142
1,57E+09	2019-08-14T04:36:40Z	KLM20R	45.230484,7.773416	8575	263	139
1,57E+09	2019-08-14T04:36:54Z	KLM20R	45.216476,7.790287	8950	282	139
1,57E+09	2019-08-14T04:37:10Z	KLM20R	45.201141,7.808794	9675	287	139
1,57E+09	2019-08-14T04:37:20Z	KLM20R	45.191006,7.824074	10200	293	128
1,57E+09	2019-08-14T04:37:30Z	KLM20R	45.18388,7.840554	10650	296	115
1,57E+09	2019-08-14T04:37:36Z	KLM20R	45.181366,7.849129	10900	296	110
1,57E+09	2019-08-14T04:37:45Z	KLM20R	45.177338,7.868173	11375	299	105
1,57E+09	2019-08-14T04:37:51Z	KLM20R	45.175503,7.8778	11625	300	104
1,57E+09	2019-08-14T04:38:10Z	KLM20R	45.168457,7.916303	12625	303	104
1,57E+09	2019-08-14T04:38:26Z	KLM20R	45.164703,7.946189	13175	307	90
1,57E+09	2019-08-14T04:38:36Z	KLM20R	45.166843,7.965758	13475	310	73
1,57E+09	2019-08-14T04:38:46Z	KLM20R	45.173126,7.984445	13650	315	57
1,57E+09	2019-08-14T04:39:03Z	KLM20R	45.191238,8.006287	14450	304	25
1,57E+09	2019-08-14T04:39:09Z	KLM20R	45.199524,8.01044	14850	298	15
1,57E+09	2019-08-14T04:39:33Z	KLM20R	45.230621,8.005013	16225	283	333
1,57E+09	2019-08-14T04:39:42Z	KLM20R	45.239838,7.995032	16675	281	316
1,57E+09	2019-08-14T04:39:48Z	KLM20R	45.244812,7.986276	16950	282	305
1,57E+09	2019-08-14T04:39:54Z	KLM20R	45.248749,7.976597	17200	285	298
1,57E+09	2019-08-14T04:40:00Z	KLM20R	45.251846,7.9675	17400	286	294
1,57E+09	2019-08-14T04:40:06Z	KLM20R	45.255524,7.956979	17650	288	298

1,57E+09	2019-08-14T04:40:12Z	KLM20R	45.260273,7.946398	17875	290	304
1,57E+09	2019-08-14T04:40:45Z	KLM20R	45.283997,7.888053	18325	330	297
1,57E+09	2019-08-14T04:41:48Z	KLM20R	45.327122,7.763917	20975	338	295
1,57E+09	2019-08-14T04:42:52Z	KLM20R	45.371567,7.633602	23050	350	295
1,57E+09	2019-08-14T04:43:16Z	KLM20R	45.391552,7.586194	23800	356	306
1,57E+09	2019-08-14T04:43:22Z	KLM20R	45.397602,7.575207	23950	358	309
1,57E+09	2019-08-14T04:43:31Z	KLM20R	45.40789,7.559062	24200	361	313
1,57E+09	2019-08-14T04:43:39Z	KLM20R	45.414825,7.549111	24350	362	314
1,57E+09	2019-08-14T04:44:40Z	KLM20R	45.492943,7.44451	25675	387	324
1,57E+09	2019-08-14T04:44:49Z	KLM20R	45.506954,7.431715	25700	395	329
1,57E+09	2019-08-14T04:44:55Z	KLM20R	45.51622,7.424404	25750	399	331
1,57E+09	2019-08-14T04:45:01Z	KLM20R	45.526199,7.417079	25800	404	332
1,57E+09	2019-08-14T04:46:00Z	KLM20R	45.628922,7.342016	26000	421	332
1,57E+09	2019-08-14T04:47:03Z	KLM20R	45.735306,7.263772	28175	391	332
1,57E+09	2019-08-14T04:48:07Z	KLM20R	45.837151,7.188423	29625	395	332
1,57E+09	2019-08-14T04:49:09Z	KLM20R	45.938095,7.113513	30950	398	332
1,57E+09	2019-08-14T04:50:13Z	KLM20R	46.045052,7.033791	31975	407	332
1,57E+09	2019-08-14T04:51:15Z	KLM20R	46.146286,6.95803	33225	402	332
1,57E+09	2019-08-14T04:52:19Z	KLM20R	46.250977,6.879317	34000	399	332
1,57E+09	2019-08-14T04:53:21Z	KLM20R	46.353607,6.80181	34000	400	332
1,57E+09	2019-08-14T04:54:25Z	KLM20R	46.458015,6.722603	34000	403	332
1,57E+09	2019-08-14T04:55:24Z	KLM20R	46.557129,6.647197	34000	401	332
1,57E+09	2019-08-14T04:56:28Z	KLM20R	46.662102,6.569138	34000	407	338
1,57E+09	2019-08-14T04:56:37Z	KLM20R	46.678535,6.560898	34000	410	342
1,57E+09	2019-08-14T04:56:44Z	KLM20R	46.689568,6.556503	34000	412	345
1,57E+09	2019-08-14T04:56:52Z	KLM20R	46.70628,6.551697	34000	416	350
1,57E+09	2019-08-14T04:56:58Z	KLM20R	46.718124,6.549459	34000	418	353
1,57E+09	2019-08-14T04:57:05Z	KLM20R	46.729614,6.547918	34000	420	355
1,57E+09	2019-08-14T04:57:13Z	KLM20R	46.745911,6.545909	34000	420	355
1,57E+09	2019-08-14T04:58:16Z	KLM20R	46.869305,6.530527	34000	419	355
1,57E+09	2019-08-14T04:59:19Z	KLM20R	46.987793,6.515579	34000	415	355
1,57E+09	2019-08-14T05:00:19Z	KLM20R	47.1026,6.500954	34000	408	354
1,57E+09	2019-08-14T05:01:22Z	KLM20R	47.223801,6.485455	34000	417	354
1,57E+09	2019-08-14T05:02:23Z	KLM20R	47.340363,6.470535	34000	422	354
1,57E+09	2019-08-14T05:03:27Z	KLM20R	47.463409,6.454674	34000	420	354
1,57E+09	2019-08-14T05:04:29Z	KLM20R	47.58514,6.438904	34000	419	354
1,57E+09	2019-08-14T05:05:33Z	KLM20R	47.70694,6.423019	34000	416	354
1,57E+09	2019-08-14T05:06:35Z	KLM20R	47.828659,6.407089	34000	416	354
1,57E+09	2019-08-14T05:07:36Z	KLM20R	47.944199,6.391983	34000	419	354
1,57E+09	2019-08-14T05:08:39Z	KLM20R	48.066284,6.375847	34000	419	354
1,57E+09	2019-08-14T05:09:43Z	KLM20R	48.185257,6.360098	34000	418	354
1,57E+09	2019-08-14T05:10:45Z	KLM20R	48.308624,6.343618	34000	419	354
1,57E+09	2019-08-14T05:11:20Z	KLM20R	48.376419,6.334604	34000	418	354
1,57E+09	2019-08-14T05:12:47Z	KLM20R	48.543274,6.312209	34000	414	354
1,57E+09	2019-08-14T05:13:42Z	KLM20R	48.648716,6.290468	34000	409	343
1,57E+09	2019-08-14T05:13:49Z	KLM20R	48.659225,6.285166	34000	408	340

