U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

BUILDING A CASE FOR A COMPETITIVE FAST RAIL-FREIGHT SERVICE

FRANCISCO MONTEIRO DE BARROS MARQUES DE AGUIAR

Dissertação submetida para satisfação parcial dos requisitos do grau de

MESTRE EM ENGENHARIA CIVIL — ESPECIALIZAÇÃO EM PLANEAMENTO

Orientador: Professor Doutor Álvaro Fernando de Oliveira Costa

JANEIRO DE 2020

MESTRADO INTEGRADO EM ENGENHARIA CIVIL 2019/2020

DEPARTAMENTO DE ENGENHARIA CIVIL

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉ miec@fe.up.pt

Editado por

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

http://www.fe.up.pt

ACKNOWLEDGMENTS

First of all, I wish to thank Professor Álvaro Costa , the mentor of this work, for his availability, insights and critical look during the development of this dissertation. Even though the geographic distance was significative, the communication flow was always very much efficient. Regarding all the suggested books, I'll do my best to return with interesting questions leading the way to both relevant and, at least from my perspective, joyful discussions.

To Time:Matters, I want to show my appreciation for the opportunity to become part of such a professional, dedicated and interesting team.
To all the colleagues I met during this internship, I wish a very pleasant future work (without all my mistakes) and the best of luck for the upcoming challenges.

To Francisca Petracchi, for her amazing support in having this dissertation printed and delivered.

Finally, I couldn't be more grateful to everyone else who, out of pure generosity, shared their knowledge and time with me. I wish you all the best and I hope to preserve the opportunity of learning from each one of you.

RESUMO

A sustentabilidade no transporte de carga é um desafio complexo, mas também uma oportunidade para a ferrovia afirmar a sua posição no mercado dos transportes rápidos. Grande parte dos países que pertencem à UE possuem atualmente uma excelente infraestrutura ferroviária de alta velocidade destinada a passageiros. Contudo, ainda não desenvolveram a capacidade de transportar carga da mesma forma que o transporte aéreo, que integra passageiros e carga no mesmo modo de transporte. A análise de dados desenvolvida mostra que, para a maioria dos transportes de carga aérea na UE, o transporte ferroviário de alta velocidade possui a capacidade de oferecer soluções competitivas, com cerca de 97% menos emissões de CO2 e custos operacionais bastante semelhantes, quando comparado com as opções de transporte aéreo. No entanto, para serem capazes de oferecer um serviço rápido e competitivo de transporte ferroviário de carga, as empresas ferroviárias precisam superar alguns desafios complexos. Nomeadamente, a falta de ligações, a baixa interoperabilidade nas fronteiras e as diferenças estruturais entre os diversos países. Para além disso, a tecnologia relacionada com o planeamento de terminais e operações de *handling*, como a carga, descarga e transferência de volumes entre meios de transporte sucessivos precisam de soluções atuais e inovadoras, de forma a lidar com a crescente procura por transportes rápidos, que se inserem num mercado extremamente competitivo. A regulamentação recente no setor ferroviário da UE resultou na liberalização do mercado de passageiros e vai continuar a aumentar pressão para que as empresas ferroviárias melhorem seu portfólio, por meio do desenvolvimento de novos produtos, serviços e mercados, como o caso estudado nesta dissertação. Os mercados liberalizados também têm a vertente de criar um ecossistema que desafia a gestão das empresas que se encontravam originalmente no mercado a maximizar os seus resultados operacionais. O fator de carga médio de 50% nos comboios de passageiros de alta velocidade abre muitas possibilidades para monetizar esse recurso desperdiçado, principalmente por meio de novos usos de espaço, potenciado pela reformulação de grande parte dos processos atuais. Contudo, muitas dificuldades surgem da enorme quantidade de entidades envolvidas no setor ferroviário, em conjunto com desafios complexos e incertezas, num mundo em rápida transformação. Por esse motivo, uma gestão da ferrovia extremamente capaz é crucial para criar um serviço rápido e competitivo de transporte ferroviário de carga, que aumente a sustentabilidade dos sistemas de transporte de carga sem afetar o seu desempenho.

Esta dissertação reflete sobre alguns tópicos dispersos, todos eles relacionados com o setor ferroviário, e mostra algumas perspetivas interessantes sobre como construir um serviço rápido e competitivo de transporte ferroviário de carga.

PALAVRAS-CHAVE: transporte ferroviário, rápido, sustentabilidade, otimização, inovação

ABSTRACT

Sustainability in freight transportation is a complex challenge but also an opportunity for rail to affirm its position in the fast shipments market. Many countries in the EU already have an outstanding high-speed rail infrastructure for passengers, but still haven't made their way into the cargo business as air-freight does today, mixing both passengers and cargo in the same mode of transportation. The data analysis developed, showed that for the majority of air-freight shipments within the EU, high-speed rail-freight could have the capacity to offer competitive solutions, with around 97% less CO2 emissions and with similar operative costs, when compared with air options. However, in order to deliver a competitive fast rail-freight service, rail enterprises need to overcome some complex challenges such as missing links, lack of interoperability along borders and different countries. Also, technology related with terminal's design and handling operations such as loading, unloading and transhipping require new and innovative solutions to be able to cope with the increasing demand for fast shipments in such a competitive market. Recent regulation in the EU's rail sector to liberalize the passenger market will continue to further increase the pressure in rail companies to optimize their portfolio through the development of new products, services and markets, such as the one studied in this dissertation. Liberalized markets create an ecosystem that will challenge the management of incumbent train companies to maximize their operational results. The average load factor of 50% in high-speed passenger trains opens many possibilities to monetize this wasted resource, mainly through new uses of space and by re-designing current processes.

Many difficulties arise as there is a huge number of stakeholders involved in the rail sector, alongside complex challenges and uncertainty in such a fast-changing world. Therefore, a very capable management of rail entities is crucial to build a competitive fast rail-freight service capable of increasing the sustainability of freight transport systems without lowering its performance.

This dissertation reflects upon some topics related with different fields that intersect the rail-sector and shows some interesting perspectives on how to build a competitive fast rail-freight service.

KEYWORDS: rail-freight, fast, sustainability, optimization, innovation.

INDEX

LIST OF FIGURES

LIST OF TABLES

SYMBOLS, ACRONYMS AND ABBREVIATIONS

ATAG – Air Transport Action Group

B2B – Business to Business

B2C – Business to Consumer

BBC – British Broadcasting Company

CAPA – Centre for Aviation

CO2 – Carbon Dioxide

COP 25 – 25th Climate Change Conference

DB – Deutsch Bahn

DEFRA – Department for Environment, Food & Rural Affairs (UK)

ECA – European Court of Auditors

EU – European Union

EUR – Euro

GHG – Green House Gases

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

ICE – Intercity Express

LH – Lufthansa

NASA – National Aeronautics and Space Administration

SCNF – French Railway Nation

SDC – Sameday Classic

TEN-T – Trans-European Transport Network

ULD – Unit Load Device

UN – United Nations

UPS – United Postal Service

WWF – World Wildlife Fund

1

INTRODUCTION

1.1 FRAMEWORK

Air-freight in EU is responsible for transporting around 4.6 million tons of cargo within its borders (Eurostat, 2017). The aviation industry accounts for 2% of global GHG emissions and for 3% in the EU.

Global warming increasing rate results of GHG emissions, where CO2 is responsible for 64% of man-made climate change (European Commission, 2019). The consequences of the increasing global temperature are becoming more common and range from melting ice and rising seas, extreme weather phenomena, shifting rainfall, heat waves, forest fires, droughts, extinction of wildlife (European Commission, 2019; WWF, 2018; Union of Concerned Scientists,2019; NASA, 2010).

From the total CO2 emissions accounted for in the field of transportation, aviation produces 12% of CO2 emissions, compared to 74% by road transport (European Commission, 2018; ATAG, 2018; ICAO, 2018). Moreover, ICAO forecasts that by 2050 CO2 emissions from aviation can grow by further 300 to 700%, relative to present figures. (European Commission, 2019. ICAO, 2010).

Although not everyone agrees with the UN's current position regarding climate change, this work main driver is producing knowledge to tackle the undeniable impact of climate change on Earth. Therefore, the backbone of this work converges with the scientific consensus on this issue: "observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver". (NASA, 2009).
Moreover, at the same time this work was being developed, the European Parliament declared climate emergency, once again urgently calling to reduce global emissions from the aviation industry (European Parliament, 2019). This declaration brought even more relevancy to this work and to its objectives.

There are many ways of inducing change in such a complex issue and many authors defend different approaches to reach similar objectives. Policy and legislation ranging from taxes, incentives, regulations, top-down or bottom-up approaches are in constant discussion and many times fail to produce measurable action and results. For instance, the COP25 summit made evident the divergence of thought regarding climate change and how to tackle it (KPMG, 2019).

This work is very much based in a market approach, as it is believed a wasted market opportunity is in place regarding the network of high-speed trains in the EU. This is, the incapacity of high-speed trains to compete in the fast shipment industry in the EU is related with not only many complex challenges, but also with non-existing to very low research on this topic. In a world where optimization is key and where resources are becoming scarcer day by day, it's an imperative job of engineering to optimize the resources already in place. In the specific frame of this work, the transportation industry, and more specifically the cargo transportation industry, it is of the utmost importance to at least maximize the operation of the transport systems already operating in the EU in every possible way. Therefore, this work aims to produce valuable knowledge that results in decreasing GHG emissions by developing a competitive rail-freight service for fast shipments, believing that rail-freight can meet market need's, with lower costs and outstanding positive environmental impact.

Although air-freight carries around 0.5% of the world trade shipment's volume, it is over 35% by value (ATAG, 2018). Goods shipped by air are very high value commodities, often perishable or time-sensitive and focus both on B2C and B2B markets. On B2C, for example, the ongoing trend in consumer behavior towards e-commerce purchasing models and on the B2B, the increasing globalization of industries, result in higher demand for longer and faster supply chains. In the EU, the only active service of high-speed rail freight is performed by Deutsche Bahn through a partnership with the company Time:Matters. But this service is not yet developed to its full potential as the maximum weight shipped in each train is 60Kgs, mainly due to the lack of specific infrastructure. Nevertheless, this service has excellent operative results and is the only one mixing cargo and passengers in high-speed trains and therefore, competing with air-freight.

With a competitive rail high-speed infrastructure present in many countries of the EU, alongside increasing demand for fast shipment services and for a sustainable transportation sector, it became evident that producing knowledge in how the train industry can adapt and develop to gain market share in this competitive industry was extremely needed. Nevertheless, many needed transformations that fall outside the decision-making capacity of the train industry are expected to be encountered during this work. Therefore, a comprehensive analysis on how to deliver a competitive rail-freight service for fast shipments in the EU is the frame where this work is inserted.

A final remark regarding the importance of the air-freight industry is thought to be relevant. Air-freight is extremely important to the global economy and to the living standards of the EU. Rail can't be an alternative for every shipment performed by the air industry but, many times, a feasible and better alternative.

1.2. OBJECTIVES

The main goal of this work is to develop knowledge that contributes to build a competitive rail-freight service for fast shipments in the EU, resulting in increasing the competitive advantages of rail-freight, delivering a positive environmental impact induced by rail enterprises wishing to explore this market opportunity.

Another goal is to open further research possibilities that derive from the idea that if high-speed rail can be superior to air-freight industry, it may also pose an alternative in the road-freight market. This perspective was not developed in this work.

The final goal is to contribute with a small piece of work that boosts curiosity and willingness to further development in this specific field.

1.3. STRUCTURE

In Chapter 1, an overview of the freight industry in the EU is performed, while also focusing on relevant general concepts related both with general and freight transportation. Some concepts are more specific than others, but all are thought to be relevant for the following chapters.

In Chapter 2, the target is to understand how the fast shipments industry works in the EU. Therefore, a theoretical approach was developed, focusing on how different actors work and how the current freight-transportation networks are organized and designed. The main target is to perceive if it is possible to set a solid base for the shift suggested in this work.

In Chapter 3, a data analysis is done to understand if indeed rail-freight could compete with air-freight through the use of the high-speed train network already available. To reach relevant conclusions, a specific methodology was put into place.

In Chapter 4, the challenge is to further develop some aspects regarding ongoing and future trends as well as identifying key actions that could deliver a competitive fast rail-freight service. The perspective in place is not to focus on any specific set of actions nor field of knowledge, but instead to perform a comprehensive analysis on how to unleash the potential of high-speed trains in the freight market. There are actions that can be done easily and in a short-term but also actions that need a longer time and investments to deliver results. They are addressed separately and with some degree of depth.

2

FREIGHT IN THE EUROPEAN UNION

Transport is a fundamental sector for and of the economy. Transport services embrace a complex network of around 1.2 million private and public companies in the EU, employing around 11 million people and providing goods and services to citizens and businesses in the EU and its trading partners (European Commission, 2019).

Efficient transport services and infrastructure are vital to exploiting the economic strengths of all regions of the European Union, to supporting the internal market and growth, and to enabling economy (European Commission, 2019).

They also influence trade competitiveness, as the availability, price, and quality of transport services have strong implications on production processes and the choice of trading partners. With such a central role, transport is by definition also inter-related with various policy areas, such as environmental policies (European Commission, 2019).

The main challenges for the transport sector in the EU include creating a well-functioning Single European Transport Area, connecting Europe with modern, multi-modal and safe transport infrastructure networks, and shifting towards low-emission mobility, which also involves reducing other negative externalities of transport (European Commission, 2019).

For freight transportation intra-European Union, the preferred mode of transportation by share in ton-kilometers is road (51.5%), followed by maritime (32.4%), rail (11.6%), inland waterways (4.1%) and air (0.4%) (Eurostat, 2017).

When analyzing EU's freight transportation macroscopic picture, it's important to understand that one mode of transport may or may not compete with other mode depending on the characteristics of each transportation service.

For instance, road and rail-freight compete both in terms of type of cargo and in travelling distance. That is why the European Commission launched the Rail Freight Forward within the rail freight vision 2030. This initiative aims to increase rail´s modal share when compared with road-freight. In order to create a bit of context, one of the main difficulties observed in the Rail Freight Forward white paper is the interoperability of train infrastructures in intra-EU international freight operations. For example, different signaling laws and regulation in different member states are a big setback to achieve a more competitive rail network when compared with road options (Rail Freight Forward, 2019).

However, following the same logic, there is no point in comparing air-freight with maritime-freight as they offer solutions to complete different industries and needs that have no connection whatsoever. Whereas maritime-freight is focused on cargo with big volumes, many times loaded in bulk, air-freight is a solution used for smaller volumes and shipments where time is of higher importance.

The air-freight industry is an industry responsible for transporting around 4.6 million tons of cargo within the EU borders (Eurostat, 2017). This mode of transport is extremely interesting as it is the only mode of transportation that can actively mix cargo and passengers, which means an airline has its business based in two different operational models.

It is hard to find other modes of transportation that mix cargo and passengers. It is possible to spot some examples of that mixing but never in such a scale as aircrafts. For instance, rail-freight hardly never mixes cargo and passengers.

2.1. DEFINITION OF FREIGHT TRANSPORT AND ITS RELEVANCE

Logistics is a fundamental part of supply chain management. It consists of the organization and management of flows of goods related to purchasing, production, warehousing, distribution and the disposal, reuse and exchange of products, as well as the provision of added value services (European Commission, 2019).

In a general business sense, logistics is the management of the flow of things between the point of origin and the point of consumption to meet requirements of customers or corporations (Stroh, 2016).

Trade can be defined as the transfer of goods or services from one person or entity to another and is powered by logistical processes that make possible to move goods from two distinct geographic locations.

Freight transport can be defined as the transportation of goods, but not passengers, that are carried from one place to another, by ship, aircraft, train, or truck, or the system of transporting these goods (Cambridge Dictionary, 2019). In other words, the term freight is commonly used to describe the movements of flows of goods being transported by any mode of transportation (McLeod *et al*., 2019).

2.2. GENERAL CONCEPTS ON FREIGHT TRANSPORTATION

Freight is mainly transported by air, rail, road, maritime or by any possible combination of two or more of these transport modes. The transportation of goods performed with at least two different modes of transportation is known as multimodal transport or combined transport (Rodrigue, 2017).

2.2.1. PERFORMANCE COMPARISON

Due to their operational characteristics, freight transportation modes have different capacities and efficiency levels. Rodrigue (2007), argues that efficiency in freight transportation is normally related with the combination of three factors: capacity, duration and cost. For instance, air-freight offers a

service with low capacity, high costs but very low transit times in long distance shipments, when compared with other modes of transportation.
Other factors, such as sustainability and cargo security may be relevant when comparing modes of transportation. However, they tend to be disregarded in most shipments' operations.

2.2.2. Atomization And Massification In Freight Transportation

In freight transportation, atomization represents the smallest load unit that can be effectively transported.

Massification for transportation modes involves the growing capacity to move load units in a single trip. The relations between atomization and massification can be paradoxical since customers tend to prefer the convenience of atomization while carriers are favoring massification and the economies of scale it confers (Rodrigue, 2017).

2.2.3. Distance, Modal Choice And Transport Cost

Transportation modes have different cost functions according to the serviced distance. Using a simple linear distance effect, road, rail and maritime transport have respectively a C1, C2 and C3 cost functions. While road has a lower cost for short distances, its cost increases faster than rail and maritime costs. At a distance D1, it becomes more profitable to use rail transport than road transport while from a distance D2, maritime transport becomes more advantageous. These are referred as break-even distances. Point D1 is generally located between 500 and 750 km of the point of departure, while D2 is near 1,500 km (Rodrigue, 2007).

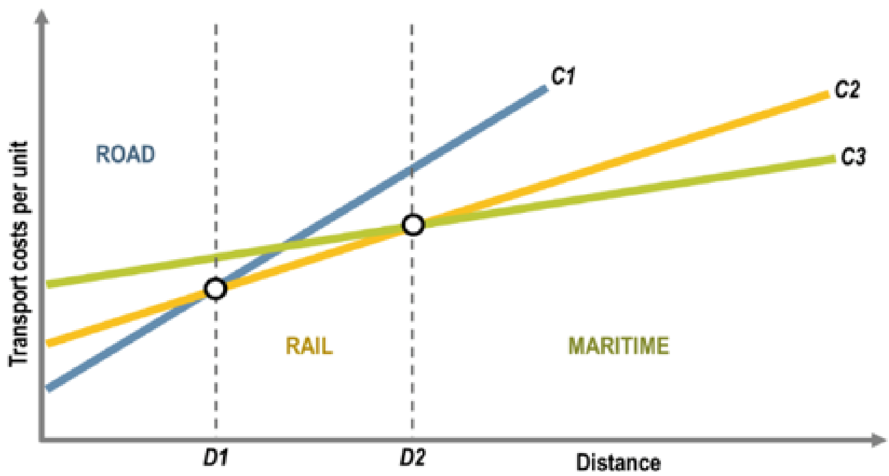

Figure 1 - Relation between Distance, Transport Cost and Modal Choice (Rodrigue, 2017)

2.2.4. DEMAND DISTRIBUTION BY TRANSPORTATION MODE

The selection of a transportation mode is the outcome of several factors, cost being important, but also level of service, frequency and the general value of time attributed to the cargo being transported. It is thus a general trade-off between cost and value of time, which illustrates the attractiveness of a specific mode in relation to others (Rodrigue, 2017).

There is therefore a range of market shares associated with the value of time of freight, leading to a range of modal (and intermodal) options. Any change in the cost (or time) effectiveness of a transportation mode is expected to have an impact on its modal share of the goods it carries (Rodrigue, 2017).

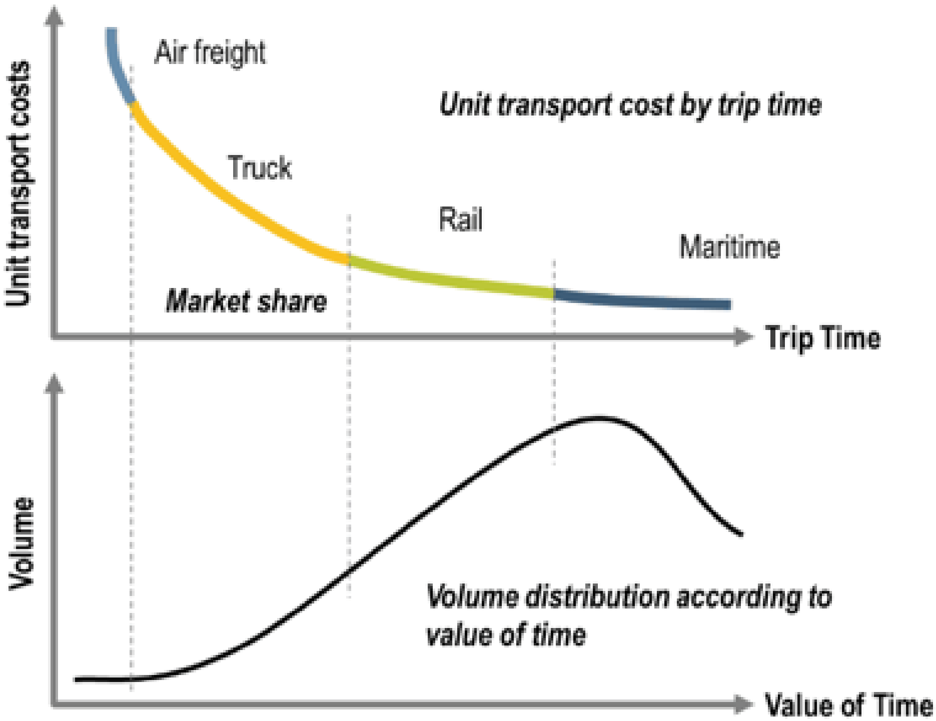

Figure 2 - Demand Distribution according to Volume, Transportation Costs, Trip Time, Value of Time and Market Share (Rodrigue, 2017)

2.2.5. MODAL COMPETITION, COMPLEMENTARITY AND SHIFT IN A TRANSPORT CORRIDOR

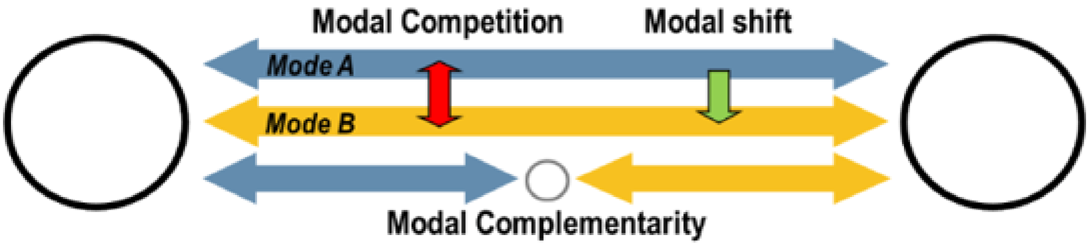

Figure 3 - Model Competition, Modal Shift and Modal Complementarity (Retrieved from Rodrigue, 2017).

