Transferring by plane or train?

A transition perspective on barriers to air-rail integration

MSc Environmental and Infrastructure Planning
University of Groningen, Faculty of Spatial Sciences
15-07-2022

Author: Nils Bruinsma (S3245632)
Supervisor: Dr. Farzaneh Bahrami

university of groningen
faculty of spatial sciences

Colophon

Master's thesis:	MSc. Environmental and Infrastructure Planning
Title:	Transferring by plane or train?
Subtitle:	A transition perspective on barriers to air-rail integration
Author:	Nils Bruinsma (S3245632)
Version:	Final
Supervisor:	Dr. Farzaneh Bahrami
Second reader:	Dr. Tim Busscher
University	University of Groningen Faculty of Spatial Sciences Landleven 1 9747AD Groningen
Date:	15 July, 2022
Place:	Groningen, The Netherlands
Cover:	Cover picture of EUROCONTROL think paper #11 - Plane and train: getting the balance right (2021)

Preface

Dear reader,

After six years of studying at the University of Groningen, starting with the bachelor of Spatial Planning and Design and finishing with the Master program of Environmental and Infrastructure Planning, this Master's thesis marks the end of my life as a fulltime student. Over the years, my studies have taught me a way of thinking and reasoning that is needed to overcome the complexities in the challenges of today's world. For that, I am very grateful.

The subject of this thesis addresses only one of the many sustainability challenges around the world. This research has showed me that for achieving air-rail integration, like with many other subjects, there is no simple solution. Although modern day society sometimes expects issues to be resolved on a short term without reducing the high standard of life, thinking that solving them is easy, simple solutions rarely exist. When diving deeper into a subject, physical limitations and other complexities that hinder the development of an easy solution, quickly rise to the surface. Here, I find that vested interests, habits, convenience, and money, are factors that often prohibit implementation of truly sustainable solutions.

During the process of writing this thesis, I had a similar experience. Interest in the topic was triggered by my own experience of travelling from Seattle (USA) to Amsterdam while having a transfer at Charles de Gaulle in Paris. Knowing that there was a frequent and high quality train connection, I wondered why it was not possible to opt for the more sustainable High Speed rail option to travel from Paris to Amsterdam. Knowing little about air-rail integration at the time, I didn't know about the many complexities that complicate the development of an air-rail product. Now, after almost a full year of conducting research on air-rail integration, I do.

First of all, I would like to thank all my interviewees for sharing their knowledge and insights with me. Knowing that aviation and the reduction of flying is a politically contested and sensitive subject, I am very grateful for all the insights they have given me. I have used the given information with as much care as possible. Secondly, I would like to thank my mom and dad for always supporting me and being interested in what I do, not only during the process of writing this thesis, but during my full six years of being in university. Thirdly, I would like to thank Farzaneh Bahrami, my supervisor, for all the feedback she has given me. Lastly, I would like to use this occasion for thanking Sander and Damin (my best friends and roommates), and my girlfriend Danika for all their support, especially during the two years of Covid.

I hope that this thesis will give you valuable new insights and I wish you an enjoyable read.

Nils Bruinsma

Groningen, July 2022

Abstract

With increasing awareness of aviation's negative environmental impacts and the rising popularity of High Speed Rail services, there is much pressure to stop flying on short haul routes where rail connections exist. One of the major reasons why short haul routes are still served by aircraft, is to serve transfer passengers who have a connecting flight. Although scholars have advocated for improved air-rail integration, air-rail products are still a niche. This research has carried out an in-depth case study with semi-structured interviews and a document analysis to uncover barriers to the development of an air-rail product at the Amsterdam-Paris corridor. The multi-level perspective from transition theory has offered an analytical framework in which air-rail integration is framed as a niche development trying to penetrate the dominant aviation and High Speed Rail regime practices. Results suggest that there are several factors that prohibit the development of the air-rail product. Firstly, because of fierce international competition for transfer passengers between airlines, airlines have the need for a high quality product to avoid losing passengers. This high quality product demands a frequent stop at the airport, a code-share agreement that guarantees passengers' connection, quick transfer times and a luggage solution for larger bags. For many years the airlines and railway operators have worked in isolation from each other while creating highly efficient working processes. This has led to the separate development of physical and digital High Speed Rail and aviation infrastructures and services. The integration of infrastructure and services is costly and time consuming, which complicates the development of an air-rail product.

Keywords: High speed rail, international rail, aviation, hub-and-spoke, integration, intermodality, air-rail integration, transition theory

Content

List of figures

List of tables

List of abbreviations

HSR	High Speed Rail
Ministry of I&W	Ministry of Infrastructure and Water Management
GHG	Greenhouse gas
MPIRPT	Ministerial Platform on International Rail Passenger Transport
CDG	Charles de Gaulle
KiM	Knowledge Institute for Mobility policy (Kennisinstituut voor mobiliteitsbeleid)
O/D	Origin Destination
KLM	Koninklijke Luchtvaart Maatschappij
VOC	Volatile Organic Compounds
CO	Carbon Monoxide
PM_{10}	Particular matter with diameters 10 micrometers or smaller
CEO	Chief Executive Officer

Introduction

1.1. Aviation and its negative impacts

In the years before the COVID-19 pandemic, worldwide exponential growth of air traffic has led to increased greenhouse gas (GHG) emissions from the aviation sector that contribute to global climate change (Baroutaji et al., 2019; Avogadro et al., 2021). With aviation being the transport mode that contributes the most to global warming per passenger-kilometer, it makes the exponential growth more problematic than that of any other form of transport. Next to contributing to global issues caused by GHG emissions, aviation also causes several local problems. By landing and taking off, aircraft create local air pollution, noise nuisance, and safety concerns, especially surrounding airports (Dobruszkes, 2011). Partly due to these negative environmental impacts, several airports around the world are not able to expand to meet the growing demand for air travel (Givoni & Banister, 2006). Consequently, airports like London Heathrow and Amsterdam Schiphol airport are now experiencing severe capacity constraints and are heavily congested (Givoni & Banister, 2006; NOS, 2021). According to several scholars, one of the options to reduce the environmental impact as well as ease congestion at airports, is to replace short haul flights by High Speed Rail (HSR) (Xia & Zhang, 2017; Givoni & Banister, 2006; Avogadro et al., 2021). Though many scholars agree on the desirability and sometimes even necessity of replacing short haul flights by HSR, airlines still offer services on many short haul routes. As an example, Schiphol airport Amsterdam still facilitates many short haul flights of up to 750 kilometers. In 2018, short haul flights of up to 750 kilometer made up for 38% of all flights departing from and arriving at Schiphol airport (RTLnieuws, 2019). This raises a question. If HSR seems able to reduce the problems caused by the aviation industry on short haul routes, why is it not widely used and implemented yet?

1.2. The aviation industry and its passengers

The aviation industry has been growing ever since the second world war (Wittmer & Bieger, 2011). It has especially done so after a series of worldwide deregulation measures (Avogadro et al., 2021) which were initiated in the United States in 1979 (Wittmer & Bieger, 2011). According to Peeters et al. (2016) the number of operational aircrafts has grown from 3.700 in 1970 to 21.000 in 2010. After the industry's deregulation, airlines signed a number of agreements (Wittmer & Bieger, 2011). These included the allowance of code sharing, where two airlines can facilitate the journey of one traveler through connecting flights on one ticket, capacity for free tariffs and freedom in the appointment of capacities and frequencies. Although the deregulation stimulated competition between the airlines, airlines also started to work together in so called alliances or airline networks. Here, instead of two airlines merging into one, multiple airlines started joining an alliance or network that shares codes for travelling. In this way they actively work together to improve their services (Wittmer & Bieger, 2011). By joining an alliance, an airline can increase its connectivity and its frequency of services while reducing its travel and connecting time. Examples of alliances include Skyteam, with airlines such as AirFrance, KLM, and Delta or STAR alliance with airlines such as Lufthansa, Swiss airways and United airways. besides joining alliances, many airlines adopted the hub-and-spoke model (Wittmer & Bieger, 2011). Here, instead of serving destinations via direct point to point flights between destinations (Figure 1), travelers transit through a hub airport where they take another connecting flight (Figure 2)(Givoni and Banister, 2006; Jiang & Zhang, 2014).

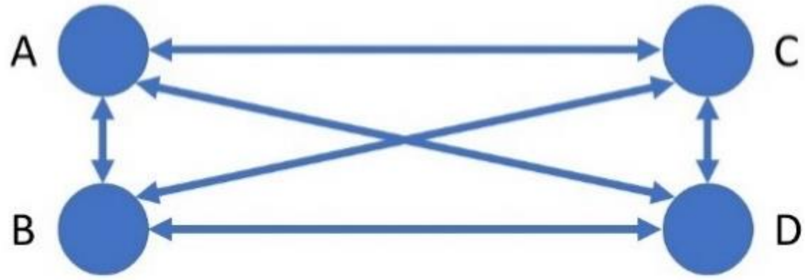

Figure 1: Point to point model

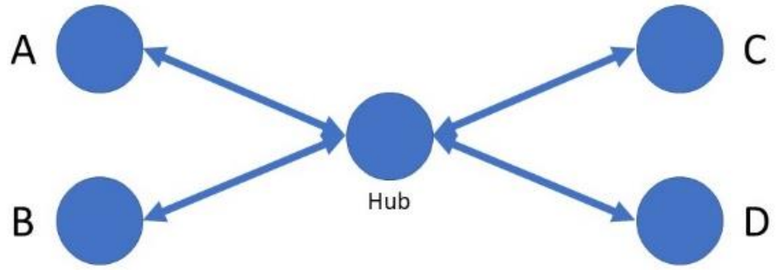

Figure 2: Hub-and-spoke model

With these developments, the airline industry has been able to steadily grow by an annual 5% over the past 50 years (Wittmer & Bieger, 2011). In 2019, before the COVID-19 pandemic hit the aviation industry, 4.5 billion passengers were carried worldwide (ICAO, n.d.). Considering these numbers, Wittmer and Bieger (2011) claim that the aviation industry has become an essential component of leisure and business-related travel. However, over the years, negative impacts of aviation have also been recognized. The constant exponential growth of aviation is, therefore, highly questioned in terms of sustainability and desirability (Peeters et al., 2016; Gössling, 2020).

The aviation industry itself is also recognizing its environmental impact and it is actively trying to reduce its environmental footprint (Peeters et al., 2016; Baroutaji et al., 2019; Gössling, 2020). To do so, the industry is largely anticipating technological innovations to reduce its environmental impact (Peeters et al., 2016). These innovations include more sustainable fuels such as biofuel, innovated airframes and frame materials, and new types of engines running on, for example, electricity. Although some of these innovations seem promising, implementation and commercialization cannot be completed on the short or medium term and the improvements will only reduce the environmental impact of planes rather than solve them (Peeters et al., 2016). In addition, if passenger numbers keep rising like they have done in the past years, technical innovations that make planes more efficient will be nullified by the extra aircrafts being operated (Peeters et al., 2016).

Moreover, even if technical innovations prove viable on the short term and are able to solve the environmental issues, the issue of congested airports is still present.

The negative environmental impact is also increasingly recognized by travelers and companies. The social norms and attitudes towards flying are changing (Gössling et al., 2019; Andersreizen, 2022) and a new phenomenon called 'flight shame' is gaining traction worldwide (Gössling et al., 2019). It touches upon the moral questionability of flying and the necessity for it due to its environmental impact. The effects of the changing norms are already visible. In the Netherlands, 70 large firms employing 550.000 people are changing their policy on flying (Andersreizen, 2022). Now well acquainted with online meetings due to COVID-19, the necessity to always meet in person has decreased, meaning that people do not have to travel as much as before. In addition, with improving high speed train connections throughout Europe, many businesses see a reasonable and more sustainable alternative to flying. As a result, several large companies do not allow their employees to fly distances under 700 kilometers (Andersreizen, 2022).

1.3. High Speed Rail as an alternative to air transport

With a lower environmental impact (Figure 3), HSR as a substitute for short haul flights has been promoted by the European Commission for a decade already (Avogadro et al., 2021). Currently, it has particularly paid off for the substitution of domestic flights, especially in Germany and France. The number of passengers on domestic flights in these countries has been reduced significantly (Clewlow et al., 2012). To give an international example, on the London-Paris corridor, HSR has captured 70% of the market share (Givoni, 2007). These examples suggest that HSR is not merely theoretical substitute for short haul flights.

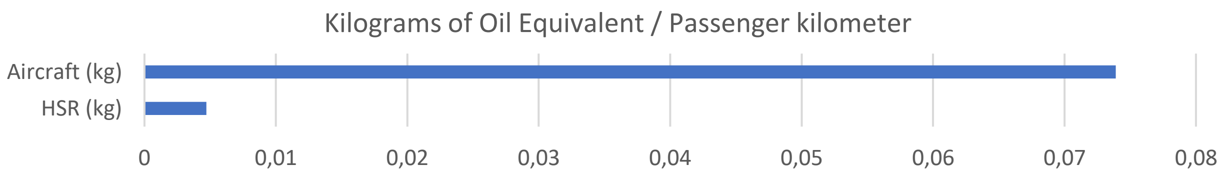

Figure 3: Energy use of HSR compared to aircraft (Based on Odyssee-Mure, 2022)

However, this argument is mainly true for point to point, or Origin/Destination (O/D) trips where a single short haul flight is replaced by HSR. This type of flight replacement by HSR is called substitution (Givoni & Banister, 2006) (Figure 4). In addition to substitution of flights, there is HSR integration into aviation. This is possible when a passenger makes use of the hub-and-spoke model. Here, short haul flights which are part of a longer journey could be replaced by HSR (Givoni & Banister, 2006) (Figure 4). In this way, one part of the journey is fulfilled by HSR and another is fulfilled by aircraft. Although there is ample literature and research on the substitution of short haul flights by HSR for O/D travelers, integration is gaining much less attention (Wang et al., 2021).

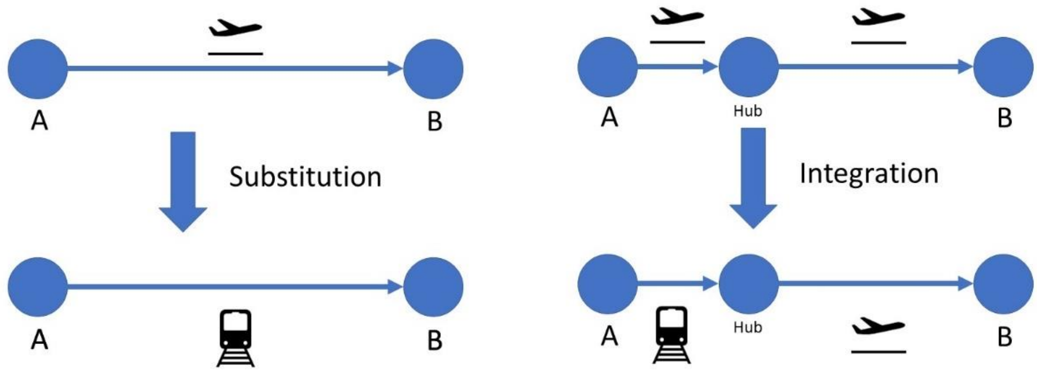

Figure 4: Air-HSR substitution and Air-HSR integration

Even though there is less attention for the subject, there seems to be potential for integration of HSR in aviation. This can be illustrated by looking at passenger numbers of people flying into or out of Amsterdam Schiphol airport. In figure 5, it can be observed that on routes between Amsterdam and Paris, Frankfurt, Brussels, or Dusseldorf, there are more passengers that transfer to another flight at one of these airports than passengers that have one of the cities as their end-destination.

Despite the apparent potential, in the case of routes to and from Amsterdam, integration of HSR into air travel rarely occurs (Givoni, 2016). Multiple scholars argue that the reason for this is that the integration of HSR into air services requires extra aspects that need to be taken into account compared to mere substitution in O/D transportation (Givoni & Banister, 2006; Román & Martín, 2015; Givoni, 2016; Xia & Zhang, 2017). One of the major obstacles that complicates the integration of HSR into air-services is the absence of a HSR station at the airport. While this is the case for several airports, some do already have a HSR station located at the airport, for example, Paris, Frankfurt, Brussels, Dusseldorf and Amsterdam.

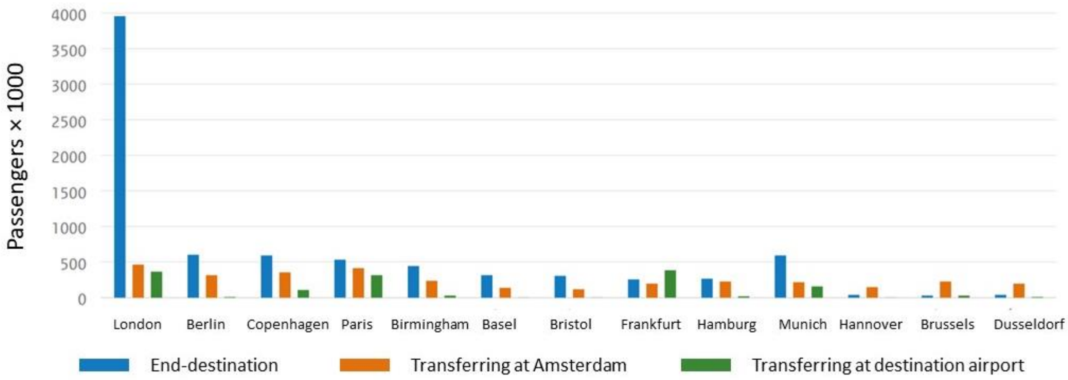

Figure 5: Passengers from Amsterdam Schiphol airport (KiM, 2018)

With an already existing railway station and high shares of transfer passengers, Amsterdam Schiphol airport seems to have high potential for integration of HSR into its hub operations. Replacing short haul flights could be very beneficial (Givoni & Banister, 2006), especially since it is a capacity constrained and congested airport (NOS, 2021). In fact, Amsterdam is already offering air-rail products for passenger to and from the Belgian cities of Brussels and Antwerp, but not for further destinations such as Paris, London, Frankfurt or Dusseldorf (Rijksoverheid, 2020).

1.4. Problem definition and research aim

The aviation industry is contributing to the global issue of climate change through its GHG emissions (Baroutaji et al., 2019; Avogadro et al., 2021). It also creates local issues at airport areas as it causes local air pollution, noise nuisance, and safety issues (Dubrozskes, 2011). Due to these negative impacts, there has been much research on whether and how short haul flights can be substituted by HSR (Avogadro et al., 2021; Dobruszkes & Givoni, 2013). These studies, however, mainly investigate the substitution of O/D travel, not taking into account the hub-and-spoke model many airlines have adopted. In addition, many studies investigate how aviation and HSR compete with each other while focusing on domestic routes (Behrens & Pels, 2021; Albalate et al., 2015; Clewlow at al., 2012; Dobruszkes, 2012). Much less research is devoted to international HSR systems and their integration into and in cooperation with aviation. Some research has investigated qualitative requirements for the integration of HSR in air-travel. Most research regarding the integration of HSR and air travel, however, is done using quantitative models, aiming to predict passenger demand and potential for HSR connecting to other flights (Jiang & Zhang, 2014; Xia & Zhang 2017; Clewlow et al., 2012). Much published research shows that there is potential for air and HSR integration, especially at capacity constrained hub airports. Yet, Givoni (2016) concluded that integration does not take place on a large scale and Román and Martín (2014) found that air-rail integration is still very much a niche product.