1,57E+09	2019-08-14T05:13:57Z	KLM20R	48.670132,6.278831	34000	407	338
1,57E+09	2019-08-14T05:14:06Z	KLM20R	48.689438,6.265235	34000	406	334
1,57E+09	2019-08-14T05:14:12Z	KLM20R	48.699226,6.258015	34000	406	333
1,57E+09	2019-08-14T05:15:19Z	KLM20R	48.812862,6.173377	34000	408	333
1,57E+09	2019-08-14T05:16:25Z	KLM20R	48.924122,6.090257	34000	406	333
1,57E+09	2019-08-14T05:16:45Z	KLM20R	48.957825,6.064959	34000	406	333
1,57E+09	2019-08-14T05:18:14Z	KLM20R	49.106373,5.953144	34000	402	333
1,57E+09	2019-08-14T05:19:19Z	KLM20R	49.211151,5.873812	34000	402	333
1,57E+09	2019-08-14T05:20:23Z	KLM20R	49.317116,5.793192	34000	401	333
1,57E+09	2019-08-14T05:21:26Z	KLM20R	49.425705,5.710144	34000	402	333
1,57E+09	2019-08-14T05:22:27Z	KLM20R	49.526413,5.632806	34000	399	333
1,57E+09	2019-08-14T05:23:32Z	KLM20R	49.633438,5.5501	34000	398	333
1,57E+09	2019-08-14T05:24:33Z	KLM20R	49.731491,5.474082	34000	398	333
1,57E+09	2019-08-14T05:25:39Z	KLM20R	49.839897,5.38961	34000	399	333
1,57E+09	2019-08-14T05:26:44Z	KLM20R	49.946686,5.306026	34000	398	333
1,57E+09	2019-08-14T05:27:44Z	KLM20R	50.045792,5.227974	34000	394	333
1,57E+09	2019-08-14T05:28:49Z	KLM20R	50.152313,5.143698	33250	394	332
1,57E+09	2019-08-14T05:29:55Z	KLM20R	50.2584,5.059352	32175	395	332
1,57E+09	2019-08-14T05:30:55Z	KLM20R	50.356487,4.981038	31175	394	332
1,57E+09	2019-08-14T05:32:00Z	KLM20R	50.461212,4.896939	30075	386	332
1,57E+09	2019-08-14T05:33:06Z	KLM20R	50.564484,4.813645	29000	383	332
1,57E+09	2019-08-14T05:34:06Z	KLM20R	50.659775,4.736444	27975	382	332
1,57E+09	2019-08-14T05:35:11Z	KLM20R	50.760372,4.654541	26300	371	332
1,57E+09	2019-08-14T05:36:11Z	KLM20R	50.850361,4.580841	24275	356	332
1,57E+09	2019-08-14T05:36:45Z	KLM20R	50.896957,4.537502	23175	346	322
1,57E+09	2019-08-14T05:36:51Z	KLM20R	50.904221,4.527969	22975	344	319
1,57E+09	2019-08-14T05:36:57Z	KLM20R	50.911621,4.516983	22750	343	315
1,57E+09	2019-08-14T05:37:03Z	KLM20R	50.918095,4.506302	22575	342	312
1,57E+09	2019-08-14T05:37:09Z	KLM20R	50.924057,4.495264	22375	342	309
1,57E+09	2019-08-14T05:37:15Z	KLM20R	50.930008,4.48361	22175	341	308
1,57E+09	2019-08-14T05:37:21Z	KLM20R	50.936005,4.471733	21975	340	308
1,57E+09	2019-08-14T05:38:21Z	KLM20R	50.993729,4.356673	20400	328	308
1,57E+09	2019-08-14T05:39:24Z	KLM20R	51.05365,4.236714	19575	343	308
1,57E+09	2019-08-14T05:40:31Z	KLM20R	51.12162,4.100189	18475	355	308
1,57E+09	2019-08-14T05:41:00Z	KLM20R	51.154392,4.047928	18000	359	330
1,57E+09	2019-08-14T05:41:08Z	KLM20R	51.164749,4.040074	17900	359	334
1,57E+09	2019-08-14T05:41:14Z	KLM20R	51.177155,4.031685	17750	360	336
1,57E+09	2019-08-14T05:41:51Z	KLM20R	51.232182,3.995361	17150	355	337
1,57E+09	2019-08-14T05:42:22Z	KLM20R	51.279152,3.963623	16625	352	336
1,57E+09	2019-08-14T05:42:41Z	KLM20R	51.306011,3.950195	16350	356	349
1,57E+09	2019-08-14T05:42:50Z	KLM20R	51.320709,3.947581	16200	359	356
1,57E+09	2019-08-14T05:43:15Z	KLM20R	51.365971,3.955536	15750	368	11
1,57E+09	2019-08-14T05:43:51Z	KLM20R	51.42572,3.975047	15175	362	11
1,57E+09	2019-08-14T05:44:27Z	KLM20R	51.48262,3.993382	14775	359	11
1,57E+09	2019-08-14T05:44:59Z	KLM20R	51.5354,4.010381	14125	350	11
1,57E+09	2019-08-14T05:45:34Z	KLM20R	51.590305,4.028091	13425	350	11