Modal competition refers to the direct competition between different modes on the same corridor, which is often a zero-sum game. Competition can take place over cost, time, reliability and niche markets. Each corridor has a freight balance reflecting their respective competitiveness level (Rodrigue, 2017).

Modal shift occurs when one mode develops better advantages over existing modes and captures a share (or the totality) of the transport demand (Faboya *et al*., 2017).

Comparative advantages take various forms, such as cost, capacity, time, flexibility or reliability. Depending on what is being transported, the importance of each of these factors vary. For some, time is of the essence and a modal shift will occur only if the new mode offers time improvements or if new capacity is no longer available, while for others it is mostly a matter of costs (Rodrigue, 2017).
Because of the topic of this work, it is relevant to better understand the details related with the phenomenon of modal shifting.

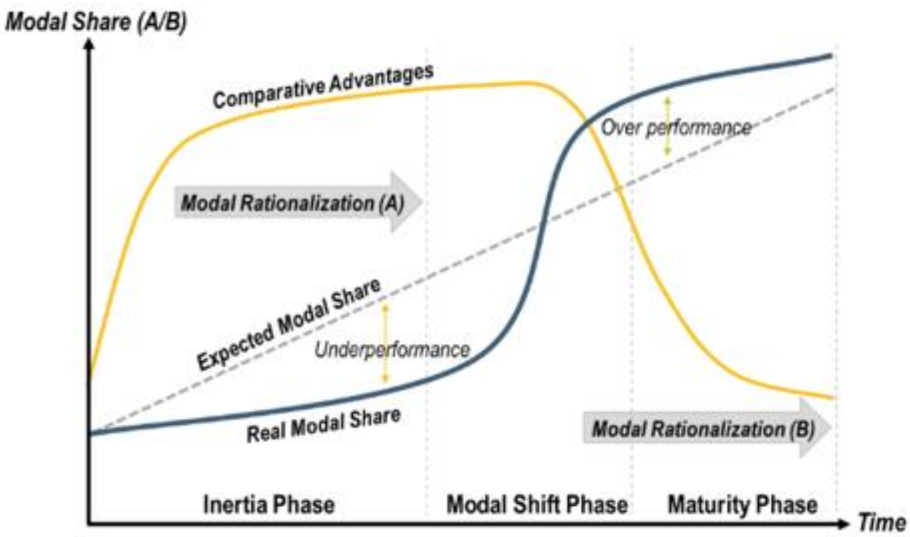

Figure 4 - Principles of Modal Shift (Retrieved from Rodrigue, 2017).

Modal shift often takes place over three phases: inertia phase, modal shift phase and maturity phase. During the **inertia phase**, a mode of transportation is much less significant than expected, leading to a situation of underperformance. The reasons behind inertia are linked to accumulated investments and assets in the existing mode and its infrastructure, management preferences and the costly and timely processes it takes to adapt to a new mode.

Modal rationalization is the moment when early adopters such as enterprises already facing high transport costs on the existing mode, entities receiving government subsidies or being regulated start developing additional efforts to shift their operational model.

The **modal shift** phase represents a fast transition from one mode to the other as the advantages are now widely acknowledged by the industry. This shift marks the transition from a situation of underperformance to one of over performance. A significant drop in comparative advantages triggers the end of this phase.

Finishing the cycle, the **maturity phase** results in a new equilibrium where the increase and later stabilization of the modal shift rate is reached, revealing its maximum potential.

Finally, **modal complementarity** or intermodality is the integration of different modes with the objective of optimizing the global operation by exploiting their respective advantages. Corridors with an integrated transport system tend to improve freight mobility (Rodrigue, 2017). 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 (Kiso et.al, 2009).

2.2.6 CARGO REVENUE IN CENT PER TON-MILE

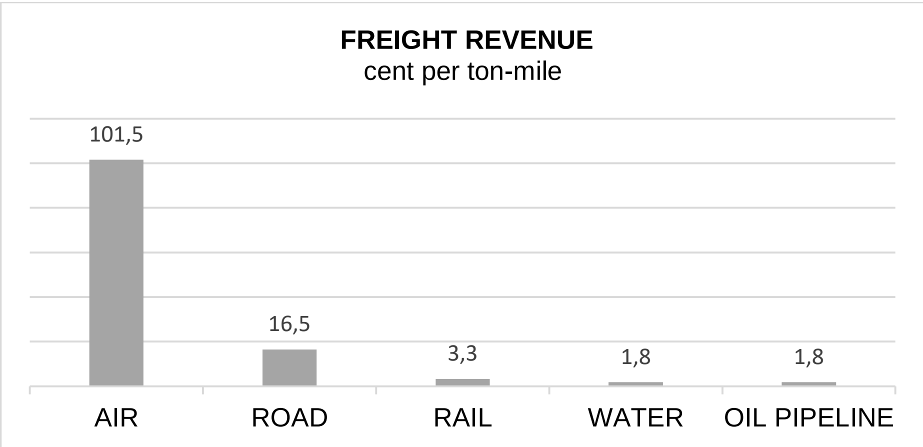

Figure 5 - Freight Revenue in Cent per Ton-Mile (Adapted from Rodrigue, 2017).

The most important factor related to the transport cost is the amount of energy spent for each unit being moved, which is commonly related to the economies of scale that can be achieved with each transport mode (Rodrigue, 2017). Over shorter distances, air transport faces stiff competition from surface modes and from combined road and sea services.

2.2.7. CLASSIFICATION OF SHIPMENTS BY SIZE

There is no universal specific guideline for the definition of a shipment by its size as it is usually related with the specific mode of transportation and with each operator definition. However, the categorization used by most of the operators group their shipments in one of the following categories (Upela, 2019; UPS, 2019; DHL, 2019):

- **Express**: Very small business or personal items like envelopes. These shipments are rarely over a few kilograms and almost always travel in the carrier's own packaging. Express shipments almost always travel some distance by air.
- **Parcel**: Larger items like small boxes are considered parcels or ground shipments. Parcel shipments are always boxed, sometimes in the shipper's packaging and sometimes in carrier-provided packaging.
- **Pallet**: A pallet comprises a loading base, usually wooden or plastic, and objects solidly attached, the whole wrapped in pallet wrap film.
- **Freight**: Beyond express, parcel and pallet shipments, movements are termed freight shipments.

3

THE FAST SHIPMENTS MARKET IN THE EUROPEAN UNION

The main purpose of this chapter is to provide general knowledge on the specific operations of the EU's fast shipments industry. We will look into both air cargo and train cargo specific supply chains, understand the difference between airlines, freight forwarders and carriers and study more closely specific examples of how some entities operate. The objective is not only to explore the differences between shipment services but mainly to understand how the fast shipments industry works.

A shipping cycle is composed by three legs: origin to handler, handler to handler and handler to destination. On the second leg (handler to handler) the cargo may be carried by one or more carriers and using one or several transport modes. It is important to specify that no customs procedures need to be applied in shipments within EU borders.

New trends such as e-commerce eliminate the need for physical distribution of some products and services resulting in a dramatic transformation on the pattern of consumption and generating new sources of business for the air-freight industry (Kiso et.al, 2009).

3.1. DIFFERENTIATING SHIPPING SERVICES

A shipping service is normally differentiated by the combination of three factors: weight, volume and urgency. A forth factor may be added in specific cases, which is the specific commodity being shipped. This forth factor is of higher relevance when dangerous goods are being shipped. Dangerous goods must follow specific regulatory procedures and therefore fall into a specific shipment service or category (ICAO, 2016).

Kiso et.al, (2009) affirms air-freight is a significantly more expensive mode of carriage of goods than other modes and will be used when the value per unit weight of shipments is relatively high and the speed of delivery is an important factor. Under these circumstances, the transport costs can comprise a small proportion of the revenue associated with the products. The advantages offered to the shippers through movement by air include speed, particularly over long distances, lower risk of damage, security, flexibility, accessibility for customers, and good frequency for regular destinations. For integrated operators, the guaranteed delivery and the facility to track consignments gives customers additional advantages over standard air-freight carriage (Kiso et.al, 2009).

There is a particular large and increasing need for fast goods transport. Products that often need fast transport are high-value products such as electronics, medicines and medical equipment, products with news value such as newspapers and perishables such as flowers, vegetables and fish (Ohnell *et al*., 2009). Furthermore, with lower stock-keeping levels and leaner logistics systems comes a demand for express deliveries as a planned backup when things go wrong. One example of this demand is when something is missing for maintaining operations, e.g. spare parts for a process industry or input material for an assembly line. It is thus not the value of the shipped product itself that is high, but the alternative cost of not having it. Demand for express freight transport is presently satisfied either through fast single mode road transport, or, for somewhat longer distances, through intermodal air-road transport (Ohnell *et al*., 2009).

3.2. DEFINITION OF FAST IN THE FREIGHT INDUSTRY

Expedited and express are also terms used to describe faster shipments and can be defined as the process of sending a parcel at a faster rate than would normally be the standard (UPS, 2019; Bizfluent, 2017). Therefore, what is deemed "expedited" will depend on the company policy of the shipper (Linbis, 2019). Expedited shipping can involve delivery that occurs anywhere from the same day to as long as three days and often has priority over other shipping products.

Table 1 - Comparison of the shipping services offered in the "fast" freight market.

SERVICE	NFO (NEXT FLIGHT OUT)	EXPRESS (SAME-DAY)	EXPRESS (NEXT-DAY)	EXPRESS (DEFERRED)	REGULAR	MAIL SERVICE
COST	Very High	Very high	High	Medium	Medium/low	Low
SPEED	Very fast	Very fast	Fast	Medium	Medium/low	Low
ITEM SIZE	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Restricted	Restricted
DELIVERY TIME	ASAP	Same day	Next day	2 or more days	2 to 7 days	Variable
MODE OF TRANSPORT	Air and road	Air and Road	Air and Road	Air and Road	Road	Road

3.3. AIR-FREIGHT WITHIN EU BORDERS

In 2017, the total weight shipped within the EU borders was around 4.6 million tons. Together, only 6 countries (Germany, France, United Kingdom, Belgium, Italy and Spain) account for 80.5% of the total weight of air-freight and mail transport (Eurostat, 2017).

Table 2 - Overview of EU-28 air-freight and mail transport by Member States in 2017: freight and mail loaded/unloaded in tons (Adapted from Eurostat, 2017).

Country	Total national	international intra-EU	International intra-EU and national	Percentage total.
EU-28	596 385	3 937 022	4 533 407	100%
Germany	128 153	1 138 813	1 266 966	28%
France	219 701	600 986	820 687	18%
United Kingdom	96 919	479 869	576 788	13%
Belgium	113	375 049	375 162	8,30%
Italy	49 388	297 557	346 945	7,70%
Spain	61 061	201 607	262 668	5,80%
…	…	…	…	…

Moreover, the three airports with the higher total air transport by weight are CDG, FRA and LHR.

3.4. AIR CARGO SUPPLY CHAIN OVERVIEW

Air cargo may originate from, and be delivered to almost anywhere in the world, most commonly as goods being sent from a seller to a buyer or from a consignor to a consignee. It can take the form of personal belongings, gifts and donations, product samples or equipment and even live animals (ICAO, 2016).

The cargo will be handled along the chain by several entities with varying responsibilities, including aircraft operators, express carriers, postal operators, regulated agents, consignors, consignees, haulers and ground handlers.

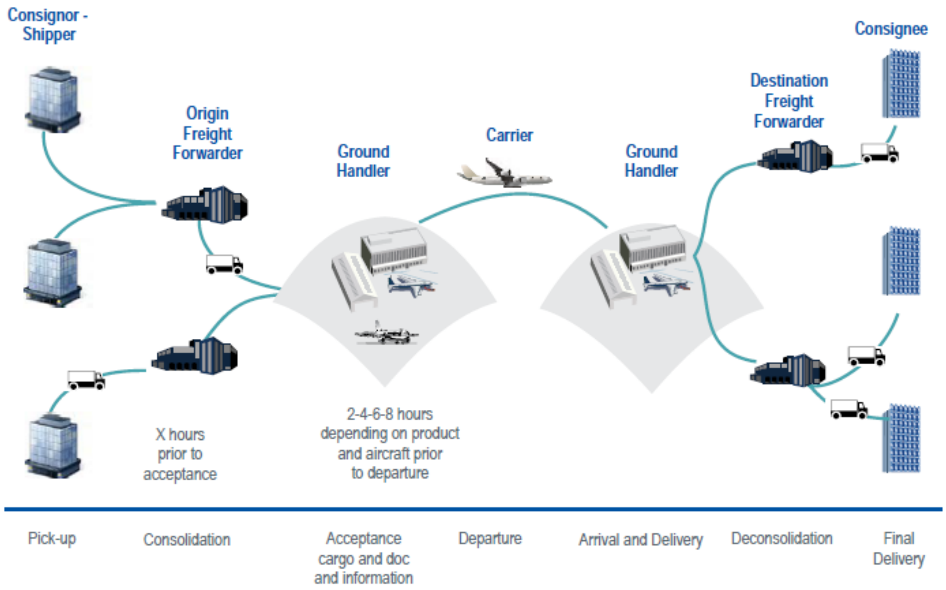

Figure 6 - Air Cargo Movement Overview (Retrieved from ICAO, 2016).

The cargo may transfer between several different flights before it reaches its destination and consignments will be subjected to a variety of procedures and documentary requirements in accordance with legal and commercial frameworks (ICAO, 2016).

Aircraft operators, known as airlines, provide air transportation for goods. A transport contract (air waybill) binds an aircraft operator with the relevant contracted parties for the safe and secure transport of cargo from one location (e.g. the airport of departure) to another (e.g. the airport of arrival).

The air cargo may be transported on passenger aircraft or all-cargo aircraft. In some instances, particularly for short distances, aircraft operators may also transport air cargo by road. Still, the transport contract remains an air waybill, and the road segment is considered as a flight, with a designated flight number. This type of operation is known as a ‘road feeder service’ (ICAO, 2016).

Express carriers combine the work of a broker, hauler, freight forwarder, ground handler and aircraft operator into one single company or group, which is why they are also sometimes referred to as “integrators”. Express delivery has thus become a specific business model in the cargo industry. Express carriers manage end-to-end multimodal supply chains spanning wide territories Express carriers typically transport high-value-added, time-sensitive cargo, with a time definite delivery (ICAO, 2016).

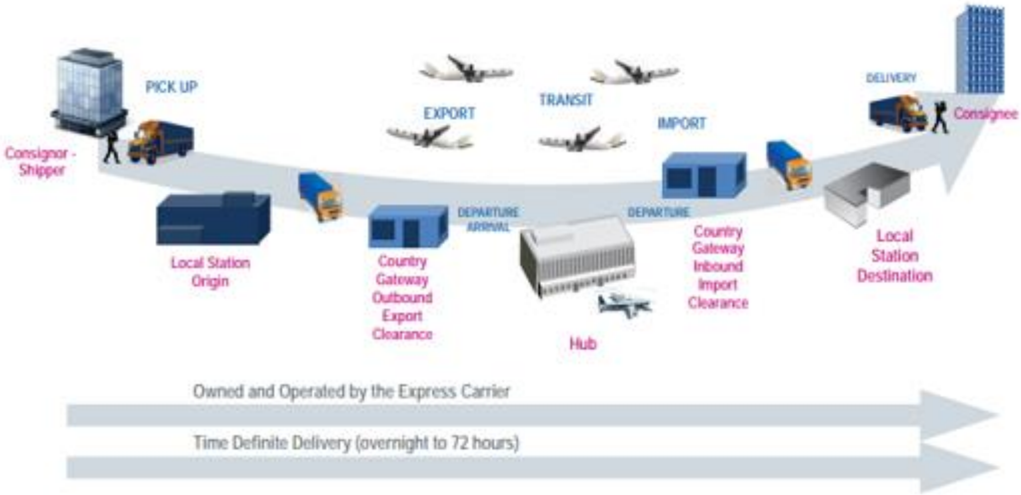

Figure 7 - The Express Model (Retrieved from ICAO, 2016).

Freight forwarders offer shippers a wide range of logistical and transport services options but have no ownership of this services. These include collection and door-to-door delivery of shipments, complete documentation and paperwork for customs purposes, customs clearance, tracking of shipments, and control. The freight forwarders act as wholesalers and earn their profit by maximizing the difference between what they pay the airlines and other carriers and what they can charge the shippers. Consolidated shipments, aggregated by forwarders and carried by the line-haul operators, typically travel under a single air waybill. Freight forwarders have access to a network of service providers and integrate operators in a way that offers a variety of services to their customers (ICAO, 2016).

Many times, it is difficult to fully classify one entity as the services offered may intersect different areas of the supply chain. For example, an airline that offers a delivery service to the final destination or consignee may be considered also an express carrier if it holds responsibility for this service or a freight forwarder in the case the airline books the delivery service with other operator and holds no responsibility for that leg of the shipment. Therefore, the classification of this entities is based on their core business and not in the cross-selling services it provides (ICAO, 2016).

3.4.1. NETWORK DISTRIBUTION

The spoke-hub distribution is a form of transport topology optimization in which traffic planners organize routes as a series of "spokes" that connect outlying points to a central "hub". Simple forms of this distribution model compare with point-to-point transit systems, in which each point has a direct route to every other point, and which modeled the principal method of transporting passengers and freight until the 1970s (Rodrigue, 2017; Alderighi et.al, 2007).

The hub and spoke model, as compared to the point-to-point model, requires fewer routes. For a network of n nodes, only $n-1$ routes are necessary to connect all nodes. That compares favorably to the $\frac{n(n-1)}{2}$ routes, which would be required to connect each node to every other node in a point-to-point network.

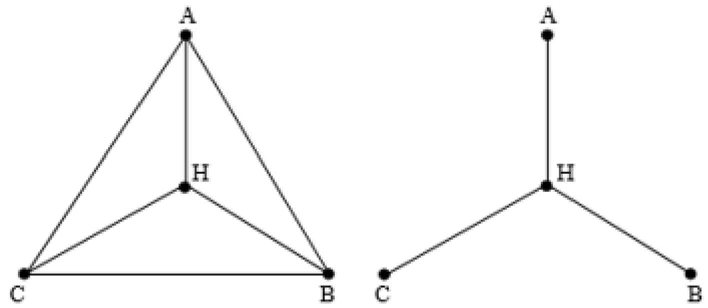

Figure 8 - Point-to-Point Network versus a Hub-and-Spoke Network (Retrieved from Alderighi et.al, 2007).

The main reasons for this network configuration are mainly related with demand and supply management as many routes may not have the volume to justify the operation of profitable flights. Nevertheless, there are many more advantages related with the hub-spoke such as the logistic costs of fleet rotation that may make it convenient for the airlines to develop operational bases. A hub also enables to reconcile more effectively long distance and regional air services.

However, according to Sorgenfrei, (2018), the hub constitutes a bottleneck or single point of failure in the network and the total cargo capacity of the network is limited by the hub's capacity. Delays at the hub (such as from bad weather conditions) can result in delays throughout the network. Cargo must pass through the hub before reaching its destination and so require longer journeys than direct point-to-point trips. That may be desirable for freight, which can benefit from sorting and consolidating operations at the hub, but it is problematic for time-critical cargo as well as for passengers.

Furthermore, since at least two trips are required to reach destinations other than the hub, distance travelled may be much longer than a direct trip between departure and destination points. The time spent at the hub increases the total duration of the journey.

Almost all airlines and express carriers in EU have been using the spoke-hub distribution model contributing to the great development of some European airports (Alderighi et.al, 2007). As result of this network configuration, the airports that handle more cargo are the hub airports.

Table 3 - Major airports in terms of cargo handled and respective hub airline (Adapted from Eurostat, 2017).