As there is potential for air-HSR integration, one might ask the question why that potential is not being fulfilled. Especially on routes where there is already a train station present at the airport. The aim of this research, therefore, is to understand why integration of HSR into air-travel does not take place on short-distance international airline routes with already existing train connections. To answer this question the Amsterdam-Paris corridor will be used as a case study. On this corridor, both Amsterdam Schiphol airport and CDG already have a HSR station and the distance between the two airports is approximately 400 kilometers by plane, making it a short haul route.

1.5. Research questions

From the research aim, the following research question is formulated:

Why does air-HSR integration not take place on international short-distance routes where train connections are already established?

The following sub questions are formulated to help find an answer to the main research question:

1. *What is air-HSR integration?*

2. *What are possible effects from air-HSR integration?*

3. *What is the potential for air-HSR integration on international short-distance routes in hub-and-spoke operations where train connections are already established?*

4. *What are current barriers to air-HSR integration on international short-distance routes in hub-and-spoke operations where train connections are already established?*

The first question is mainly theoretical and aims to define what integration of air and HSR is and in what forms it exists. This forms the basis for this research and for answering sub questions 2,3, and 4. These questions are both theoretical and empirical. Question 2 aims to uncover what the exact benefits and other effects of HSR and air integration are. Taking a more critical attitude to the potential effects can lay a basis for the investigation on why the potential of HSR is not fulfilled. Building on the answers of sub question 2, the potential for air-HSR integration is being assessed and sub question 4 tries to uncover what the current barriers are to air-HSR integration and why these have not been overcome to fulfill the possible potential.

2. Theoretical framework

2.1. A transitions perspective to sustainable aviation

2.1.1. Socio technical systems

Air transport is part of the overall mobility system. With air transport being the most polluting mode of transport per passenger-kilometer (Dobruszkes, 2011), moving away from air transport can be seen as a way to achieve a more sustainable mobility system. Much research on sustainable mobility has been dedicated to land-transport with a special focus on a move away from the private car running on fossil fuels (Nykvist & Whitmarsh, 2008; Banister, 2008; Köhler et al., 2009; Geels, 2012). According to Köhler et al., (2009), transport in general poses a dilemma for society as it presents major challenges from a sustainability perspective while it is also crucial for economic competitiveness and commercial and cultural exchange. To achieve a more sustainable land-based mobility system, the transport sector's focus has generally been on incremental technological improvements of vehicles reducing emissions (Köhler et al., 2009; Geels, 2012). However, like in aviation (Peeters et al., 2016), these improvements have always been outstripped by the growing demand for mobility (Nykvist & Whitmarsh, 2008). With technical improvements proving unable to produce truly sustainable outcomes, multiple scholars argue that a broader view is needed (Geels, 2012). According to Geels (2012), an interdisciplinary systems perspective needs to be applied to the mobility system, seeing it as a socio-technical system, in order to come to truly sustainable development.

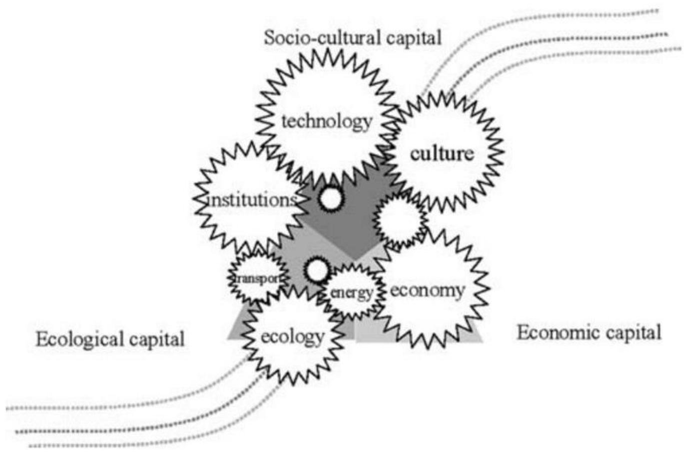

Figure 6: Visual representation of a socio-technical system (Van der Brugge et al. (2005)

Socio-technical systems are configurations of multiple elements including technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge (Figure 6) (Geels, 2012). These systems are characterized by stability, lock-in and path dependence, which causes only predictive and incremental change. Predictive and incremental change, however, is not able to produce the needed outcomes and, therefore, more radical system innovation is needed to move away from the current unsustainable mobility system (Nykvist & Whitmarsh, 2008; Köhler et al., 2009; Geels, 2012). What is needed, Geels (2012) argues, is a mobility transition.

2.1.2. A mobility transition

A transition is a long-term process of between 25 and 50 years that embodies a structural change in the way a socio-technical system operates (Van de Brugge et al, 2005). The structural change is enabled by a co-evolution of the various elements of a socio-technical system such as markets, networks, institutions, policies, technology, culture, and individual preferences. It is this co-evolution that is critical for a transition as developments within the different elements positively reinforce each other so that a system moves from one steady equilibrium to another (Van Der Brugge et al., 2005; Geels, 2012). According to Nykvist & Whitmarsh (2008), a mobility transition should (I) improve the efficiency and reduce the impact of vehicles, (II) involve the use of more sustainable transport modes, and (III) reduce the demand for travel. Only then can a truly sustainable mobility system be accomplished.

When researching a mobility transition, looking at it from a Multi-Level Perspective can offer an analytic framework to help guide relevant issues and questions (Geels, 2012). Within the Multi-Level Perspective, there are three different levels that are distinguished: the macro (landscape) level, the dominant meso (regime) level, and the micro (niche) level (Figure 6).

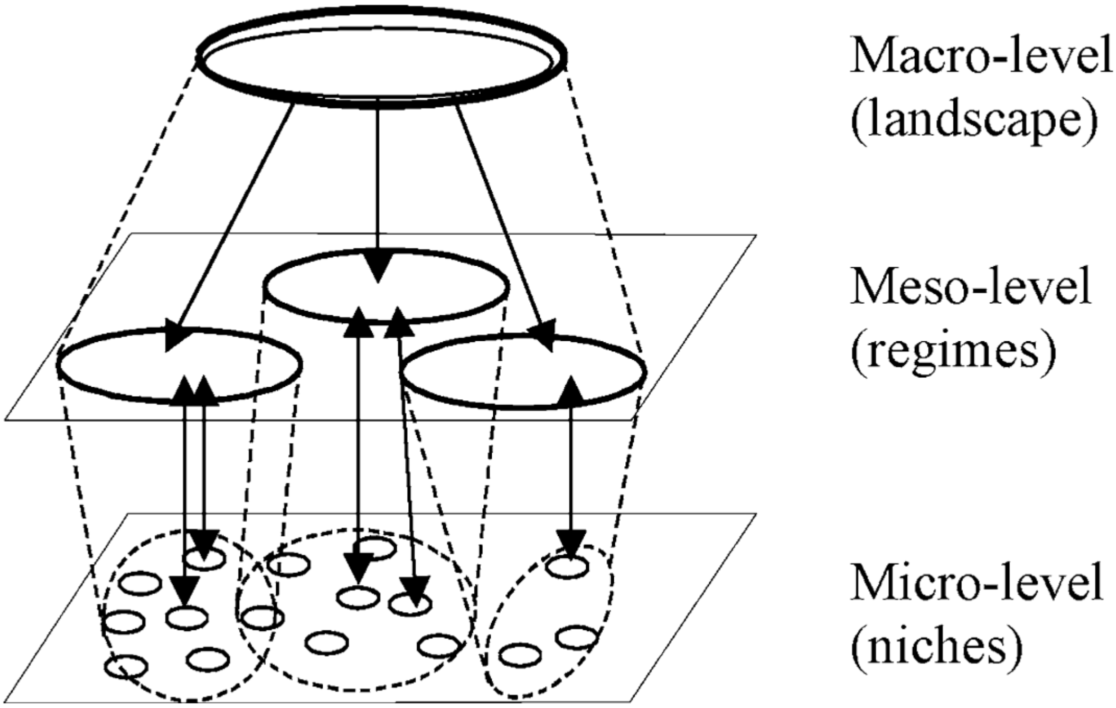

Figure 7: Multi-Level Perspective (Van der Brugge et al., 2005)

At the highest level, there is the macro level. The macro level consists of dominant culture, worldviews, macro-economic trends and politics. The macro level changes slowly and these changes are beyond the control of individuals (Geels & Kemp, 2000). Some developments at the macro level reinforce the meso level, while others put pressure on it (Geels, 2012). Reinforcing macro level trends for the unsustainable mobility system are the cultural values of private car ownership being linked to higher social status and wealth, but also the growing demand for transport (Nykvist & Whitmarsh, 2008). On the other hand, trends putting pressure on the current mobility system are the growing awareness of the environmental issues caused by transport, and, especially after the COVID-pandemic, the growing recognition that you can work from home, reducing the demand for transport.

At the middle level, there is the dominant meso, or regime, level (Geels & Kemp, 2000). This level represents the current status quo of a socio-technical system and according to Geels (2012), existing technologies, regulations, infrastructures, user patterns and cultural discourses are well aligned, creating path dependencies and lock-in situations. These lock-ins can be created by several factors such as attractive low costs due to created economies of scale or sunk investments into machines, people, and infrastructure (Geels, 2012). In addition, existing regulations and laws often create market entry barriers to new ideas. Change within the regime, hereby, occurs, but it is slow and predictable and it mainly optimizes the current system rather than change it (Köhler et al., 2009). Actors within the regime level encompass not only firms or engineers, but also social groups such as policy makers and users (Geels, 2012). Within the mobility system, there is not just one regime but multiple. For example, the automobile, the public transport, and the aviation regime. These mobility regimes have all developed their own institutionalized practices and beliefs. In aviation for example, a dominant practice at the regime level is the wide adoption of the hub-and-spoke model using airplanes for both long and short haul services (Givoni & Banister, 2006).

At the lowest level, there is the micro, or niche, level (Geels & Kemp, 2000). At this niche level, alternative technologies and practices are developed that create pressure on the regime level from the bottom up (Geels, 2012). Examples of niches within the mobility system include the development of green propulsion technologies, mobility sharing, and intermodality (Nykvist & Whitmarsh, 2008; Geels 2012). Niche-actors typically aim for their radical new ideas and innovations that deviate from the existing regime to eventually be used by the regime or even replace it (Geels, 2012). Hereby, the existing regime and a niche innovation can have either a competitive or symbiotic relationship (Nykvist & Whitmarsh, 2008). Within niches, there are learning processes regarding user behavior, policy instruments and infrastructure requirements, but also about imperfections and how these can be overcome. Before niches can exert pressure on the existing regime, the various learning processes must align while social networks that facilitate the recognition of, and resource base for, a niche innovation becomes bigger (Geels, 2012). The social network can particularly expand when powerful actors start to participate and add legitimacy to the niche developments. Niche practices and technologies that are less compatible, and therefore have a competitive relationship with the regime, are often resisted or opposed by some or even all regime actors (Nykvist & Whitmarsh, 2008).

2.1.3. Guiding a transition

Because socio-technical systems are a configuration of many elements at different levels, transitions cannot be steered by the government in a top-down manner (Van der Brugge 2005; Loorbach, 2010). Over the last decades, we have seen a shift from top-down steering by centralized governments towards more market-based decentralized decision making (Loorbach, 2010) The deregulation of the airline industry is a good example of this trend (Wittmer & Bieger, 2011). However, it is currently recognized that a liberal free market is also not able to produce sustainable outcomes (Loorbach, 2010). Loorbach (2010) claims that both top-down steering and the liberal free market are needed to govern societal change and develop niches in such a way that they can penetrate the dominant regime.

In line with Loorbach's claim that both top-down steering and free markets are needed, Van der Brugge et al. (2005) argue that managing a transition that aims for long-term sustainability entails the coordination of a multi-actor process that takes place at different levels. There needs to be a creation of a joint problem perception, a long-term vision, and experimental playgrounds for niches to develop.

2.1.4.Intermodality as a niche development

Although intermodal travel has existed for a long time already, Geels (2012) claims that intermodality as a practice can still be considered a niche innovation. According to Geels (2012), the decades before 2012 have seen a rise in projects and schemes that facilitate and stimulate intermodal travel. Initiatives include ticket integration for different modes, integration of bus and rail schedules so that they connect well, and facilitating bike-rail integration through the development of bicycle parking facilities and bike rentals at stations. Until 2012, many initiatives remained small or failed and relied too heavily on local factors such as a particular coalition of actors or policy entrepreneurs (Geels, 2012). In their research on intermodality, Parkhurst et al. (2012) found several reasons for this including, (I) time losses because of transfers, (II) low support from regime actors (such as bus and railway companies) as it is not seen as their core business while also having little to no economic incentive, and (III) absence of a powerful coalition acting on behalf of intermodality.

Although Parkhurst et al., (2012) and Geels (2012) have focused on land-based intermodal transport as a niche development, recent research has also focused on air-rail intermodality and like with the land-based modes. However, air-rail integration has remained a small and local practice (Givoni, 2016). The next sections will provide a literature review, focusing on the relationship between air transport and HSR which serves as a framework for the investigation into why air-rail integration has only remained a piecemeal development. By framing air-rail integration as a niche development within socio-technical systems, findings can be put into the perspective of an overall transition towards cleaner transport.

2.2. Air transport and HSR

Among the many policies to mitigate GHG emissions from air transport, a crucial initiative is a modal shift to other, greener modalities (Avogadro et al., 2021). Consequently, many countries have opted for HSR development to fulfill the demand for travel at a lower environmental cost (Dobruszekes, 2011). Here, rail transport is considered high speed when it reaches 250 kilometers per hour on certain parts of the journey (Givoni & Dobruszkes, 2013). Although not specifying the exact distance, the goal within the European Union is to convert the majority of medium distance passengers from air- to rail transport by the year 2050 (Avogadro et al., 2021). As a result of all the efforts, the HSR network in Europe has increased from just under 3000 kilometers in 2000 to 9000 kilometers in 2017 (European Court of auditors, 2018). With ongoing investments and improvements of the European Rail network, air and rail are increasingly competing for passengers (Behrens & Pels, 2012). In addition to providing an alternative to flying, governments are also using legislative measures to reduce the number of flights. France and Austria, for example, have banned flights where reasonable

HSR alternatives exists (Avogadro et al., 2021). The next sections will elaborate on what conditions need to be met for HSR to be a reasonable alternative to air-transport before discussing the actual effects of HSR introduction on passenger numbers, and the effect of HSR introduction on the environment.

2.2.1. Requirements for and effects of HSR substitution

Often, maximum distances are taken as a benchmark to assess what airline routes are viable for HSR substitution. Givoni and Banister (2006) claim that routes up to 600 kilometers are viable for substitution and Román and Martín (2014) mention that especially routes between 400 and 600 kilometers are suitable for HSR substitution. Some research indicates that routes up to 750 or even 800 kilometers may also be viable for substitution (Román & Martín, 2014). However, Albalate et al. (2015) claims total travel time is a better indicator for the substitutability of air transport. This infers that for the assessment of a route, it is important to consider for what part of the journey a train can travel at speeds of 250 kilometers per hour or faster. The distance between destinations can for example be below 600 kilometers, but when the train is travelling at lower speeds for a significant amount of time or when it has many intermediary stops along the route, travel time on a 600 kilometer journey might not be able to compete with air transport. Therefore, travel time rather than distance is argued to be the most important determinant for passengers when it comes to choosing between air and rail transport (Dobruszkes, 2011; Behrens & Pels, 2012; Albalate et al., 2015). According to Dobruszkes & Givoni (2013), HSR is able to capture more than 50% of the market share for trips of up to 3.5 hours. Yet, the tipping point for HSR attractiveness seems to be around 3 hours of travel time. When HSR travel times exceeds 3 hours, its share rapidly decreases (Albalate et al., 2015). Other determinants for the distribution of passengers over air and HSR transport include the frequency at which the service is offered and the fares (Dobruszkes, 2011; Behrens & Pels, 2012; Avogadro et al., 2021). Here, HSR is able to capture a larger share of the passenger market when frequencies are high, and fares are low. An advantage that HSR tends to have over air transport in general, is that stations are often located in, or in close proximity to, city centers (Albalate et al., 2015). As many travelers' final destination is often the city center, arriving at a HSR station within the city center is preferable over arriving at an airport that is often located somewhat out of the city. For air travelers to reach their final destination at the city center, they need to take an extra, mode of transport, adding travel time (e.g. Figure 8).

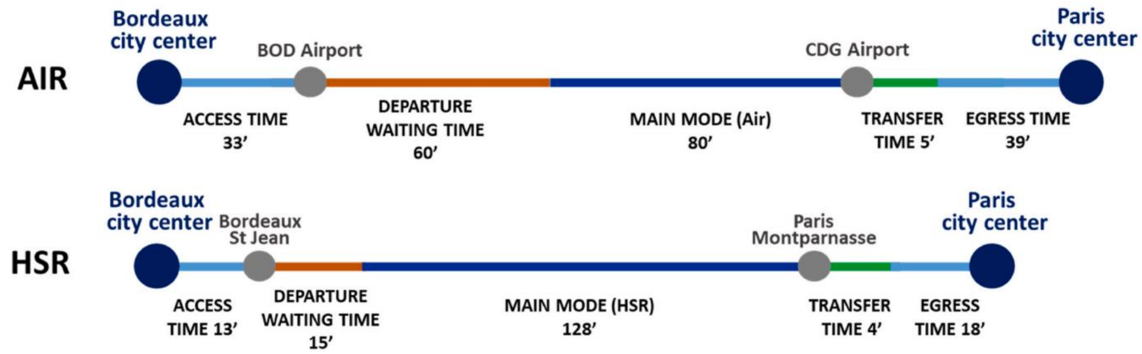

Figure 8: Example of HSR and air journey time paths (Avogadro et al., 2021)

Over the years, introduction of HSR has been able to decrease the number of air services on several routes with the greatest decrease of flight services at hub airports (Albalate et al., 2015). According to Dobruszkes (2011), there has been a major reduction of flights on the routes Brussels-London, Brussels-Paris, Paris-Marseille, and Paris-Metz after the introduction of HSR services. Between the peak of flights per year between 1991 and 2010 and 2010 itself, there has been a 46 % reduction on the Paris-Marseille route, a 53% reduction on Brussels-London, 92% on Brussels-Paris, and even a 100% reduction, on Paris-Metz in. On the London-Paris corridor, 71 % of all passengers travelling by either plane and HSR was fulfilled by HSR (Givoni & Banister, 2006). Success of HSR, however, is not just limited to Europe. Also in Korea, several routes have seen drastic reductions of air services after the introduction of HSR (Behrens & Pels, 2012). For example, air services have even been terminated between Seoul-Daegu because the route was not profitable anymore (Givoni & Dobruszkes, 2013).