1,57E+09	2019-08-14T05:46:07Z	KLM20R	51.6427,4.044973	12775	348	11
1,57E+09	2019-08-14T05:46:40Z	KLM20R	51.694771,4.06189	12125	349	11
1,57E+09	2019-08-14T05:47:13Z	KLM20R	51.746769,4.078751	11450	349	11
1,57E+09	2019-08-14T05:47:25Z	KLM20R	51.766113,4.084984	11225	350	11
1,57E+09	2019-08-14T05:47:36Z	KLM20R	51.785408,4.091263	10975	350	11
1,57E+09	2019-08-14T05:47:49Z	KLM20R	51.801682,4.096639	10775	348	11
1,57E+09	2019-08-14T05:48:02Z	KLM20R	51.822189,4.103319	10500	339	11
1,57E+09	2019-08-14T05:48:12Z	KLM20R	51.840664,4.109344	10250	327	11
1,57E+09	2019-08-14T05:48:23Z	KLM20R	51.856064,4.11438	10050	318	11
1,57E+09	2019-08-14T05:48:38Z	KLM20R	51.874695,4.120467	9800	308	11
1,57E+09	2019-08-14T05:48:51Z	KLM20R	51.892059,4.126205	9525	300	12
1,57E+09	2019-08-14T05:49:01Z	KLM20R	51.907608,4.134369	9375	294	23
1,57E+09	2019-08-14T05:49:10Z	KLM20R	51.918182,4.143372	9250	290	31
1,57E+09	2019-08-14T05:49:16Z	KLM20R	51.923859,4.149704	9200	291	36
1,57E+09	2019-08-14T05:49:26Z	KLM20R	51.934158,4.163742	9050	291	41
1,57E+09	2019-08-14T05:49:33Z	KLM20R	51.940426,4.172764	8975	291	41
1,57E+09	2019-08-14T05:49:39Z	KLM20R	51.948578,4.184723	8850	291	42
1,57E+09	2019-08-14T05:49:53Z	KLM20R	51.96035,4.201957	8700	290	42
1,57E+09	2019-08-14T05:50:04Z	KLM20R	51.972977,4.220428	8525	289	42
1,57E+09	2019-08-14T05:50:18Z	KLM20R	51.987396,4.241508	8350	289	42
1,57E+09	2019-08-14T05:50:31Z	KLM20R	51.999313,4.259007	8175	289	42
1,57E+09	2019-08-14T05:50:42Z	KLM20R	52.011234,4.276428	8025	289	42
1,57E+09	2019-08-14T05:50:55Z	KLM20R	52.023987,4.295026	7850	288	42
1,57E+09	2019-08-14T05:51:09Z	KLM20R	52.036057,4.312744	7700	288	42
1,57E+09	2019-08-14T05:51:20Z	KLM20R	52.047729,4.329869	7550	287	42
1,57E+09	2019-08-14T05:51:33Z	KLM20R	52.059402,4.347	7375	286	42
1,57E+09	2019-08-14T05:51:43Z	KLM20R	52.070709,4.363556	7225	284	41
1,57E+09	2019-08-14T05:51:57Z	KLM20R	52.08284,4.381332	7050	286	42
1,57E+09	2019-08-14T05:52:08Z	KLM20R	52.094238,4.398041	7000	284	42
1,57E+09	2019-08-14T05:52:19Z	KLM20R	52.106152,4.415641	7000	284	42
1,57E+09	2019-08-14T05:52:31Z	KLM20R	52.118408,4.43367	7000	286	42
1,57E+09	2019-08-14T05:52:43Z	KLM20R	52.129986,4.45064	7000	286	42
1,57E+09	2019-08-14T05:52:55Z	KLM20R	52.141937,4.468307	7000	286	42
1,57E+09	2019-08-14T05:53:07Z	KLM20R	52.153542,4.485404	7000	287	42
1,57E+09	2019-08-14T05:53:20Z	KLM20R	52.165649,4.503174	7000	288	42
1,57E+09	2019-08-14T05:53:32Z	KLM20R	52.177185,4.520187	7000	288	42
1,57E+09	2019-08-14T05:53:45Z	KLM20R	52.189156,4.537982	7000	288	42
1,57E+09	2019-08-14T05:53:55Z	KLM20R	52.201073,4.55556	7000	287	42
1,57E+09	2019-08-14T05:54:08Z	KLM20R	52.212708,4.572754	7000	286	42
1,57E+09	2019-08-14T05:54:20Z	KLM20R	52.224628,4.59048	7000	286	42
1,57E+09	2019-08-14T05:54:31Z	KLM20R	52.236191,4.60762	7000	287	42
1,57E+09	2019-08-14T05:54:44Z	KLM20R	52.247635,4.624557	7000	288	42
1,57E+09	2019-08-14T05:54:55Z	KLM20R	52.259773,4.642509	7000	288	42
1,57E+09	2019-08-14T05:55:09Z	KLM20R	52.271805,4.660416	7000	287	42
1,57E+09	2019-08-14T05:55:19Z	KLM20R	52.283569,4.677963	7000	287	42
1,57E+09	2019-08-14T05:55:31Z	KLM20R	52.295109,4.695086	7000	288	42

1,57E+09	2019-08-14T05:55:45Z	KLM20R	52.30719,4.713058	6850	289	42
1,57E+09	2019-08-14T05:55:55Z	KLM20R	52.319,4.730759	6650	289	42
1,57E+09	2019-08-14T05:56:07Z	KLM20R	52.330811,4.748688	6450	287	43
1,57E+09	2019-08-14T05:56:21Z	KLM20R	52.342117,4.767456	6250	287	46
1,57E+09	2019-08-14T05:56:31Z	KLM20R	52.353207,4.786508	6050	286	46
1,57E+09	2019-08-14T05:56:43Z	KLM20R	52.36396,4.804792	6000	285	46
1,57E+09	2019-08-14T05:56:55Z	KLM20R	52.375271,4.824018	6000	286	46
1,57E+09	2019-08-14T05:57:09Z	KLM20R	52.385792,4.842067	6000	278	46
1,57E+09	2019-08-14T05:57:20Z	KLM20R	52.396126,4.859959	6000	264	46
1,57E+09	2019-08-14T05:57:32Z	KLM20R	52.406296,4.876938	6000	252	41
1,57E+09	2019-08-14T05:57:39Z	KLM20R	52.411816,4.883187	6000	247	29
1,57E+09	2019-08-14T05:57:48Z	KLM20R	52.42173,4.88868	6000	243	10
1,57E+09	2019-08-14T05:57:54Z	KLM20R	52.428387,4.890093	6000	241	6
1,57E+09	2019-08-14T05:58:02Z	KLM20R	52.438339,4.891434	6000	239	4
1,57E+09	2019-08-14T05:58:08Z	KLM20R	52.444977,4.892197	6000	239	3
1,57E+09	2019-08-14T05:58:25Z	KLM20R	52.464294,4.894257	6000	238	3
1,57E+09	2019-08-14T05:58:37Z	KLM20R	52.477982,4.895706	6000	239	3
1,57E+09	2019-08-14T05:58:49Z	KLM20R	52.491302,4.897003	6000	239	3
1,57E+09	2019-08-14T05:59:02Z	KLM20R	52.504269,4.898333	6000	240	3
1,57E+09	2019-08-14T05:59:13Z	KLM20R	52.517899,4.89975	6000	240	3
1,57E+09	2019-08-14T05:59:23Z	KLM20R	52.52787,4.899667	6000	238	353
1,57E+09	2019-08-14T05:59:30Z	KLM20R	52.534199,4.897156	5975	232	342
1,57E+09	2019-08-14T05:59:36Z	KLM20R	52.539734,4.892578	5925	224	327
1,57E+09	2019-08-14T05:59:44Z	KLM20R	52.546024,4.882638	5725	219	307
1,57E+09	2019-08-14T05:59:50Z	KLM20R	52.549164,4.873123	5575	217	291
1,57E+09	2019-08-14T05:59:58Z	KLM20R	52.550446,4.863177	5400	218	276
1,57E+09	2019-08-14T06:00:04Z	KLM20R	52.550766,4.852753	5275	218	271
1,57E+09	2019-08-14T06:00:15Z	KLM20R	52.550583,4.833755	5025	218	268
1,57E+09	2019-08-14T06:00:23Z	KLM20R	52.550354,4.818573	4825	217	268
1,57E+09	2019-08-14T06:00:35Z	KLM20R	52.549484,4.800186	4600	216	259
1,57E+09	2019-08-14T06:00:41Z	KLM20R	52.547104,4.789734	4425	217	242
1,57E+09	2019-08-14T06:00:49Z	KLM20R	52.541748,4.779053	4225	220	221
1,57E+09	2019-08-14T06:00:56Z	KLM20R	52.536621,4.772932	4125	218	213
1,57E+09	2019-08-14T06:01:02Z	KLM20R	52.531269,4.767596	4025	213	210
1,57E+09	2019-08-14T06:01:09Z	KLM20R	52.526379,4.763358	3900	212	206
1,57E+09	2019-08-14T06:01:19Z	KLM20R	52.517761,4.758072	3725	211	193
1,57E+09	2019-08-14T06:01:25Z	KLM20R	52.509899,4.756138	3575	209	184
1,57E+09	2019-08-14T06:01:37Z	KLM20R	52.500683,4.755589	3350	208	181
1,57E+09	2019-08-14T06:01:44Z	KLM20R	52.491886,4.755353	3150	205	181
1,57E+09	2019-08-14T06:01:51Z	KLM20R	52.48645,4.75502	3025	203	181
1,57E+09	2019-08-14T06:01:57Z	KLM20R	52.480946,4.754569	2875	202	183
1,57E+09	2019-08-14T06:02:09Z	KLM20R	52.469913,4.753392	2650	197	184
1,57E+09	2019-08-14T06:02:21Z	KLM20R	52.458832,4.751979	2425	192	184
1,57E+09	2019-08-14T06:02:27Z	KLM20R	52.454041,4.751358	2325	190	183
1,57E+09	2019-08-14T06:02:38Z	KLM20R	52.443283,4.75029	2100	186	183
1,57E+09	2019-08-14T06:02:51Z	KLM20R	52.433182,4.74939	1900	181	183