RANK	AIRPORT	HUB
1	CDG	Air France
2	FRA	Lufthansa
3	LHR	British Airways
4	MAS	KLM
5	LEJ	DHL
6	LUX	Cargolux
7	CGN	UPS
8	LGG	ASL Cargo Air Lines
9	MXP	Air Italy
10	BRU	Brussels Airlines

Reynolds-Feighan (2001) identified the spoke-hub configuration of a carrier when its network has a high concentration level of air traffic in both space and time. In contrast, a network is point-to-point structured when traffic flows are temporally and spatially dispersed. The number of routes may increase but hardly ever reaches the ideal point-to-point configuration where all the airports are connected to each other (Alderighi et.al, 2007).

Therefore, from an empirical point of view, it is expected that a point-to-point network will show low levels of temporal concentration, but not necessarily low levels of spatial concentration. However, a hub-spoke structure is a network spatially and temporally concentrated in one or few airports, called hubs, where the flights schedule is organized in wave systems in order to have the maximal number of flight connections (Alderighi et.al, 2007).

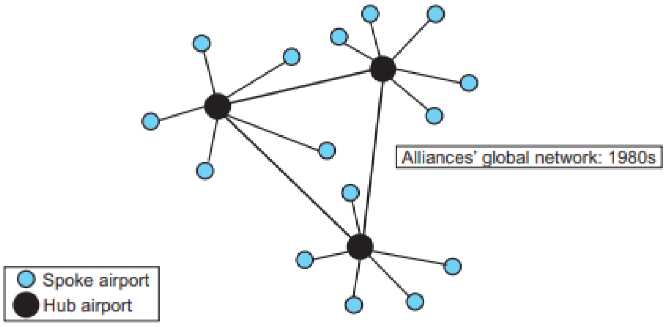

Figure 9 - Scheme of Topology of Airline's Alliance (Retrieved from Teodorovic *et al*., 2017)

Furthermore, in order to guard market position and even strengthen it, many larger passenger airlines have created the airline alliances including themselves and several smaller airlines. Airline alliances are formed when different airlines agree to substantially cooperate with each other (Teodorović et.al, 2017).

3.4.2. AIRLINE EXAMPLE: LUFTHANSA CARGO

Lufthansa Cargo AG is a German cargo airline and a wholly owned subsidiary of Lufthansa. It operates worldwide air-freight and logistics services and is headquartered at Frankfurt Airport, the main hub of Lufthansa. Besides operating dedicated cargo planes, the company also has access to cargo capacities of 350 passenger aircraft of the Lufthansa Group (Lufthansa Group, 2019).

Lufthansa Cargo Group comprises 18 air-freight related companies in the Lufthansa Group whose portfolios of destinations, capacity, products and services complement each other. Lufthansa Cargo AG and seven other providers of hold and main deck capacity form the core of the group (Lufthansa Group, 2019).

With a transport volume of around 1.6 million tons of cargo and postage deliveries and 8.9 billion freight ton kilometers sold in 2017, Lufthansa Cargo is one of the biggest cargo airlines in the world (IATA, 2019; Aircargo News, 2019).

Lufthansa Cargo has 361 stations around the world and Frankfurt is the central hub of the air-freight network. Other than Frankfurt, LH Cargo operates two more hubs: Munich and Vienna. Lufthansa Cargo's Munich hub connects southern Europe, while Vienna's hub is focused on the operations of Austrian Airlines, a subsidiary of Lufthansa Group (Lufthansa Cargo, 2019).

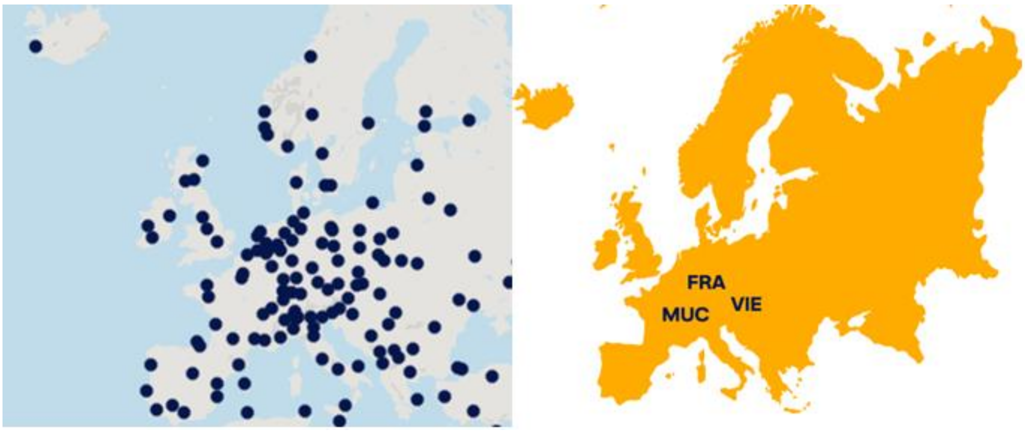

Figure 10 - Lufthansa Cargo Stations and Hubs in the European Union (Retrieved from Lufthansa Group, 2019).

LH Cargo offers a bunch of different shipping services with varying characteristics such as speed, priority and cost. A wide range of additional services may be applied to a shipment, such as cold storage, security and many more. On the following table it's possible to compare the services offered by LH cargo (Lufthansa Cargo, 2019).

Table 4 - Lufthansa Cargo Services and Characteristics (Adapted from LH Cargo, 2019)

LH CARGO SERVICE	CHARACTERISTICS
Td.Basic	Cargo's entry-level model. It combines a lower price with the quality. Option for when time is key, but isn't everything.
Td.Pro	Model for standard cargo, regardless of its size and weight.
Td.Flash	Combines speed, the highest level of quality, and rapidly available capacity. This product is for your highest-priority shipments;
Courier.Solutions	Solution for particularly time-sensitive and valuable air cargo.
Emergency.Solutions	Providing immediate assistance in a logistics emergency

3.4.3. EXPRESS CARRIER EXAMPLE: UPS (UNITED POSTAL SERVICE)

UPS services the market for logistics services, which includes transportation, distribution, contract logistics, ground freight, ocean freight, air-freight, customs brokerage, insurance and financing. The two main business areas are the global small package operations and the supply chain & freight (UPS, 2019).

UPS's market strategy is to provide customers with advanced logistics solutions based on a portfolio of differentiated services and capabilities assembled and integrated in a way to support a global multimodal network (UPS, 2019).

The global small package operations provide time-definite delivery services for express letters, documents, small packages and palletized freight via air and ground services. UPS serves more than 220 countries and territories around the world along with domestic delivery service in more than 50 countries (UPS, 2019).

In the EU, the only air hub is located in Cologne, Germany, which is the 7th airport in the EU in terms of total freight and mail loaded/unloaded in 2017 (Eurostat, 2017).

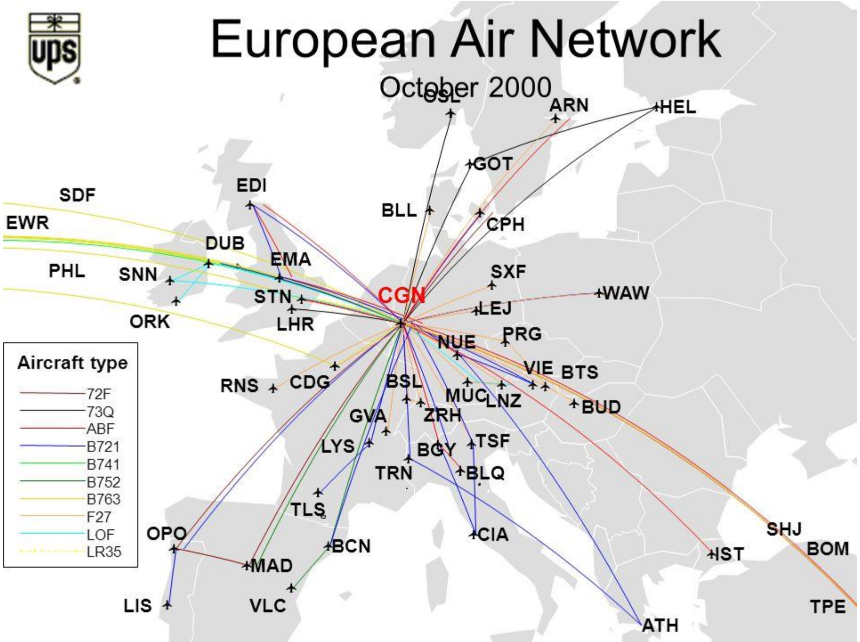

Figure 11 - UPS European Air Network (Retrieved from UPS, 2000).

3.5. Rail-freight within EU Borders

Rail-freight is not a transportation mode of choice for fast shipments as it is not prepared to handle small individual shipments and because it competes in the shipping operations of high volumes cargo, many times loaded in containers or in bulk. Rail is an important service that many times complements the maritime freight services as it feeds ships and distributes cargo from ports to the inner countries' geography (Rodrigue, 2017).

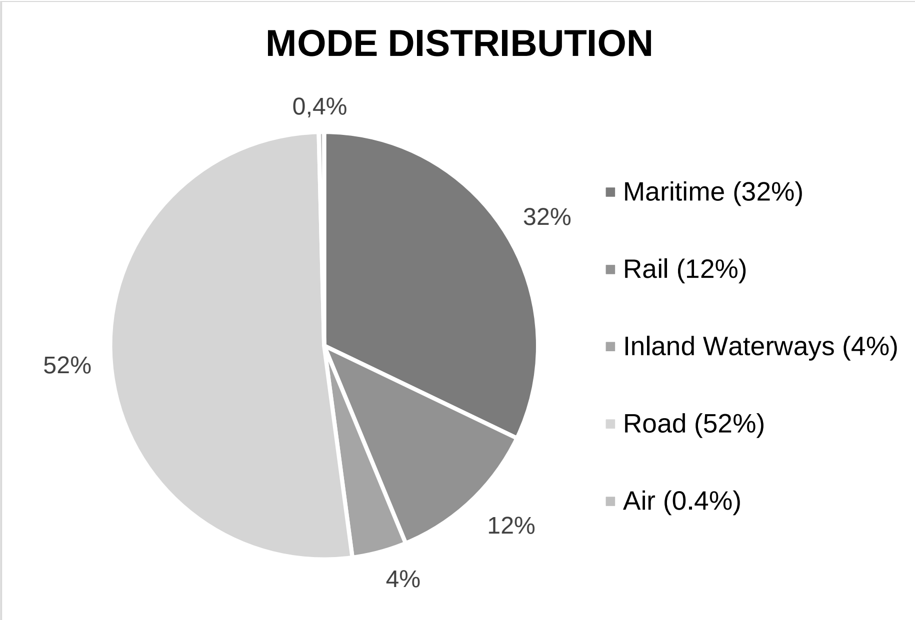

Figure 12 - Cargo Transportation Mode Distribution in the European Union (Retrieved from Eurostat, 2017).

Rail-freight services suffer from low quality and reliability. This is due to the lack of coordination in cross-border capacity offer, traffic management and planning of infrastructure works (European Commission, 2019).

The EU country that is responsible for the highest number of ton-kilometers in rail-freight is, by far, Germany, with around 117 million-ton kilometers. Following Germany, Poland accounts for around 58 million-ton kilometers.

However, rail has not yet successfully offered services "faster than road but cheaper than air", although there are technical, logistical and economic opportunities for competing with air for intra-continental shipments and co-operate for intercontinental ones (Ohnell *et al*., 2009).

The market for express and high-speed freight trains is small in terms of volume, but it is an expansive market and offers considerable revenue potential (Troche, 2005).

Thanks to its intense passenger traffic, Europe has a high-class rail network designed for high speeds. The infrastructural prerequisites for high-speed freight traffic in Europe are thus comparatively good and the European high-speed network now taking shape will further improve these prerequisites (Troche, 2005).

Troche, (2005) further argues that the railways in Europe have still not yet managed to exploit this potential to any great extent for freight traffic. In some countries mail traffic by rail has ceased – and the ancillary infrastructure has been dismantled – while in other countries it has entered a new phase of development. Under these circumstances, no continuous international rail network has been able to be established.

3.5.1. NETWORK DISTRIBUTION

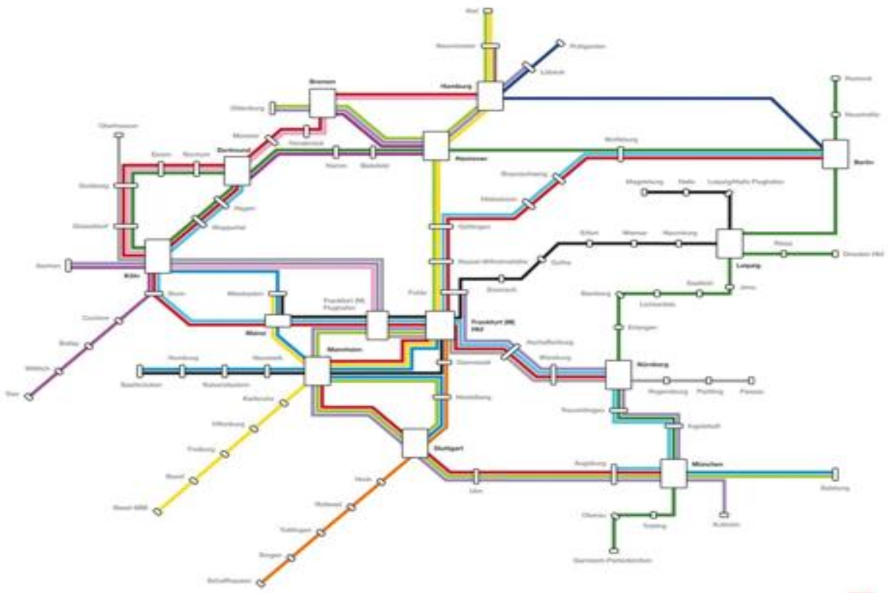

Figure 13 - Rail Network in Germany (Retrieved from Deutsche Bahn, 2018).

A rail network is composed by a set of different characteristics, such as carts and gauges. However, three different line configuration that serve distinct objectives may be observed in a rail network. A penetration line links a port city with its hinterland, particularly in order to access natural resources such as minerals, agricultural products and wood products. The purpose of a penetration line is to convey large amounts of materials in a manner that would be prohibitive for road transport. Regional lines serve high density population areas of developed countries with the goal to support massive shipments of freight. Regions with the highest rail density are Western Europe, the Northeastern part of North America, Coastal China and Japan. Transcontinental lines are a contiguous network railroad track that crosses a continental land mass with terminals at different oceans or continental borders (Rodrigue, 2017).

Rail systems are characterized by a high level of economic and territorial control since most rail companies are operating in situation of monopoly or almost monopoly even after liberalization in some countries. (Rodrigue, 2017).

Operating a rail system involves using regular (scheduled), but rigid, services since a limited number of slots on a rail track are available within a time period (European Commission; Rodrigue, 2017).

Rail transportation has a low level of space consumption along lines, but its terminals are can occupy large portions of real estate, especially in urban areas. This increases operation costs substantially. Still, rail terminals tend to be centrally located and accessible (Rodrigue, 2017; Yi, 2018).

Rail network design trend in the EU is to create and develop a Single European Rail Area alongside efforts to achieve technical interoperability and to ensure that rolling stock is able to run across national borders. In particular, the Trans-European Transport network (TEN-T) requires investment in new infrastructure, refurbishment and modernization of the existing network. Selected projects are mostly concentrated on the strategic sections the TEN-T Core Network to ensure the highest EU added-value and impact (European Commission, 2019).

3.5.2 TRAIN COMPANY EXAMPLE: DEUTSCHE BAHN CARGO

The DB Cargo business unit manages Deutsche Bahn's Europe rail-freight business. Its network comprises 16 subsidiaries in different countries. In the EU, DB Cargo operates in Bulgaria, Czech Republic, Denmark, France, Germany, Hungary, Italy, Netherlands, Poland, Romania, Russia, Spain, Switzerland and United Kingdom (Deutsche Bahn, 2019).

Figure 14 - Deutsche Bahn's Rail Network (Retrieved from Deutsche Bahn, 2018).

Service at the European level accounts for nearly 60% of DB Cargo's transport volumes today. With around 92,000 freight cars and about 3,000 locomotives, DB Cargo has the largest fleet on the European continent.

Each subsidiary is known as a national company and is led by a management team based in the country where it is located. The national companies are assigned to the five board divisions at DB Cargo (Chairman, Sales, Production, Finance and Human Resources) in a way that dovetails regional and functional management optimally, fostering an effective European network. In addition, internationally specialized sales, forwarding and logistics companies operate in national markets as well as across borders (Deutsche Bahn, 2019).

The key industries served by DB Cargo are metals and coal, chemicals, automotive, building materials, industrial and consumer goods, and intermodal transport. DB Cargo's customers are primarily key accounts. Most of the company's services are carried out using its own fleet of locomotives and freight cars (Deutsche Bahn, 2019).

3.5.3. FAST RAIL-FREIGHT EXAMPLE: DEUTSCHE BAHN AND TIME:MATTERS PARTNERSHIP

A rail courier-goods service can be found in Germany where Time:Matters, a subsidiary company of Lufthansa Cargo, buys capacity onboard of Deutsche Bahn's ICE, IC and EC trains and sells it to customers (Troche, 2005). Shipments can be delivered and picked up at all major stations, but door-to-door service is also available. The system offers frequent services, fast transport times, with same-day and high geographical coverage, especially in Germany (Time:Matters, 2019).

This partnership is the first of this kind and is the only service that actively uses fast passenger trains to ship urgent critical goods. The fast shipments use a network of more than 140 stations and have four international services: Paris, Vienna, Basel Bad and Amsterdam. All stations have at least on associated courier that provides an option for a fast last-mile delivery service (Deutsche Bahn, 2019).

However, as the infrastructure and operational processes are still in a test phase, the maximum capacity in each train is of three shipments with no more than 40*40*20 cm and 20Kgs each.

3.6. FREIGHT FORWARDER EXAMPLE: TIME:MATTERS

Time:Matters is a freight forwarder company for particularly urgent transports and complex logistics. Urgently needed spare parts, medical samples and important documents can be transported quickly and reliably from A to B via air, rail and road. This is achievable due to the integration of global network with around 500 courier partners and airlines. Time:Matters maintains close cooperation with more than 21 airlines, in particular with the Lufthansa Group, with whom it has a preferential relation (Time:Matters, 2019). Also, Time:Matters is an exclusive partner of Deutsche Bahn, offering the only service in the EU of fast shipments by rail, as we have seen before (Time:Matters, 2019).

Within their network of partners, a wide range of flight routes is possible: more than 3,000 connections a day to over 500 destinations in around 100 countries. Besides speed and reliability, providing an individual, flexible service is their main business value (Time:Matters, 2019).

As a specialized freight forwarder company, Time:Matters holds barely no operational process, except for their own terminal in Frankfurt and Munich's airport, which are responsible for import, export, transit and customs procedures. Other than that, Time:Matters is keen in using the available network of service providers in the air, road and train logistics sector around the world.

Table 5 - Time:Matter's Services and Description (Adapted from Time:Matters, 2019).

SERVICE	DESCRIPTION
SAMEDAY CLASSIC AIR	Same day service for shipments below 32Kgs and 90*50*50cms
SAMEDAY AIR UNLIMITED (ZXO)	Same day service for shipments below 200Kgs
GLOBAL EXPRESS	Service for shipments outside same day network
IC:KURRIER	Same day shipment by rail for shipments below 40*20*20 and 20Kgs.
OBC	Shipment is taken by an on board carrier

Time:Matters most used service is the Sameday Classic Air, with close to 50% of the total number of shipments performed. This service is also the one that was developed from scratch by Time:Matters as a part of their value proposition. The Sameday Classic Air (SDC) is composed by a plastic bag of 90*50*50 cm that can transport a maximum weight of 32Kgs. Because of its maximum size and weight, it can be handled as normal luggage by the handling agents accordingly to the regulation issued by IATA (International Air Transport Association). Therefore, the Sameday Classic Air bag is handled faster, with handling times of about 1 hour, and has priority over other cargo.

Both Sameday products are shipped within the so called Sameday Network composed by a network of airports and several service providers. The Sameday Network has SOP's (standardized operations procedures) for every connection and therefore is extremely capable of shipping with high control of operational procedures. One interesting result of this standardization is the reduced handling times for export and import that Time:Matters has contracted with different handling agents in its Sameday Network.

This network contains locations on both Africa, Asia, Europe and the USA but it is more developed in Europe, mainly the European Union.

Figure 15 - Time:Matter's Sameday Network (Time:Matters, 2019).

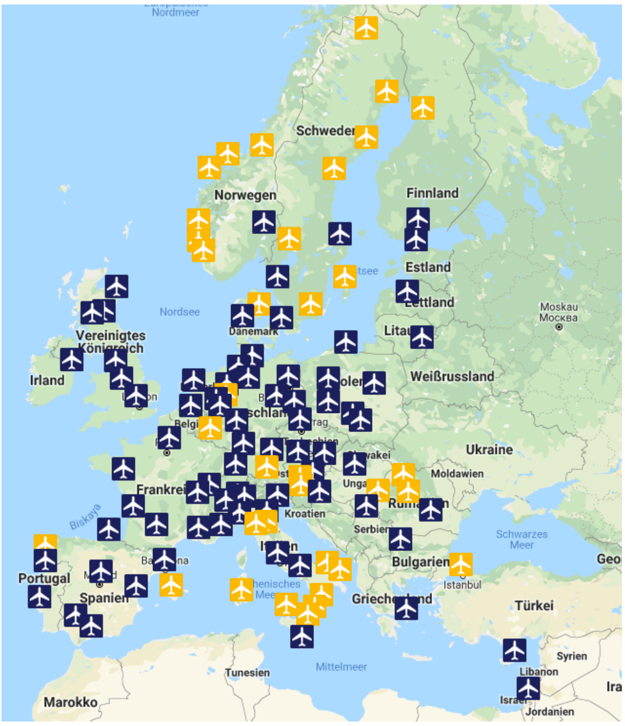

Figure 16 - Time:Matter's Sameday Network (Time:Matters, 2019).