2.2.2. Benefits of HSR introduction

2.2.2.1. Passenger numbers

When planning and constructing new HSR infrastructure, estimations of future travelers are important to determine the desirability and feasibility of the infrastructure that must be developed. According to Givoni and Dobruszkes (2013), estimations of passenger numbers are, generally, highly overestimated. In their paper, Givoni and Dobruszkes (2013) take the Eurostar train between London and Paris as an example. The forecast for this corridor in 1998 was an annual 25 million passengers in 2006. However, in 2011 the total number of passengers was only 9.7 million, 60% lower than expected. In addition, although the HSR line has been able to reduce air services, it has not been able to eliminate the air services. Albalate et al. (2015) found that on several other European routes, even though the demand for air transport has fallen due to the introduction of HSR, airlines still keep up high frequencies of services to ensure they stay competitive. They do so because when airlines reduce their number of services, they become less appealing to passengers and over time, because HSR services are more frequent, HSR will increase its market share while the airline will have to abandon the route because it is not profitable anymore. Another reason for airlines to keep offering services on routes where HSR is able to capture a large share of the passenger market, is because of passengers connecting to other flights at hub airports (Dobruszkes, 2011). These passengers do not need to travel to the city center, but they need to travel to the airport. Therefore, HSR stations located at the city center, usually perceived as an advantage, are considered a disadvantage in the case of transfer passengers. Especially in London, this leads to numerous air services still being offered as London Heathrow, the largest hub airport of the UK, has a poor train connection which is not even high speed (Givoni & Banister, 2006). Passenger numbers on the Brussels-London route (Figure 9) give a nice illustration of how demand for air services has fallen, but not irradicated in the year 2010. The Brussels-London route is not unique in this sense. Givoni & Banister

(2006), make similar claims for the Paris-London route. Although HSR has been able to capture 71% of the passenger market, airlines still offered 60 flights a day between the two cities, mainly to offer passengers an easy transfer to another plane (Givoni & Banister, 2006). Now, 15 years later, airlines are still offering 40 flights a day between Paris CDG and London Heathrow alone (Google, 2022), leaving out other possible airports in London such as Gatwick, Luton, Stansted, London city, and London Southend.

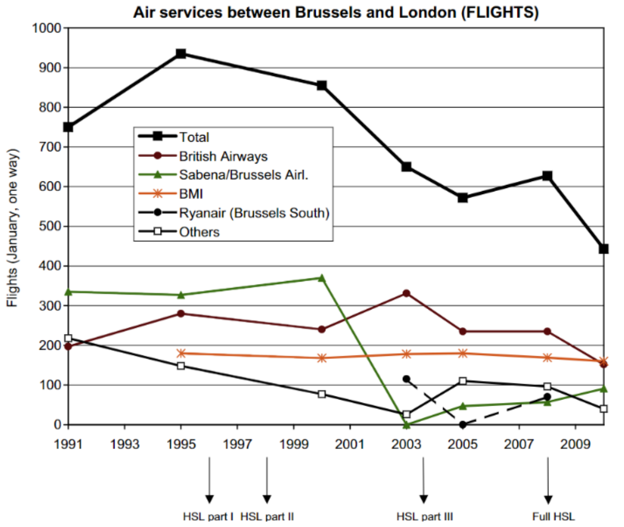

Figure 9: Flights offered on the Brussels-London route (Dobruszkes, 2011)

Although not always being able to fully eliminate demand for air services on short haul routes, HSR can reduce it. The introduction of HSR can, however, also create induced demand for services. Goodwin (1996) defines the induced demand as newly created demand for services (i.e. more passengers wanting to travel), as an effect of service or infrastructural improvements. Induced demand is created in two different ways: (I) by people that did not travel on the concerning route before, but do now after improvements have made it more attractive, or (II) by people who already travelled on the concerning route, but start to travel more often. Including the notion of induced demand is important as it allows one to make the distinction between shifted demand (people who first travelled by plane) and induced demand as a result from HSR introduction. By taking this distinction into account, a more accurate assessment of the effects of HSR introduction can be made. For example, when trying to determine the environmental benefit. In their research Givoni & Dobruszkes (2013) nicely illustrate how HSR introduction instigates shifted demand as well as induced demand by comparing passenger numbers of both air and HSR services at two different moments in time (Table 1).

Table 1: Passenger numbers on Cross-Channel routes (Based on Dobruszkes & Givoni, 2013)

	Passengers in 1993	Passengers in 2010	2010/1993
London - Paris			
Airlines	3.665.000	1.626.000	-56%
	100%	19%	-81%
HSR	0	6.728.000	
	0%	81%	
Total	3.665.000	8.345.000	+128%
London - Brussels			
Airlines	1.160.000	490.000	-58%
	100%	15%	-85%
HSR	0	2.801.000	
	0%	85%	
Total	1.160.000	3.291.000	+184%

As can be seen, the overall passenger numbers have increased considerably. This increase in total passengers reduces the positive environmental impact of the introduction of HSR, simply because transporting more people has a higher environmental cost (Chester & Hórvath, 2010). In the next paragraph, taking induced demand into account, the environmental impact of the introduction of HSR is examined.

2.2.2.2. Infrastructure costs and environmental impact of HSR

An advantage of air transport over HSR is that air transport does not need as much infrastructure as HSR (Takebayashi, 2015). Next to airport facilities, air transport only needs a takeoff and landing strip to be able to operate. HSR on the other hand requires vast railway infrastructure. The construction of HSR infrastructure is highly expensive. According to Campos and de Rus (2009), HSR infrastructure construction costs, not including planning and land acquisition costs, have ranged between 6 and 45 million euro's per kilometer as of the year 2005. Constructing a 500-kilometer HSR route would costs at least three billion euro's and likely more. This is why, for a 500-kilometer HSR line, at least 8 million annual passengers are needed to make the construction of the line viable (De Rus & Nombela, 2007). Translating this number to daily frequencies of trains, a 750-seat train, which is considered relatively large (Dobruszkes & Givoni, 2013), must be completely full for 29 rides a day (De Rus & Nombela, 2007). At this time, these passenger flows and frequencies rarely exists. The Thalys High Speed Train between Amsterdam and Paris, for example, now operates a 399-seat train (Thalys, 2021) at a frequency of between 9 and 12 times a day between Amsterdam and Paris and the other way around (Thalys, 2022a; Thalys, 2022b).

Next to the high financial costs that are concerned with the construction of infrastructure for HSR, there is also an environmental cost associated with it. When HSR is in operation, it produces significantly less GHGs than air transport. The precise difference between HSR and aviation's environmental impacts per passenger-kilometer, however, also depends on the fuel used by a train. For airplanes, fossil fuel in the form of kerosene with, in some cases, added biofuels is the only reasonable option (Peeters et al., 2016). HSR on the other hand can make use of either fossil fuels, or electricity (Dobruszkes & Givoni & 2013). Here, electricity can be produced by renewable energy sources such as solar or wind energy. If a train is able to make use of electricity instead of fossil fuels, the environmental impact of travel can be the lowest. However, it is important to take the whole life cycle of HSR into consideration when assessing the environmental impact of HSR compared to air traffic (Chester & Horváth, 2010; Givoni & Dobruszkes, 2013). Although the operation phase of a HSR system uses most of the lifecycle's energy, the construction and maintenance phase have a significant impact on the environment. This is because of the vast infrastructure in the form of many kilometers of railways. Chester & Horváth (2010) have assessed life cycle costs of HSR by analyzing a planned HSR system in California. Here, they compared aviation and HSR considering different load factors. They conclude that if HSR is not able to achieve high load factors, overall environmental costs of HSR will be higher compared to the operation of aircraft due to the construction and maintenance costs (Chester & Horváth, 2010). Here, they considered 1200 people

(CAHSR(1200)) and 120 people in a train (CAHSR(120)). While total energy consumption for HSR's construction and maintenance phase does long not exceed energy consumption in the operation phase, Chester & Horváth (2010) do find that the construction phase emits significantly more polluting CO, VOC and PM_{10} than the operation phase (Figure 10).

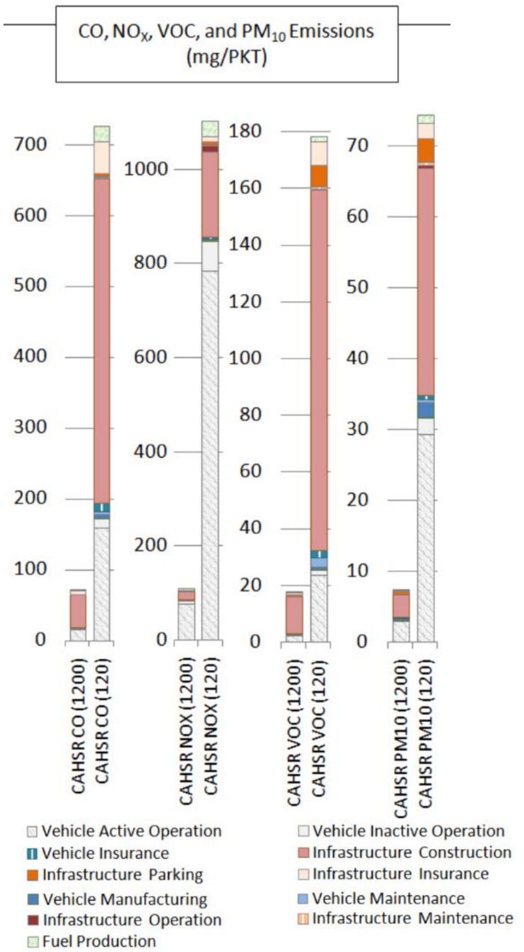

Figure 10: Life-cycle emissions of HSR per passenger kilometer travelled (PKT) (Chester & Horváth, 2010)

Next to the direct impact on the environment caused by HSR itself, there are also doubts about the environmental gains after the cancellation of short haul flights. Because these flights are cancelled, time slots at airports open up. If these slots are not used to accommodate other flights and are removed from the pool of slots, there are direct environmental benefits. However, filling these slots with long-haul flights is appealing for both airports as well as airlines since long haul flights are more profitable than short haul flights (Górecka & Horák, 2014). Therefore, these slots opening up are often being used for long haul flights (Dobruszkes & Givoni, 2013). This is especially likely to happen at congested airports with capacity constraints (Clewlow et al., 2012). Clewlow at al. (2012) even state that the possibility of using HSR to free up slots for more profitable long-haul services is a key reason for airports to improve air-HSR connectivity. Although commercially attractive, long haul flights have a large negative environmental impact. Although long haul flights emit less GHGs per passenger kilometer due to low air resistance at cruising altitude, the extra kilometers flown negates the higher efficiency (Dobruszkes & Givoni, 2013). Therefore, time slots being used for long haul flights instead of short haul flights might be good for airport and airline business, but is not good for the environment. Dubroszkes and Givoni (2013) have illustrated this nicely by comparing CO2 emissions emitted on several routes (Table 2).

Table 2: CO2 emissions per route (Based on Dobruszkes & Givoni, 2013)

Flights substituted by HSR	Avoided CO2 emissions per passenger	Long haul flights taking up vacant airport slots	Added CO2 emissions per passenger
Stuttgart-Frankfurt	60 kg	Frankfurt – Tokyo	3.410 kg
Marseille-Paris	200 kg	Paris – New York	1.950 kg
Paris – Brussels	60 kg	Brussels – Kinshasa	2.020 kg

2.3. Integration of HSR in the Hub-and-spoke model

2.3.1. The hub-and-spoke model

Within the airline industry, there is a coexistence of two different business models. The first one being the hub-and-spoke model, often used by so called full service carriers such as KLM or British airways, and the second one being the point to point model, often adopted by low cost carriers such as Ryanair or Easy Jet (Alderighi et al., 2005). According to Alderighi et al. (2005), the full service carriers offer inclusive services such as catering and seat choice, and they make use of main airports, aiming to cover all passenger market segments. Low cost carriers on the other hand do not offer many services and make use of secondary airports to avoid high airport taxes, charged by the main airports.

Within the hub-and-spoke model, airlines make use of feeding and de-feeding services arriving and departing at a hub airport (Givoni & Banister, 2006; Jiang & Zhang, 2014). By adopting the hub-and-spoke model, passengers with the same travel origin but different travel destinations and vice versa can be grouped, creating economies of density in feeder as well as in de-feeder services (Alderighi et al., 2005). The ultimate objective of the hub-and spoke model is to maximize the number of city pairs and with that optimize the network. Within the model, Givoni and Banister (2006) have distinguished two different types which are presented in Figure 11. In the hinterland-model, short haul flights are used to feed into long haul flights while in the hourglass model, long haul flights are used to feed into other long haul flights. Although not the most profitable (Górecka & Horák, 2014), the short haul flights in the hinterland model are important for airlines. This is because these flights feeding into the hub are necessary to fill other short haul flights as well as to fill the larger airplanes operating on lucrative intercontinental routes (Alderighi et al., 2005). The short haul connections operated by full service carriers, however, are under increasing competitive pressure from low cost carriers and more recently also from HSR (Givoni, 2016). Especially the passengers who do not need to transfer at a hub airport and are making a point to point trip are likely to choose a low cost carrier or HSR over full service carriers (Givoni, 2016).

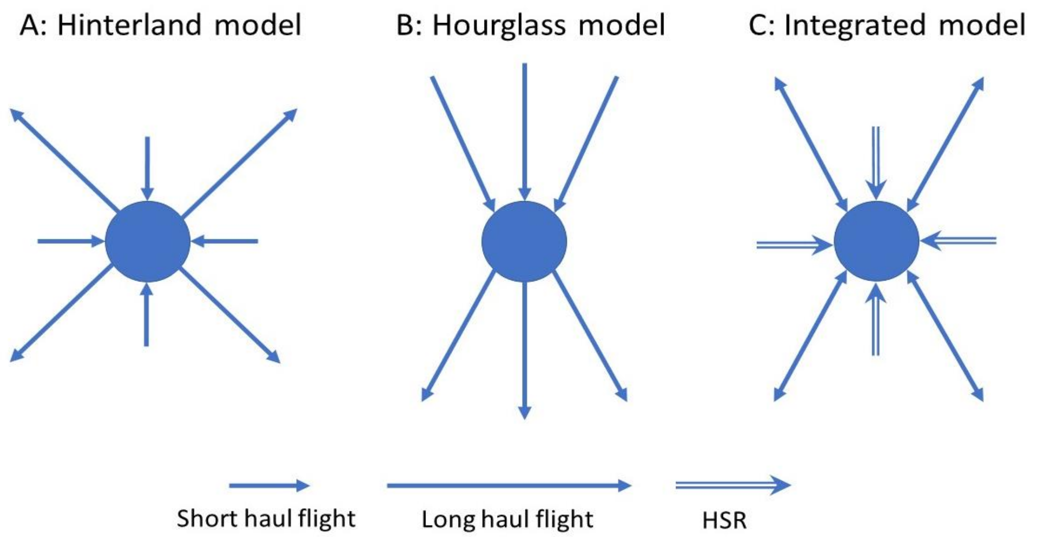

Figure 11: Hub & Spoke models (Based on Givoni & Banister, 2006)

2.3.2. Defining air-rail integration

With increasing pressure on short haul connections and capacity constraints at hub airports, several scholars have suggested to replace short haul flights feeding into a hub by HSR (Givoni & Banister, 2006; Jiang & Zhang, 2014; Albalate et al., 2015 Xia & Zhang, 2017). In this way, instead of having a unimodal air-air trip, people will have a multimodal air-HSR trip. By anticipating the integrated model, one can have the benefits of both the hinterland as well as the hourglass model (Figure 11).

Usage of rail services in combination with air services is not a new phenomenon. In their research, Givoni & Banister (2007) make the distinction between simple and full integration of air and rail. With simple integration, rail is an access mode for people to reach an airport. Separate tickets need to be bought for both modes and train schedules are not coordinated with flight schedules. This type of rail is often not high speed, for shorter distances, and predominantly substitutes car-trips to the airport. Therefore, simple integration of rail services into the airport has mainly been pursued to relieve road congestion (Givoni & Banister, 2007). On the other hand, there is full integration of train services into aviation. This is comparable to how airline alliances work (Jiang & Zhang, 2020) and showing similarities to other intermodal concepts (Geels, 2012). HSR and air enter into code-share agreements, offering people a well aligned, integrated HSR and air trip on one ticket with integrated baggage handling. According to Román & Martín (2014), code-sharing is most important for travelers when choosing for an integrated air-rail journey. One integrated ticket namely ensures that if a train or the plane is delayed, causing one to miss their transfer, one is assured a place on a later train or plane without additional costs. Unlike the simple type of integration, full integration is considered not merely an access mode competing with cars, it is an integrated part of the air transport network competing with short haul air services, especially if the train is high speed. For this research the concept of full integration of rail services, with integrated ticketing through code-sharing, integrated baggage handling, and usage of HSR and will be used to analyze the barriers to the niche development of air-rail integration.

2.3.3. Requirements for HSR integration in the hub-and-spoke model

Similar to the substitution of flights in O/D traffic, total travel time, frequencies and fares are important factors for the potential of full integration of HSR in aviation (Dobruszkes, 2011). According to Givoni & Banister (2006), travel times are the most important and must be comparable to an air-air journey. There is, however, one major additional requirement that has to be met to be able to integrate air and HSR. This, although an obvious one, is that there should be a HSR station in or adjacent to the airport (Jiang et al., 2019). The distance between the railway platform and gates should be as short as possible so that the time needed to travel between the two is minimized (Givoni & Banister, 2006). Here, distances could be minimized through, for example, escalators and lifts (Givoni, 2007). In addition to the need for a HSR station in, or adjacent to an airport, the station is ideally a through station on a main railway line, and it should have many different destinations at high frequencies to justify its presence (Givoni, 2007). Hereby, demand for rail services does not have to be generated by the airport alone, but also by other stops along the route. With high investment- and environmental costs for infrastructure development, Givoni & Chen (2017) propose that HSR should only replace short haul flights on high demand routes, while on low demand routes airplanes would be most desirable.

Next to several infrastructural requirements, full air-rail integration also requires cooperation of the organizations involved (Givoni & Chen, 2017). Givoni (2007) claims that here, especially airlines have a large role to play. This is because they must give up short haul routes and make their costumers travel by train instead of by aircraft. Railway operators on the other hand can assume an increase in passenger numbers when cooperating with airlines, making it interesting for them to initiate the cooperation. According to Givoni & Chen (2017), commercial agreements between the airlines and railway operators are crucial for the development of a successful integrated air-rail product of as these can guarantee benefits for airlines, even though they cancel short haul flights. These agreements could take the same form as current code share agreements within airline alliances where airlines can increase their network by cooperating with other airlines (Givoni & Chen, 2017; Jiang & Zhang, 2020).

2.3.4.Effects of integration of HSR in the hub-and-spoke model

The effects of air-rail integration in the hub-and-spoke model are similar to substitution of air transport by HSR in O/D travel. By cancelling short haul flights, airport slots free up, reducing airport congestion and environmental pollution (Givoni & Banister, 2006). However, where the substitution of short haul flights for O/D passengers often seems unable to fully eliminate air services on short haul routes, integration of HSR in aviation could be the final push to avert airlines from operating short-haul flights.

Short-haul flights that are to be substituted are currently important for full service carriers as they enable the carriers to fill their long haul flights and maintain a large network consisting of many destinations (Alderighi, 2005). Albalate et al. (2015) claim that on routes with a HSR connection with a travel time between 2 and 3 hours, the majority of remaining services are used by people connecting to another flight. Givoni and Dobruszkes (2013) present similar findings. They found that 53 % of all passengers on the Madrid-Seville route (Figure 12) were flying because they had a connecting flight. By venturing into an agreement, airlines cannot only maintain their network while cancelling unprofitable short haul flights, they can also increase the size of their network (Dobruszkes & Givoni, 2013; Givoni & Chen, 2017; Román & Martín, 2014). By partnering with railway operators, cities which are inaccessible to airlines because they do not have an airport can now become part of their network. The same goes for cities that do have an airport but who do not generate enough demand to justify adding it to the airline's network by air services.