1,57E+09	2019-08-14T06:03:03Z	KLM20R	52.423096,4.748383	1700	168	183
1,57E+09	2019-08-14T06:03:09Z	KLM20R	52.418839,4.748001	1650	160	183
1,57E+09	2019-08-14T06:03:15Z	KLM20R	52.414581,4.747543	1550	153	183
1,57E+09	2019-08-14T06:03:26Z	KLM20R	52.406067,4.74678	1375	152	183
1,57E+09	2019-08-14T06:03:32Z	KLM20R	52.401665,4.746329	1300	153	183
1,57E+09	2019-08-14T06:03:38Z	KLM20R	52.397552,4.745941	1225	153	183
1,57E+09	2019-08-14T06:03:46Z	KLM20R	52.391281,4.745407	1100	152	182
1,57E+09	2019-08-14T06:03:53Z	KLM20R	52.387161,4.745026	1000	147	183
1,57E+09	2019-08-14T06:04:06Z	KLM20R	52.379471,4.744339	850	132	183
1,57E+09	2019-08-14T06:04:12Z	KLM20R	52.375717,4.743958	775	125	183
1,57E+09	2019-08-14T06:04:23Z	KLM20R	52.368988,4.743271	625	120	183
1,57E+09	2019-08-14T06:04:29Z	KLM20R	52.366241,4.743033	600	119	183
1,57E+09	2019-08-14T06:04:35Z	KLM20R	52.362656,4.742719	525	119	182
1,57E+09	2019-08-14T06:04:42Z	KLM20R	52.359116,4.742484	475	119	182
1,57E+09	2019-08-14T06:04:53Z	KLM20R	52.352833,4.741935	350	117	183
1,57E+09	2019-08-14T06:05:00Z	KLM20R	52.349945,4.741592	300	117	183
1,57E+09	2019-08-14T06:05:07Z	KLM20R	52.34613,4.741307	225	118	182
1,57E+09	2019-08-14T06:05:16Z	KLM20R	52.339966,4.740829	100	121	183
1,57E+09	2019-08-14T06:05:30Z	KLM20R	52.332211,4.74013	0	121	183
1,57E+09	2019-08-14T06:06:25Z	KLM20R	52.316036,4.740353	0	25	154
1,57E+09	2019-08-14T06:06:52Z	KLM20R	52.313332,4.741346	0	23	185
1,57E+09	2019-08-14T06:07:01Z	KLM20R	52.312252,4.741209	0	24	185
1,57E+09	2019-08-14T06:07:07Z	KLM20R	52.31163,4.741154	0	25	182
1,57E+09	2019-08-14T06:07:14Z	KLM20R	52.310955,4.741096	0	26	182
1,57E+09	2019-08-14T06:07:24Z	KLM20R	52.309528,4.740973	0	27	182
1,57E+09	2019-08-14T06:07:31Z	KLM20R	52.308491,4.740856	0	28	182
1,57E+09	2019-08-14T06:07:37Z	KLM20R	52.307762,4.740791	0	29	182
1,57E+09	2019-08-14T06:07:46Z	KLM20R	52.306629,4.740679	0	24	182
1,57E+09	2019-08-14T06:07:53Z	KLM20R	52.30608,4.74062	0	22	185
1,57E+09	2019-08-14T06:07:59Z	KLM20R	52.305244,4.740542	0	22	180
1,57E+09	2019-08-14T06:08:31Z	KLM20R	52.302799,4.743818	0	22	132
1,57E+09	2019-08-14T06:08:48Z	KLM20R	52.301624,4.746015	0	25	129

ANNEX C. Input files used for simulations with AEM

A330F-150km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT

VLG13NY;1;A332;7PW082;2;05:17:44;05:25:54;16/08/2019;16/08/2019;0;600;0;ALC;IBZ;38.284687;-0.55741;38.279526;-0.540609;18;18;;;;
VLG13NY;2;A332;7PW082;3;05:25:54;05:29:12;16/08/2019;16/08/2019;600;9650;0;ALC;IBZ;38.279526;-0.540609;38.363617;-0.272087;18;18;;;;
VLG13NY;3;A332;7PW082;35;05:29:12;05:36:47;16/08/2019;16/08/2019;9650;10550;2;ALC;IBZ;38.363617;-0.272087;38.638275;0.627176;18;18;;;;
VLG13NY;4;A332;7PW082;27;05:36:47;05:38:47;16/08/2019;16/08/2019;10550;8300;2;ALC;IBZ;38.638275;0.627176;38.683281;0.832825;18;18;;;;
VLG13NY;5;A332;7PW082;27;05:38:47;05:40:38;16/08/2019;16/08/2019;8300;6000;2;ALC;IBZ;38.683281;0.832825;38.722755;1.01178;18;18;;;;
VLG13NY;6;A332;7PW082;10;05:40:38;05:42:13;16/08/2019;16/08/2019;6000;3525;1;ALC;IBZ;38.722755;1.01178;38.773407;1.134338;18;18;;;;
VLG13NY;7;A332;7PW082;3;05:42:13;05:46:07;16/08/2019;16/08/2019;3525;300;7;ALC;IBZ;38.773407;1.134338;38.857246;1.33551;18;18;;;;