4

DATA ANALYSIS: COULD RAIL BE COMPETITIVE?

4.1. OBJECTIVES

The main target in this chapter is to study if a developed rail-freight service using high-speed passenger trains could be capable of competing with the air-freight industry both in terms of operational performance and costs. Obviously, not all air routes have a possible rail option and therefore, the process of selecting the comparable routes was thought meticulously. The objective is to analyze a certain number of different scenarios and develop relevant knowledge that allows to deliver concrete conclusions.

The goal is not only to understand if a rail option may be favorable when comparing to air option but also to study the impact of a passenger train network as an option for express freight. This aims to not only compare transit times of both air and rail, but also to understand that if a longer time is added to the requested time for shipping an order, than the best solution may be a rail option. This means that this analysis will also look to express freight, for example an option with a timed delivery in 48 hours, from point A to B, and study if an alternative using high-speed passenger trains would be possible for that route.

The ultimate challenge of this analysis is to provide valuable information and results for rail stakeholders in order to develop further knowledge in this specific industry.

4.2. SELECTION OF AIRPORTS AND RAIL STATIONS

The selection of the most relevant airports to address in this analysis was developed in a three-phase process.
Firstly, all the stations belonging to the network of Time:Matters in the EU were selected. Thus, the result is 106 stations spread across the EU.
Secondly, a first filter containing the top-20 airports in the EU-28 in terms of total freight and mail loaded and unloaded in 2017 (Eurostat, 2017) was applied, resulting in 17 airports selected. The reason why there are 3 airports amongst the top-20 airports in the EU-28 and not in the list of the stations used by Time:Matters is simply explained by the fact that these 3 airports are hubs for airlines

owned by carriers. Specific characteristics regarding these airports will be addressed in detail.
Thirdly, a second filter was applied containing the top-10 airports used by Time:Matters NL for departures and for arrivals in the period from January to November of 2019. This list contains 20 entries, divided in two tables. The first table comprises the 10 most used airports for departures, while the second one aggregates the 10 most used airports for arrivals. After dismissing repetitive airports, such as OPO which belongs to both top-10 lists, this filter is composed by 13 airports.

One relevant particularity is the fact that these filters are not applied cumulatively over the same set of airports. They are applied separately, and the duplicates are removed afterwards. Using a mathematical expression, the desired result is: $C = ((A \cap 1) + (A \cap 2) + (A \cap 1 \cap 2) - (1 \cap 2)$, where C is the set of airports that will be used in further analysis, 1 and 2 represent the filters and A the initial list of airports.

Regarding the three airports that belong to the second filter but don't belong to the group of stations used by Time:Matters, one important decision was made. Since the airports in the EU's top-20 are selected based on the total cargo they handle, it may result in airports that belong to this top because they are hubs and not because there is an actual demand for shipping within that route. Although most of the airports in both lists are hubs for at least one airline, they are also located in important regions such as capital cities or relevant economical centers, which means they are also the departure and arrival station of one shipment.
Therefore, for the sake of a wider study, these three airports were selected to stay on the final list meaning they were added in the end. Moreover, it is relevant to be aware that the list containing the 13 most used airports by Time:Matters only includes airports that are a departure or a arrival station, meaning there is demand for that air-route.
Following this process, the selected 26 airports are as follows:

Table 6 - Time:Matter's Airports Selected.

AIRPORTS SELECTED								
AMS	BRU	CGN	DUS	HEL	LUX	MAN	EMA	OPO
BCN	BUD	CPH	FCO	LEJ	LYS	MUC	LGG	VIE
BHX	CDG	DUB	FRA	LHR	MAD	MXP	STN	

The selection of the railway stations located in the same region as the airport was easily done by using some of the many available journey planning tools such as Google Maps and by consulting the official website of the train companies operating in the selected countries. The railway station selected was always based on the station from where longer journey trains departure. After being selected, the railway stations were also classified as high-speed or not. This classification was made by the definition of high-speed train issued by the International Union of Railways which states that new lines with speed in excess of 250 kilometers per hour and existing lines in excess of 200 kilometers per hour are to be considered high-speed routes. To double-check this classification, the list of high-speed lines in the world, published by IUC was also used.

The result of this process is as follows:

Table 7 - Time:Matter's Airports respective Train Station and Type of Train.

AIRPORT	RAIL STATION	HIGH-SPEED	AIRPORT	RAIL STATION	HIGH-SPEED
AMS	Amsterdam Central	Y	**HEL**	Helsinki Central Railway Station	Y
BCN	Barcelona Sants Train Station	Y	**LEJ**	Leipzig Central Station	Y
BHX	Birmingham New Street Station	N	**LGG**	Liège-Guillemins	Y
BRU	Brussels Central Station	Y	**LHR**	Euston Station	Y
BUD	Budapest-Nyugati	N	**LUX**	Luxembourg, Gare Centrale	N
CDG	Paris Gare du Nord Train Station	Y	**LYS**	Lyon Part-Dieu Station	Y
CGN	Cologne Central Station	Y	**MAD**	Madrid-Puerta de Atocha	Y
CPH	Copenhagen Central Station	Y	**MAN**	Manchester Piccadilly	N
DUB	Heuston Station	N	**MUC**	Munich Central Station	Y
DUS	Dusseldorf Central Station	Y	**MXP**	Milano Centrale	Y
EMA	Birmingham New Street Station	N	**OPO**	Campanhã Station	N
FCO	Rome Tiburtina Train Station	Y	**STN**	Euston Station	Y
FRA	Frankfurt Central Station	Y	**VIE**	Wien Hauptbahnhof	Y

4.3. SELECTION OF ROUTES

The objective is to select the most relevant air routes within the spectrum of the selected airports on Table 6. In theory, and as seen before, the number of possible routes from n different airports is $\frac{n(n-1)}{2}$, which would result in 325 possible routes. Studying in detail 325 different routes would be extremely complex and therefore, once again a filtering process was developed.

The first filter was done with the routes most flown by Time:Matters. In order to do so, routes used over 100 times were selected and compiled into Table 8.

Table 8 - Time:Matter's selected routes frequency.

DEPARTURE	ARRIVAL	COUNT
LHR	FRA	540
DUS	DUB	427
FRA	DUB	321
DUS	LHR	302
FRA	LHR	275
CDG	SJJ	253
MAN	AMS	236
CDG	FRA	212
AMS	DUB	194
AMS	BUD	147
CDG	DUB	144
CDG	BUD	126
LHR	TXL	110
DUS	MAN	102

Due to the specific business Time:Matters is specialized, a high dispersion may be found in Time:Matters used routes. To quantify, the 14 most used routes seen in Table 8, comprise only 17% of the total routes flown globally.

With this limitation in mind, there was a need to add some data to this specific part of the analysis. Based on the latest available data regarding air cargo flows within the EU member countries published by Eurostat, Table 9 was developed. However, the statistics provided by Eurostat don't specify the departure and arrival airport. Instead, only the cargo flow between two countries is provided in weight. Therefore, the procedure used was to choose the top-5 country pairs and use as airport of departure and destination the most relevant airport in that country. The airport selected in each country is the main airport in terms of cargo loaded and unloaded accordingly, once more, to Eurostat. The chosen routes are as follow.

Table 9 - Missing country pairs and respective airport pairs based on total air cargo weight (Adapted from Eurostat, 2015)

Country pair	Total air cargo (t)	Airport pair
UK-Germany	224,815	LHR-FRA
France-Germany	177,192	CDG-FRA
Italy-Germany	134,524	MXP-FRA
Spain-Germany	100,244	MAD-FRA
Belgium-Germany	62,554	BRU-FRA

To finish, both Table 8 and Table 9 were added in order to create Table 10 containing all the air routes to be addressed in the following steps of this analysis. Also, duplicates on Table 8 and 9 were removed. The result is Table 10 containing 17 different routes, using 13 different airports.

Table 10 - Routes addressed in the data analysis.

#ROUTE	DEPARTURE	ARRIVAL	#ROUTE	DEPARTURE	ARRIVAL
1	AMS	DUB	**10**	DUS	MAN
2	AMS	BUD	**11**	FRA	DUB
3	BRU	FRA	**12**	FRA	LHR
4	CDG	SJJ	**13**	LHR	FRA
5	CDG	FRA	**14**	LHR	TXL
6	CDG	DUB	**15**	MAD	FRA
7	CDG	BUD	**16**	MAN	AMS
8	DUS	DUB	**17**	MXP	FRA
9	DUS	LHR			

4.4. DURATION COMPARISON

At this point, the total duration of each route presented on Table 10 will be analyzed both by air and rail.

The total duration of a shipping service needs to include the times of all the processes a shipment has to go through before it is loaded in the selected mode of transportation. For example, if the handling times at origin and destination are of 1 hour, a total of 2 hours must be added to the total duration. The same happens, for instance, when passengers arrives 2 hours early to the airport, relative to the departure time of their flight. For air cargo, handling times differ depending on service type, size, and weight of the cargo.

In this analysis we will only look to flight times of each route based on Lufthansa Cargo available connections. Also, the flight time of a direct route based on a random airline will be added for comparison, although that specific connection may even not be viable for cargo.

In the case of a route with more than 1 connection, it would have been unrealistic not to consider the transit times on connecting airports. Therefore, an extra time of 2 hours is added to each stop in any given route.

Another relevant note has to do with the use of optimal connection schedules, meaning the total duration is the sum of all the flight times with the transit times, in such cases. For example, the total duration considered in a route from A to B with one stop in X is the sum of flight times from A to X and from X to B plus 2 hours instead of the real case where a time gap could occur between flights. This means, any possible gap was eliminated from this calculation, resulting in optimal flight time's results.

The result of this analysis is presented on Table 11.

Table 11 - Air routes duration.

#ROUTE	DEP	ARR	LH CARGO ROUTE			OPTIMAL ROUTE
			Stops	Flights	Duration	
1	AMS	DUB	1	AMS-FRA-DUB	05:15	01:45
2	AMS	BUD	1	AMS-MUC-BUD	04:40	02:00
3	BRU	FRA	0	BRU-FRA	01:00	01:00
4	CDG	SJJ	1	CDG-MUC-SJJ	04:50	02:30
5	CDG	FRA	0	CDG-FRA	01:15	01:15
6	CDG	DUB	1	CDG-FRA-DUB	05:20	01:45
7	CDG	BUD	1	CDG-MUC-BUD	04:40	02:15
8	DUS	DUB	1	DUS-FRA-DUB	05:55	02:00
9	DUS	LHR	1	DUS-FRA-LHR	04:35	01:35
10	DUS	MAN	1	DUS-FRA-MAN	04:35	02:00
11	FRA	DUB	0	FRA-DUB	02:05	02:05
12	FRA	LHR	0	FRA-LHR	01:45	01:45
13	LHR	FRA	0	LHR-FRA	01:45	01:45
14	LHR	TXL	1	LHR-FRA-TXL	04:45	01:50
15	MAD	FRA	0	MAD-FRA	02:40	02:40
16	MAN	AMS	1	MAN-FRA-AMS	04:55	01:20
17	MXP	FRA	0	MXP-FRA	01:20	01:20

The next step in this analysis is to develop a similar table to Table 11, but this time with the duration of train connections within the selected rail routes. This analysis is of higher complexity due to the different options within each rail route. In the rail infrastructure there is a coexistence of different trains and of different possibilities to go from any given origin to any given destination. While in the aviation industry it is also possible to encounter different aircrafts flying the same route, the difference is on size and capacity and not in speed, resulting in the same approximate durations.

With this in mind, the following table considers the best possible duration by doing the sum of every train connection within a rail route, which will be designated as the optimal route. Theoretically, this optimal route is the best possible total duration of a journey where there are no interruptions or handling times between transit times. However, the true optimal time would be the sum of every train connection within a rail route minus the acceleration and breaking times. Therefore, in some understandings, the optimal time in this analysis would have to be considered sub-optimal but due to the lack of knowledge in the specifics of rail speed variations and because that is not the real objective of this work, the next table focuses on optimal times as described earlier.

One other relevant note has to do with the consideration of transit times in this analysis. One hour was added for each stop and as many cities have different train station, always the most direct route was used.

Finally, in routes where there is an impossible full journey using train connections due, for example, to missing connections between train stations, an approximate time was used considering the sum of the duration of each train journey. Many times, connecting from the arrival train station to the new departure station is done using urban modes of transport, often urban- rail connections. Also, in routes where a full journey can’t be completed, no option was displayed. Such cases occur mainly in train routes to Ireland (Heuston Station).

The result of this analysis is presented on Table 12.

Table 12 - Train Routes Duration

#Route	DEPARTURE	ARRIVAL	Train Route		Optimal Route
			Stops	Duration	Duration
1	Amsterdam Central	Heuston Station	n/a	n/a	n/a
2	Amsterdam Central	Budapesht Keleti	2	18:41	16:39
3	Bruxelles-Nord	Frankfurt Central Station	0	02:53	02:53
4	Paris Gare du Nord Train Station	Sarajevo Railway Station	ROUTE NOT POSSIBLE		
5	Gare de l'Est	Frankfurt Central Station	0	03:38	03:38
6	Paris Gare du Nord Train Station	Heuston Station	ROUTE NOT POSSIBLE		
7	Gare de Lyon	Budapesht Keleti	1	16:52	15:52
8	Dusseldorf Central Station	Heuston Station	n/a	n/a	n/a
9	Dusseldorf Central Station	Euston Station	1	07:14	06:14
10	Dusseldorf Central Station	Manchester Piccadilly	4	11:20	06:20
11	Frankfurt Central Station	Heuston Station	ROUTE NOT POSSIBLE		
12	Frankfurt Central Station	Euston Station	1	06:32	05:32
13	Euston Station	Frankfurt Central Station	2	06:32	05:32
14	Euston Station	Berlin Hauptbahnhof	2	12:59	10:59
15	Madrid Chamartín Railway Station	Frankfurt Central Station	3	16:44	13:44
16	Manchester Piccadilly	Amsterdam Central	2	06:58	08:58
17	Milano Centrale	Frankfurt Central Station	1	06:33	07:33

4.5. CAPACITY COMPARISON

Capacity is the total amount that something can contain (Cambridge Dictionary, 2019) and is a by itself insufficient to compare the way how goods can be loaded in a given space. Capacity in modes of freight transport refers to the maximum weight and size a piece could virtually have if no loading constrains were to apply. For instance, when comparing two similar aircrafts, the capacity can be relevant but if the objective is to compare a train with an aircraft, using only the capacity wouldn't be correct. Many more considerations need to be done when comparing how much cargo, how many pieces and or how many different sizes fit into a mode of transportation. For instance, the size of the door, the capacity of the ULD's (Unit load device), which is a pallet or container used to load luggage, freight, and mail on wide-body aircraft and specific narrow-body aircraft (IATA, 2019).

The main objective of this comparison is to provide a first degree of understanding over the different aircrafts and train carriages most used in the EU market. Three considerations need to be applied to this analysis. Firstly, a lot more information is accessible for aircrafts than for trains due to the fact that freight is already transported in passenger aircrafts since a long time ago. Secondly, the capacity of a train carriage was calculated using approximate values and therefore is not extremely accurate. Thirdly, the aircrafts in which this comparison is based belong to the Lufthansa Cargo short and medium-haul network, which is considered to provide an overall perspective.

Table 13 - Volume and weight capacity by aircraft model. (Adapted from Lufthansa, 2019).

AIRCRAFT MODEL	VOLUME(m^3)	WEIGHT(Kg)
Airbus A319-100	27,3	4000
Airbus A320-200	44	1750
Airbus A321-100	59	2830
Airbus A330-200	178	17230
Embraer 195/190	19	1000

The model carriage to be used in this comparison is the ICE 4, which is the new Deutsche Bahn's high-speed train for intercity and long-distance services. The ICE 4 first trains have been in trial operation since early 2017 and will gradually replace the Intercity and Eurocity fleets built between 1971 and 1991 (Siemens, 2009). This will contribute to an updated comparison that reflects the ongoing changes and future trends. The most relevant specifications of this train follow on table 14.

Table 14 - ICE 4 Technical Data (Retrieved from Siemens AG, *et al*., 2011).

ICE 4 TECHNICAL DATA		
TRAIN COMPOSITION	7-car train set	12-car train set
MAXIMUM SPEED	230 km/h	250 km/h
TRAIN LENGTH	200 m	346 m
CAR LENGTH	28 m	28 m
NUMBER OF CARS PER TRAIN	7	12
NUMBER OF SEATS (TOTAL/FIRST CLASS)	456 / 77	830 / 205
CAR HEIGHT	2,5m	2,5m
CAR WIDTH	2,64	2,64

Based on table 14 it is possible to simply calculate the available volume of one train car by multiplying the 3 axial dimensions (length, width and height). The mathematical expression is $\mathbf{28 \times 2.64 \times 2.5 = 184.8\ m3}$. Moreover, according to the information available regarding a TGV all-cargo train car, the maximum weight in each train car is **10900 Kgs**. Also, frequently in passenger transportation modes, an average passenger weight of 100 Kgs is used for calculations. In the ICE 4 specific case, if the total number of seats is multiplied by 100 Kgs, the maximum weight in each train car would be **7600 Kgs** for the 7-car train set configuration and **8625 Kgs** for the 12-car train set.

As mentioned before, capacity can't provide a complete comparison between to modes of transport by itself. However, it allows to draw some conclusions regarding the possibility of loading a certain amount of goods into a closed compartment. In other words, the difference in dimensions and capacity between two modes of transportation could be so huge that continuing this analysis would be at least incorrect.

4.6. SUSTAINABILITY: GREEN-HOUSE-GASES EMISSIONS

Until this moment, no attention was given to the externalities of the transportation activity. Transport systems support complex economic and social interactions and are thus a component of society and an active actor that shapes the way society evolves (Rodrigue, 2017). As not only benefits result from transport activity, one of the objectives this work wishes to achieve is to create knowledge that contributes to tackling this specific aspect. Therefore, developing a sustainability analysis is of very high importance.

Nowadays, sustainability and sustainable development have an increasing importance over the decisions made by governments, companies and individuals. According to the European Commission, CO2 emissions and air pollution from transport are the major environmental concerns related to transport activity (European Commission, 2019). Also, it also states that greater efforts will be needed after 2020 if the global targets to reduce greenhouse gas emissions are to be met (European Commission, 2019).

Thus, it is of the highest importance to develop specific knowledge into this topic in order to address the trend in the transportation industry and to compare the CO_2 emissions of both rail and air modes of transportation. Carbon dioxide (CO_2) is not the only gas that results from fossil fuels combustion engines. A wider number of pollutants and gases such as hydrocarbon (HC) or sulfur dioxide (SO_2) result from flights.

CO_2 is the greenhouse gas most commonly produced by human activities and it is responsible for 64% of man-made global warming. Other greenhouse gases are emitted in smaller quantities, but they trap heat far more effectively than CO_2, and in some cases are thousands of times stronger. Methane is responsible for 17% of man-made global warming, nitrous oxide for 6%. (European Commission, 2019)

As atmospheric levels of carbon dioxide continue to escalate and drive climate change (Bierwirth, 2019) and attending to the fact that CO_2 is the gas most responsible for the negative transport externalities of the transportation sector, the objective of this analysis is only to compare CO_2 emissions. Unlike other modes of transport, emissions from aircraft’s operation occur mainly above ground level and at high altitudes. This influences the impact from aircraft emissions on the environment and makes the evaluation even more challenging, because even less is known about the impact of emissions at high altitude (Givoni, 2007).

Moshe Givoni (2007) concluded that environmental benefits are likely to occur on all routes on which aircraft and high-speed train substitution is likely to take place. He also estimates that during 2004, 19,853 flights were operated between Heathrow and CDG airports. Using this figure and assuming the flights were operated by A320 (150 seats), the environmental benefit estimate from mode substitution is almost €7 million.

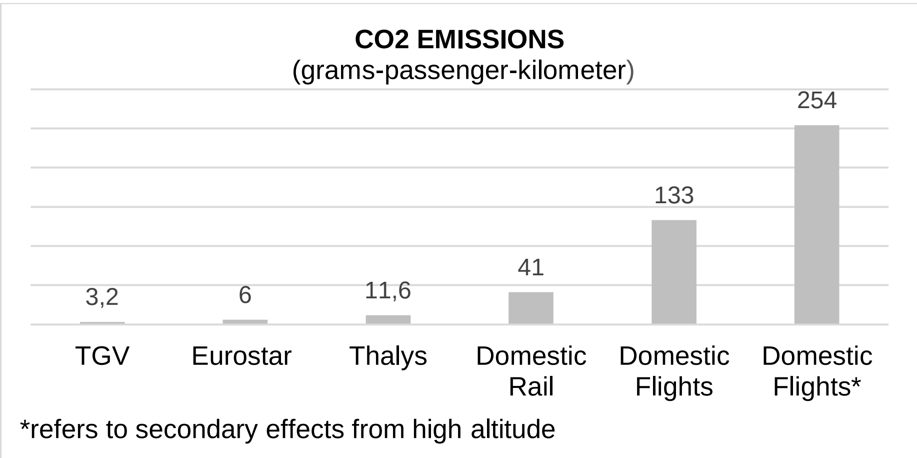

Figure 17 - CO_2 Emissions Comparison (Adapted from BBC, EBIS, DEFRA, SCNF, 2019).