Figure 12: Visual representation of Madrid-Seville route

Currently, air-rail integration is pursued for both network expansion and substitution of short-haul flights. Finnair has ventured into an agreement with a Swiss railway operator to transport passengers from Zürich airport to Basel, Bern, Lausanne, and Luzerne. These cities were previously not part of the airline's network but are now included. The service originally included integrated baggage handling but that was halted due to underutilization (Jiang & Zhang, 2014). In Belgium and the Netherlands KLM offers a HSR connection from Brussels and Antwerp central to connect people to their flights departing from Schiphol airport (Jiang et al., 2019). In France, Air France and SNCF launched a cooperation already back in 1994. The SNCF would operate on the route between Lille and CDG airport while cancelling all Air France flights (Jiang & Zhang, 2014). In Germany, Lufthansa cooperates with the Deutsche Bahn on the routes Frankfurt-Cologne and Frankfurt-Stuttgart (Givoni & Chen, 2017).

In short, the air-rail product seems to be good for business with the ability to cancel unprofitable short-haul routes while maintaining, or even increasing the size of the network. Hereby, unlike with other intermodal efforts (see Parkhurst et al., 2012), there seems to be an economic incentive for both airlines and railway operators to offer air-rail products.

However, the effects on air pollution and emissions are less positive. Like with substitution of O/D traffic, environmental effects are likely to be negative since freed airport slots will be used for long haul flights (Givoni & Dobruszkes, 2013). Another potential negative environmental effect arises from the network expansion. When airlines choose to increase the size of their network through air-rail integration, airports are able to increase their catchment area, especially when they are able to compete on prices with other airports. This implicates that people could have a longer journey to the airport than they originally used to. Even though HSR is relatively energy efficient, travelling extra kilometers is not good for the environment (Givoni & Dobruszkes, 2013). This can be illustrated by the hand of the HSR integration on the route Antwerp-Schiphol. Here, people who previously flew via Brussels airport (+- 50 kilometers from Antwerp) can now easily fly from Schiphol airport as well (+- 165 kilometers from Antwerp). If the passenger chooses Schiphol airport, they extend their trip by 100 kilometers, and with that increase emissions.

2.3.5. Barriers to the integration of HSR in the hub-and-spoke model

Even though there are several benefits associated with the integration of HSR services into aviation, integration does not take place on a large scale (Givoni, 2016). This indicates that there are some barriers, prohibiting the implementation of the air-HSR integration niche into the hub and spoke model. First and foremost, there are several infrastructural barriers. Currently, not every airport has a train station (Givoni, 2016) and in some cases, when there is a train station, the tracks are not suitable for high speed trains, making them unable to compete with air transport (Givoni & Chen, 2017). The roots behind the lack of infrastructure can be found in the institutional division between air and rail transport. Often, different governmental bodies are in charge of either railway development or airport/air transport development. Both bodies have their own regulations and operating procedures which are different from each other (Givoni & Chen, 2017). The same argument goes for the railway operators and airlines where their business cases, as well as organizational cultures are rather different.

For the successful implementation of transport policies that facilitate integration, Givoni and Rietveld (2008) found six factors that are important. In their research, they specifically studied transport policies concerning infrastructure facilitating air-rail integration. The important factors are:

- Role of the national government
- Degree of centralization
- Institutional consolidation
- Role of the private sector
- Degree of regulatory intervention
- Coordination across modes.

Public authority has a large influence and can be the advocate of intermodality that was lacking at other land-based intermodal efforts (e.g. Parkhurst et al., 2012). When pursuing successful integration of air and HSR, there needs to be a public authority that enhances coordination between the industries but also has the power to enforce change (Givoni & Rietveld, 2008). However, public authority should also not be too dominant as it hinders the collaborative process (Givoni & Rietveld, 2008). With the privatization of transport industries, competition for resources takes place which often limits the adoption of a truly intermodal philosophy (Givoni & Rietveld, 2008). This seems to be especially the case in the competitive environment of short haul routes where air and HSR compete for the same costumers, aiming to catch the largest market share possible (Xia & Zhang, 2019). In addition, Givoni & Rietveld (2008) claim that under intermodal competition, the industries may be influencing the ministry, rather than the ministry influencing the industries. With unimodal privatized companies seeking a profit, intermodal agreements are hard to reach.

2.4. Conceptual model

The conceptual model (Figure 13) represents the Multi-Level Perspective to the development of the air-HSR integration niche. It represents how the different levels, and developments in these levels, influence each other. Here, air-HSR integration is ultimately influenced by the aviation and High Speed Rail regime. The willingness and ability of these two regimes to develop and use air-HSR integration in their own practices is crucial for the realization of air-HSR integration. This research takes an actor-based approach, examining how all actors influence the air-HSR integration and how they adapt their own dominant practices and structures to accommodate or resist the air-HSR integration.

At the macrolevel, there are the dominant world views as well as macro-politics and economics. These influence both the HSR and aviation regime, putting pressure on, or reinforcing the dominant practices of the actors involved. In this way, the macro level has an indirect influence on the adoption or resistance of air-HSR integration through the regime levels.

At the meso level, there are both the aviation and HSR regime. These both contain the current infrastructural arrangements as well as dominant practices embedded in the different actors. Next to being influenced by both niche and macrolevel developments, these regimes also influence each other. Especially on short haul routes, both modes compete for passengers and thereby actors are forced to take one another into account, thereby influencing each other’s practices.

At the lowest level, there are also other niche developments that indirectly influence the air-HSR integration through the regime level. Here, developments in other niches can stimulate air-HSR integration by failing to deliver promised results. This would reinforce the need for air-HSR integration. On the other hand, when alternative niche developments prove successful, they can hamper the development and implementation of air-HSR integration as the alternative niches might be easier to implement and adapt to by the regimes.

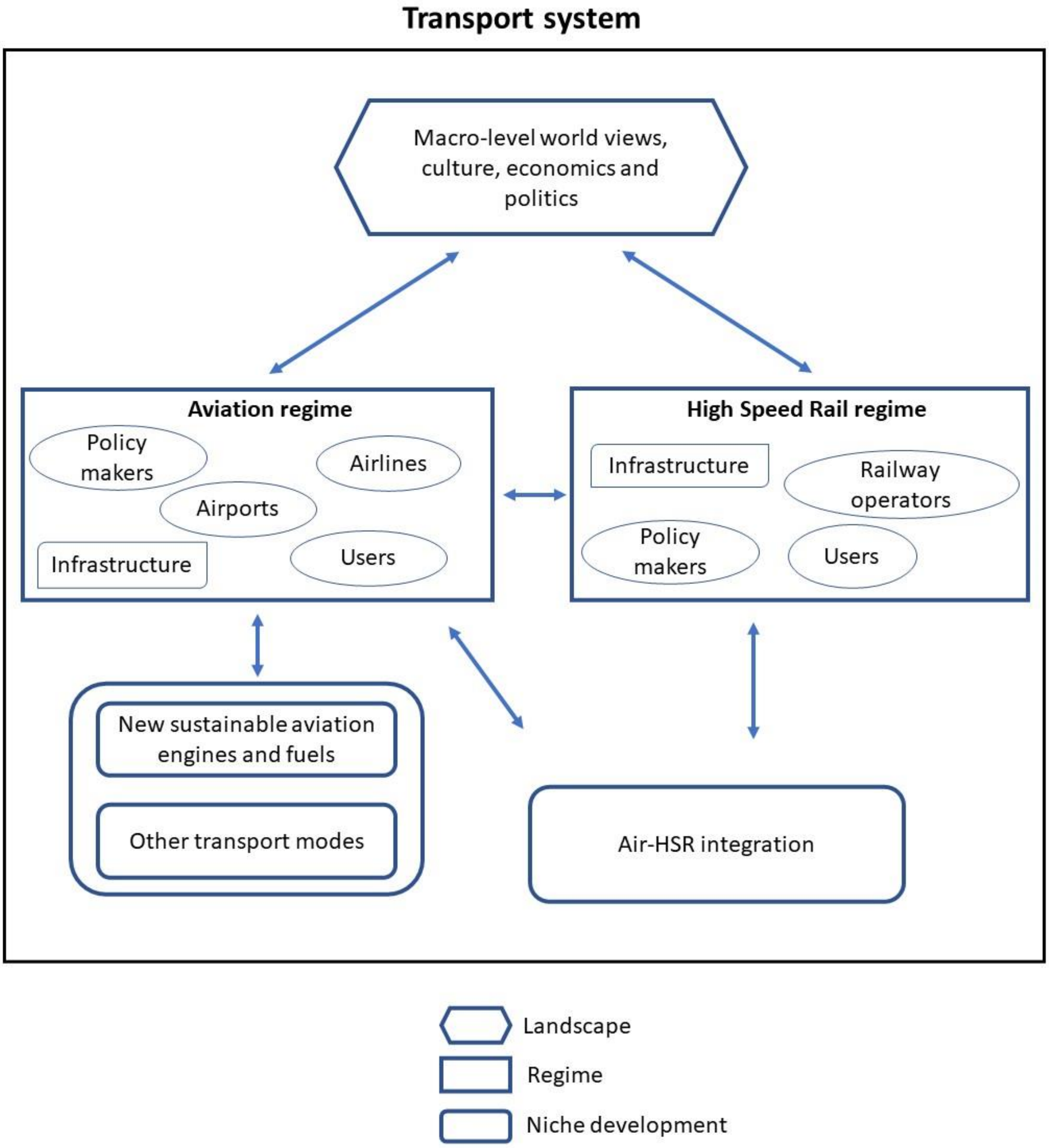

Figure 13: Conceptual model

3. Methodology

3.1. A case-study approach

This research anticipates a case study approach using both primary and secondary data sources to answer the question why air-HSR integration does not take place on short haul international routes with an already existing rail connection. A case-study is a flexible research strategy, ideal for an in-depth study of a phenomenon (Clifford et al., 2016). A case-study allows one to study a case in its contemporary 'normal' context rather than in a laboratory setting. Currently, the laboratory setting is the research design that has been dominant in research on air-rail integration. Many studies have aimed to uncover potential for air-rail integration through quantitative passenger demand models (e.g. Clewlow et al., 2012; Jiang & Zhang, 2014; Xia & Zhang, 2017), while only few have done qualitative research, aiming to understand the complexity of upscaling and developing air-rail integration initiatives. A case-study approach also helps to understand the complexity of a situation and the meanings constructed within it (Clifford et al., 2016). As the intermodal niche of air-rail integration is situated within a complex socio-technical system (Geels, 2012), it is this understanding of the complexity that can add various insights to the existing quantitative laboratory setting research.

Within case-study research, it is common to draw from multiple data sources and triangulate the results (Clifford et al., 2016). According to Delyser (2010), triangulation strengthens the findings and gives a research high validity. Therefore, this research makes use of multiple data sources, both primary and secondary, to find answers to the research questions. Before starting the primary data collection, secondary data has been analyzed. Firstly, an academic literature review on air-rail integration, presented in chapter two, has been conducted to give a preliminary, theoretical answer to the formulated sub-questions. The studied literature also gave necessary input for the later data-collection that did relate to the case. After the literature review, a characterization of the spatial structure of the Amsterdam-Paris corridor and its potential, based on theory, for air-HSR integration has been developed. This has been done by analyzing the spatial characteristics of the corridor, assessing travel information from airlines and railway companies, and analysis of quantitative passenger data in the form of passenger numbers and the share of transfer passengers. Hereafter, a document analysis was conducted before starting semi-structured interviews with important actors regarding air-rail integration at the Amsterdam-Paris corridor.

3.2. Case selection: the Amsterdam-Paris corridor

For this study, Amsterdam Schiphol airport is chosen as the case study object. More specifically, the Amsterdam-Paris corridor is being investigated. The reason for this is twofold. Firstly, because of the case's characteristics, it is highly suitable for answering the research question. The Netherlands is too small for the operation of profitable domestic flights and hence, there are none (Trouw, 1999). Its capital, Amsterdam, does, however, have one of the largest hub airports in the world: Amsterdam Schiphol airport (Schiphol, 2016). In its business model, Schiphol airport and its main air carrier KLM facilitate many short haul flights of up to 750 kilometers. In 2018 these short haul flights made up for 38% of all flights departing from and arriving at Schiphol (RTLnieuws, 2019). Taking these numbers into account, Schiphol airport seems to make use of the hinterland hub-and-spoke model (Givoni & Banister, 2006).

Schiphol airport does also have a HSR station and, therefore, seems to have great potential for HSR integration. Turning to the Amsterdam-Paris corridor, it can be observed that Paris has multiple HSR stations, with Paris Nord and CDG airport being most important for this study. Trains between the two cities already travel at a high frequency and with travel times of around 3 hours and 10 minutes (NS international, 2022) HSR seems competitive to air-transport. Many conditions for HSR-air integration are to be met; however, an air-rail product is not being offered (Prorail, 2020).

Next to the characteristics of Schiphol airport and the Amsterdam-Paris corridor that make the case suitable as a case study object, Schiphol airport is also well known by the researcher. The background knowledge the researcher already has about the case was expected to help him understand and critically analyze the study's findings.

3.3. Document analysis

Within the document analysis, a wide variety of relevant documents regarding air-HSR integration in general and specific for the Amsterdam-Paris corridor have been selected and analyzed. This constitutes a mix of policy documents from different levels of government and documents produced by actors relevant to air-rail integration at the Amsterdam-Paris corridor. In addition, research and advisory reports on air and rail have been selected. An overview of all selected documents can be found in Table 3. The documents have been listed through recommendations of academics from the Faculty of Spatial Sciences (University of Groningen) and interviewees as well as via online searches with key words through search engines, government, and other relevant actors' websites. All documents have been coded with Atlas.ti and appendix 1 provides a representation of the codes that have been used.

The primary aim of the document analysis was to gain an understanding of what actors are important at the Amsterdam-Paris corridor, how these different actors perceive the development of the air-HSR integration niche, and what their goals are. The secondary aim of the document analysis was to give input for the various interview guides that have been composed to aid the semi-structured interviews. By already having case-specific knowledge, the researcher was able to ask better targeted questions.

Table 3: Documents used for the document analysis

Document (EN/NL)	Publisher	Year
Long-distance cross-border passenger rail services	European Commission	2021
CEF support to North Sea- Mediterranean Corridor	European Commission	2020
Better rail connections for Europe's passengers 2nd progress report	Ministerial Platofrm International Rail Passenger Transport	2022
A European high-speed rail network: not a reality but an ineffective patchwork	European court of auditors	2018
Waypoint 2050	Air Transport Action Group	2021
The importance of mainport Schiphol (Het belang van mainport Schiphol)	KLM	2020
Vision 2050	Royal Schiphol Group	2020
Vision 2020-2050 (Visie 2020-2050)	Dutch Association of Airports (Nederlandse vereniging van Luchthavens)	2018
Responsible flying to 2050: Aviation bill 2020-2050 (Verantwoord vliegen naar 2050: Luchtvaartnota 2020-2050)	Dutch Ministry of Infrastructure and Watermanagement (Ministerie van IenW)	2020
Execution agenda aviation bill (Uitvoeringsagenda Luchtvaartnota)	Dutch Ministry of Infrastructure and Watermanagement (Ministerie van IenW)	2020
Kingdom of the Netherlands State Action Plan for the reduction of CO2 emissions from aviation	Dutch Ministry of Infrastructure and Watermanagement (Ministerie van IenW)	2022
Action agenda Train and Aviation (Actieagenda Trein en Luchtvaart)	Rijksoverheid	2022
On the green tour: the contribution of behaviour interventions to more sustainable aviation (Op de groene toer: De bijdrage van gedragsinterventies aan het verduurzamen van de luchtvaart)	Knowledge Institute for Mobility (KiM) (Kennisinstituut voor mobiliteitsbeleid)	2020
Substitution possibilities from Aviation to Rail (Substitutiemiogelijkheden van Luchtvaart naar Spoor)	Knowledge Institute for Mobility (KiM) (Kennisinstituut voor mobiliteitsbeleid)	2018
Move the switch: towards better international passenger transport via rail (Verzet de wissel: naar beter reizigersvervoer per trein)	Council for the Environment and Infrastructure (Raad voor de Leefomogeving en Infrastructuur)	2020
Potential AirRail substitution ZWASH-corridor (Potentie AirRail substitutie ZWASH-corridor)	Royal HaskoningDHV (RHDHV)	2020

3.4. Semi-structured interviews

A large part of the empirical data-collection was done through semi-structured interviews. Through interviewing important actors from both the aviation as well as HSR sector, drivers of and barriers to the development of an air-HSR product found in the document analysis have been verified and new ones have been uncovered. Interviewees were asked about what role their organization has regarding air-HSR integration at the Amsterdam-Paris corridor, what their goals are, what drives them to pursue those goals, and what barriers they experience or see regarding the development of an air-HSR product. The interview guides that have been used can be found in appendix 3.

Interviewees were selected based on general knowledge on the air-HSR integration subject and corridor specific knowledge. Hereby, selected interviewees constitute a mix between representatives from organizations that are in the process of developing an air-rail product at the Amsterdam-Paris corridor, and persons who are not directly involved with air-HSR integration at the corridor, but who do have relevant knowledge regarding the subject in the Netherlands. Table 4 gives a representation of all interviewees. They have been listed in random order to guarantee anonymity. What interviewee number is attributed to what interviewee is only known to the first and second reader, and the researcher himself.

Table 4: Overview of interviewees

Organization	Function	Language
KLM	Costumer Experience manager	NL
Thalys	Business strategy and development manager	EN
Private company with expertise on Air-Rail integration	Consultant	NL
ProRail	Head of international passenger travel and sustainability	NL
Ministry of infrastructure and watermanagement	Policy advisor at the Aviation Department	NL
Council for the Environment and Infrastructure	Advisor	NL
NS international	Implementation manager	NL
Knowledge Institute for Mobility	Researcher	NL
Ministry of infrastructure and watermanagement	Policy advisor at the Public Transport and Rail Department	NL
Royal Schiphol Group	Advisor Airport Strategy and Development	NL

Interviewees have all been approached via email after finding their contact details online, or after receiving them from other interviewees. All but one interview were conducted online via various platforms by interviewees' choice such as Google Meets or Microsoft Teams. In preparation for interview, an interview guide was composed with general questions regarding air-rail integration on the Amsterdam-Paris corridor, including organization specific questions. Hereby, the interview guide differed for every interviewee. Conducting the interviews took 50 minutes on average and they were held in a semi-structured way. A semi-structured interview, in contrast to a structured interview, allows for more freedom of extra (follow up) questions that were initially not listed in the interview guide and allows for a more conversation-like setting (Gill et al., 2008).

All interviews have been recorded with permission of the interviewee and fully transcribed afterwards. After all interviews were finished and transcribed, the transcripts have been coded and analyzed in Atlas.ti. The codes used for the analysis of the interviews differ from the codes used in the document analysis and can be found in appendix 2. Quotations that have been coded with 'other barrier' have been given an extra review before being assigned the fitting code.

3.5. Ethics

Preventing biases and protecting respondents and their confidentiality and anonymity was of high priority while conducting this research. Firstly, preventing biases was achieved through finalizing the academic literature and document analysis before conducting the interviews. Flying and Schiphol are contested subjects in the Netherlands at the moment. By first analyzing objective, scientific literature and reading opinions and views on the subject from all parties involved, a coherent instead of a one-sided overview has been created. Based on this overview, interviews have been conducted in an objective manner without prejudice. To maintain objectivity in later stages as well, interviews have all been coded and analyzed at the same time after the full data collection was completed.

Protecting interviewees was done in several ways. Before the start of the interview, interviewees were informed about the topic of the research and the goal of the interview. In addition, interviewees were asked consent for the use of the results and have been informed about their rights. Interviewees always had the right to not answer questions if they did not wish to and could withdraw from the interview at any moment. They have also been given the opportunity to read the transcript and have data withdrawn from it if they wanted to.