A330F-200km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
RYR7216;1;A332;7PW082;3;09:11:42;09:23:18;16/08/2019;16/08/2019;0;100;0;VLC;IBZ;39.489864;-0.474233;39.488449;-0.47937;18;18;;;;
RYR7216;2;A332;7PW082;7;09:23:18;09:25:14;16/08/2019;16/08/2019;100;4000;0;VLC;IBZ;39.488449;-0.47937;39.428879;-0.375147;18;18;;;;
RYR7216;3;A332;7PW082;10;09:25:14;09:27:08;16/08/2019;16/08/2019;4000;9525;0;VLC;IBZ;39.428879;-0.375147;39.352421;-0.2052;18;18;;;;
RYR7216;4;A332;7PW082;36;09:27:08;09:31:02;16/08/2019;16/08/2019;9525;16000;2;VLC;IBZ;39.352421;-0.2052;39.170746;0.230892;18;18;;;;
RYR7216;5;A332;7PW082;31;09:31:02;09:34:31;16/08/2019;16/08/2019;16000;10100;2;VLC;IBZ;39.170746;0.230892;39.009007;0.636108;18;18;;;;
RYR7216;6;A332;7PW082;25;09:34:31;09:37:42;16/08/2019;16/08/2019;10100;5400;1;VLC;IBZ;39.009007;0.636108;38.862507;0.96875;18;18;;;;
RYR7216;7;A332;7PW082;11;09:37:42;09:39:49;16/08/2019;16/08/2019;5400;3700;1;VLC;IBZ;38.862507;0.96875;38.789749;1.132129;18;18;;;;
RYR7216;8;A332;7PW082;4;09:39:49;09:40:58;16/08/2019;16/08/2019;3700;2250;7;VLC;IBZ;38.789749;1.132129;38.807419;1.215482;18;18;;;;

A330F-300km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_AC

FT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
AEA4025;1;A332;7PW082;13;06:56:50;06:59:30;16/08/2019;16/08/2019;6575;9025;0;ALC;PMI;38.357788;-0.286898;38.405613;-0.172659;;;;;;
AEA4025;2;A332;7PW082;4;06:59:30;07:00:44;16/08/2019;16/08/2019;9025;1050;0;ALC;PMI;38.405613;-0.172659;38.433277;-0.07038;;;;;;
AEA4025;3;A332;7PW082;19;07:00:44;07:03:10;16/08/2019;16/08/2019;1050;12000;2;ALC;PMI;38.433277;-0.07038;38.502132;0.091166;21;21;;;;
AEA4025;4;A332;7PW082;21;07:03:10;07:08:10;16/08/2019;16/08/2019;12000;15000;2;ALC;PMI;38.502132;0.091166;38.596821;0.447043;21;21;;;;
AEA4025;5;A332;7PW082;28;07:08:10;07:13:48;16/08/2019;16/08/2019;15000;16050;2;ALC;PMI;38.596821;0.447043;38.694679;0.917105;21;21;;;;
AEA4025;6;A332;7PW082;52;07:13:48;07:25:38;16/08/2019;16/08/2019;16050;16050;2;ALC;PMI;38.694679;0.917105;38.859989;2.036575;21;21;;;;
AEA4025;7;A332;7PW082;29;07:25:38;07:32:00;16/08/2019;16/08/2019;16050;14800;2;ALC;PMI;38.859989;2.036575;39.160252;2.505645;21;21;;;;
AEA4025;8;A332;7PW082;22;07:32:00;07:36:46;16/08/2019;16/08/2019;14800;10034;2;ALC;PMI;39.160252;2.505645;39.463081;2.81651;21;21;;;;
AEA4025;9;A332;7PW082;11;07:36:46;07:38:07;16/08/2019;16/08/2019;10034;8050;1;ALC;PMI;39.463081;2.81651;39.507954;2.941058;;;;;;
AEA4025;10;A332;7PW082;25;07:38:07;07:47:40;16/08/2019;16/08/2019;8050;2175;7;ALC;PMI;39.507954;2.941058;39.641743;2.913657;;;;;;

A330F-800km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
KLM20R;1;A332;7PW082;5;04:26:49;04:33:17;14/08/2019;14/08/2019;0;925;0;TRN;AMS;45.193325;7.645814;45.193176;7.649166;;;;;;
KLM20R;2;A332;7PW082;12;04:33:17;04:37:10;14/08/2019;14/08/2019;925;9675;0;TRN;AMS;45.193176;7.649166;45.201141;7.808794;;;;;;
KLM20R;3;A332;7PW082;25;04:37:10;04:49:09;14/08/2019;14/08/2019;9675;30950;0;TRN;AMS;45.201141;7.808794;45.938095;7.113513;;;;;;
KLM20R;4;A332;7PW082;74;04:49:09;04:56:52;14/08/2019;14/08/2019;30950;34000;2;TRN;AMS;45.938095;7.113513;46.70628;6.551697;24;24;;;;
KLM20R;5;A332;7PW082;120;04:56:52;05:27:44;14/08/2019;14/08/2019;34000;34000;2;TRN;AMS;46.70628;6.551697;50.045792;5.227974;24;24;;;;
KLM20R;6;A332;7PW082;37;05:27:44;05:41:51;14/08/2019;14/08/2019;34000;17150;2;TRN;AMS;50.045792;5.227974;51.232182;3.995361;24;24;;;;
KLM20R;7;A332;7PW082;37;05:41:51;05:52:08;14/08/2019;14/08/2019;17150;7000;1;TRN;AMS;51.232182;3.995361;50.094238;4.398041;;;;;;
KLM20R;8;A332;7PW082;84;05:52:08;06:05:16;14/08/2019;14/08/2019;7000;100;1;TRN;AMS;50.094238;4.398041;52.339966;4.740829;;;;;;

KLM20R;9;A332;7PW082;12;06:05:16;06:08:48;14/08/2019;14/08/2019;100;0;7;TRN;AMS;52.339966;4.740829;52.301624;4.746015;;;;;;

B737-400F-150km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
VLG13NY;1;B734;1CM007;2;05:17:44;05:25:54;16/08/2019;16/08/2019;0;600;0;ALC;IBZ;38.284687;-0.55741;38.279526;-0.540609;;;;;;
VLG13NY;2;B734;1CM007;3;05:25:54;05:29:12;16/08/2019;16/08/2019;600;9650;0;ALC;IBZ;38.279526;-0.540609;38.363617;-0.272087;;;;;;
VLG13NY;3;B734;1CM007;35;05:29:12;05:36:47;16/08/2019;16/08/2019;9650;10550;0;ALC;IBZ;38.363617;-0.272087;38.638275;0.627176;;;;;;
VLG13NY;4;B734;1CM007;27;05:36:47;05:38:47;16/08/2019;16/08/2019;10550;8300;2;ALC;IBZ;38.638275;0.627176;38.683281;0.832825;;;;;;
VLG13NY;5;B734;1CM007;27;05:38:47;05:40:38;16/08/2019;16/08/2019;8300;6000;2;ALC;IBZ;38.683281;0.832825;38.722755;1.01178;;;;;;
VLG13NY;6;B734;1CM007;10;05:40:38;05:42:13;16/08/2019;16/08/2019;6000;3525;1;ALC;IBZ;38.722755;1.01178;38.773407;1.134338;;;;;;
VLG13NY;7;B734;1CM007;3;05:42:13;05:46:07;16/08/2019;16/08/2019;3525;300;7;ALC;IBZ;38.773407;1.134338;38.857246;1.33551;;;;;;