Due to the inherent complexity in measuring emissions impact from each mode of transportation, this specific analysis will focus only on CO_2 emissions by passenger kilometer.

4.7. COST ANALYSIS

Transport costs are the costs internally assumed by the providers of transport services. They come as fixed (infrastructure) and variable (operating) costs, depending on a variety of conditions related to geography, infrastructure, administrative barriers, energy, and on how passengers and freight are carried (Rodrigue, 2017).

It's interesting to reflect on the fact that the Lufthansa Cargo fleet is composed by 17 all-freight aircrafts and 350 passenger aircrafts. When compared, only approximately 5% of its fleet is meant for cargo only. The way aircrafts can transport both cargo and passengers allow for the highly efficient and dynamic design of optimal freight transportation routes (Nahum, *et al*., 2018). As addressed previously, the capacity of airlines to mix both cargo and passengers is of extreme importance because it may be used to draw innovative solutions for other transport networks.

Cost analysis plays an important role in every organization within the decision-making process. The detailed analysis of costs, the calculation of production cost, the loss quantification, the estimating of work efficiency provides a solid basis for the financial control (Lepădatu, 2012). However, performing a cost analysis is somehow complex and may not be realistic due for example to lack of capacity to accurately measure costs within an organization.

In this chapter, a comparable key performance indicator that allows to withdraw a general conclusion on the costs of a transport system operation will be selected. The most suitable indicator for this analysis can be discussed as many indicators are calculated to answer to different questions. In this case, our aim is to have an indicator that compares the costs of a kilometer traveled in both rail and air. But this cost results of the occupation percentage and mainly in air costs calculation, an enormous number of factors is considered. To tackle this difficulty, the cost per available seat kilometer was chosen. The cost per available seat kilometer (CASK) is a common unit of measurement used to compare the efficiency of various airlines. It is obtained by dividing the operating costs of an airline by available seat kilometer (ASK). The operating costs are the expenses associated with the maintenance and administration of a business on a day-to-day basis. Generally, the lower the CASK, the more profitable and efficient the airline (Investopedia, 2019). Although the cost per freight-ton-kilometer (CFTK) is normally used to compare costs in freight operations, as high-speed trains are not currently involved in cargo operations, there is no data that could support such comparison.

According to CAPA (Centre for aviation), the CASK of Lufthansa Group was 0.0996 EUR in 2012. In order to provide some context, in 2010 Air France had a CASK of 0.089, Iberia of 0.078, British Airways of 0.065 and Turkish Airlines of 0.057(Statista Research Department, 2010). In the rail sector, the CASK of the rail companies operating in the UK were in the interval of 0.097 EUR for East Company to 0.16 EUR for London Midland in 2011 (TOC Management, 2011). The UK train market is very interesting in the perspective of this analysis as it was one of the first rail liberalized markets in the EU, achieving so in the 1990s (McKinsey, 2019).

Table 15 comprises this information.

Table 15 - CASK per airlines in EUR (Retrieved from Statista, 2011; CAPA, 2013; GOV-UK, 2012).

MODE	COMPANY	CASK (EUR)	YEAR	MODE	COMPANY	CASK (EUR)	YEAR
AIR	Scandinavian Airlines	0.13	2010	RAIL	Cross Country	0.12	2011
	Lufthansa	0.10	2012		East Coast	0.10	2011
	Air France	0.09	2010		East Midlands Trains	0.12	2011
	Iberia	0.08	2010		First Great Western	0.11	2011
	British Airways	0.07	2010		London Midland	0.16	2011
	Turkish Airlines	0.06	2010		Virgin Trains	0.11	2011

4.8. OVERALL CONCLUSIONS

Based on this analysis, in the indicators used and in the chosen methodology, some general and specific conclusions can be drawn. The most relevant conclusion is that high-speed train routes can indeed compete with air solutions for small and medium size shipments. It was observed that from the 17 air routes studied, 10 have a continuous option using high-speed trains, that trains can compete in terms of capacity, having far lower CO2 emissions and that the operative costs tend to be competitive. Although that many times air-freight is still the fastest route, it is also evident from the previous chapters that in the majority of shipments, that extra speed is not needed nor valued by the customer. Therefore, it's evident that a very interesting and growing opportunity is not being explored by the train industry, with very small exceptions as seen in chapter 2. As it will be brought into focus in detail, high-speed trains in the EU run with a relatively low occupation meaning that not exploring the vacant capacity of high-speed trains is a waste of resources that is absorbed by the air-freight industry, leading to increased revenues for airlines and worse environmental impacts.

As concluded, a competitive rail-freight fast service is possible in the studied scenario, even though many challenges can be anticipated. This is the motto for the next chapter, where the main challenges, present and future trends will be addressed with the objective of building knowledge for train enterprises to tackle their weaknesses in pursuing this opportunity with many foreseeable positive environmental impacts.

4.9. IMPORTANT FINAL CONSIDERATIONS AND REMARKS

During this chapter some context was given on the approach and method being used to produce the desired base work that resulted in the conclusions drawn. This was done by having a specific perspective on each part of this analysis.

However, some meaningful considerations and remarks are thought to be extremely relevant and therefore will be addressed separately.

The first one is focuses in the concept of a missing link, which can be classified as a neglected link, lack of infrastructure elements or entirely missing link. Other than understanding in depth the specifics of this subject, which is not the objective of this work, the objective is to understand the problems associated in the specific routes taken into consideration on this analysis. For instance, when traveling from Spain to France, a missing link can be observed between the station of Irun and Hendaia. Although there is a connection using a city train, having a small interference with the total journey, if cargo was to be transported along this route, huge constrains would arise. These constrains would mainly be related with the distance between the unloading point to the following loading point, which is too far away to dismiss the need for a connecting mode of transportation and not close enough to be handled in the same infrastructure. As shortly explained in 4.4, in routes where missing links exist, an alternative calculation was done by adding the main train connections duration and by not considering that missing links exist. It was thought that by having such approach a global perspective of the possible train route is given also allowing to withdraw conclusions regarding the importance of having a continuous rail network.

The second one has to do with time gaps between connecting flights, which are not accounted for in 4.4. This is, in 4.4 the LH Cargo flight durations are based in an optimal transit perspective as it is not considered that the connection flight may arrive before the second flight's departure time. In order to provide some real context, the majority of flights that have a late departure only connect with flights in the following morning, meaning cargo has a longer transit time, normally at the hub airport. Therefore, it was reflected upon the idea of not considering such real scenarios and, as done with train route duration's calculation, consider the most favorable result. Moreover, the complexity of taking into account all possible scenarios in the calculation of duration times was also a relevant reason to proceed this way.

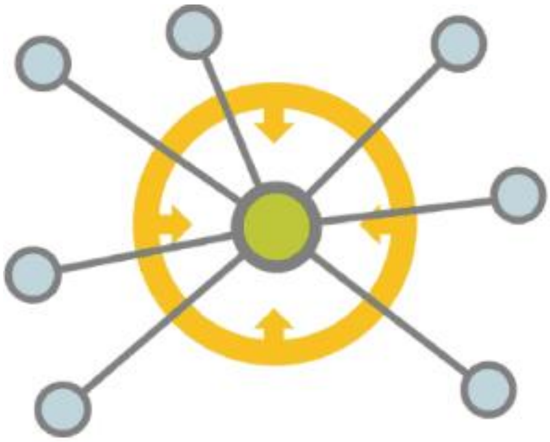

Figure 18 - Scheme of Demand Consolidation (Retrieved from Rodrigue, 2017).

The third one is related with a possible demand disparity when comparing the demand for transportation from the origin of the cargo and the origin station, being this applied more to air-freight than to rail-freight. Although this topic was already shortly addressed, a deeper explanation at this point was thought to be beneficial. The demand disparity occurs because air-freight stations are many times an attractor of demand due to their central geographic location and because there is no option to enter the network from other points. In reality, demand for transportation could be much more disperse and therefore deviate significantly from the analyzed routes. Yet, main train stations follow the same location pattern as airports meaning that the possible error in this analysis intersects both modes of transportation. It is also relevant to reflect upon the fact that this study wishes to analyze long distance routes and it is not focused in quantifying the origin of the demand. Therefore, although the principles of this approach can be of further discussion and different approaches, this methodology was considered to be sufficiently accurate in providing the desired knowledge. It's also relevant to state at this point that more discussion on this topic will be developed in chapter 5.

The fifth and last consideration is a very specific remark with low impact on the overall results of this analysis. Many of the rail stations that belong to the routes analyzed are inserted in cities that have more than one main rail train station. For instance, Paris has long distance trains departing from Gare du Nord, Gare Saint-Lazare, Gare de l'Est, Gare de Lyon, Gare d'Austerlitz and Gare de Montparnasse. Thus, it was always considered the train stations where the studied train route starts or ends.

5

BUILDING A CASE FOR A COMPETITIVE FAST RAIL-FREIGH SERVICE

This chapter wishes to explore the present and near-future trends and challenges that are extremely relevant for the development of a competitive fast rail-freight service. It is possible to consider this as a set of topics that if used and developed in the right way can contribute to a new rail-freight service. It focuses in aspects of policy and legislation, engineering, planning and technology and are the result of the research done during this work, while also having in consideration the outcome of the data analysis performed in chapter 4.

5.1. DESIGNING TRAINS AND TERMINALS

Nowadays, new passenger trains are being designed to carry only passengers and, as addressed before, no mixture of cargo and passengers can be found except in very specific cases without real impact on the global market. Moreover, if new high-speed trains are to be designed and engineered in a way they can offer a service for fast cargo, they need to compete in terms of capacity with air options.

One may reflect upon the necessity of increasing capacity by raising the number of train connections or even by adding new trains to the fleet. However, it is important to consider that, for instance, high-speed rail routes in Germany have an occupation of around 50%. To be specific, in 2018, Deutsche Bahn's long-distance trains had a load factor of 50%. This means that 50% of the available space is not used, resulting in loss of revenue and in a sub-optimal solution. This fact is positive for building a case for a competitive rail-freight service in high-speed trains. Airlines also have issues regarding occupation and manage to minimize it effect on the global result of their operation by calculating available space for cargo in aircrafts using data analysis and artificial intelligence. That way, they can maximize their revenue by optimizing their two revenue streams: passengers and cargo.

One problem high-speed rail-freight faces is that new passenger rolling stock is often fixed in multiple unit train-sets, making it practically impossible to attach existing express parcel or mail vans to them. The new passenger trainsets themselves are normally not intended to carry larger amounts of goods, and subsequently do not provide any space for this or only very small compartments, like on the French

TGV. However, there are exceptions: In the United States, Talgo America offers a version of its Talgo XXI tilting train for 300 to 400 passengers with a maximum speed of 200 km/h and with two cars reserved for express parcels (Troche, 2015).

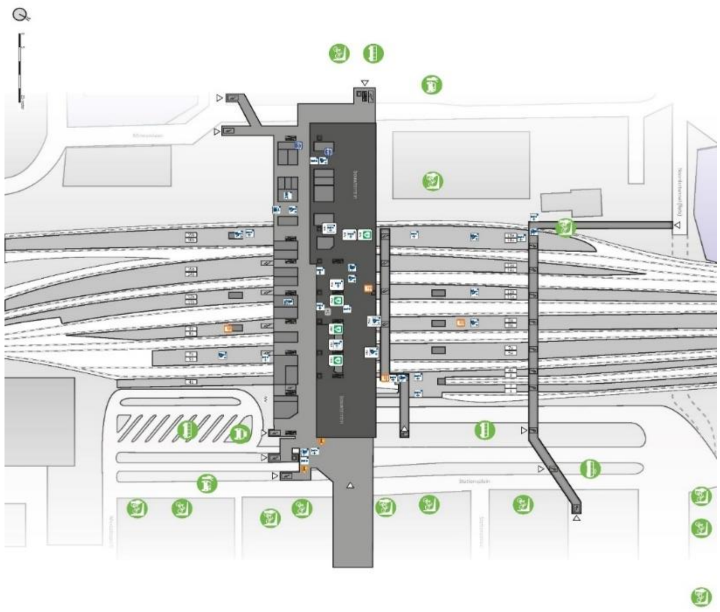

Figure 19 - Example of the recently built Utrecht's train station (Retrieved from NS Trein, 2019)

Terminals are any location where freight and passengers either originate, terminate, or are handled in the transportation process. Terminals are central and intermediate locations in the mobility of passengers and freight. They often require specific facilities and equipment to accommodate the traffic they handle (Rodrigue, 2017). Consequently, terminals play a crucial role when designing a high-speed rail-freight transport system. The localization and design of terminals are key factors, which to a high degree determine the performance and efficiency of the system. A terminal can therefore not be designed without taking a decision on operation principles and types of trains, choices which in their turn are closely related to technique chosen for transloading (Troche, 2015).

Terminals for high-speed rail-freight already exist today, mainly in form of mail-train terminals. However, there is a big and urgent need for further development if the traffic potential of high-speed rail-freight is to be widened and if larger volumes are to be brought onto the train. The integration of airports into the rail-freight system is crucial if rail is to take a bigger share in the international express freight market. However, the integration of airports in the rail-freight system is today almost none. This means that the today small amount of air-cargo carried by train often has to be trucked between the airport and a nearby distribution terminal, adding a further link to the transport-chain with the result of reduced competitiveness for rail and thereby effectively limiting the prospects for an increased use of rail for this kind of transportation (Troche, 2015).

Loading and unloading processes represent a critical moment in the transport chain. It is both time-consuming and connected with costs. The sorting and transshipment of express freight must happen quick, reliable and cost-efficient. Numerous factors can affect the flow of goods in such a highly integrated system. These include numbers and types of equipment, physical layout, storage capacity and operating strategies (Corry *et al*., 2017)

Handling equipment must be flexible in respect to both extreme peak loads and a heterogeneous goods structure with different weight, size, format and packaging techniques. Increasing express freight volumes have already led to a high automation of the sorting process in mail and express freight terminals. Due to the high costs of the necessary equipment, the result is a concentration on few high capacity hubs, as discussed previously. The goal is in to reduce time consumption and costs while increasing capacity and quality (Troche, 2015).

Transshipments techniques can be divided into three groups, according to their grade of automation: manual, semi-automated and automated (Woxenius, 1998; Rodrigue, 2017). The importance of transshipment methods is even more relevant in mixed cargo and passenger transportation modes as passenger are the priority and loading and unloading times can't jeopardize the passenger's total journey duration more than what is considered acceptable.

One of the very few cases of a fast rail-freight service is the French TGV La Poste, which were a set of dedicated trains for high-speed rail-freight and mail transportation by the French railway company SNCF on behalf of the French postal carrier La Poste (Railway Gazette, 2014). However, La Poste stopped operating these TGVs in 2015 due to lack of demand that resulted in a non-profitable operation (La Poste, 2015). In the peak of its service, the TGV La Poste had a fleet of 7 train sets, each one constituted by 4 carriages and 1 power car, operating 8 daily routes.
The former existence of such service is indicative that a competitive fast rail-freight service is possible, at least from a solely operative perspective.

5.2. EUROPEAN UNION POLICY: THE 4TH RAILWAY PACKAGE AND THE TEN-T CORE NETWORK

The 4th Railway Package is a set of 6 legislative texts designed to complete the single market for Rail services (Single European Railway Area). Its overarching goal is to revitalize the rail sector and make it more competitive with other modes of transport (European Commission, 2016).

It does so by fostering the right for railway undertakings established in one member state to operate all types of passenger services everywhere in the EU and lays down rules aimed at improving impartiality in the governance of railway infrastructure and preventing discrimination (European Commission, 2016).

The EU's point of view is that competition in rail passenger service markets will encourage railway operators to become more responsive to customer needs, improve the quality of their services and their cost-effectiveness. Therefore, the lack of effective competition may explain why in many EU countries rail transport has not developed customer-oriented services, innovative business models and costs/price reductions that can be witnessed after market opening in other transport modes (Troche, 2005). The degree of competition in the railway sector, measured as the total market share of all but the biggest railway companies, is low.

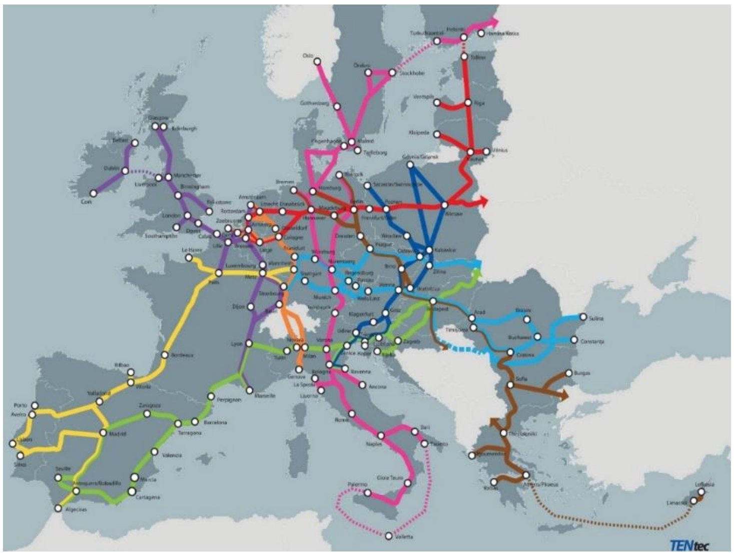

Figure 20 - TEN-T Core Network (Retrieved from European Commission, 2019).

Other relevant policy is the trans-European transport network (TEN-T) published in 2013 addressing the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals. According to the European Commission, the main objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU. As seen before, many of the constraints the TEN-T wishes to solve have been considered as challenges to a normal flow of cargo within the European network of high-speed trains.
The TEN-T is divided into nine core network corridors and comprises two network phases. The core network contains the most important connections, linking the most important nodes, and is to be completed by 2030 whereas the comprehensive network covers all European regions will be completed by 2050 (European Commission, 2013).

In the rail sector, the TEN-T network requires investment in new infrastructure, refurbishment and modernization of the existing network. Better coordination is needed between EU countries on cross-border infrastructure projects as for instance the example of the Spanish border with France addressed on the chapter 4. While for some EU countries the main issue is to upgrade and maintain existing infrastructure, others need to develop or expand their transport network.

Building missing links at borders between EU countries and along key European routes and interconnecting transport modes in terminals is seen as vital for the single European market. Integration and interconnection of all modes of transport, including equipment for traffic management and innovative technologies can contribute to a connected EU rail network.

According to the article 26, one of the four priorities for the air transport infrastructure development is to improve multimodal interconnections between airports and infrastructure of other transport. This increases the likelihood of an integration between air and rail that results in a relevant high-speed train service for freight. Although extra-EU shipments are not the focus of this work, this increasing integration could also open new possibilities in extra-EU air shipments fostering a collaboration with rail-freight.

The European Court of Auditors (ECA), the EU's independent external auditor, produced a special report entitled the “A European high-speed rail network: not a reality but an ineffective patchwork” with reflections regarding the development status of the European high-speed rail network. The key findings of this report that add value to this work are as follows:

- It was found that the EU’s current long-term plan is not supported by credible analysis, is unlikely to be achieved, and lacks a solid EU-wide strategic approach
- There is no European high-speed rail network, and the commission has no legal tools and no powers in the decision making to ensure that member states make rapid progress towards completing the core network corridors set out in the TEN-T regulation. As a result, there is only a patchwork of national high-speed lines, planned and built by the member states in isolation.
- The patchwork system has been constructed without proper coordination across borders: high-speed lines crossing national borders are not amongst the national priorities for construction, even though international agreements have been signed and provisions have been included in the TEN-T regulation requiring core network corridors to be built by 2030.

- The decision to build high-speed lines is often based on political considerations, and cost-benefit analyses are not used generally as a tool to support cost-efficient decision-making.

- The rail passenger market is not open in France and Spain. There is on-track competition in Italy and, to a limited extent, in Austria. In these member states, services were more frequent and of higher quality, whereas ticket prices were lower

In one hand it is possible to observe that a favorable policy is in place and that it can contribute to solve some challenges that nowadays don’t allow for a true European high-speed rail network. In the other hand, implementation difficulties might delay this transformation and undermine the development of such service. Also, as mentioned by ECA, on average, it takes around 16 years for new high-speed lines to proceed from the start of works to the beginning of operations. Moreover, many lines construction works had experienced delays of more than one decade (ECA, 2018).

Further examples include the high-speed train connection between Spain and France, regarding which the European Court of Auditors reports that because most of the section between Bordeaux and the Spanish border is not a priority for France, infrastructure at the border remains antiquated, incompatible and poorly suited to a modern high-speed rail network. France is not ready to invest in this infrastructure and this will negatively effect on Spain and Portugal's connections to the EU network along the Atlantic corridor (ECA, 2018).