In several interviews, interviewees indicated that they wanted to stay anonymous and that results were to be used with care. Therefore, when using direct quotes from the transcript, interviewees have been informed by email so that they could notify the researcher in case that quote could not be used. To guarantee anonymity and confidentiality of interviewees, only a general description of their job function has been presented.

4. Results

This chapter presents the results from the document analysis and the semi-structured interviews. First the Amsterdam-Paris corridor is analyzed and characterized to determine the theoretical potential for air-HSR integration. Hereafter, goals and drivers of different actors and organizations regarding the development of an air-rail product at the Amsterdam-Paris corridor are discussed. After establishing an overview of the drivers and the goals specific to the Amsterdam-Paris corridor, barriers in achieving air-HSR integration goals are discussed. These barriers broadly encompass difficulties in integrating IT systems, increasing HSR services, establishing short connection times, and creating an integrated luggage solution. In addition, environmental impact of air-HSR integration at the Amsterdam-Paris corridor is discussed, as well as the investment dilemma and impact of other niche developments. Figure 14 and 15 represent the code trees that have been used for the document analysis, and the analysis of the semi-structured interview transcripts. Within the figures, it is also indicated how many times individual codes have been applied to quotations.

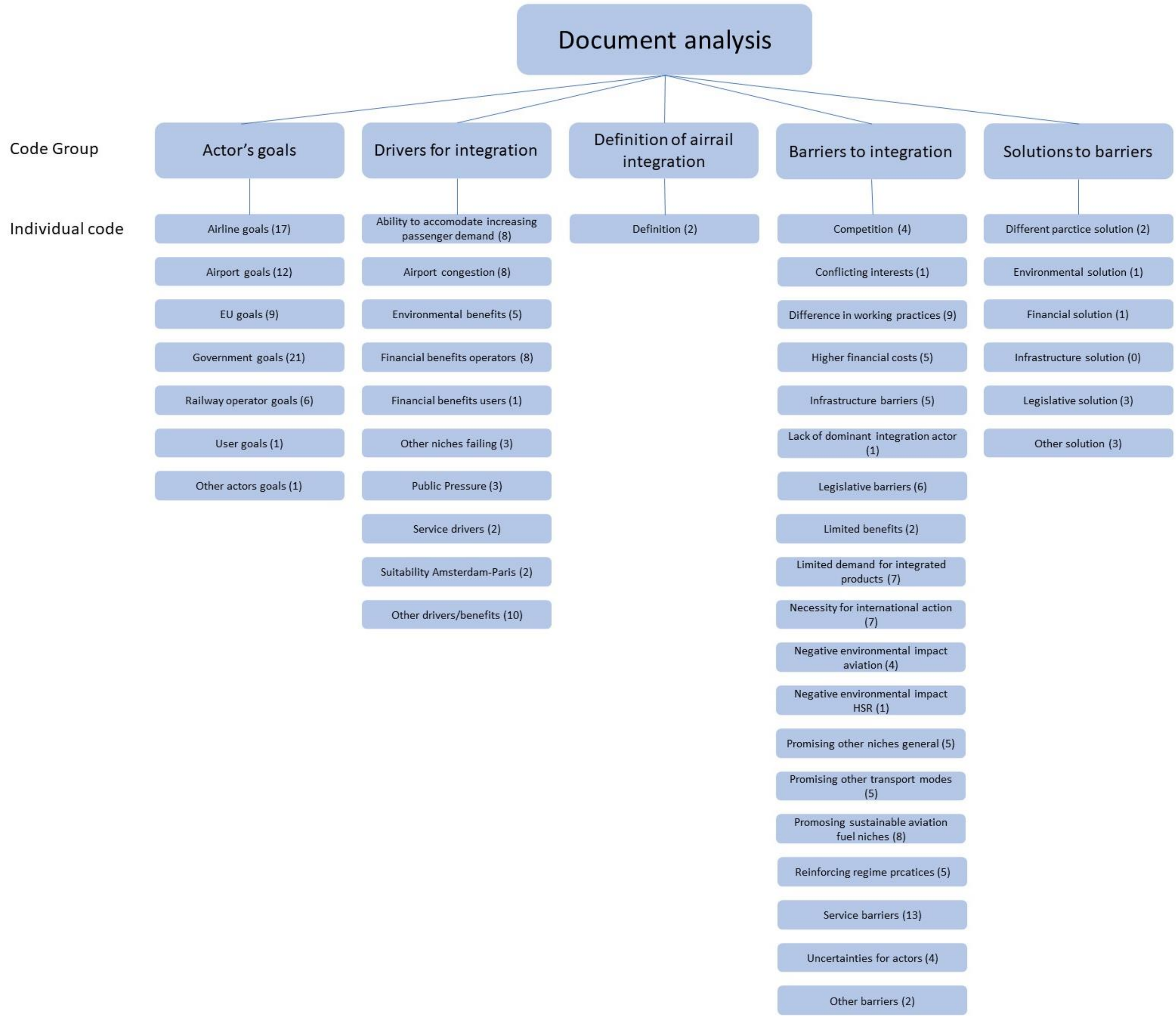

Figure 14: Code tree used for Document analysis

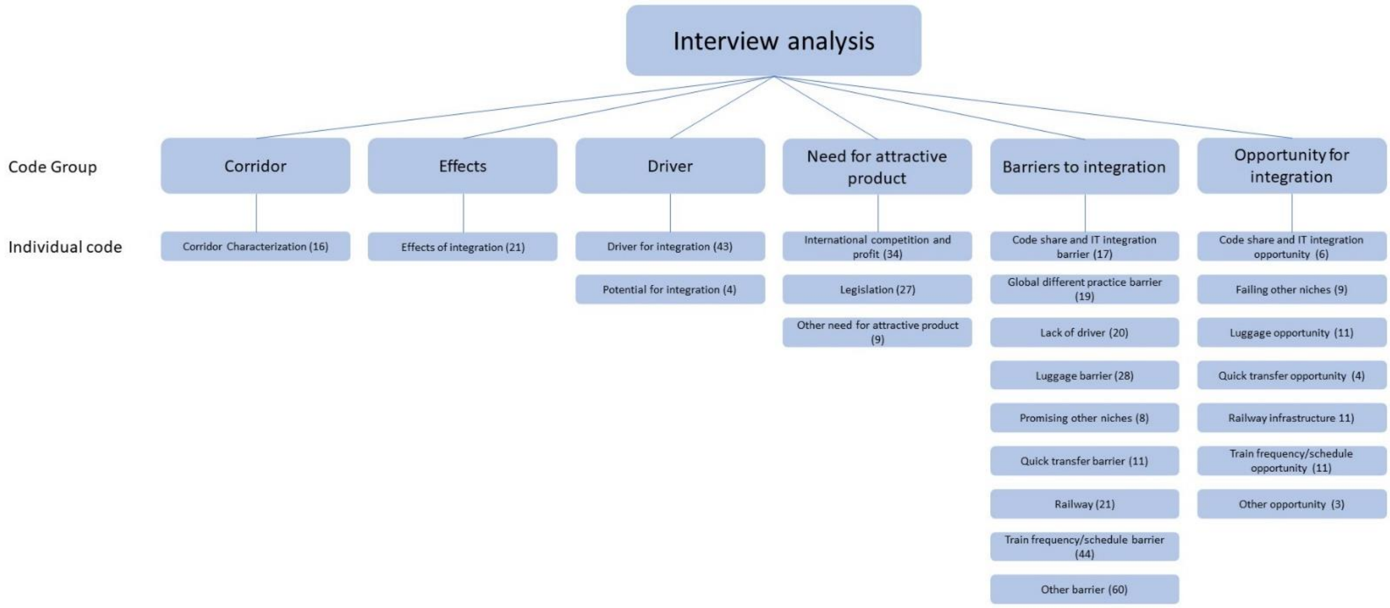

Figure 15: Code book used for interview analysis

4.1. Amsterdam Schiphol and the Amsterdam-Paris corridor

Spatial layout and transport connections

Figure 16 represents the current Amsterdam-Paris Corridor regarding air and HSR connections. By air, both cities are connected through Schiphol airport in Amsterdam, and CDG and Orly airport in Paris. Airlines operating between the two cities are full service carriers KLM and Air France, which are both part of the same holding company: Air France-KLM, and the same holdings' low cost subsidiary airline, Transavia. Transavia operates a maximum of only two flights per day between Schiphol and Orly airport while Air France and KLM operate the majority of flights between the cities through Schiphol, of which KLM is its main carrier, and CDG Airport, of which Air France is its main carrier. Both airports and their main carriers have adopted the hub-and-spoke model, which has made them two of the largest hub airports in Europe (European Court of Auditors, 2018). However, according to the European Court of Auditors (2018), these two airports are currently also two of the most congested airports in Europe.

The Air France-KLM holding company uses both hubs in a so called 'dual hub system' (#2). Within this system, both airports are highly important for both airlines to maintain a high-quality network and connect passengers to their end-destinations. In addition, the connection between the airports is important for other strategic and operational reasons such as easy transfer of personnel (#10). Keeping a quick and high quality connection is, therefore, a priority for Air France and KLM.

By rail, the two cities are most connected by a service via Amsterdam Central station and Paris Nord. Schiphol and CDG, however, are also connected by train with a (High Speed) train station present at both airports. Both stations are well integrated into the design of the airports, thus minimizing distance between the platform and check-in areas. The only company that operates a direct service between the two cities' main stations is Thalys (red route). All interviewees agreed that this service is a highly competitive alternative to air transport for O/D passengers between Amsterdam and Paris. On this service, there are several intermediate stops, such as Schiphol airport, but it does not have an intermediate stop at Paris CDG airport. There is a HSR service that does have a stop at both Schiphol and CDG, being the Amsterdam central – Marne la vallée service (green route). Yet, this service is operated at a significantly lower frequency of only once a day, for only three days a week (#4). A service that does frequently stop at CDG airport and facilitates a part of the same trajectory as Thalys, is the TGV high speed train service between Brussels Midi and CDG (blue route).

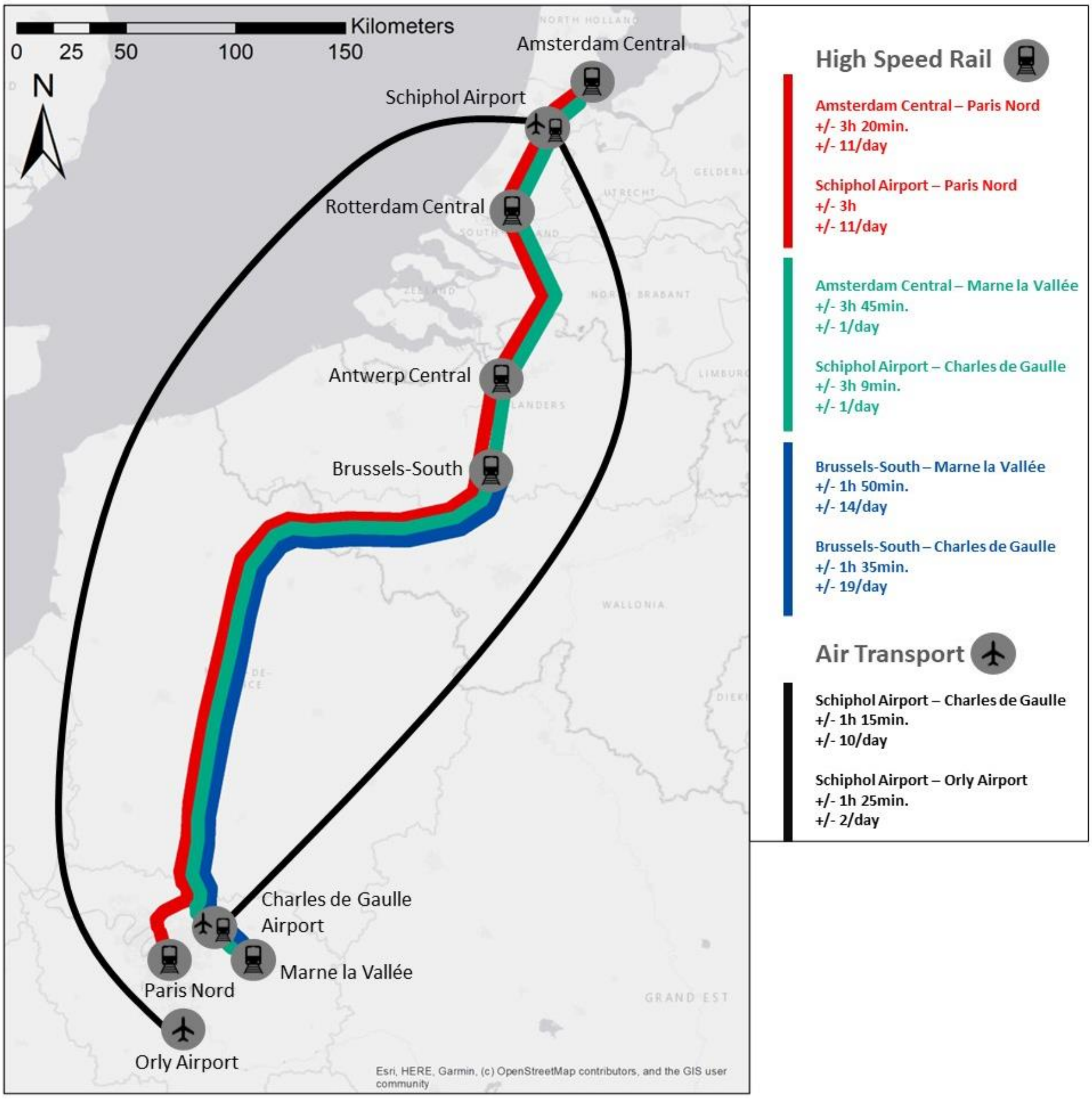

Figure 16: The Amsterdam Paris corridor (Based on KLM (2022a); Thalys (2022a); Trainline (2022a); Trainline (2022b); #3)

Passengers

With a highly competitive HSR connection, the vast majority of passengers travelling between Amsterdam and Paris are travelling by train (#9). Although no exact numbers are available, the Amsterdam-Paris route is Thalys' most important route. With a total of 7.85 million passengers served by Thalys in 2019, it can be deducted that there are several million passengers who travel between Amsterdam and Paris by HSR (#3). On the other hand, a lot of passengers are also still flying between the cities (Figure 17). In 2019, around 1.3 million passengers flew between Schiphol Airport and Paris CDG. Of these 1.3 million passengers, only 26% were O/D passengers. All other passengers were having a connecting flight at either Schiphol or CDG airport. Although there is a lot of transfer traffic between the cities which would make flights commercially unattractive, the aviation bill (Ministry of I&W, 2020a) notes that between Amsterdam and Paris, there are also many business travelers. It is these business travelers that still make flights attractive to operate since they usually pay more for a ticket (Ministry of I&W, 2020a). Therefore, flights between Schiphol and CDG have two faces. On the one hand, they seem commercially unattractive since the relative bulk of the passengers on board are transfer passengers. On the other hand, the large number of passengers in an absolute sense shows how important the connection is. Additionally, high shares of business travelers might make up for the high share of transfer passengers.

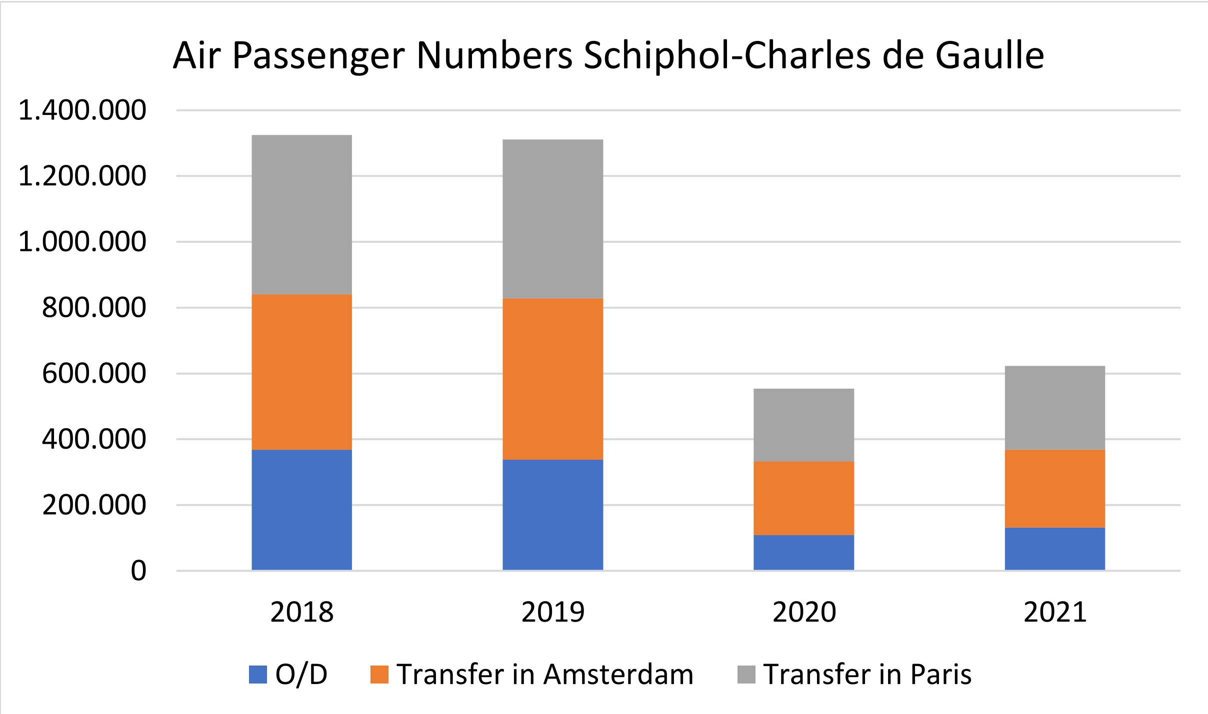

Figure 17: Air Passenger Numbers Schiphol- Charles de Gaulle (Based on Cirium data, 2022[1])

4.2. Goals and drivers for Air-HSR integration

4.2.1. Goals for Air-HSR integration at the Paris-Amsterdam corridor

Unlike academic literature from recent years suggests, the document analysis and interview results find that there has been a shift in goals of both aviation and HSR regime actors regarding air-HSR integration efforts. Many documents presented by involved parties state that short distance flights should not be operated on routes where a viable alternative exists. Moreover, the document analysis finds that there is a broad desire to stimulate air-HSR integration.

---

[1] Cirium delivers data and analytics solutions globally to airline industry actors. For this research, they have provided passenger data on the Schiphol-Charles de Gaulle corridor upon which the graph is based.

The Air Transport Action Group (ATAG) which represents numerous organizations in the aviation industry has recently produced a report in which they claim that air and rail should be seen as complementary. They see that, especially in Europe, there is a strong case to be made for rapid and reliable interconnectivity between long haul flights and HSR connections at hub airports (ATAG, 2021). Similarly, the Ministerial Platform on International Rail Passenger Transport (MPIRPT), consisting of Switzerland's, Norway's and EU member states' ministries of transport, lays out the desire to strengthen air-rail connectivity for all core EU airports as part of the Green Deal (MPIRPT, 2022). In addition, the platform claims that it is vital to continue to increase air-rail initiatives such as the German Rail&Fly product or the Dutch Air-Rail pilot between KLM and Thalys.