B737-400F-200km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
RYR7216;1;B734;1CM007;3;09:11:42;09:23:18;16/08/2019;16/08/2019;0;100;0;VLC;IBZ;39.489864;-0.474233;39.488449;-0.47937;;;;;;
RYR7216;2;B734;1CM007;7;09:23:18;09:25:14;16/08/2019;16/08/2019;100;4000;0;VLC;IBZ;39.488449;-0.47937;39.428879;-0.375147;;;;;;
RYR7216;3;B734;1CM007;10;09:25:14;09:27:08;16/08/2019;16/08/2019;4000;9525;2;VLC;IBZ;39.428879;-0.375147;39.352421;-0.2052;;;;;;
RYR7216;4;B734;1CM007;36;09:27:08;09:31:02;16/08/2019;16/08/2019;9525;16000;2;VLC;IBZ;39.352421;-0.2052;39.170746;0.230892;;;;;;
RYR7216;5;B734;1CM007;31;09:31:02;09:34:31;16/08/2019;16/08/2019;16000;10100;2;VLC;IBZ;39.170746;0.230892;39.009007;0.636108;;;;;;

RYR7216;6;B734;1CM007;25;09:34:31;09:37:42;16/08/2019;16/08/2019;10100;5400;1;VLC;IBZ;39.009007;0.636108;38.862507;0.96875;;;;;
RYR7216;7;B734;1CM007;11;09:37:42;09:39:49;16/08/2019;16/08/2019;5400;3700;1;VLC;IBZ;38.862507;0.96875;38.789749;1.132129;;;;;
RYR7216;8;B734;1CM007;4;09:39:49;09:40:58;16/08/2019;16/08/2019;3700;2250;7;VLC;IBZ;38.789749;1.132129;38.807419;1.215482;;;;;

B737-400F-300km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
AEA4025;1;B734;1CM007;13;06:56:50;06:59:30;16/08/2019;16/08/2019;6575;9025;0;ALC;PMI;38.357788;-0.286898;38.405613;-0.172659;;;;;
AEA4025;2;B734;1CM007;4;06:59:30;07:00:44;16/08/2019;16/08/2019;9025;1050;0;ALC;PMI;38.405613;-0.172659;38.433277;-0.07038;;;;;
AEA4025;3;B734;1CM007;19;07:00:44;07:03:10;16/08/2019;16/08/2019;1050;12000;2;ALC;PMI;38.433277;-0.07038;38.502132;0.091166;;;;;
AEA4025;4;B734;1CM007;21;07:03:10;07:08:10;16/08/2019;16/08/2019;12000;15000;2;ALC;PMI;38.502132;0.091166;38.596821;0.447043;;;;;
AEA4025;5;B734;1CM007;28;07:08:10;07:13:48;16/08/2019;16/08/2019;15000;16050;2;ALC;PMI;38.596821;0.447043;38.694679;0.917105;;;;;
AEA4025;6;B734;1CM007;52;07:13:48;07:25:38;16/08/2019;16/08/2019;16050;16050;2;ALC;PMI;38.694679;0.917105;38.859989;2.036575;;;;;
AEA4025;7;B734;1CM007;29;07:25:38;07:32:00;16/08/2019;16/08/2019;16050;14800;2;ALC;PMI;38.859989;2.036575;39.160252;2.505645;;;;;
AEA4025;8;B734;1CM007;22;07:32:00;07:36:46;16/08/2019;16/08/2019;14800;10034;2;ALC;PMI;39.160252;2.505645;39.463081;2.81651;;;;;
AEA4025;9;B734;1CM007;11;07:36:46;07:38:07;16/08/2019;16/08/2019;10034;8050;1;ALC;PMI;39.463081;2.81651;39.507954;2.941058;;;;;
AEA4025;10;B734;1CM007;25;07:38:07;07:47:40;16/08/2019;16/08/2019;8050;2175;7;ALC;PMI;39.507954;2.941058;39.641743;2.913657;;;;;

B737-400F-800km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT

KLM20R;1;B734;1CM007;5;04:26:49;04:33:17;14/08/2019;14/08/2019;0;925;0;TRN;AMS;45.193325;7.645814;45.193176;7.649166;;;;;
KLM20R;2;B734;1CM007;12;04:33:17;04:37:10;14/08/2019;14/08/2019;925;9675;0;TRN;AMS;45.193176;7.649166;45.201141;7.808794;;;;;
KLM20R;3;B734;1CM007;25;04:37:10;04:49:09;14/08/2019;14/08/2019;9675;30950;0;TRN;AMS;45.201141;7.808794;45.938095;7.113513;;;;;
KLM20R;4;B734;1CM007;74;04:49:09;04:56:52;14/08/2019;14/08/2019;30950;34000;2;TRN;AMS;45.938095;7.113513;46.70628;6.551697;;;;;
KLM20R;5;B734;1CM007;120;04:56:52;05:27:44;14/08/2019;14/08/2019;34000;34000;2;TRN;AMS;46.70628;6.551697;50.045792;5.227974;;;;;
KLM20R;6;B734;1CM007;37;05:27:44;05:41:51;14/08/2019;14/08/2019;34000;17150;2;TRN;AMS;50.045792;5.227974;51.232182;3.995361;;;;;
KLM20R;7;B734;1CM007;37;05:41:51;05:52:08;14/08/2019;14/08/2019;17150;7000;1;TRN;AMS;51.232182;3.995361;50.094238;4.398041;;;;;
KLM20R;8;B734;1CM007;84;05:52:08;06:05:16;14/08/2019;14/08/2019;7000;100;1;TRN;AMS;50.094238;4.398041;52.339966;4.740829;;;;;
KLM20R;9;B734;1CM007;12;06:05:16;06:08:48;14/08/2019;14/08/2019;100;0;7;TRN;AMS;52.339966;4.740829;52.301624;4.746015;;;;;

B747-800F-150km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
VLG13NY;1;B748;11GE139;2;05:17:44;05:25:54;16/08/2019;16/08/2019;0;600;0;ALC;IBZ;38.284687;-0.55741;38.279526;-0.540609;;;;;
VLG13NY;2;B748;11GE139;3;05:25:54;05:29:12;16/08/2019;16/08/2019;600;9650;0;ALC;IBZ;38.279526;-0.540609;38.363617;-0.272087;;;;;
VLG13NY;3;B748;11GE139;35;05:29:12;05:36:47;16/08/2019;16/08/2019;9650;10550;2;ALC;IBZ;38.363617;-0.272087;38.638275;0.627176;;;;;
VLG13NY;4;B748;11GE139;27;05:36:47;05:38:47;16/08/2019;16/08/2019;10550;8300;2;ALC;IBZ;38.638275;0.627176;38.683281;0.832825;;;;;
VLG13NY;5;B748;11GE139;27;05:38:47;05:40:38;16/08/2019;16/08/2019;8300;6000;2;ALC;IBZ;38.683281;0.832825;38.722755;1.01178;;;;;
VLG13NY;6;B748;11GE139;10;05:40:38;05:42:13;16/08/2019;16/08/2019;6000;3525;1;ALC;IBZ;38.722755;1.01178;38.773407;1.134338;;;;;
VLG13NY;7;B748;11GE139;3;05:42:13;05:46:07;16/08/2019;16/08/2019;3525;300;7;ALC;IBZ;38.773407;1.134338;38.857246;1.33551;;;;;