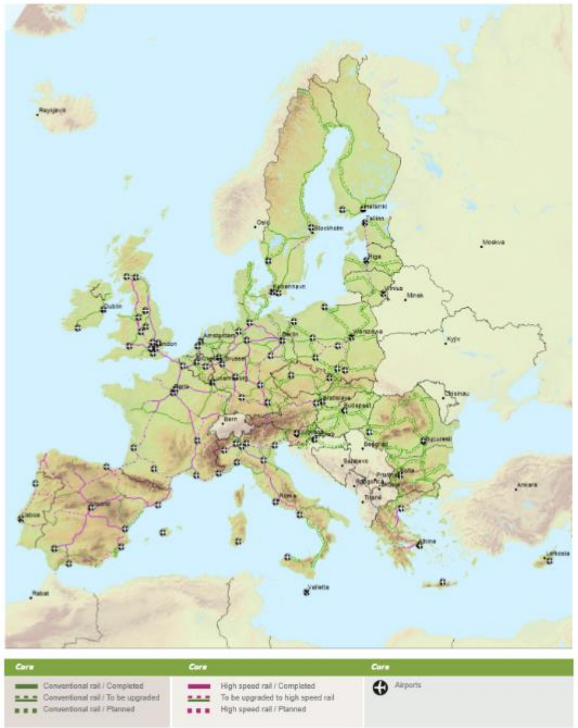

Figure 21 - Rail and Airport Maps of the TEN-T Network (Retrieved from European Commission, 2019)

McKinsey & Company produced a report in 2019 where it addresses the liberalization of the EU passenger rail market. It focuses on growth opportunities and new competition such as significant boost of market revenue pool, the pressure on profitability level for the incumbent train company, better services potentially at lower prices and additional frequencies. On the overall, it is expected that the EU's fourth railway package will have a sizable impact on the EU rail market, including providing the opportunity to generate benefits for the entire landscape (McKinsey & Company, 2019). In order to build a fast rail-freight service, rail enterprises should have an open mind when it takes to experimenting new business models. As stated in different reports, the liberalization of the EU passenger rail market may actively contribute to a fast rail-freight service.

5.3. ENABLING A BETTER DISTRIBUTION MODEL

Demand for transport is a derived demand as most of the transportation is consumed to supply the demand for other goods or services. As demand for goods to be delivered to the final consumer increases through, for example, e-commerce, new transportation services need to supply the increasing derived demand that results from the changing consumption patterns. As discussed during this work, transport systems design tends to centralize its network in order to reduce operative costs, among many other favorable results. Therefore, one of the main challenges of supplying the actual model of consumption is the dispersion of the origin and final locations.

In Europe, shopping habits have changed fast during the last decade and a high percentage of consumers now shop online resulting in major structural changes as a result of the increasing power of customers demanding greater variety of quality products at low cost. Also, e-commerce for physical goods generates a significant demand for dedicated delivery services, and results in increasingly difficult logistics (Morganti *et al*., 2014).
E-commerce is likely to support longer transport distances and often higher delivery frequencies, increasing demand for land, due to the establishment of new transshipment points (distribution centers) and, to a certain extent, a shift towards truck and air-freight transport modes (Hesse, 2002).

These customer demands have increased the competition between businesses, and at the same time more complicated and longer supply chains have emerged as a result of the globalization of many businesses in their search for low-cost production locations and access to new skills. In response, hub-and-spoke systems are increasingly used to deal with product flows from many origins and to many destinations (Triantafyllou *et al*., 2014).

Shipment consolidation, a commonly used strategy in freight transportation, is the practice of consolidating several small items and then dispatching them on the same vehicle. If applied appropriately, a shipment consolidation program may drive out substantial costs in the logistics supply chain (Ülkü, 2009).

In air-freight, the location of consolidation is always at the airports as aircrafts can’t distribute freight at different points of the route. This creates the need for a shipment to always be shipped from an airport to another, many times doing one or more stops resulting in sub-optimal solution in terms of distance traveled. Yet, due to the much higher speed aircrafts can travel when compared to other modes of transportation, they are still very much competitive. Intermodality plays a key role in air-freight as the majority of shipments don’t finish their journey at the airport they arrive to.

On the contrary, high-speed trains travel routes with a considerable number of stops and therefore offer the possibility of loading and unloading freight in specific locations far away from airports. Look for example to the direct high-speed train between Amsterdam and Berlin, which takes around 6 hours to be completed. This train stops at 15 train stations during its route, having the capacity to unload and load cargo at all these different locations.

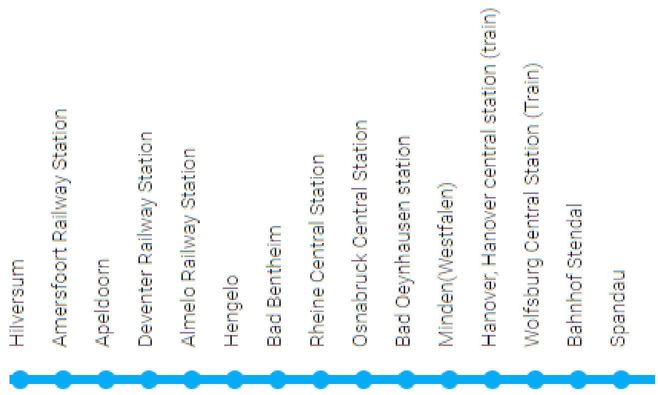

Figure 22 - Train stops in a train route (Retrieved from Google Maps, 2019).

One characteristic of air-freight within mixed cargo and passenger airlines is the constant supply of available space on the routes scheduled. On mixed passenger and cargo aircrafts, freight operations are a secondary product and route scheduling is done primarily in consideration of passenger’s demand (Kulliane, 2019). The supply of routes over time is of extreme importance for the fast shipments market as these shipments often can be booked until the last minute before LAT (Latest acceptance time). This work is not intended to explore the specifics of road service logistics, however, in this case, it cannot be avoided to perform the following considerations: the majority of road routes depart during the night from the loading station and arrive in the morning to their destination. In the fast freight market segment, many times this solution is not viable as for instance if a shipment is ready in the morning of Day 1, it will only be dispatched on the night of Day 1, meaning availability will be at the early hours of Day 2. If the destination of Day 2 is the final one, the final delivery will still need to be done, which means loading the shipments from all ending routes into smaller vehicles meant for last-mile distribution. But if this is not the case, a new long drive will be done, meaning it will be delivered to a new distribution center on the morning of Day 3, followed by distribution to the final destination. Many times, this can be avoided if a direct shipment is performed. A direct shipment may be defined as a method of delivering goods from the supplier to the customer directly. But direct shipments can be extremely costly and usually can´t compete with air-freight. This may be a specific logistical challenge that high-speed rail-freight could help to solve.

Nowadays, rail-freight services are meant to compete with road-freight options meaning the solutions used for fast shipments will mostly tend to air-freight options followed by road delivery. The Rail Freight Forward is the European Rail Freight Vision for 2030 and its main objective is “30 by 2030”, meaning an increasing of the modal share of rail to 30% by 2030, when compared to the actual modal share of 17%. Although the objective of this white paper targets the market segment of large volume shipments, such as containers, bulk shipments and raw materials, it is possible to perceive a lack of research and evaluation of the possible relevance high-speed rail services could have in the shipment of smaller goods. As concluded on chapter 4, rail options are not always competitive when compared to air options, specifically in the segment of urgent shipments but are an extremely interesting option in other segments.

As addressed before, a very competitive characteristic in air-freight services is the possibility of shipping in a constant supply of available flight routes. The lack of existing competition to air-freight options is relevant for building a competitive rail-freight fast service with many of the same characteristics of the air-freight logistics.

Moreover, it is possible to observe that the ideas upon the definition of railway location is also extremely beneficial for the possibility of a fast rail-freight service. Firstly, for passengers' convenience and trip attraction, the lines should not deviate far from the main direction, and cover major cities along the railway, connecting with secondary towns along the line within a reasonable range. Secondly, to ensure a railway has enough carrying capacity, can carry out necessary technical work and handle passenger and freight service, stations must be reasonably distributed. The distribution of stations has close relationship with regional passenger and freight transportation service and national economic development. These stations, especially large stations, enjoy large quantity of work and many personnel, with dense equipment and buildings, which requires large investment and large area of land and is hard to remove after construction. Thirdly, to distribute the passing station, overtaking station and intermediate station on the mixed passenger-freight railway is to meet the desired carrying capacity of the railway and therefore, serve the passenger and freight transportation of urban and rural along the line. The intermediate station for passengers and freight transportation shall be properly distributed as per the average daily volume and in combination with other transport ways in local areas, and in coordination with the urban and regional programs. In particular, the intermediate station with technical working shall comply with the technical operation requirements, if any. Fourthly, in theory, the distribution of high-speed railway shall be good for attracting passengers from large and small cities along the railway. But, if the average distance between stations is too low, it is hard to increase the speed of stopping trains. Finally, it is relevant to add that high-speed railway has promoted regional interaction and balanced development (Yi, 2018)

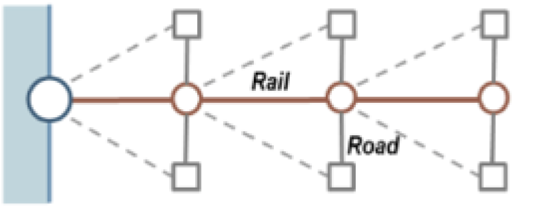

Figure 23 - Possible distribution model using a rail line (Retrieved from Rodrigue, 2017).

Although the average distances between stations of high-speed rail in different countries are quite different, some examples from within and outside the EU will follow. The average distance between stations in Japanese Tokaido Shinkansen, connecting Tokyo, Nagoya and Osaka, is 34.3 km and its longest section is 68.06 km. In France, longest and shortest distances between two the high-speed railway stations are 100 km and 9.9 km, respectively (Yi, 2018).

These large intermediate stations of high-speed railway are usually set in the railway junction terminal, municipality, and provincial capital city, and these serve abundant passenger transportation business.

Trip assignment can generally be defined as how goods travel through the network (Chow, 2007). The most accurate measure combines the average distance from the demand locations to a central location and the mutual distances between neighboring demand locations. The average of the distances between all pairs of locations forms a good alternative measure (Turkensteen et.al, 2012).

The possibility of the existence of a competitive fast rail-freight would create new possibilities in the route assignment methodology. With the increase of possible origin and delivery stations, the outcome would be an extensive set of new possibilities and once again, the possibility to decentralize freight. New solutions are sure to arise from the on-going changing demand for freight transportation services resulting in even more new interesting opportunities for rail.

5.4. MANAGEMENT IMPORTANCE

Air cargo was traditionally considered as a by-product of passenger air transport. However, in the last decade a defined strategy for air cargo has gained a key position in the strategies of most airlines. The global air cargo industry is nowadays a mature industry. The strategic context, is therefore, far beyond the basic entrepreneurial framework in which an emerging and young industry tends to operate (Cullinane, 2019).

The demand for air cargo is a derived demand from external factors and does not stand on its own. It is at times volatile and subject to local and global economic cycles and external shocks. Therefore, drafting a strategy for air cargo carriers is an absolute necessity for the firms to survive in the longer term (Cullinane, 2019).

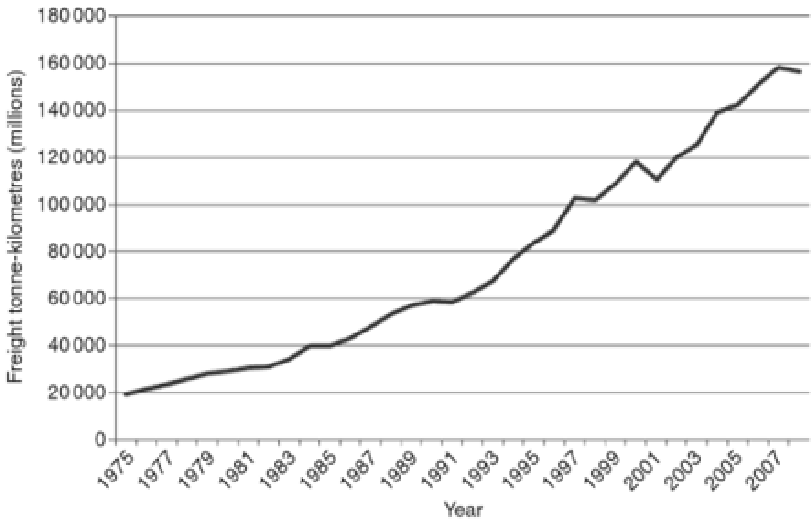

Figure 24 - Evolution of worldwide air-freight traffic in FTKs (millions), 1975-2008 (Adapted from Cesariá *et al*., 2011).

As air cargo was traditionally seen as a by-product of passenger transport (Herman *et al*., 2006). Pricing was based on a “marginal cost plus” standard, and no separate cargo took responsibility for sales and operations (Gronlund and Skoog, in Gronlund and Skoog, 2005). The relatively low variable costs in the cargo business “naturally” boosted load factor optimization for the airlines as even a price of a few cents is favored over the alternative of flying an empty space (Reifenberh *et al.*, 2005). In the last decade this has changed considerably as air cargo became a mature product, often differentiated through innovative market-driven segmentation. Therefore, new marketing concepts for time-definite products and “specials”, such as valuable goods, dangerous goods, shock-sensitive goods, cool chain products such as pharmaceuticals, and transportation of livestock were implemented (Cullinane, 2019).

The challenge of the air cargo product lays in the fact that it offers a premium product that competes with surface transport on the basis of speed and reliability. Compared to surface modes, air-freight offers a faster speed and greater reliability (Macário, 2011). A shift in modes will take place if the value proposition changes due to a shift in price or perceived level of service.

Closely related to product differentiation is yield management. This is, a close monitoring of available and booked capacity on each route on each direction for a specific period and price, accordingly, can significantly increase revenues per freight-ton-kilometer and hence per available-ton-kilometer. This results in empty space being offered in the market at a high or low price, depending on the level of supply of and demand for air cargo space at a specific time. Rates are set through negotiation between customer and airlines and substantial discounts are generally offered to customers willing to accept a deferred delivery (Shaw, 2007). Product differentiation is a very important parameter in this area. Such a product-based approach to pricing is simple to administer and fair between different types of customers. Not surprisingly, it has been followed by many combination airlines which have launched their own cargo brands.

Cullinane (2019) identified, based on literature review and field-interviews with air cargo executives, a set of influencing components that determines primary and support management activities of an air cargo operator. The primary components are “capacity management”, “geographical market coverage” and “alliance strategy”, while “competitive market behavior” and “deployment of e-portals” are considered as support activities. A crucial part in the market strategy is high-performing capacity management, through the adjustment of the product capacity to the demand on certain routes. Additional capacity at the right price can also attract additional demand, hence the importance of a well-designed revenue management system. However, Cullinane, (2019) also concludes that air cargo operator can do little to aggregate or influence demand for their services. To maintain a well-balanced capacity management, air cargo carriers often sell portions of a flight’s total cargo capacity to freight forwarders (Hellerman, 2006).

To understand how relevant air cargo operations are within a mixed cargo and passenger’s airline, the share of passenger and cargo revenue comparison can be used. According to the Lufthansa Group combined management annual report of 2018, the “Network Airlines” had a revenue of 22.7 billion euros and Lufthansa Cargo of 2.7 billion euros. If compared, the Lufthansa Cargo business segment accounts for around 12% of the total revenue from “Network Airlines”. In order to provide a more complete understanding, the “Network Airlines” comprises Lufthansa German Airlines, SWISS and Austrian Airlines. When all the Lufthansa Group is considered, Lufthansa Cargo’s share revenue drops to 7% of the total revenue, mainly due to the existence of other business owned by the Lufthansa Group. Although this work aims to study the EU´s air-freight market, it is pertinent to see how the shared revenue of passenger and cargo is in other airlines from different geographies. For North American airlines, the share of cargo in operating revenue is usually less than 5% and in Asian and Latin American airlines have a higher share of cargo revenue. For instance, around 1 to 2% in Southwest Airlines and 29% in EVA Airways during the year of 2013 (Rodrigue, 2017). The following graph shows this data for different airlines in the world.

Figure 25 - Cargo and passenger revenue in selected airlines. (Adapted from Rodrigue, 2017).

In an organization with a strong customer relation management, customer attention is provided by building an extensive sales force, a costly structure to set up and maintain. However, a long-term relationship with the customer, often contractually agreed, is beneficial for both yield and capacity management planning. Therefore, the larger air cargo operators such as Lufthansa Cargo or KLM Cargo have dedicated sales teams to sell their cargo products and fill up capacity (Cullinane, 2019).

Rail-freight faces some interesting challenges in order to deliver a reliable fast rail-freight service to the market. Airlines have been developing tangible and intangible assets for a long time now hence acquiring the capacity to deliver a value proposition. Similar to UPS, a courier company addressed in this work, FedEx was founded in 1971 with the clear objective of becoming the premier carrier of high-priority goods (FedEx, 2019). In that time, low assurance of a valid business was in place as, at the time, there was a big difficulty getting packages and other air-freight delivered within one to two days (FedEx, 2019).

Contrarily to FedEx's example and rather similarly to the airline's example, rail operators need a capable management to deliver a value proposition to this market segment. In one hand, train companies don't have to start from zero as they already manage an ongoing business, many times lucrative and often possess skilled management teams (McKinsey, 2014). In the other hand, train companies lack the experience in the cargo business that airlines have succeeded to develop during the last decades of operations. Building a competitive fast rail-freight service will hardly succeed if, among other challenges, train enterprises don't have a skilled, strategy-driven management teams.

Cullinane, (2019) states that strategic management is concerned with relating a firm to its environment in order to successfully meet long-term objectives. Strategic management also involves the formulation and implementation of the major goals and initiatives by an organization's top management on behalf of owners, based on considerations of resources and an assessment of the internal and external environments in which their organization operates. Managers are continuously looking for innovative ways to align the strengths and weaknesses of the company with the opportunities and threats of the environments. To be successful, firms need to gain a competitive advantage over rival organizations operating in the same business area. How firms create a sustainable competitive advantage in the business in which they operate is the central issue concerning mangers engaged in business level strategy. This means a competitive new rail-freight service can only be implemented if capable teams are in place.

5.5. SUSTAINABILITY, GREEN LOGISTICS, INCREASING EFFICIENCY AND WASTE REDUCTION

The centric pointy of this work is to develop knowledge within the field of logistics and good's transportation that in the end results in a more sustainable approach on how the rail sector can adapt its business to overtake at least a percentage of the air-freight business and by doing so, decrease the negative impacts of transportation, contributing to a more sustainable world. If the variable of sustainability was not to be present in the backbone of this work, the conclusions developed were above all related with a new business approach to the fast freight services, where the main conclusion would be that building a competitive fast rail-freight service is a valuable business proposition for rail operators. The ongoing trends such as the expected increase of greenhouse gas emissions, the increasing number of population and its tendency to concentrate in urban areas as never seen before are the main driver of this work. However, a moderate perspective is also part of the structuring lines of this work as it is considered that a good balance between economic and sustainable development is key to perform adequate adjustments to the *status quo.*

Thus, it's of the utmost importance to explore how the concepts of sustainability, green logistics and sharing economy are connected with building a case for a fast rail-freight service.

Sustainable development is one of the leading issues in the contemporary development discourse. It is an approach to development that takes the environmental dimension, which owes its origin to various debates and environmental movements in 1970s and 1980s regarding the connection between environment and economic development (Rodrigue, 2017; Jibril, 2011).

The approach seeks to reconcile human needs and the capacity of the environment to cope with the economic system so that these needs can be met not only in the present, but also for future generations. It holds that wealth of nations does not rest solely on its economic wealth but also on the smooth development and protection of environmental resources (Jibril, 2011).

The major principle of the concept is that the natural resources should be used in a manner which does not eliminate or degrade them, or otherwise diminish their usefulness for future generations.

Rodrigue (2017) argues that sustainable development is a complex concept that is subject to numerous interpretations since it involves several disciplines and interconnections. And Lele (1991), goes further by defending a lack of consistency in interpretation of sustainable development that still endure nowadays Klarin (2018). Many research documents also focus on a critical approach to sustainable development but during the last years strong progress was done leading, for instance, to the 17 sustainable development goals of the United Nations. In a wider perspective, the fundamental constraints on the implementation of the concept of sustainable development are the degree of socio-economic development that many countries have not yet achieved, associated with a lack of financial resources and technology, but also the diversity of political and economic goals on a global scale (Klarin, 2018).

The European Union has a strong starting position and track record in sustainable development and agrees that the sustainability challenges the world faces are undeniable. Accordingly, the EU is well placed to be the global frontrunner in the sustainability transition, helping to set global standards and reap the societal and economic benefits of being a first mover (European Commission, 2019).

The basic definition of sustainability is the three-pillar conception of (social, economic and environmental) sustainability, commonly represented by three intersecting circles with overall sustainability at the center, became ubiquitous (Rodrigue, 2017; Purvis *et al*., 2018, Investopedia, 2019). The three pillars may be defined as follows:

- **Social equity** relates to conditions favoring a distribution of resources among the current generation based upon comparative levels of productivity. Social equity is usually the most difficult element of the concept of sustainability to define.
- **Economic efficiency** concerns the conditions permitting higher levels of economic efficiency in terms of resource and labor usage. It focuses on capabilities, competitiveness, flexibility in production and providing goods and services that supply a market demand.
- **Environmental responsibility** involves a “footprint” which is lesser than the capacity of the environment to accommodate. This includes the supply of resources (food, water, energy, etc.), but also the safe disposal of numerous forms of wastes. Its core tenets include the conservation and reuse of products and resources. This idea boosts the actual trend to shift from linear to circular economic models, very much observed in the developed countries.