Turning to the parties directly involved at the Paris Amsterdam corridor, KLM (2020) recognizes that rail is more sustainable than aviation and claim that air and rail should reinforce each other. KLM sees that multimodal transport is necessary for the sustainable growth of Schiphol airport and that, therefore, a proper connection to the EU's HSR network is crucial. KLM finds that, especially on destinations below 500 kilometers, other transport modes should be complementary to flying on transfer journeys. However, in the same document, they also state that for destinations such as London, Brussels, Berlin, and most importantly, Paris, HSR should even be the first choice considering travel time and fares. Schiphol airport itself also finds HSR to be a crucial part of the airport's operations. In their vision for 2050 (Schiphol, 2020), Schiphol foresees that for Nort West European cities, HSR is the dominant mode of transport, and that air transport is more part of an integrated, multimodal journey. In addition, the Union of Dutch Airports, including Schiphol, claims that aviation should not compete with alternative transport modes, but rather cooperate, also beyond international borders (Dutch Union of Airports, 2018).

The Dutch government is also rather explicit in its goals. They want to make alternative travel modes more attractive compared to flying and are explicitly interested in improving the air-rail product for transfer passengers. The Dutch government would like to do this by setting up a joint action plan with the involved parties (Ministry of I&W, 2020a).

The result of the effort to set up a joint action plan has been presented in November of 2020 as the action plan train and aviation is presented (Rijksoverheid, 2020). This document, jointly drafted by the Dutch ministry of infrastructure and water management, Schiphol airport, KLM, NS (railway operator), and Prorail (railway manager), hereafter 'the actors', is to guide actions that are taken to improve air-rail connectivity. Within this document, it is stated that all parties involved are aiming to improve the opportunities for people to use HSR for distances up to 700 kilometers. Proposed actions are to strengthen the position of HSR as a substitute for air travel, as well as being complementary to it. Six cities, being Brussels, London, Dusseldorf, Frankfurt, Berlin, and Paris are appointed as prioritized destinations on which air-rail connectivity should be improved. In the document, especially Brussels and Paris are regarded as promising destinations as a HSR connection is already present.

4.2.2.Drivers for air-HSR integration at the Amsterdam corridor

Goals regarding air-HSR integration at the Amsterdam-Paris corridor are fairly aligned. Especially with the drafted action plan, all parties involved are committed to making efforts for the development of an air-rail product. Motivations for these parties to participate in the development of possible air-rail product, however, vary. A motivator of all parties is sustainability. As according to KLM (2020), 'With CO2 emissions seven times higher than high speed rail, flying is less sustainable'. Improving air-rail connectivity can, therefore, decrease passengers' carbon footprint and reduce the number of short-haul flights (Rijksoverheid, 2020).

Competition and profit

At the European level, air-rail integration is pursued so that major airports such as Heathrow, Frankfurt, CDG and Schiphol Airport (Figure 18) can be decongested (MPIRPT, 2022; European Court of Auditors, 2018). In addition, the European Court of Auditors (2018), #1, #9, and #10 find that improving air-HSR connectivity can increase airports' catchment areas, and therefore stimulate competition between them.

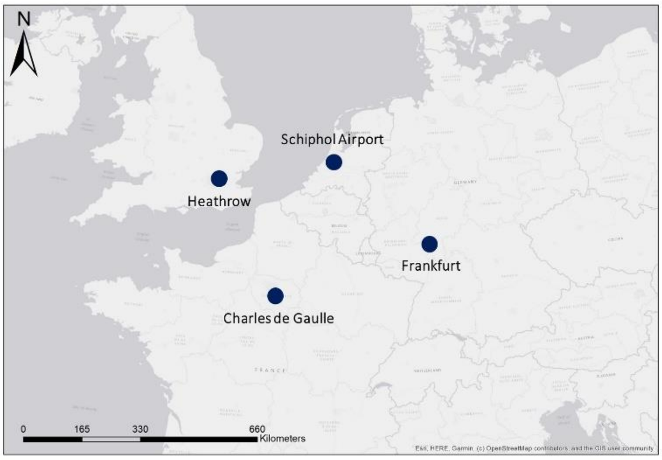

Figure 18: Congested hub airports in Europe

For KLM, NS, and Thalys, improving air-HSR connectivity is also seen as a business opportunity. For NS and Thalys, offering an air-rail product can increase ridership on their trains and, with that, increase their revenue (#1, #3, #9). For KLM, the enlarged catchment area of Schiphol is in their benefit (#3,#9,#10). In addition, slots that would no longer be used by short haul flights can be utilized for long haul flights, for which there is no viable alternative (KLM, 2020). According to KLM (2020), this reduction of short haul feeder flights will allow the company, and Schiphol, to focus on economically important intercontinental flights which can improve Schiphol's international position. Making a profit is key and Interviewee #9 indicated that KLM, therefore, mainly wants their profitable long haul flights to be full. It does not matter to them whether passengers arrive at Schiphol by a short haul feeder flight, or by train.

The Dutch national government is rather ambiguous about replacing short haul flights with long haul flights. In the action plan aviation bill (Ministry of I&W, 2020b) that has come forth out of the aviation bill from 2020 (Ministry of I&W, 2020a), the Dutch ministry claims that it is actively trying to make room for long haul flights as replacing short haul flights with long haul flights adds to Dutch welfare and wellbeing. However, the state action plan for the reduction of CO2 emissions from aviation (Ministry of I&W, 2022), drafted in 2022, does not claim that it is active policy to replace short haul flights with long haul ones. Here, there is only the mere notion that short haul slots might be used by long haul flights, leading to an overall increase in CO2 emissions.

'It is important to note that airport capacity that becomes available for substituting short flights with trains may be used for long-haul flights and thus may lead to an increase in CO2 emissions.' (Ministry of I&W*, 2022)*

This effect, where long haul flights fill empty airport slots, makes the goal of more sustainability by air-rail integration rather paradoxical. Individual journeys can become more sustainable, but overall CO2 emissions, according to current policies, will likely increase. During the interview (#6; #7), the ministry indicated that their main goal is to keep the Netherlands accessible despite current capacity issues. They want to be able to accommodate the increasing demand for international travel while reducing nuisance and CO2 emissions. How this is achieved, is irrelevant, but the train is seen as part of the solution.

Public pressure and individuals

One other reason for involved parties at the Amsterdam corridor, which is indirectly derived from sustainability goals, is that they see that there is the desire from travelers, politics, and the sectors themselves to use both trains and airplanes as efficiently as possible and have them reinforce each other (Rijksoverheid, 2020). Aviation has been under a lot of pressure to change (#9) and it is because of this broad societal desire, in combination with the increasing popularity of the international train, that now there is societal and political momentum to make push for air-HSR integration (Rijksoverheid, 2020). In addition, #9 indicated that at the time the action plan train and aviation was drafted, there was a secretary of state that had a particular interest in substitutability of aviation by HSR. Because of her particular interest, the subject got significant attention during her tenure. Currently her term has ended, but with the new CEO of Schiphol's main carrier KLM being the former CEO of NS, #1 and #5 indicate that air-HSR integration has a good chance of being a priority on the agenda for future years.

4.2.3.The air-rail product: What will be offered?

The ATAG (2021) lays out a few requirements that need to be met to facilitate air-rail journeys. They mention inter ticketing, direct connections between airports and railway stations, but also a shared responsibility for the passenger by the different operators. It is the passenger, that also gets a lot of attention within the action plan for train and aviation, and therefore at the Paris-Amsterdam corridor (Rijksoverheid, 2020). When offering people an air-rail product, the actors agree individual preferences should be taken into account. Business travelers, for example, find total travel and arrival times important, but they also desire a comfortable and reliable journey. Leisure travelers on the other hand make their decision based on price, habits, and clarity of the journey. The action plan also states that sustainability is becoming increasingly important in choosing a mode of transport.

Taking these preferences into account NS and KLM would investigate whether a similar air-rail product that is currently offered for Schiphol-Brussel is also possible for Schiphol-Paris (Rijksoverheid, 2020). At that time, it excluded the possibility to check in luggage for the whole journey but included a code-share agreement. In a more recent announcement, (KLM, 2022b) has laid out 5 essential conditions that need to be met before they can offer an attractive air-rail product. They are the following:

- IT systems of airlines and railway companies must be able to communicate for check-in purposes and rebooking passengers in case of disruptions.
- International trains should stop at Schiphol Airport.
- Arrival and departure times of trains and planes should be attuned to each other to have minimum connecting times.
- An integrated luggage solution on board of the train in the form of a secured compartment and an efficient luggage transfer system at Schiphol.
- Availability of a separate route for HSR passengers to get to the gate.

It is also these conditions that lie at the basis of the current barriers for the development of an air-rail product for Paris-Amsterdam. Although all interviewees agreed that these conditions are indeed, to a certain degree, important for offering a good air-rail product that could potentially replace short-haul feeder flights, there is disagreement as to what actions should be taken to sufficiently meet the conditions.

4.3. The necessity of a well-developed product

Because of past deregulation measures, governments have very limited capacity to steer airlines. It is completely up to the airlines to decide whether they want to develop and offer an air-rail product or not (#6). It is, for example, not possible for European governments to ban international short haul flights if their goal is to reduce emissions (#7). This is because although removing a short haul flight from the schedule initially leads to a reduction in emissions, the airport slot that was used by the airline to operate that flight stays in possession of that same airline. Because that airline is not allowed to fly on that short distance destination anymore, it will most likely use that slot for a destination further away, and with that increase emissions (Figure 19). It is this increase in emissions from the added flight that makes the overall effect of the banning-measure negative from an emissions point of view. Because of this effect, European governments are not allowed to ban international short haul flights. As airlines are commercial businesses and seek to make a profit, they will only replace a short haul feeder flight by HSR for commercial or other business induced reasons (#6, #10).

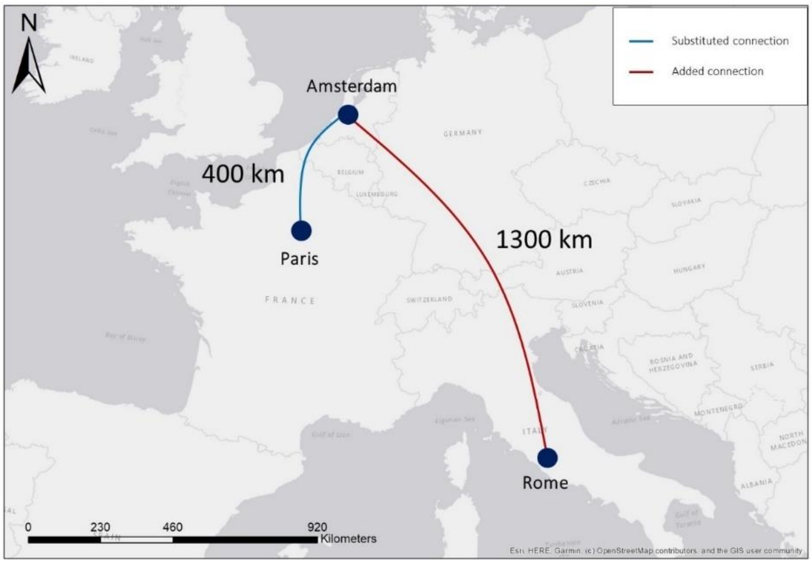

Figure 19: Effect of flight substitution

'That is where KLM says, and it is just they say so, it is their decision to replace a flight by a train. It is no governmental decision. As a government we cannot say: 'And now you have to do it by train'. That is a KLM decision.'
(Policy worker at the Public Transport and Rail department, ministry of I&W)

Schiphol and railway operators find themselves in similar positions since they are privatized and profit driven (#1; #4; #5). They too cannot be forced to develop an air-rail product and will only do so for commercial or other business induced reasons.

Although, in the past, sections have shown that there are several commercial incentives to develop and start facilitating air-rail journeys. However these financial benefits can only be realized when there is a high quality air-rail product that people are willing to buy. Within KLM's current business model, costumer experience (offering passengers a highly comfortable travel experience) is important and highly valued (#2). This is especially the case for transfer passengers. Currently, KLM, in cooperation with other Skyteam alliance members, is able to offer high quality transfer products with often short transfer times of only 40 to 90 minutes at Schiphol airport (#2; #4; #9). Other hub airports and their main carriers have also developed similar well-integrated products. The high quality is important because transfer passengers often do not care at what specific airport they transfer (#7). For transfer passengers, price of the trip and quality of the transfer are the most important factors in choosing a certain airline and airport.

Because current air-air products are of such high quality and adopted worldwide, the air-rail product is at a disadvantage because many people do not know the concept behind it yet (#2; #9). Because of the unfamiliarity, people are often anxious and hesitant to buy it (#8,#9). In addition, air-rail products are very western European because of the present HSR infrastructure and services (#2; ATAG, 2021). People who are from western Europe might, therefore, be able to quickly understand and adopt the concept because they already know about HSR. However, for travelers from other continents who are less familiar with HSR, an air-rail product is likely to be even more unknown and maybe a bit scary (#2). Therefore, interviewee #2 claims that the costumer experience of an air-rail product should not deviate too much from the high quality of air-air products that transfer passengers are currently used to. If it is too different, it will prohibit people from buying it (#2).

In addition, within the transfer journey segment, many trips are made for business purposes (#9; #10). Where leisure travelers often choose their destination based on the availability of a direct connection, business travelers are bound to their end-destination. For these business travelers, time is valuable and, therefore, business travelers are more likely to spend more on a journey that is comfortable and quick. As an air-rail journey likely takes more time than an air-air journey, it is per definition hard to capture business travelers (#10). Therefore, to keep serving these passengers, airlines need to ensure that the air-rail product on the Amsterdam-Paris corridor is as attractive as possible in terms of service. This allows them to be able to compete with an air-air product of a rival airline through another hub airport and, with that, maintain their market position.

"Because they (business travelers) are more often bound to their destination, they have to be at a certain city, a certain country because that's where their headquarters are, or because the client is there, or because the execution of a project takes place over there. So, they have a transfer journey more often. But what you see there, is that time is money. And then it is very dependent on how well that air-side machine arranged, and the quality of it. Then how attractive is air-rail?" (Researcher, Knowledge institute for Mobility policy)

The consequences of offering a poor air-rail product while cancelling feeder flights would be that airlines and airports lose customers to rival airlines and airports that do still operate the well-known and comfortable air-air product (#2; #10). This would mean a loss in revenue and, in addition, when choosing to fly with another airline through another hub airport, the total route length might be much longer than the initial route of which Amsterdam-Paris was part (#2; #4) (e.g. Figure 20). Not only does the airline that is offering a poor air-rail product then is lose costumers, but overall emissions also go up. Therefore, it is important that the air-rail product is attractive, not only for commercial gains, but also for environmental reasons.

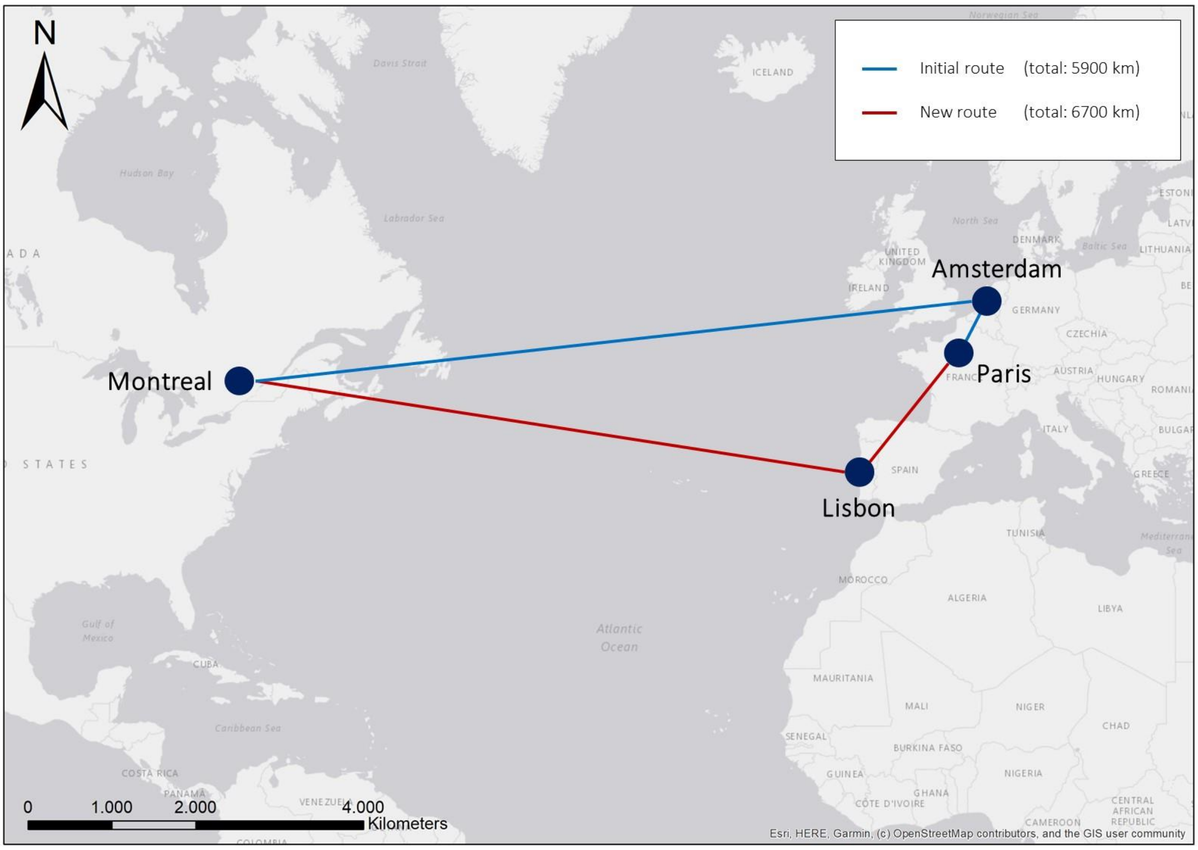

Figure 20: Illustration of possible longer travel distance

4.4. Barriers to air-rail product development

4.4.1. Connecting different worlds

For the development of a good air-rail product one needs to connect and integrate the two very different worlds of HSR and airlines. Between them, there are many fundamental differences that complicate the development of a high quality product.

Airlines, especially in Europe, are inherently international businesses, created for international travel. They are used to dealing with different countries and their regulations, and have mastered working together with other airlines across the world (#2). Railways and railway operators on the other hand have originally been established to serve domestic travel, which is still their top priority, and are much less familiar with cooperating with other parties (#2; #4; #10).

"Train companies mainly serve the domestic market, in contradiction to airlines such as KLM who serve an international market. Because of the international character, KLM has much more experience in cooperating with other partners and a higher understanding of the connectivity that is needed to cooperate."
(Costumer experience and design innovation leader, KLM)

International train services are often not a top priority of railway companies, which leads to numerous sub-optimalizations (#5). Booking a train ticket for a national trip, for example, is often relatively easy and clear, while booking a ticket for an international train trip is rather complicated, much more complicated than booking an international flight (#2). In addition, because of railways' domestic focus, all countries have different regulations which are not attuned to one another (#5). Operating an international train service, therefore, requires a company to have knowledge of legislation and practices in all countries it travels through, making the operation of international services more complicated than operation of a domestic service. These barriers to easy and comfortable international rail transport are also acknowledged by the Ministerial Platform on International Rail Passenger Transport. They, as a matter of fact, look at the aviation industry as an example for international travel and aim to adopt similar practices to optimize the international rail system (MPIRPT, 2022). In short, international rail itself is still very much in the progress of developing, improving, and integrating their own rail products.