B747-800F-200km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
RYR7216;1;B748;11GE139;3;09:11:42;09:23:18;16/08/2019;16/08/2019;0;100;0;VLC;IBZ;39.489864;-0.474233;39.488449;-0.47937;;;;;;
RYR7216;2;B748;11GE139;7;09:23:18;09:25:14;16/08/2019;16/08/2019;100;4000;0;VLC;IBZ;39.488449;-0.47937;39.428879;-0.375147;;;;;;
RYR7216;3;B748;11GE139;10;09:25:14;09:27:08;16/08/2019;16/08/2019;4000;9525;0;VLC;IBZ;39.428879;-0.375147;39.352421;-0.2052;;;;;;
RYR7216;4;B748;11GE139;36;09:27:08;09:31:02;16/08/2019;16/08/2019;9525;16000;2;VLC;IBZ;39.352421;-0.2052;39.170746;0.230892;;;;;;
RYR7216;5;B748;11GE139;31;09:31:02;09:34:31;16/08/2019;16/08/2019;16000;10100;2;VLC;IBZ;39.170746;0.230892;39.009007;0.636108;;;;;;
RYR7216;6;B748;11GE139;25;09:34:31;09:37:42;16/08/2019;16/08/2019;10100;5400;1;VLC;IBZ;39.009007;0.636108;38.862507;0.96875;;;;;;
RYR7216;7;B748;11GE139;11;09:37:42;09:39:49;16/08/2019;16/08/2019;5400;3700;1;VLC;IBZ;38.862507;0.96875;38.789749;1.132129;;;;;;
RYR7216;8;B748;11GE139;4;09:39:49;09:40:58;16/08/2019;16/08/2019;3700;2250;7;VLC;IBZ;38.789749;1.132129;38.807419;1.215482;;;;;;

B747-800F-300km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
AEA4025;1;B748;11GE139;13;06:56:50;06:59:30;16/08/2019;16/08/2019;6575;9025;0;ALC;PMI;38.357788;-0.286898;38.405613;-0.172659;;;;;;
AEA4025;2;B748;11GE139;4;06:59:30;07:00:44;16/08/2019;16/08/2019;9025;1050;0;ALC;PMI;38.405613;-0.172659;38.433277;-0.07038;;;;;;
AEA4025;3;B748;11GE139;19;07:00:44;07:03:10;16/08/2019;16/08/2019;1050;12000;2;ALC;PMI;38.433277;-0.07038;38.502132;0.091166;;;;;;
AEA4025;4;B748;11GE139;21;07:03:10;07:08:10;16/08/2019;16/08/2019;12000;15000;2;ALC;PMI;38.502132;0.091166;38.596821;0.447043;;;;;;
AEA4025;5;B748;11GE139;28;07:08:10;07:13:48;16/08/2019;16/08/2019;15000;16050;2;ALC;PMI;38.596821;0.447043;38.694679;0.917105;;;;;;
AEA4025;6;B748;11GE139;52;07:13:48;07:25:38;16/08/2019;16/08/2019;16050;16050;2;ALC;PMI;38.694679;0.917105;38.859989;2.036575;;;;;;

AEA4025;7;B748;11GE139;29;07:25:38;07:32:00;16/08/2019;16/08/2019;16050;14800;2;ALC;PMI;38.859989;2.036575;39.160252;2.505645;;;;;
AEA4025;8;B748;11GE139;22;07:32:00;07:36:46;16/08/2019;16/08/2019;14800;10034;2;ALC;PMI;39.160252;2.505645;39.463081;2.81651;;;;;
AEA4025;9;B748;11GE139;11;07:36:46;07:38:07;16/08/2019;16/08/2019;10034;8050;1;ALC;PMI;39.463081;2.81651;39.507954;2.941058;;;;;
AEA4025;10;B748;11GE139;25;07:38:07;07:47:40;16/08/2019;16/08/2019;8050;2175;7;ALC;PMI;39.507954;2.941058;39.641743;2.913657;;;;;

B747-800F-800km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
KLM20R;1;B748;11GE139;5;04:26:49;04:33:17;14/08/2019;14/08/2019;0;925;0;TRN;AMS;45.193325;7.645814;45.193176;7.649166;;;;;
KLM20R;2;B748;11GE139;12;04:33:17;04:37:10;14/08/2019;14/08/2019;925;9675;0;TRN;AMS;45.193176;7.649166;45.201141;7.808794;;;;;
KLM20R;3;B748;11GE139;25;04:37:10;04:49:09;14/08/2019;14/08/2019;9675;30950;0;TRN;AMS;45.201141;7.808794;45.938095;7.113513;;;;;
KLM20R;4;B748;11GE139;74;04:49:09;04:56:52;14/08/2019;14/08/2019;30950;34000;2;TRN;AMS;45.938095;7.113513;46.70628;6.551697;;;;;
KLM20R;5;B748;11GE139;120;04:56:52;05:27:44;14/08/2019;14/08/2019;34000;34000;2;TRN;AMS;46.70628;6.551697;50.045792;5.227974;;;;;
KLM20R;6;B748;11GE139;37;05:27:44;05:41:51;14/08/2019;14/08/2019;34000;17150;2;TRN;AMS;50.045792;5.227974;51.232182;3.995361;;;;;
KLM20R;7;B748;11GE139;37;05:41:51;05:52:08;14/08/2019;14/08/2019;17150;7000;1;TRN;AMS;51.232182;3.995361;50.094238;4.398041;;;;;
KLM20R;8;B748;11GE139;84;05:52:08;06:05:16;14/08/2019;14/08/2019;7000;100;1;TRN;AMS;50.094238;4.398041;52.339966;4.740829;;;;;
KLM20R;9;B748;11GE139;12;06:05:16;06:08:48;14/08/2019;14/08/2019;100;0;7;TRN;AMS;52.339966;4.740829;52.301624;4.746015;;;;;

MD11-150km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT

VLG13NY;1;MD11;1PW052;2;05:17:44;05:25:54;16/08/2019;16/08/2019;0;600;0;ALC;IBZ;38.284687;-0.55741;38.279526;-0.540609;;;;;
VLG13NY;2;MD11;1PW052;3;05:25:54;05:29:12;16/08/2019;16/08/2019;600;9650;0;ALC;IBZ;38.279526;-0.540609;38.363617;-0.272087;;;;;
VLG13NY;3;MD11;1PW052;35;05:29:12;05:36:47;16/08/2019;16/08/2019;9650;10550;2;ALC;IBZ;38.363617;-0.272087;38.638275;0.627176;;;;;
VLG13NY;4;MD11;1PW052;27;05:36:47;05:38:47;16/08/2019;16/08/2019;10550;8300;2;ALC;IBZ;38.638275;0.627176;38.683281;0.832825;;;;;
VLG13NY;5;MD11;1PW052;27;05:38:47;05:40:38;16/08/2019;16/08/2019;8300;6000;2;ALC;IBZ;38.683281;0.832825;38.722755;1.01178;;;;;
VLG13NY;6;MD11;1PW052;10;05:40:38;05:42:13;16/08/2019;16/08/2019;6000;3525;1;ALC;IBZ;38.722755;1.01178;38.773407;1.134338;;;;;
VLG13NY;7;MD11;1PW052;3;05:42:13;05:46:07;16/08/2019;16/08/2019;3525;300;7;ALC;IBZ;38.773407;1.134338;38.857246;1.33551;;;;;