In the specific field of transportation, Rodrigue (2017) defines sustainable transportation as the capacity to support the mobility needs of a society in a manner that is the least damageable to the environment and does not impair the mobility needs of future generations. Under the economic dimension, the objective consists of orienting progress in the sense of economic efficiency. Transport must be cost-effective and capable of adapting to changing demands (Rodrigue, 2017). The idea of economic efficiency is somehow complex but in the field of transportation is very much related with the *sharing economy*. *Sharing economy* was first mentioned in 2008 and denotes the collaborative consumption made by the activities of sharing, exchanging, and rental of resources without owning the goods (Lessig, 2008; Van Duln, *et al*., 2018).

Rodrigue (2017) debates most considerations in sustainable transportation focus on passengers, leaving freight issues somewhat marginalized. Yet, logistics is a crucial part of the operation of modern transport systems and implies a degree organization and control over freight movements that only modern technology could have brought into being (Rodrigue, 2017; Sipos *et al*., 2015). *Green logistics* can be defined as supply chain management practices and strategies that reduce the environmental and energy footprint of freight distribution. It focuses on material handling, waste management, packaging and transport.

However, standard characteristics of logistical systems reveals several inconsistencies with regards to the mitigation of environmental externalities. The inconsistencies that are more relevant to this work are related with the cost, time and information technology and have been identified by Rodrigue, (2017):

- **Cost**: The purpose of logistics is to reduce costs, notably transport costs. In addition, economies of time and improvements in service reliability, including flexibility, are further objectives. Corporations involved in the physical distribution of freight are highly supportive of strategies that enable them to cut transport costs in a competitive setting. On some occasions, the cost-saving strategies pursued by logistic operators can be contrarily to the environmental impact, which becomes externalized. This means that the benefits of logistics are realized by the users and the environment assumes a wide variety of burdens and costs. An example of such inconsistency concerns food supply chains that have been impacted by lower transport costs, enabling a diversification of the suppliers and longer transport chains.

- **Time**: In logistics, time is often the essence. By reducing the time of flows, the velocity of the distribution system is increased, and consequently, its efficiency. This is mainly achieved by using the most polluting and least energy efficient transportation modes. The significant increase of air-freight and trucking is partially the result of time constraints imposed by logistical activities. Other modes cannot satisfy the requirements as effectively, leading to a vicious circle: the more time efficiency is required, the more negative environmental consequences of are created.

- **Information technology (IT):** IT have led to new dimensions in retailing where one of the most dynamic markets is e-commerce. Even if for the online customers there is an appearance of a movement-free transaction, the distribution online transactions create may consume more energy than other retail activities. These distribution activities have benefited mostly e-commerce are parcel-shipping companies that rely solely on trucking and air transportation.

The European Commission (2018) refers the main external costs of transport are those linked to greenhouse gas emissions, local air pollution, congestion, capacity bottlenecks, accidents and noise. CO2 emissions and air pollution from transport are the major environmental concerns related to transport activity. A growing demand for transport is expected and unlike other sectors, aviation emissions are forecasted to increase as air traffic increases in Europe and worldwide (European Commission, 2018). According to Eurostat and to the European Environment Agency, the whole transport accounts for 25% of the greenhouse gas emissions in the European Union.

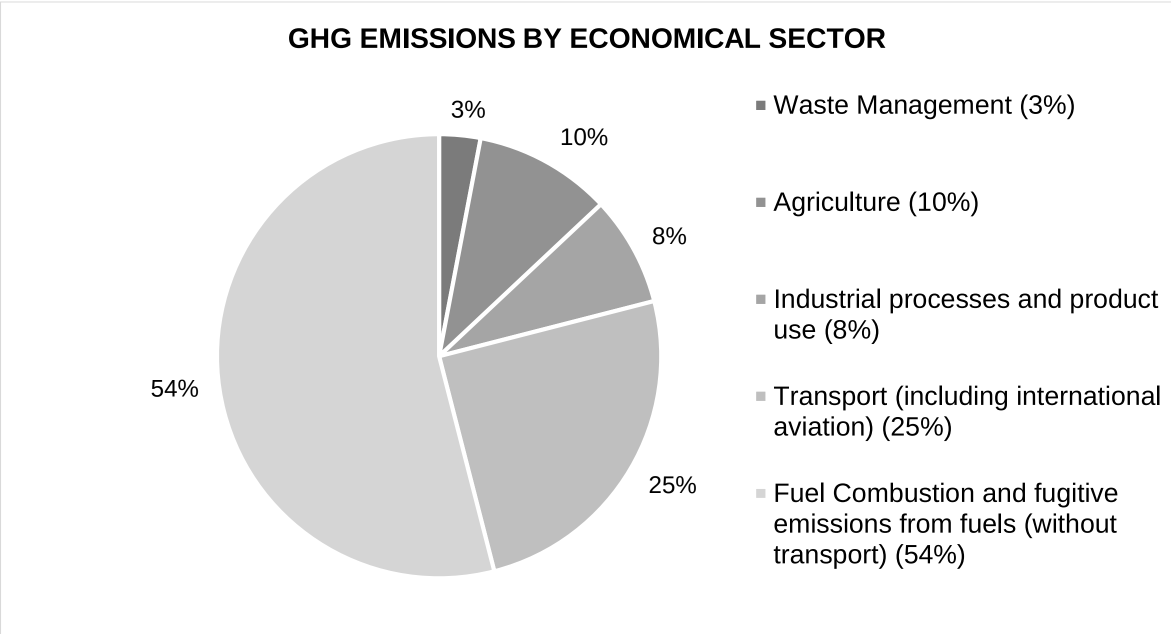

Figure 26 - GHG Emission by Economical Sector (Eurostat, 2018).

A shift towards greener logistics consists of both mitigation and adaptation. Mitigation concerns the improvement of productivity and efficiency of existing modes, terminals and managerial approaches so that environmental externalities are reduced while adaptation is the change in the level of use and the market share of respective modes to better reflect long-term trend. This shift can occur by a combination of the following approaches: a top-down approach, a bottom-up approach and a compromise. A top-down approach is imposed by government policies through regulations. A bottom-up approach is achieved by the industry itself through the adoption of better practices, fostered by innovation. A compromise is done between the government and industry, notably through targets definition and incentives (Rodrigue, 2017).

Sustainability is also very much connected with reducing waste, increasing efficiency and minimizing underutilized tangible assets. Thus, optimizing transportation logistics is also an objective as transportation is a resource that can't be stored and accounts for 50% of the total cost of freight transportation. In the passenger's urban mobility many examples of sharing economy can be commonly observed, for example car-sharing platforms such as BlaBla Car, where seats in a private vehicle can be put up for sale. Cycling schemes using shared bicycles have erupted in European Union, for example in Lisbon the sharing scheme Gira has been placed in several locations. Many more concrete business models that are built upon the sharing economy concepts can be find throughout the world. Görög (2018) argues that Internet was the main driver in the creation of such new business models, though the development of platforms that connect both the resource provider with possible users.

Van Dull et.al. (2018) states that transport capacity sharing is a phenomenon tremendously growing with many startups rushing into freight brokerage platforms to help matching shippers and carriers to maximize truckload utilization, decrease empty miles, and accelerate shipping times. Examples of these platforms are Saloodo! and QuiCargo in Europe, Freightos, Convoy, and Loadsmart in the U.S., and Huochebang in China. Specifically, in the city logistics field, DHL recently has developed the such as: Truly Shared Warehousing, Urban Discreet Warehousing, Community Goods On-demand, Logistics Asset Sharing, Transport Capacity Sharing, On-demand Staffing and Logistics Data Sharing (Gesing, 2017).

However, a less commonly seen transport capacity sharing model is related with the unused capacity of public transportation and the usage of such extra space for freight. Indeed, sharing infrastructure increases the utilization of vehicles and tracks while, at the same time, reduces transportation costs, CO2 emissions and congestion (Van Dull et.al, 2018). However, many of these models have been applied only to short-haul routes and in distribution operations within urban areas. There is a lack of examples in transport capacity sharing in longer journeys, such as the routes analyzed in chapter 3. Yet, Van Dull et.al, (2018) reviewed several studies regarding the possibilities of mixed cargo and passenger's transportation concluding that positive synergies may exist when logistic service providers are cooperating with scheduled passenger service providers.

A competitive rail-freight fast service could contribute to ease the environmental impact of cargo transportation and to increase the degree of optimization in the rail industry. It is of extreme importance to produce competitive solutions that focus, among many other aspects, on an environmental positive impact.

6
CONCLUSION

The majority of high-speed trains in the EU aren't available for rail-freight fast shipments and run far below their maximum passenger capacity, as observed in the DB's load factor of around 50%. Therefore, train companies possess a resource that is not being used and that can't be stored, resulting in a waste of opportunity and in a sub-optimal operation.

Nevertheless, this condition does not imply directly that high-speed passenger trains must be used for fast rail-freight shipments, as initially thought. Some different innovative and classic solutions may be thought as long as the objective is to increase develop the competitiveness of the rail sector.
However, the reason of this work was to study the feasibility and possibility of mixing both cargo and passengers in high-speed trains.

From the beginning, for a reader who may already have some degree of knowledge in the field of transportation, and due to the marketing strategies, that aim at showing passengers that many rail routes pose a better option, it could be already foreseeable that the same could apply for cargo. Still, it was thought that a technical approach, based on a comparison of reliable data, would show that this is indeed a scenario to be considered in depth. That was the maxim for the data analysis done in Chapter 4, right after exploring general concepts of cargo transportation in Chapter 2 and understanding the overall cargo operational procedures in Chapter 3.

From the data analysis, which was based on the comparison of the duration, capacity, CO2 emissions and operative costs on selected routes, it was possible to understand that high-speed train routes can indeed compete with air solutions for small and medium size shipments, although many times air routes are still faster. Nonetheless, with the knowledge acquired on Chapter 3, mainly regarding the different shipping service, synthetized on Table 1, it is also known that many of these services don't require a next-flight-out option nor a same-day delivery. This means that for most shipping services that nowadays use air-routes, rail alternatives could be competitive and a viable option. Furthermore, it was also evident that some specific cases of high-speed rail-freight already exist (the case of the ongoing partnership of Time:Matters with Deutsche Bahn) or existed (the case of TGV La Poste).

Up till now, everything seems quite straightforward, but difficulties emerged when gathering the information needed about train routes (Table 12), evidencing a very fragmented rail infrastructure, lacking continuous routes and revealing logistical nightmares. Think for instance in route 16 from

Manchester to Amsterdam, where a transfer from Euston Station to St. Pancras station using a subway train is needed. As later explored in Chapter 5, transshipments cargo requires some very specific handling techniques, which contrarily to airports, are not standardized or developed to such degree of efficacy.

The irrefutable fact that high-speed trains emit much less GHGs, having a much smaller impact on Earth's increasing temperature, responsible for boosting climate change, became evident by the CO2 emissions comparison performed, where it was found that high-speed trains emit less 97% when compared to domestic flights. Therefore, more than a market opportunity for train enterprises, this is a matter of environmental urgency, as all the forecasts from IATA, ICAO and the European Commission show an increase in air-freight over the next years. Fortunately, as seen before from various perspectives, the European Union is very much focused on the environmental challenge, lately declaring climate emergency. This should be positive for the future transport policies that intersect this work.

Soon, it was realized that a major transformation in the rail industry cannot be imposed by a single entity, due to the complexity of the challenge and the many different areas intersected. Therefore, in chapter 5, a general approach was performed over the topics though to be relevant. In this chapter, there are no full solutions presented or project matrixes with detailed actions, but instead an overview of some very complex topics that pose both an opportunity and a challenge to overcome. Structured and efficient actions need to be brought into place by stakeholders under capable coordination. Together, engineering, policy and management need to deliver solutions for an integrated and continuous rail-freight for fast shipments.

In a way, the main conclusion is that urgent change is needed due to the need for a more sustainable development. Stakeholders have a crucial role in producing the needed transformation and should be willing to put this matter on the top of the agenda. Of course, it is impossible to achieve a unified European rail network in an extreme short-term. Yet, small steps are required to develop a wider change. These small steps may start within each member state, using only some trains, in very selected routes. An iterative process must be in place to unleash the potential of rail in the fast shipments market. That can only be achieved if stakeholders have a mindset of progress, growth and evolution.

From a practical perspective, this work may receive critics from all sources. A fast rail-freight service in the EU may be considered impossible by some, the wrong approach by others or even a complete nonsense. All those critics are welcome, and their opinions should be valued for future developments in the rail industry. As already defended, action to explore the rail potential is needed, in every viable direction.

Finally, this work hopes to have achieved some of its objectives, such as boosting curiosity and maybe serve as framework for future developments in some specific topics here addressed.

REFERENCES

Air Cargo News (2019). *Top 25 cargo airlines: FedEx at the top as Qatar closes in on Emirates*. https://www.aircargonews.net/airlines/top-25-cargo-airlines-fedex-at-the-top-as-qatar-closes-in-on-emirates/. 12 Oct. 2019.

Alderighi, M., Cento, A., Nijkamp, P., Rietveld, P. (2007). *Assessment of New Hub-and-Spoke and Point-to-Point Airline Network Configurations*. Routledge, London. http://dx.doi.org/10.1080/01441640701322552.

ATAG (2018). *Facts & Figures*. https://www.atag.org/facts-figures.html. 29 Dec. 2019.

BBC (2019).*Climate change: Should you fly, drive or take the train?*. https://www.bbc.com/news/science-environment-49349566. 2 Dec. 2019.

Bierwirth, P. (2019). *Carbon dioxide toxicity and climate change: a serious unapprehended risk for human health*. https://www.researchgate.net/publication/311844520. 15 Dec. 2019.

Bîzoi, A., Sipos, C. (2015). *GREEN LOGISTICS – A CONDITION OF SUSTAINABLE DEVELOPMENT*. https://www.researchgate.net/publication/280094799.

Cambridge Dictionary (2019). *Meaning of Freight in English*. https://dictionary.cambridge.org/dictionary/english/freight. 17 Oct. 2019.

Chow, A.H.F. (2007). *Trip Assignment – A Literature Review. California PATH, UC Berkeley*. http://www./path.berkeley.edu/topl/reports/071101_AndyChow_DTAReview.pdf. 12 Dec. 2019.

Cook, G.N., Billig, B. (2017). *Airline Operations and Management: A Management Textbook. Routledge,* New York. ISBN 978-1-138-23752-0.

Culliane, Kevin (2019). *Airline Economics in Europe*. Emerald Publishing Limited, Bingley. ISBN 978-1-78973-282-5.

Daily Mail (2012). *Regulator reveals how much it costs train companies to carry their passengers*. https://www.dailymail.co.uk/news/article-2237772/How-costs-train-companies-carry-passengers-results-surprise-you.html. 21 Dec. 19.

Deutsche Bahn AG (2019). *2018 Integrated Report - On track towards a better railway*. https://ib.deutschebahn.com/ib2018/fileadmin/PDF/IB18_e_web.pdf. 15 Dec. 2019.

DHL (2019). *DHL EXPRESS WEIGHT & DIMENSIONS*. https://www.dhl.com/content/dam/downloads/g0/express/shipping/weights_and_dimensions/weights_and_dimensions_en_lm.pdf. 20 Nov. 2019.

European Commission (2015). *Study on the Cost and Contribution of the Rail Sector*. https://ec.europa.eu/transport/sites/transport/files/modes/rail/studies/doc/2015-09-study-on-the-cost-and-contribution-of-the-rail-sector.pdf.

European Commission (2017). *Delivering TEN-T – Facts and Figures September 2017*. http://www.connectingeu.eu/documents/Delivering_TEN_T.pdf.

European Commission (2018). *REFLECTION PAPER - TOWARDS A SUSTAINABLE EUROPE BY 2030*. https://ec.europa.eu/commission/sites/beta-political/files/factsheets_sustainable_europe_012019_v3.pdf. 28 Dec. 2019.

European Commission (2019). *Causes of climate change*. https://ec.europa.eu/clima/change/causes_en. 15 Dec. 2019.

European Commission (2019). *Climate change consequences*. https://ec.europa.eu/clima/change/consequences_en. 1 Jan. 2019.

European Commission (2019). *Logistics and multimodal transport.* https://ec.europa.eu/transport/themes/logistics-and-multimodal-transport/logistics_en. 30 Sep. 2019.

European Commission (2019). *Reducing emissions from aviation.* https://ec.europa.eu/clima/policies/transport/aviation_en. 29 Dec. 2019.

European Commission (2019). *Transport in the European Union – Current trends and issues*. https://ec.europa.eu/transport/sites/transport/files/2019-transport-in-the-eu-current-trends-and-issues.pdf.

European Court of Auditors (2018). *A European high-speed rail network: not a reality but an ineffective patchwork.* Special Report. ISBN 978-92-847-0098-1.

European Parliament (2019). *The European Parliament declares climate emergency.* https://www.europarl.europa.eu/news/en/press-room/20191121IPR67110/the-european-parliament-declares-climate-emergency. 27 Dec. 2019.

Eurostat (2017).*Freight transport statistics - modal split*. https://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split. 21 Nov. 2019.

Eurostat (2019*). Modal split of freight transport, EU-28, 2012 and 2017 (% share in tonne-kilometres).* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Modal_split_of_freight_transport,_EU-28,_2012_and_2017_(%25_share_in_tonne-kilometres).png#file. 27 Nov. 2019.

Faboya, O., Siebers, P., Ryan, B., Figueredo, G. (2017). *A Novel Modal Shift Modelling Framework for Transport Systems*. https://www.researchgate.net/publication/318852842.

FedEx, *Connecting People and Possibilities: The History of FedEx*. https://about.van.fedex.com/our-story/history-timeline/history/. 15 Dec. 2019.

Givoni, M. (2007). *Environmental Benefits from Mode Substitution - Comparison of the Environmental Impact from Aircraft and High-Speed Train Operations.* Taylor & Francis Group, online. http://dx.doi.org/10.1080/15568310601060044.

Hellermann, Rolf (2006). *Capacity Options for Revenue Management*. Springer-Verlag, Berlin Heidelberg. ISBN 978-3-540-34420-9. DOI 10.1007/3-540-34420-9.

Hesse, M. (2002). *The implications of electronic commerce for logistics and freight transport*. https://www.researchgate.net/publication/222645693. 23 Dec. 2019.

IATA (2019). *IATA's Annual Review*. https://www.iata.org/en/publications/annual-review/. 13 Dec. 2019.

ICAO, WCO (2016). *Moving Air Cargo Globally - Air Cargo and Mail Secure Supply Chain and Facilitation Guidelines.* https://www.icao.int/Security/aircargo/Moving%20Air%20Cargo%20Globally/ICAO_WCO_Moving_Air_Cargo_en.pdf. 25 Nov. 2019.

International Railway Journal (2015). *Last post for French high-speed freight as postal TGVs bow out*. https://www.railjournal.com/freight/last-post-for-french-high-speed-freight-as-postal-tgvs-bow-out/. 15 Nov. 2019.

International Union of Railways (2018). *High Speed lines in the World – UIC Passenger Department. https://uic.org/IMG/pdf/20181001-high-speed-lines-in-the-world.pdf.* 10 Dec. 2019.

Investopedia (2019). *Available Seat Miles (ASM).* https://www.investopedia.com/terms/a/availableseatmiles.asp. 20 Dec. 19.

Investopedia (2019). *Cost Per Available Seat Mile (CASM).* https://www.investopedia.com/terms/c/casm.asp. 20 Dec. 19.

Investopedia (2019). *Revenue per Available Seat Mile (RASM).* https://www.investopedia.com/terms/r/revenue-per-available-seat-mile-rasm.asp. 20 Dec. 19.

Jibril, A. (2011). *THE CONCEPT AND PRINCIPLES OF SUSTAINABLE DEVELOPMENT*. https://www.researchgate.net/publication/3325932.

Kiso, F., Deljanin,A (2009). *Air Freight and Logistics Services*. https://www.researchgate.net/publication/271261088.

Klarin, T. (2018). *The Concept of Sustainable Development - From its Beginning to the Contemporary Issues.* Zagreb International Review of Economics & Business, Vol. 21, No. 1, 2018, pp. 67-94, Zagreb. https://www.researchgate.net/publication/326164068.

KPMG International (2019). *COP25 - Key outcomes of the 25th UN Climate Conference*. https://home.kpmg/xx/en/home/insights/2019/12/key-outcomes-of-cop25.html. 16 Dec. 2019.

la Lettre du cheminot (2014). Les TGV de La Poste seront remplacés par des wagons en 2015. https://www.lettreducheminot.fr/materiel/011-16283-les-tgv-de-la-poste-seront-remplaces-par-des-wagons-en-2015/. 15 Nov. 2019.

Linibis. *What is expedited shipping? How long does expedited shipping take?*. https://www.linbis.com/expedited-shipping/. 03 Jan. 2020.

Lufthansa Cargo (n/a*). Our aircraft bellies: more space for your logistics requirements*. https://lufthansa-cargo.com/fleet-ulds/fleet/belly-fleet. 18 Dec. 19.

Lufthansa Group AG (2019). *STRIVING FOR EXCELLENCE - Annual Report 2018.* https://investor-relations.lufthansagroup.com/fileadmin/downloads/en/financial-reports/annual-reports/LH-AR-2018-e.pdf. 15 Dec. 2019.