While doing so, the railway industry predominantly focuses on O/D passengers (#1; #2; #3). On the other hand, within the full service carriers' hub and spoke model, airlines predominantly facilitate transfer passengers. These transfer passengers are used to a higher level of service than is currently being offered to international train passengers (#5). For the development of the air-rail product, however, both HSR and airlines argue that it is their target group's needs and offered level of service that is most important (#4; #10). This implies a fundamental difference in perception as to what level of service should be offered.

This difference in the perception of needs of air-rail passengers, but also the fundamentally different business models of the rail and aviation industries are important as they lie at the basis of the current barriers that prohibit the development of a proper air-rail product.

4.4.2. Code-share and IT integration

For the air-rail product, all parties agree that a similar codeshare agreement to the air-air model is desirable. This is especially important because, among a lot of people there is the sentiment that trains are less punctual than planes, even though aircraft and HSR have similar punctuality levels (#7; #10; Royal HaskoningDHV, 2020).

Implementing a code-share in such a way that it functions the same as with airline alliances poses a challenge. To be able to guarantee people that they will arrive at their destination, KLM needs to be able to follow a passenger throughout their whole journey (#1; #2). KLM needs to know exactly where a passenger is so that, in the case of a delay or another disruption, KLM can pro-actively rebook a passenger to another plane or train or tell a plane to wait.

"It is very important that you should always be able to manage the product that you sell."
(Implementation manager, NS international)

Therefore, IT systems of airlines and railway operators need to be integrated so that they are able to communicate with one another regarding the whereabouts of a passenger. In addition, IT system integration is also necessary for a comfortable check-in process where passengers can receive both their boarding pass as well as their train ticket at the same time (#2). Here, airlines work with globally operating systems, developed to communicate with other airline systems. Train companies on the other hand work with locally designed systems, that are not able to communicate with airlines (#6). Currently, there are European projects that aim to improve IT connectivity between airlines and railway companies, but this is a multi-year process because of the complexity (#2). Although not yet for the Amsterdam-Paris corridor, KLM and Thalys have recently designed an IT solution for the Amsterdam-Brussels corridor. There will be a pilot on this route with an air-rail product that replaces one feeder flight per day in the summer of 2022 (#2; #3). In the concept, KLM prebooks a certain number of seats on Thalys trains and they import them into their own system as if they were seats on an airplane (#2). These seats are then owned by KLM and only KLM can sell tickets for those seats. The success of this system is yet to be determined but the pilot should bring valuable insights for the air-rail product development. If successful, the developed solution could also serve as a basis for a possible air-rail product between Amsterdam and Paris (#1; #2; #3).

4.3.3.Train services, frequencies, and timetables

Currently, there is a train service with a frequency of around 11 times a day that runs between Amsterdam central and Paris Nord which has an intermediate stop at Schiphol airport (#3). In contrast, there is only one train a day, running only on a few days per week, between Amsterdam central and Paris Marne la vallée that has intermediate stops at both Schiphol airport and CDG (#3). There is a high demand for international transport between Amsterdam and Paris and the largest share of the passengers on the Amsterdam Central – Paris Nord service are O/D passengers with either Amsterdam or Paris as their end-destination (#1; #3). As a consequence, Thalys trains operating between Amsterdam central and Paris Nord are often fully booked (#5; #10). Because of the high share of O/D passengers, the service has been designed in such a way that their needs are met with comfortable time-tables and a direct connection. Unfortunately, these current services that are ideal for O/D passengers do not always fulfill the needs of transfer passengers.

Firstly, the current time-table does not offer train departures at the edges of the day (#5; #7; #10). Because there are no trains in the early morning or late evening, there is no train service available for people who depart on an early or arrive on a late flight. Without a connecting train service available, it is impossible to offer an air-rail product (#2).

Secondly, people who depart from Paris Nord and have a transfer at Schiphol are currently well served with a train frequency of 11 times a day from Paris Nord to Schiphol Airport (#1) (Table 5). With increasing demand for O/D journeys between Paris and Amsterdam the frequency is more likely to go up than down, reinforcing the possibility of offering an attractive air-rail product (#5). However, to offer an inclusive air-rail product and potentially substitute all flights between Schiphol and CDG, there also needs to be a frequent, direct service between Amsterdam (and Schiphol) and CDG (#1; #2; #3; #6; #10). This is important for people who depart from Amsterdam and transfer at CDG but also for people who, by the dual hub model of Air France-KLM, have a journey with a double transfer (e.g. figure 21). To be able to offer an attractive product to these passengers as well, interviewee #2 indicated that there is a need for at least six services a day between Amsterdam, Schiphol, and CDG. To have acceptable transfer times.

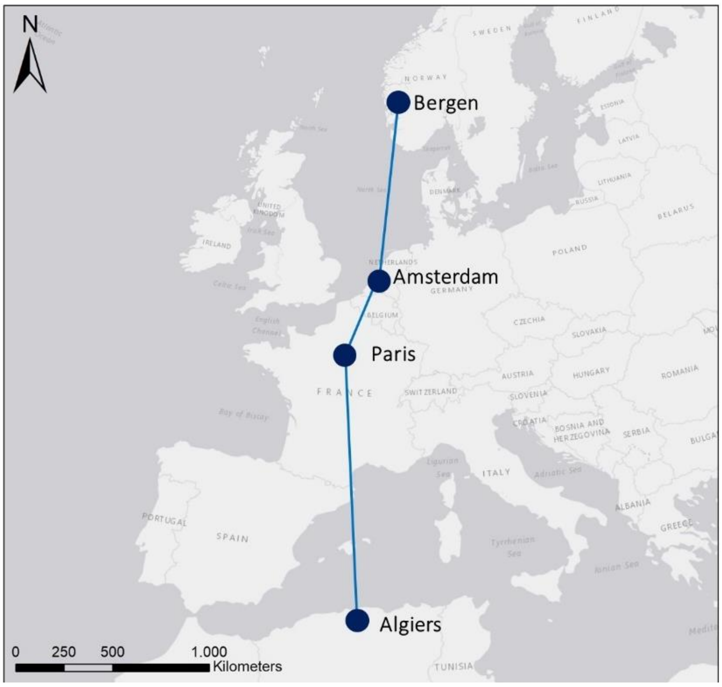

Figure 21: Possible double transfer

Table 5: Time-table for Thalys trains on Amsterdam-Paris route (Based on Thalys, 2022a; Thalys, 2022b)

Timetable Amsterdam Central - Paris Nord	Timetable Paris Nord – Amsterdam Central
06 :15 – 09 :35	06 :13 – 09 :44
07 :15 – 10 :38	07 :25 – 10 :44
08 :15 – 11 :35	08 :25 – 11 :44
09 :15 – 11 :35	09 :22 – 12 :44
11 :15 – 14 :35	10 :25 – 13 :44
13 :15 – 16 :38	12 :25 – 15 :44
15 :15 – 18 :35	14 :25 – 17 :44
16 :15 – 19 :35	16 :25 – 19 :44
17 :15 – 20 :53	17 :25 – 20 :44
18 :15 – 21 :38	18 :25 – 21 :44
19 :15 – 22 :38	19 :25 – 22 :44

An obvious solution would be to simply add extra services at both the edges of the day as well as between Amsterdam and CDG. However, adding an extra service is not easy and cannot, and will not, be done overnight for a number of reasons. Firstly, before deciding to add extra services, train companies must be sure that there is enough demand to make these services profitable. Secondly, even if there is enough demand, there are possible capacity constraints at both the railway infrastructure as well as the railway company side which prohibit the addition of extra services.

Demand

Operating an international train service is very costly, more costly than operating a domestic one. Because of the railway sector's domestic focus, all countries have different, unharmonized requirements for personnel and equipment. To be allowed and able to use a country's railway, train companies must meet all the different requirements (#5; #10). It is because of these international differences that it is, for example, currently not possible for the TGV service, operating between Brussels and Marne la Vallée, to continue into the Netherlands (#5). If they wanted to do so, they would have to invest and adapt their equipment so that it meets Dutch standards and conditions. Another factor that drives up the cost of operating an international train is the ways in which the usage of railway infrastructure is charged across countries. Here, all countries also have a different system (#5).

The reason why there is currently no direct service between Schiphol and CDG is because demand is too low to operate a train with a profit (#1). This is partly induced by the very competitive, high frequency HSR service between Brussels and Marne la Vallée operated by the TGV (#3) which is also used for an air-rail product offered by Air France. Because of this high quality TGV service, capturing market share between Brussels and Marne la Vallée will be hard for Thalys, making it tough to achieve high ridership on a Amsterdam-Marne la Vallée connection.

Therefore, the train companies say, if KLM wants them to add services for the sake of an attractive air-rail product, there has to be an assurance that at least a part of that train will be filled with air-rail passengers (#1,#3). One way to do so would be to cancel all feeder flights. Yet, an airplane is 3 to 4 times smaller than a Thalys train (RHDHV, 2020). Therefore, even if airlines decide to cancel all 10 daily feeder flights and transport their transfer passengers by HSR, the number of passengers will not be able to completely fill a minimum of six trains between Schiphol and CDG per day.

Capacity

If train companies decide to increase the number of services, there are still capacity constraints at both the infrastructure as well as the operator side that prohibit the swift addition of extra services.

Where air-transport is very flexible, trains are bound to physical railway infrastructure. This infrastructure is highly inflexible and it is unsafe for trains to drive closely behind each other (#3; #5; #9; #10). Therefore, within the railway sector, a company has to apply for so-called train paths which they want to use for their services (#3; #5; #10). These paths are highly inflexible and there is limited availability or international train paths because domestic rail traffic is often given priority. Although there are still train paths available at the moment (#5), train companies usually have to order these train paths at least two years in advance and when granted, the train path is in the company's possession for a full year (#3). Having to order a train path for a full year is an issue regarding the air-rail product because air-travel has a higher seasonal effect than rail-traffic (#3) with higher demand for air transportation during holidays. Here, airlines are rather flexible and can quite easily add extra flights during these periods (#3). In contrast, because train paths are awarded for a full year, train companies are not able to flexibly add extra trains to the schedule during holiday periods without having to pay for a full year. From a business case perspective, it is therefore unattractive to apply and pay for extra train paths, that will only be heavily used for 2 or 3 months a year (#3). In addition, interviewee #3 indicated that train companies are not going to produce multiple complicated schedules for different periods of the year for only a limited number of (transfer) passengers, just so they can serve airlines' needs.

A last issue regarding railway infrastructure constraints is stopping times at Schiphol airport. The Schiphol railway station in the Schiphol tunnel is at a very central point in the Dutch railway network and is therefore operating at maximum capacity (#10). Because of the heavy use of the tunnel, trains can only stop for 2 or 3 minutes (#4). For 120 transfer passengers including all their luggage to exit a train, 2 to 3 minutes can be rather short.

The other issue regarding capacity, is the capacity of railway companies themselves. Thalys only has a limited number of trains and personnel available and this is, at the moment, a large bottleneck (#1). Currently, there are not enough trains available to serve both Paris Nord and Marne la vallée at high frequencies (#1; #2; #6). Thalys could order new trains, but it will take at least 5 to 7 years before they are operable (#4). Deciding to increase services to Marne la vallée right now would therefore imply that Thalys has to reduce services between Amsterdam central and Paris Nord (#3). However, as already explained, demand for transport between Amsterdam and Paris Nord is high and trains are often fully booked, making the service highly profitable (#10). Demand for transport between the two cities is expected to increase even further, especially with the start of the air-rail product pilot between Amsterdam and Brussels. Therefore, with limited demand for a service to Marne la Vallée, shifting capacity is a business risk for Thalys and not commercially attractive. Moreover, extra trains that are already ordered and arriving soon, are likely to be more profitable for the Amsterdam – Paris Nord service than the Marne la Vallée service.

The matter of time

Setting up new services is a long term process. With the air-rail action agenda presented barely two years ago in 2020, efforts aimed at improving the connection between airports and HSR have only started recently (#6). It is only now that organizations are learning what is actually needed to increase air-HSR connectivity and how to act accordingly (#2; #6). Therefore, it is not possible, on the short term, to add extra services that serve the air-rail product. On the long-term, however, there are possibilities to increase services towards CDG, even with limited demand for a stop at CDG airport.

In the first place, because it is the long-term, parties can take action now, apply for train paths, and order extra trains so that there is enough capacity available in the future. Another future opportunity can be found in the increasing popularity of the international train. The expectation is that, in the future, HSR will also be used more frequently for destinations further south of Paris (#5). For these destinations such as Lyon, Barcelona, or cities in Italy, it is much faster to travel via Marne la Vallée than via Paris Nord. The focus for the air-rail product should, therefore, maybe not be on the combined facilitation of O/D passengers bound for Paris but on the combination with O/D passengers to destinations further south.

4.4.3. Maintaining a short connection time

As discussed above, maintaining a short connection time can partially be done by the harmonization of railway and aviation schedules. However, the actual transfer between a train and aircraft - the travelling between the railway platform and the gate - should also take place in a quick and seamless way (#2). Ideally, transferring between a train and an aircraft is at least as swift and easy as between aircraft (#1). This implies that a passenger should be able to get from the railway platform to the gate, or the other way around, within 40 or 50 minutes for European flights (#4) and 90 minutes for intercontinental flights (#2). These short transfer times for air-air journeys can currently be achieved because passengers arriving by plane arrive at the secured air-side area. Here, passengers do not have to go through security again and if they are staying within the Schengen area, passengers also do not have to go through immigrations before getting onto their connecting flight (#1; #2). Currently, there is no direct route for air-rail passengers between the HSR platform and the air-side (Figure 22). Passengers who arrive at the airport by HSR, arrive at the land-side together with other passengers for whom Schiphol is their point of origin. Hereby passengers using an air-rail product have to go through the same security and immigration checks as other land-side passengers. A process for which travelers are advised to arrive at least two or even three hours prior to their flight. Arriving at the land-side hereby means that currently, even though at Schiphol the walk from the platform to the check-in and security area is only three minutes, short connection times cannot be guaranteed (#2; #4, #5; #10).

Figure 22: Division between air-side and land-side

A possible solution would be to construct a direct route between air-side and the HSR platform, but with the railways being in a tunnel, that would take much time and cost too much money to make a viable business case (#2). In addition, interviewee #2 stated that having to go through security and immigrations is not an issue per se. It is simply important that they have to be able to do so swiftly and comfortably so that they can easily make their connection. Therefore, another solution that would not require vast investments is the creation of a priority lane for air-rail passengers so that they do not have to stand in the same lines as other departing passengers (#2; #4; #5). However, here Schiphol foresees a potential conflict. At the moment, around 22 million out of 45 million O/D passengers departing from Schiphol travel to Schiphol by train. In essence, interviewee #4 indicates, these passengers are also air-rail passengers. When opening a separate air-rail lane, it must be understandable for them that that lane is not meant for people who arrived from, for example, Groningen, but only for people who bought an air-rail ticket from, for example, Paris. It could potentially be hard for passengers to understand why those people arriving by train with an air-rail product are given priority above themselves who also arrived by rail (#4).

"I think it is difficult to discriminate between OD- and transfer-passengers arriving by rail. Both arrive at Schiphol plaza: landside. If the airport puts up a sign saying "priority for air-rail passengers", how do we explain that you, arriving by rail from Groningen travelling to NYC, should follow normal check-in processes, while your co-student, coming from Brussels on an integrated ticket to NYC, receives transfer priority?"
(Advisor Airport Strategy and Development, Royal Schiphol Group)

Apart from long lines at security and immigrations, another point that increases transfer times at Schiphol airport is luggage. With no integrated system available at the moment, air-rail passengers have to drop off their luggage at Schiphol once they arrive, or pick it up when they leave by HSR. Increased transfer times, however, are not the only complication originating from luggage.

4.4.4. Luggage solutions

The separation of checked luggage from the passenger is one of the premium services airlines offer to their customers. Passengers are able to drop their bag at their place of origin and pick it up at their end destination. With HSR, this is done differently. Here, passengers keep their bags with them throughout the whole journey. KLM claims that for an air-rail product, similar services to their transfer model should be offered for a number of reasons. Firstly, journeys including a transfer, are often trips that cover large distances. People who travel to distant destinations often stay there for longer and therefore need to bring more luggage than they can fit in their carry-on luggage. Therefore, transfer passengers more often travel with an extra bag which needs to be checked in (#9). Secondly, because a train has intermediate stops, there is an extra risk of theft. People leaving on an intermediate station could take a bag with them that is not theirs (#4). Thirdly, the current luggage system is adopted and well known worldwide. KLM foresees issues with passengers who do not realize that they have to pick up their luggage before boarding the train. They particularly fear for these kinds of situations with intercontinental passengers such as from the United states, who are not used to rail transport (#2). Because of these matters, KLM desires a proper luggage solution including a secured luggage compartment on board the train, and a secured transfer point at Schiphol that feeds the luggage into Schiphol's main luggage system (#2; KLM, 2022). Unfortunately, both requirements are not met at the moment.

Thalys trains currently do not have a luggage compartment on the train (#1; #3). Where aircraft have a so called 'belly', empty space under the seating area, that can only be used for cargo or luggage, Thalys trains do not have similar spaces on their trains. In their trains, every square meter available could be used for seating. Creating a luggage compartment would therefore go at the expense of seating space. With high demand for HSR transport and a higher willingness to pay for seats than for luggage, converting seating space into a luggage compartment would mean losing income for train companies. Therefore, unless KLM is willing to pay the difference in income, which they are not, realizing a secure luggage compartment is highly unprofitable for train companies (#1; #4; #10).

As for the transfer point at Schiphol, there is currently not enough room to construct an integrated system in the Schiphol tunnel (#5; #7; #10). Space on the rail platforms is limited and adapting the tunnel in such a way that it would be possible to create a transfer point would be a costly endeavor. In addition, when a transfer point would be present, trains would have to stop at the exact same location every time. According to interviewee #7, this is difficult to arrange, especially in the case of disruptions or delays. Moreover, with current stopping times at the station being a maximum of three minutes, it is nearly impossible to unload all checked bags within the given time frame, especially if ridership goes up (#3).

In essence, meeting KLM's requirements for luggage by the creation of a secured luggage compartment and a transfer point will be expensive and only produce limited monetary returns which will not cover the cost of development (#2; #3; #4). Therefore, there is much discussion about who should pay for the adjustments, but also about the necessity of the secured luggage compartment and the transfer point. On the one side, airlines claim that it is important because their costumers desire the service, but on the other hand, train companies see that for their costumers, taking their bags with them into the train is not an issue. Both sectors assume the needs of their core costumers but do not consider that an air-rail costumer may have needs that differ from both classic airline customers and classic train users (#4).

Other, successful air-rail products produce mixed signals when it comes to luggage integration. On the corridor Brussels-Paris, there is a successful air-rail product offered that does have luggage integration. The TGV service has a secured compartment behind the locomotive and bags are manually transported from check in desks to the train and vice versa (#7; #10). It is a rather labor intensive process, but it has been functioning quite well for 15 years already (#10). The air-rail product that is offered in Germany to and from Frankfurt, on the other hand, does not include luggage integration. Yet, this air-rail product is also a great success (#3). The air-rail product that is currently offered by Thalys and KLM from Brussels and Antwerp towards Schiphol does also not include luggage integration. The product has been offered for 15 years now and Thalys claims that only rarely, there are luggage issues.

4.5. Barriers beyond the development of a good product

4.5.1. Air-air journey competition and maintaining positive effects.

If all barriers that prohibit the offering of a high quality air-rail product on the Amsterdam-Paris corridor can be resolved and parties are ready to offer it, it is important that people can easily find the product and decide to buy it instead of a usual transfer ticket.