MD11-200km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
RYR7216;1;MD11;1PW052;3;09:11:42;09:23:18;16/08/2019;16/08/2019;0;100;0;VLC;IBZ;39.489864;-0.474233;39.488449;-0.47937;;;;;
RYR7216;2;MD11;1PW052;7;09:23:18;09:25:14;16/08/2019;16/08/2019;100;4000;0;VLC;IBZ;39.488449;-0.47937;39.428879;-0.375147;;;;;
RYR7216;3;MD11;1PW052;10;09:25:14;09:27:08;16/08/2019;16/08/2019;4000;9525;0;VLC;IBZ;39.428879;-0.375147;39.352421;-0.2052;;;;;
RYR7216;4;MD11;1PW052;36;09:27:08;09:31:02;16/08/2019;16/08/2019;9525;16000;2;VLC;IBZ;39.352421;-0.2052;39.170746;0.230892;;;;;
RYR7216;5;MD11;1PW052;31;09:31:02;09:34:31;16/08/2019;16/08/2019;16000;10100;2;VLC;IBZ;39.170746;0.230892;39.009007;0.636108;;;;;
RYR7216;6;MD11;1PW052;25;09:34:31;09:37:42;16/08/2019;16/08/2019;10100;5400;1;VLC;IBZ;39.009007;0.636108;38.862507;0.96875;;;;;
RYR7216;7;MD11;1PW052;11;09:37:42;09:39:49;16/08/2019;16/08/2019;5400;3700;1;VLC;IBZ;38.862507;0.96875;38.789749;1.132129;;;;;
RYR7216;8;MD11;1PW052;4;09:39:49;09:40:58;16/08/2019;16/08/2019;3700;2250;7;VLC;IBZ;38.789749;1.132129;38.807419;1.215482;;;;;

MD11-300km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGI

TUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
AEA4025;1;MD11;1PW052;13;06:56:50;06:59:30;16/08/2019;16/08/2019;6575;9025;0;ALC;PMI;38.357788;-0.286898;38.405613;-0.172659;;;;;
AEA4025;2;MD11;1PW052;4;06:59:30;07:00:44;16/08/2019;16/08/2019;9025;1050;0;ALC;PMI;38.405613;-0.172659;38.433277;-0.07038;;;;;
AEA4025;3;MD11;1PW052;19;07:00:44;07:03:10;16/08/2019;16/08/2019;1050;12000;2;ALC;PMI;38.433277;-0.07038;38.502132;0.091166;;;;;
AEA4025;4;MD11;1PW052;21;07:03:10;07:08:10;16/08/2019;16/08/2019;12000;15000;2;ALC;PMI;38.502132;0.091166;38.596821;0.447043;;;;;
AEA4025;5;MD11;1PW052;28;07:08:10;07:13:48;16/08/2019;16/08/2019;15000;16050;2;ALC;PMI;38.596821;0.447043;38.694679;0.917105;;;;;
AEA4025;6;MD11;1PW052;52;07:13:48;07:25:38;16/08/2019;16/08/2019;16050;16050;2;ALC;PMI;38.694679;0.917105;38.859989;2.036575;;;;;
AEA4025;7;MD11;1PW052;29;07:25:38;07:32:00;16/08/2019;16/08/2019;16050;14800;2;ALC;PMI;38.859989;2.036575;39.160252;2.505645;;;;;
AEA4025;8;MD11;1PW052;22;07:32:00;07:36:46;16/08/2019;16/08/2019;14800;10034;2;ALC;PMI;39.160252;2.505645;39.463081;2.81651;;;;;
AEA4025;9;MD11;1PW052;11;07:36:46;07:38:07;16/08/2019;16/08/2019;10034;8050;1;ALC;PMI;39.463081;2.81651;39.507954;2.941058;;;;;
AEA4025;10;MD11;1PW052;25;07:38:07;07:47:40;16/08/2019;16/08/2019;8050;2175;7;ALC;PMI;39.507954;2.941058;39.641743;2.913657;;;;;

MD11-800km

FLIGHT_ID;SEGMENT_ID;AIRCRAFT_ID;ENGINE_CODE;DISTANCE_NM;START_TIME;END_TIME;START_DATE;END_DATE;START_ALTITUDE_FT;END_ALTITUDE_FT;ATTITUDE;ADEP;ADES;START_LATITUDE;START_LONGITUDE;END_LATITUDE;END_LONGITUDE;START_ACFT_FF_KGM;END_ACFT_FF_KGM;START_MACH_NB;END_MACH_NB;START_TAS_KT;END_TAS_KT
KLM20R;1;MD11;1PW052;5;04:26:49;04:33:17;14/08/2019;14/08/2019;0;925;0;TRN;AMS;45.193325;7.645814;45.193176;7.649166;;;;;
KLM20R;2;MD11;1PW052;12;04:33:17;04:37:10;14/08/2019;14/08/2019;925;9675;0;TRN;AMS;45.193176;7.649166;45.201141;7.808794;;;;;
KLM20R;3;MD11;1PW052;25;04:37:10;04:49:09;14/08/2019;14/08/2019;9675;30950;0;TRN;AMS;45.201141;7.808794;45.938095;7.113513;;;;;
KLM20R;4;MD11;1PW052;74;04:49:09;04:56:52;14/08/2019;14/08/2019;30950;34000;2;TRN;AMS;45.938095;7.113513;46.70628;6.551697;;;;;
KLM20R;5;MD11;1PW052;120;04:56:52;05:27:44;14/08/2019;14/08/2019;34000;34000;2;TRN;AMS;46.70628;6.551697;50.045792;5.227974;;;;;
KLM20R;6;MD11;1PW052;37;05:27:44;05:41:51;14/08/2019;14/08/2019;34000;17150;2;TRN;AMS;50.045792;5.227974;51.232182;3.995361;;;;;
KLM20R;7;MD11;1PW052;37;05:41:51;05:52:08;14/08/2019;14/08/2019;17150;7000;1;TRN;AMS;51.232182;3.995361;50.094238;4.398041;;;;;

KLM20R;8;MD11;1PW052;84;05:52:08;06:05:16;14/08/2019;14/08/2019;7000;100;1;TRN;AMS;50.094238;4.398041;52.339966;4.740829;;;;;;
KLM20R;9;MD11;1PW052;12;06:05:16;06:08:48;14/08/2019;14/08/2019;100;0;7;TRN;AMS;52.339966;4.740829;52.301624;4.746015;;;;;;