Macário, R., Voorde, V. (2011). *Critical Issues in Air Transport Economics and Business*. Routledge, New York. ISBN 978-0-415-57055-8.

McKinsey & Company (2014). *Getting freight back on track*. https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/getting-freight-back-on-track. 25 Oct. 2019.

McKinsey & Company (2019). *The liberalization of the EU passenger rail market - Growth opportunities and new competition*. https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/navigating-the-eu-rail-market-liberalization. 10 Nov. 2019.

McLeod, Sam., Schapper, J., Curtis, C., Graham, G. (2019). *Conceptualizing freight generation for transport and land use planning - A review and synthesis of the literature*. Transport Policy, Volume 74, Pages 24-34. https://doi.org/10.1016/j.tranpol.2018.11.007.

Morganti, E., Seidel, S., Blanquart, C., Dablanc, L., Lenz, B. (2014). *The Impact of E-commerce on Final Deliveries - Alternative Parcel Delivery Services in France and Germany*. https://www.researchgate.net/publication/273834549. 23 Dec. 2019.

Morrel, Peter S. (2007). Moving Boxes by Air – *The Economics of International Air Cargo*. Cranfield University, Cranfield. ISBN 978-1-4094-0252-7.

NASA (2009). *Scientific Consensus - Earth's Climate is Warming*. https://climate.nasa.gov/scientific-consensus/. 29 Dec. 2019.

NASA (2010). *How Will Global Warming Change Earth?.* https://earthobservatory.nasa.gov/features/GlobalWarming/page6.php. 28 Dec. 19.

Ohnell, S., Woxenius, J. (2009). *An industry analysis of express freight from a European railway perspective*. International Journal of Physical Distribution & Logistics Management. Vol. 33 No. 8, 2003 pp. 735-751. MCB UP Limited, online. DOI 10.1108/09600030310502902.

Paul Corry, Erhan Kozan (2006). *An assignment model for dynamic load planning of intermodal trains.* Computers & Operations Research,Volume 33, Issue 1, 2006, Pages 1-17. https://doi.org/10.1016/j.cor.2004.05.013.

Purvis, B., Mao, Y., Robinson, D. (2018). *Three pillars of sustainability - in search of conceptual origins*. Sustainability Science, Vol. 14, 03/09/2018, pp. 681-695, Springer. https://www.researchgate.net/publication/327404334.

Rad, S., Gulmez, Y. (2017). *GREEN LOGISTICS FOR SUSTAINABILITY*. https://www.researchgate.net/publication/320132070_GREEN_LOGISTICS_FOR_SUSTAINABILITY. DOI 10.17130/ijmeb.2017331327.

Rail Freight Forward (2019). *30 by 2030 - Rail Freight strategy to boost modal shift*. https://www.railfreightforward.eu/sites/default/files/usercontent/white_paper-30by2030-150dpi6.pdf. 27 Sep. 2019.

Railway Gazette (2014). *Swap bodies to carry mail by rail*. https://www.railwaygazette.com/news/freight/single-view/view/swap-bodies-to-carry-mail-by-rail.html. 15 Nov. 2019.

Rodrigue, J. P. (2020). *The Geography of Transport Systems*. Routledge, New York. https://transportgeography.org/. ISBN 978-0-367-36463-2.

Siemens AG, Deutsche Bahn (2011). *The ICx - A new era in the Deutsche Bahn's main-line service*. https://new.siemens.com/global/en/products/mobility/rail-solutions/rolling-stock/high-speed-and-intercity-trains/ice-4.html. 10 Nov. 2019.

SNCF (2018). *Calculation of CO2 emissions on your train journey*. https://be.oui.sncf/en/help-be/calculation-of-co2-emissions-on-your-train-journey. 22 Dec. 19.

Sorgenfrei, J. (2018). *Port Business*. Walter de Gruyter Inc., Boston. ISBN 978-1-5474-1702-5

Statista (2010). *Cost per seat per kilometer of selected airlines in euro cents*. https://www.statista.com/statistics/269532/cost-per-seat-per-kilometer-of-selected-airlines/. 21 Dec. 19.

Stroh, M. (2006). *A Practical Guide to Transportation and Logistics*. Logistics Network Inc.. ISBN 978-0970811516.

Teodorović, D., Janić, M. (2017). *Transportation Engineering - Theory, Practice and Modeling.* Elsevier Inc., Oxford. ISBN 978-0-12-803818-5

Time:Matters (2019). *SAMEDAY AIR - Sameday transports worldwide*. https://www.time-matters.com/transport-solutions/sameday-air/. 2 Nov. 2019.

Time:Matters, Deutsche Bahn (2010). *PRESS RELEASE - Deutsche Bahn and time: matters open the first international ic:courier station in Paris*. https://www.time-matters.com/press/2010-2/deutsche-bahn-and-timematters-open-the-first-international-iccourier-station-in-paris/. 11 Oct. 2019.

Triantafyllou, M., Cherrett, T., Browne, M. (2014). *Urban Freight Consolidation Centers Case Study in the UK Retail Sector.* Transportation Research Record Journal of the Transportation Research, vol. 2411, no. 1, 24/06/2012, pp. 34–44, 2 Elsevier Science B.V., Berlin. https://www.researchgate.net/publication/222645693

Troche, G. (2005). *High-speed rail freight - Sub-report in Efficient train systems for freight transport*. Report, KTH Royal Institute of Technology. https://www.kth.se/polopoly_fs/1.87134.1550157093!/Menu/general/column-content/attachment/0512_inlaga.pdf.

Turkensteen, M., Klose, A. (2012). *Demand dispersion and logistics costs in one-to-many distribution systems.* European Journal of Operational Research, Vol. 223, 15/06/2012, pp. 499–507, Elsevier, Denmark. https://www.researchgate.net/publication/257196274.

Ülkü, M. (2009). *Comparison of Typical Shipment Consolidation Programs - Structural Results*. Management Science and Engineering, Vol.3, No.4, 12/20/2009, Canadian Research & Development Center of Sciences and Cultures, Quebec City. https://www.researchgate.net/publication/43245432.

Union of Concerned Scientists (2019). *Climate Impacts*. https://www.ucsusa.org/climate/impacts. 02 Jan. 2019.

Upela (2019). *Different types of shipments available*. https://www.upela.com/en/types-shipments-upela-47.html. 20 Nov. 2019.

UPS (2019). *Determine your package size*. ht tps://www.ups.com/us/en/help-center/packaging-and-supplies/prepare-overize.page#contentBlock-13. 20 Nov. 2019.

Van Duin, J.H.R., Wiegmans, B., Tavasszy, L.A.,Hendriks, B., He, Y (2018). *Evaluating New Participative City Logistics Concepts: The Case of Cargo Hitching*. https://www.researchgate.net/publication/329625614.

Woxenius, J. (1998). *INTERMODAL TRANSSHIPMENT TECHNOLOGIES - AN OVERVIEW.* https://www.researchgate.net/publication/281274705. DOI: 10.13140/RG.2.1.1155.2481.

Yi, Sirong (2018). *Chapter 4 - Railway Location*. Principles of Railway Location and Design. Academic Press. Pages 273-367. ISBN 9780128134870. https://doi.org/10.1016/B978-0-12-813487-0.00004-4.

ANNEX 1

REAL CASE SCENARIOS

The following tables present 10 real case scenarios for shipping options within Time:Matters network for the ic:kurrier, the rail-freight service and the sameday classic. These scenarios are done based on an availability time at 09:00 on the 7th of January of 2020 and in random origins and destinations, ranging from international shipments to national shipments.

No interpretation or critical analysis will be done over this results and conclusions will be left to the reader, as it is believed the context offered during this dissertation dismisses further lecturing. One remark, however, is relevant: The route specification on the rail option.is missing because it is not relevant.

Table 16 - Real Case Scenario 1: Amsterdam (AMS) to Paris (CDG)

AMSTERDAM (AMS) TO PARIS (CDG)		
	AIR	**RAIL**
LAT	9:30h	12:18h
TOA	16:05h	20:56h
ROUTE	AMS-MUC-CDG	n/a
FLIGHTS/TRAINS	LH2303 > LH2230	ICE 125 > TGV9560
DURATION (h)	6:35h	8:38h

Table 17 - Real Case Scenario 2: Amsterdam (AMS) to Cologne (CGN)

AMSTERDAM (AMS) TO COLOGNE (CGN)		
	AIR	**RAIL**
LAT	9:30	10:18
TOA	16:50	13:30
ROUTE	AMS-MUC-CGN	n/a
FLIGHTS/TRAINS	LH2303 > LH1988	ICE123
DURATION (h)	7:20	3:12

Table 18 -Real Case Scenario 3: Amsterdam (AMS) to Berlin (TXL)

AMSTERDAM (AMS) TO BERLIN (TXL)		
	AIR	**RAIL**
LAT	9:25	10:40
TOA	15:40	17:21
ROUTE	AMS-FRA-TXL	n/a
FLIGHTS/TRAINS	LH989 > LH186	IC145 > ICE549
DURATION (h)	6:15	6:41

Table 19 - Real Case Scenario 4: Amsterdam (AMS) to Frankfurt (FRA)

AMSTERDAM (AMS) TO FRANKFURT (FRA)		
	AIR	**RAIL**
LAT	9:25	10:18
TOA	12:50	14:36
ROUTE	AMS-FRA	n/a
FLIGHTS/TRAINS	LH989	ICE123
DURATION (h)	3:25	4:18

Table 20 - Real Case Scenario 5: Amsterdam (AMS) to Vienna (VIE)

AMSTERDAM (AMS) TO VIENNA (VIE)		
	AIR	**RAIL**
LAT	9:25	10:18
TOA	15:15	23:05
ROUTE	AMS-FRA-VIE	n/a
FLIGHTS/TRAINS	LH989 > OS130	ICE123 > ICE229
DURATION (h)	5:50	12:47

Table 21 - Real Case Scenario 6: Berlin (TXL) to Munich (MUC)

BERLIN (TXL) TO MUNICH (MUC)		
	AIR	**RAIL**
LAT	9:50	9:07
TOA	13:10	14:18
ROUTE	TXL-MUC	n/a
FLIGHTS/TRAINS	LH2035	ICE703
DURATION (h)	3:20	5:11

Table 22 - Real Case Scenario 7: Berlin (TXL) to Stuttgart (STR)

BERLIN (TXL) TO STUTTGART (STR)		
	AIR	**RAIL**
LAT	9:10	9:07
TOA	12:20	15:23
ROUTE	TXL-STR	n/a
FLIGHTS/TRAINS	EW8002	ICE703 > ICE597
DURATION (h)	3:10	6:16

Table 23 - Real Case Scenario 8: Paris (CDG) to Munich (MUC)

PARIS (CDG) TO MUNICH (MUC)		
	AIR	**RAIL**
LAT	10:20	14:35
TOA	13:45	21:32
ROUTE	CDG-MUC	n/a
FLIGHTS/TRAINS	LH2229	ICE9563 > IC2269
DURATION (h)	3:25	6:57

Table 24 - Real Case Scenario 9: Paris (CDG) to Leipzig (LEJ)

PARIS (CDG) TO LEIPZIG (LEJ)		
	AIR	**RAIL**
LAT	10:20	10:10
TOA	16:10	18:39
ROUTE	CDG-MUC-LEJ	n/a
FLIGHTS/TRAINS	LH2229 > LH2168	ICE9579 > ICE278 > ICE1653
DURATION (h)	5:50	8:29

Table 25 - Real Case Scenario 10: Hannover (HAJ) to Dresden (DRS)

Hannover (HAJ) to Dresden (DRS)		
	AIR	**RAIL**
LAT	9:00	10:22
TOA	14:00	15:04
ROUTE	HAJ-FRA-DRS	n/a
FLIGHTS/TRAINS	LH053 > LH210	IC2443
DURATION (h)	5:00	4:42

ANNEX 2

DATA ANALYSI’S MISSING TABLES

Table 26 - Intersection of filters 1 and 2 with data set A

An1	An2	An1n2
VIE	BRU	LYS
BRU	CDG	DUS
CPH	LYS	BUD
HEL	FRA	OPO
CDG	DUS	MAN
MUC	BUD	BHX
FRA	AMS	
CGN	OPO	
LEJ	MAD	
MXP	DUB	
FCO	MAN	
LUX	BHX	
AMS	LHR	
MAD		
BCN		
DUB		
LHR		

Table 27 - Time:Matter's EU Routes

TIME:MATTERS'S EUROPEAN UNION STATIONS				
VIE	NCE	MXP	WRO	GLA
GRZ	LYS	NAP	KTW	EDI
KLU	HAM	BRI	KEK	ABZ
INN	BRE	BDS	LIS	DUB
LNZ	HAJ	SUF	OPO	LHR
BRU	STR	REG	BEG	MAN
LGG	MUC	CTA	ZAG	BHX
OTP	FRA	PMO	VGO	EMA
SBZ	DTM	CAG	SVQ	STN
CLJ	FMO	FCO	AGP	
TSR	TXL	RIX	BIO	
SOF	CGN	VNO	VLC	
LCA	DRS	LUX	PMI	
PRG	LEJ	MLA	MAD	
BLL	DUS	AMS	BCN	
CPH	ATH	OSL	RNB	
TLL	BUD	SVG	GOT	
OUL	GOA	HAU	VBY	
HEL	TRN	BGO	KSD	
TLS	MXP	AES	BMA	
MRS	LIN	KSU	ARN	
NCE	VCE	TRD	SDL	
BOD	BLQ	GDN	UME	
NTE	PSA	WAW	LLA	
CDG	FLR	POZ	KRN	

ANNEX 3

TEN-T MAPS

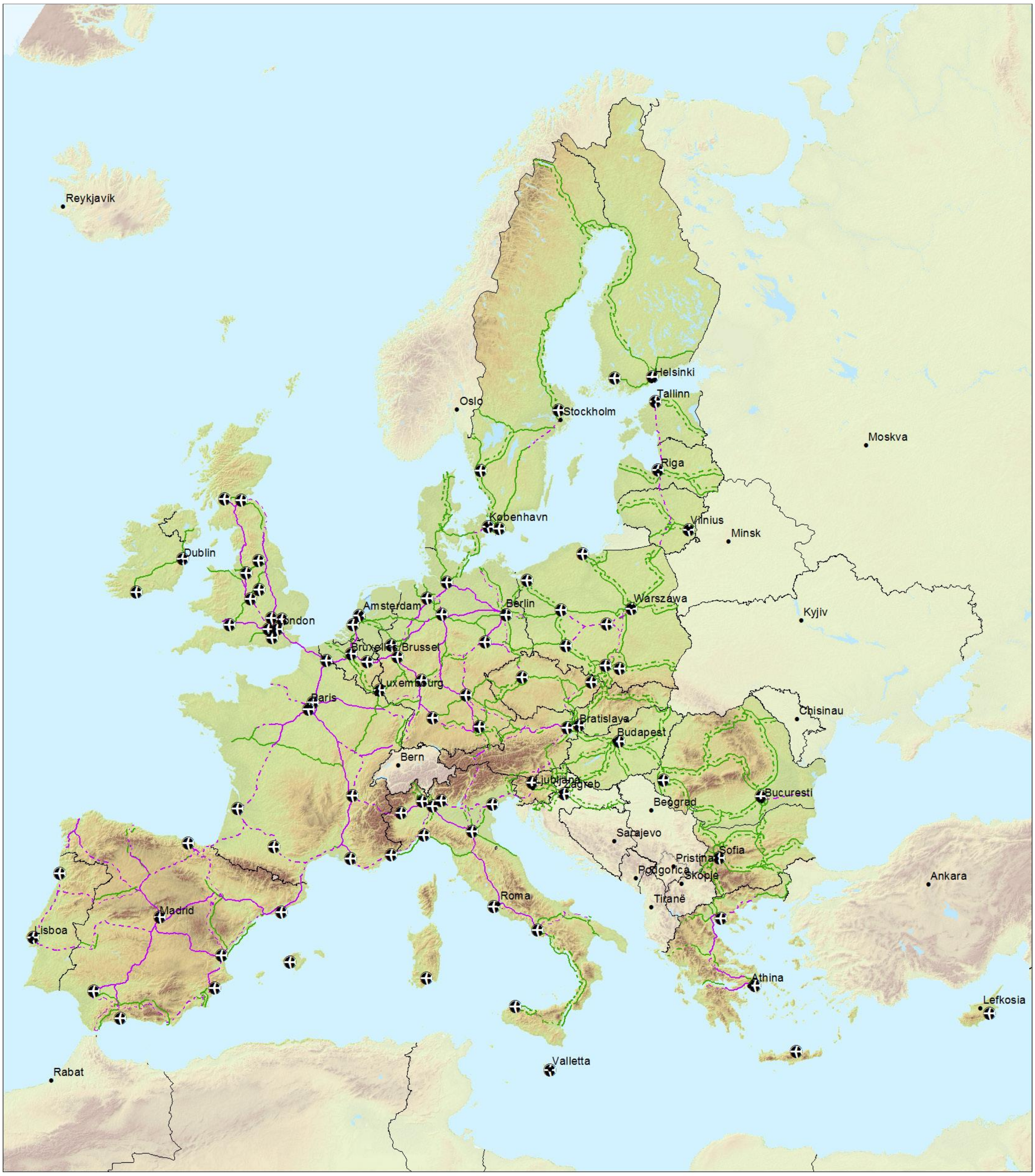

Figure 27 - TEN-T Core Network Railways (Passengers) and airports (Retrieved from European Commission, 2013).

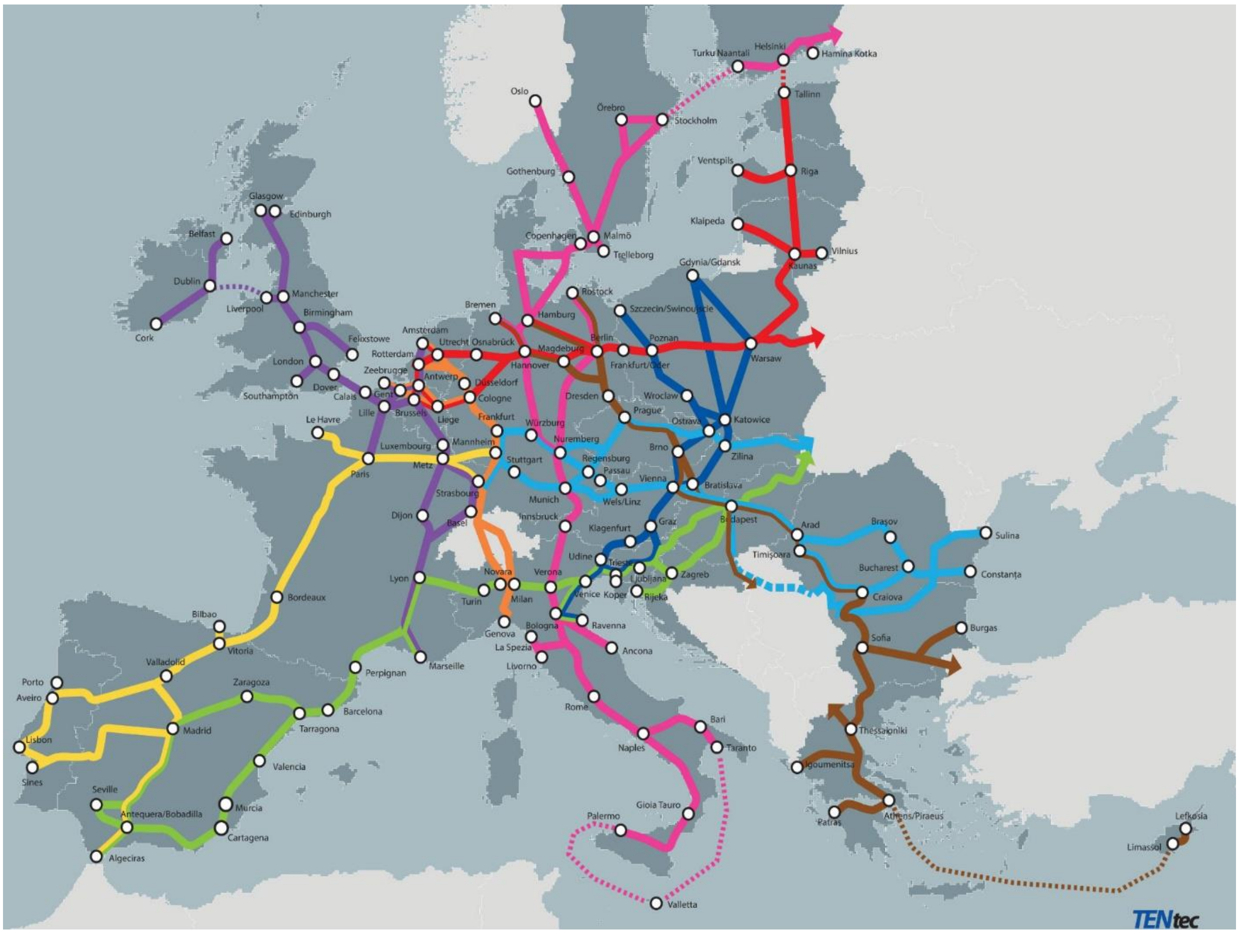

Figure 28 - TEN-T Core Network Corridors (Retrieved from European Commission, 2013).