Currently, people usually buy tickets based on costs and travel time, and these are also the two dominant filters that determine what airline product and routes are at the top of the list in search engines (#1). Since there is no need to be at a train station two or three hours in advance, an air-rail product including Amsterdam-Paris does not have to have longer travel times than an air-air ticket. Yet, search engines still portray air-rail tickets as products with longer journeys. This is because the in-vehicle time is longer for air-rail tickets and search engine results do not consider door-to-door travel time. The other factor, price, is also not in the benefit of air-rail tickets. Flying is currently very cheap and often cheaper than the international train. One reason for this is that airlines are paying lower taxes, especially environmental taxes, or are even exempt from them, while train companies do have to pay these (#1). Recently, airport taxes in the Netherlands have been increased to 25 euro’s per ticket, but these are not charged to transfer passengers (#5; #7). Also increasing taxes for transfer passengers could promote the use of air-rail tickets and increase their competitiveness. Yet, if only done nationally, the consequence would be that Schiphol’s international market position as a hub airport would weaken. Over the years, Schiphol has claimed to be vital to the Dutch economy and is enjoying a privileged position in the national government making it unlikely that the government would impose extra taxes that would weaken Schiphol’s position (#8). Moreover, with the ministry of finance as Schiphol’s main shareholder (#4), and holding approximately 10% of the shares of Air France-KLM (NOS, 2022), it is in the government’s direct disinterest for them to lose market share to other airports and airlines.

Another option that could increase the findability of air-rail products is the banning of short haul flights, leaving only the air-rail option. However, as already explained earlier, this is not possible at the moment (#7). Nevertheless, the European Commission and individual countries in Europe are pushing to ban, mainly national, short-haul flights where a viable HSR alternative exists (#3). Although this could further stimulate the development of air-rail products, interviewees find it debatable whether this is the best policy solution to boost the air-rail product while trying to become more sustainable (#8; #9; #10). As already explained, airport slots will stay in possession of airlines who will use them for long-haul flights, being worse for the environment. Therefore, a policy intervention that could capture environmental benefits while stimulating air-rail products would be to reduce the number of available slots in general (#5; #10). This is already possible (#7) and because Schiphol is violating too many environmental standards, it is also being done as of November 2023 (BNR, 2022). This could stimulate airlines to abandon unprofitable feeder flights, leaving only the air-rail product. Yet, this effect is not a given.

4.5.2. Investment dilemma

One of the main barriers regarding the development of a high quality air-rail product is the vast investments that are needed to facilitate it. Especially when the goal is to offer air-rail products for other destinations than Paris, large investments are needed to adapt infrastructure at Schiphol so that it can accommodate more international HSR for transfer passengers. Because Schiphol station is in a tunnel, adapting it to accommodate more international trains would cost billions and it is already nearly impossible for technical reasons (#4). This is especially the case if an air-rail product is also to be offered between London and Amsterdam. Because London is not part of the EU or the Schengen agreement, there is an additional need for a passport control which is not needed for other European destinations.

Currently, there are projects underway and in the planning phase that aim to free up capacity in the Schiphol tunnel. These include the construction of a large international train station, Zuidasdok, at the Amsterdam South station, and the extension of the Noord-Zuid metro line. However, the Zuidasdok is set to be finished in 2035 (#5) and although the investment for the metro extension is said to be a no regret measure, there has been no formal decision to start the project. Even if the decision is made to complete the metro extension today, it will only be operable around 2040 (#4).

Therefore, several interviewees question whether it is the best option to start investing vast amounts of money into a high quality air-rail product that can only serve a limited amount of transfer passengers and, therefore, also provide limited environmental benefits. Afterall, short haul flights only cause 4% of all CO2 emissions produced by the aviation industry (#9; ATAG, 2021). In addition, even if decisions to invest billions of euro's to make all the infrastructure fit to offer a high quality air-rail product for multiple destinations were made today, it is likely only operable after 2040. It might be more efficient to invest in just O/D passengers who are easier to capture and accommodate (#8), or in other niche developments that increase the sustainability of the whole aviation industry. In other words, can money not be spent in a more efficient way with more environmental benefits on a shorter term?

4.5.3. Other niche developments

The aviation industry and Dutch government are pushing hard for green propulsion techniques (#7; ministry of I&W, 2020). It is deemed necessary because HSR is no alternative to all international and especially intercontinental travel, but also because HSR itself has its capacity limits and is not able to keep accommodating more and more passengers (#7). KLM is also investing in sustainable aviation fuels and cleaner, more efficient aircrafts next to air-rail integration. Despite all investments in sustainable aircraft, completely sustainable aviation is not to be achieved any time soon (#5). Yet, electrical flying on short distances is highly promising and quickly being developed (#9). Batteries are improved at a fast pace and there are already aircrafts running on battery power that can carry 9 or 10 people for up to 300 kilometers (#9). With ongoing improvements expected Amsterdam-Paris is one of the routes for which new generations of electric aircrafts are highly suitable. For KLM, as long as there are airport slots available, it would be easier to operate electric aircraft than to engage with air-rail initiatives. The main reason for this, is that by adopting electric aircrafts, KLM can maintain its well developed and efficient business model (#2). KLM expects to be operating electric aircrafts around the year 2030 (#2) meaning that sustainable aviation on the Amsterdam-Paris corridor could be achieved even before the Zuidasdok and the metro extension are finished, let alone other projects that benefit air-rail products that are initiated today.

Even though electric aircraft are set to arrive rather soon, interviewees indicate that it is not hindering the progress and development of the air-rail product. Rather than there being one dominant mode of transport, they expect that there will likely be a co-existence of the air-rail product and electric feeder flights (#2,#3,#6). Afterall, demand for transport on the Amsterdam-Paris corridor is at such a high level that both are needed to accommodate the passengers. The Amsterdam-Brussels corridor justifies the validity of this claim as it is already the case where both feeder flights and HSR is offered as an access mode to Schiphol (#3).

5. Conclusion

This research has aimed to uncover why air-HSR integration has not taken place on international short distance routes where train connections are already established. By taking a transition perspective and portraying air-HSR integration as a niche development, it has been uncovered what both the aviation and HSR regimes attitudes towards air-HSR integration are, and how they, also influenced by macro-economic trends and other niche developments, are influencing the development of air-HSR integration. It is found that both regimes have built very different business models which are both highly effective for their core customers. The aviation regime has developed itself into a sector with high levels of service. It has an international outlook and network with much experience in cooperating with other airlines while facing international competition. HSR, on the other hand finds its basis in the national railway sector with a domestic network and only few long distance routes that cross borders while offering a much lower level of service. Although rapidly developing, the railway sector still has a domestic focus, which complicates the development of international HSR connections, and, with that, international connections with air transport. Although offering a different product, HSR has been able to reduce the number of passengers using air transport on short distances and even now continues to do so, especially capturing O/D passengers.

Over the last years the main focus has been on competition between aviation and HSR for O/D passengers. It is only recently that air transport and HSR are acknowledging that they can be of assistance to each other regarding the transport of transfer passengers. However, because both regimes have developed in isolation, they are currently not attuned to each other. Meeting requirements that enable proper integration is, therefore, a time consuming and costly endeavor, especially on the HSR side.

Before providing a wholesome answer to the main research question, sub-questions will be answered. Figure 23 presents a brief overview of the conclusions.

Figure 23: Summary of conclusions

Sub-questions

What is air-HSR integration?

The academic literature review has uncovered that air-HSR integration in its most optimal form can be defined as an integrated product for transportation which includes at least one leg being done by HSR, and one leg by air transport. This product includes luggage handling where luggage can be dropped off at the point of origin and picked up at the end-destination. It also includes short connection times and a code-share agreement that ensures a passenger's connection, also in the case of disruptions. Empirical results show that the code-share agreement is agreed to be highly important. Yet, the necessity for an integrated luggage solution is still up to debate. Other air-rail products being offered throughout Europe also show varying results regarding the need for an integrated luggage solution in order to be able to offer a high quality air-rail product. Therefore, there is not one air-rail product. It rather exists in different forms.

What are possible effects from Air-HSR integration?

Academic literature shows that Air-HSR integration can have both positive and negative effects from both an economic and environmental perspective. The case study has uncovered that the effects of air-rail integration are highly dependent on the quality of the product that is being offered. In the case of a high quality product, passengers can successfully be substituted from air to HSR on their original route. This would increase ridership on trains and enables airlines to maintain their network while cancelling unprofitable, polluting short haul flights. The airport slot previously used for a short haul flight will, after substitution, likely be used for a longer haul flight, which increases an airlines' profit. However, these longer haul flights also increase GHG emissions due to the longer distances flown. Therefore, although the connection Amsterdam-Paris becomes more sustainable, the overall effect of air-HSR integration on the environment will be negative.

In the case of a low quality air-HSR product, environmental impact will be even more negative. Results indicate that several passengers will likely choose to fly through another hub airport because an air-rail journey is not fast or comfortable enough. In this case, next to freed slots being used for longer haul flights, passengers who do not want to use the air-rail product will possibly fly longer distances and emit more GHGs. Next to the potential extra negative impact on the environment, airports and airlines will also lose customers. Offering a low quality product, therefore, has a potential negative effect on both the environment and on individual companies' revenues.

The potential negative environmental impact from added longer haul flights, however, is not a given, as it sometimes appears. It is rather a political decision. By ensuring that slots opening up by the cancellation of short haul flights are taken away from the total number of slots, environmental gains could be consolidated. The issue of airport congestion will, on the other hand, not be resolved in this case.

What is the potential for air-HSR integration on international short-distance routes in hub-and-spoke operations where train connections are already established?

Academic literature has uncovered a large potential for air-HSR integration on international short haul routes in hub and spoke operations where train connections are already established. On these flights, the majority of passengers are transfer passengers and effects of integration can be positive for airlines as well as railway operators. Because train connections are already established, the vast investments regarding railway infrastructure, including the environmental impact do not have to be made. In line with results from earlier research, the Amsterdam-Paris corridor has a large share of transfer passengers on board flights between Schiphol and CDG. With just under one million transfer passengers travelling between Paris and Amsterdam by plane per year, and an already high frequency HSR service between the cities, there is much potential for an air-rail product. Lastly, all parties have dedicated themselves to the improvement of air-rail connectivity. Yet, with many business travelers that increase the profitability of the route, total eradication of services is debatable. It is more likely that there will be a coexistence of an air-rail and an air-air product.

What are current barriers to air-HSR integration on international short-distance routes in hub-and-spoke operations where train connections are already established?

All parties involved want to develop a high quality product before offering it to the public. In line with theory, the case study found that there is a need for a code-share agreement, a luggage solution, and a train stop at an airport at a high frequency. The case study has given an in-depth insight into how meeting these requirements is currently posing barriers to the development of an air-rail product. Firstly, IT systems of both a railway operator and airline need to be able to communicate about delays and the whereabouts of a passenger before a code-share can be offered. Although progress is being made, this is not possible yet on the Amsterdam-Paris corridor due to the large differences in the design of IT systems. Secondly, although the train service from Paris Nord to Amsterdam central stops at Schiphol at a high frequency, it does not stop at CDG. Induced by the dual-hub model of Air France-KLM, a stop at CDG is highly necessary to offer a good product. Increasing services to CDG, however, is not done by Thalys because of capacity constraints. With the Amsterdam-Paris Nord route having a higher demand and, Thalys is not willing to reduce services there to accommodate Schiphol and CDG. Thirdly, because international trains do not arrive on the so-called air-side of Schiphol, all passengers have to go through time consuming security and immigration. Hereby, short connecting times that are currently offered on air-air journeys cannot be guaranteed for air-HSR journeys, meaning that the overall travel time is increased. Fourthly, there is no integrated luggage solution available and the costs associated with the creation of a secured luggage compartment and luggage transfer point do not outweigh the benefits. Investments would not return a profit, making it unattractive for Schiphol and Thalys to invest. In addition, there is disagreement about the need for an expensive integrated luggage solution which makes it hard to resolve the issue.

Main research question

Based on the answers of the sub questions, the main research question '*Why does air-HSR integration not take place on international short-distance routes where train connections are already established?'* can be answered.

The operators needed to facilitate an integrated air-HSR journey are private actors seeking a profit. Deciding to facilitate an integrated air-rail journey will therefore only be done for commercial or other business induced purposes. Although there are many potential benefits for both operators, these can only be achieved when a high quality product is offered. Although parties agree on the need for a code-share agreement and a more frequent connection between Schiphol and CDG, fulfilling the requirements is hard due to difference in IT systems and capacity constraints. In addition, there is disagreement between HSR and aviation actors about the need for a high quality luggage solution. Both railway companies and airlines think from their own regime's users' needs, which makes it hard to find common ground. There is thus no monetary incentive for railway operators to honor the airlines' wishes for an integrated luggage solution or add services between Schiphol and CDG.

Despite these barriers that problematize the offering of an air-HSR product, involved actors have committed themselves on the improvement of air-rail integration. With the action agenda drafted recently, air-rail integration is a subject that has only gotten more attention in recent years. Hereby, after many years of working individually, involved actors are also only realizing just now what is needed to facilitate air-HSR integration. Actions to improve air-rail integration are currently being taken, for example, with the initiation of the air-rail pilot between Amsterdam and Brussels. Amsterdam-Paris is considered a logical next route to be served with an air-rail product and it is likely only to be a matter of time.

Yet, whether that would be an air-rail product in its most optimal form including luggage integration, is debatable. To be able to offer that high quality air-HSR product, especially if being done on a larger scale than just for the Amsterdam-Paris corridor, vast investments are needed to adapt infrastructure and increase HSR capacity. Next to the doubts about the return on these investments, there are also doubts about whether the money could not be better spent on other, more effective initiatives that make transportation more sustainable. Large investments might be better spent on niches that are adoptable worldwide, such as electric flying or sustainable aviation fuels.

Contribution to literature

Until now, only limited research has been conducted on the integration of HSR into aviation practices. Although sharing many characteristics with substitution of O/D traffic, integration into hub-and-spoke practices also differs on several fundamental aspects. Past research has uncovered what an air-HSR product should entail and what requirements need to be met to come to air-HSR integration. This study has added an in-depth insight into how meeting these requirements is currently posing problems to the development of an air-rail product. In addition, by taking a transition perspective as a framework to investigate these issues, underlying mechanisms that problematize the meeting of requirements have been uncovered.

Lastly, adding the international lens to the subject of air-HSR integration, has revealed for international routes, there are additional factors that influence the development of an air-HSR product. Here, particularly the issue of international competition, especially between airlines, is of great importance. Because airlines are competing on an international and even global scale, it is not only the route at which aircrafts are to be substituted by HSR that should be investigated. The competition for passengers between airlines goes beyond a single route and therefore, the scope of research should be expanded to the wider network.

Recommendations for further research

With growing attention for air-HSR substitution and integration (Rijksoverheid, 2020), the air-HSR integration subject is a highly relevant topic for further research. This research has done an in-depth investigation on a single corridor. It has showed that the aviation and HSR regime still differ on their position regarding the needs of air-rail passengers, especially regarding luggage. Other air-HSR concepts throughout Europe show varying forms. Some do and some do not include an integrated luggage solution while still all being successful. To resolve the question on whether an integrated luggage solution is needed, a comparative study could be conducted, comparing the different air-HSR concepts. Next to resolving the luggage question, comparing successful cases could also reveal how other barriers found in this research can be overwon.

Next to the performance of a comparative research on air-rail products, future research could also have a larger focus on the air-HSR passengers by directly investigating their needs in real life settings. Past studies have mainly used models to predict demand and this study has focused on the operator and facilitator side of air-HSR integration. These operators and facilitators do take a passengers' needs into account, but they do so based on assumptions from their own aviation or HSR regime passengers' needs. Perhaps, air-rail passengers have needs that differ from both aviation and HSR regime standards. Conducting passenger oriented research in a real life setting can add valuable insights.

6. Reflection

Theory

The multi-level perspective within transition theory has given me a good framework to study the development of air-HSR integration. Framing air-HSR integration as a niche gave a good indication for what barriers to the development of air-HSR integration could be expected. Especially research by Parkhurst et al. (2012), who has researched intermodality as a niche development before, has been of much help. Like in their research, air-HSR integration can be seen as an intermodal niche, caught between regimes where both regimes do not consider facilitating intermodality as their core business, making the development of it not their top-priority.

A point found in theory I have started to have my doubts about, is regarding the negative environmental impact of HSR development in relation to aviation. I found the findings of Dobruszkes and Givoni (2013) somewhat too deterministic. It is true that slots used for short haul flights will often be used for longer haul flights which increase CO_2 emissions. However, it sometimes seems like this is a direct negative effect and a reason not to develop HSR connections to substitute aircraft. As already mentioned in the conclusion, the fact that the addition of long-haul flights is possible, seems to me as a political decision and not a direct negative effect from HSR development. The route itself becomes more sustainable. The fact that the amount of reduced emissions is being nullified by extra longer haul flights is solvable by a political intervention.

Methods

This study has made use of a single case-study approach to come to in-depth insights into why air-HSR integration is not taking place on short distance international routes where train connections already exist. By choosing Schiphol airport and the Amsterdam-Paris corridor as a case, I have been able to find barriers beyond the necessity of a railway station at or adjacent to an airport and comparable travel times. At first, the Amsterdam-Paris corridor seemed to meet all the requirements. With Air France-KLM being one holding company using both airports as their main hubs, it was expected that there would be very limited competition on the route, perhaps making it extra viable for air-HSR integration. However, although competition for passengers on this corridor was indeed not present, keeping an aerial connection between the two airports was deemed important for others. In addition, rival airports and their main carriers are in close proximity to both Paris and Amsterdam, creating overlapping catchment areas. Thereby, although not directly at the Amsterdam-Paris corridor, there actually was heavy competition for passengers. Therefore, the Amsterdam-Paris route turned out not to be as suitable for air-HSR integration as it first appeared. Yet, regardless of the fierce competition, the case study did give many valuable in-depth insights, which are also generalizable to other cases.

I have found it very useful to conduct the academic literature and document analysis before conducting the interviews. By reading about air-HSR integration, a first feel for the subject beyond news articles has been created. I often perceive news articles as rather negative about flying, mainly induced by the negative environmental impact. Reading objective academic literature and documents produced by different organizations from both the HSR and aviation regime, have enabled me to create an objective and holistic overview of the available information before proceeding with the interviews. In addition, the document analysis has uncovered several motives to pursue air-HSR integration beyond sustainability. Especially analyzing the jointly drafted action agenda for air-HSR integration (Rijksoverheid, 2020) has been of much help to understand the process of developing an air-rail product. It showed that, unlike academic literature suggests, air-HSR integration is actually getting attention from the HSR and aviation regime. In addition, during the interviews, many interviewees also referred to the action agenda. Knowing the content already helped in asking more targeted and in-depth questions. The coding of the document analysis has been done with very detailed codes and this has made the initial results too detailed, complicating the analysis process. Although extra time was spent on the document analysis, it has helped me improve the codebook for the interviews.

The interviewees consisted of people who are directly involved in the realization of an air-rail product (airlines, HSR operators) as well as people who are a more distant from the realization itself but who do have knowledge about it and have a more objective view (e.g. researchers and consultants). This enabled me to see both the aviation regime point of view, the HSR point of view as well as get a more holistic and objective opinion on air-HSR integration. Although all sectors have been involved, the majority of interviewees are now Dutch, who have a Dutch centered perspective. Also involving the French counterparts such as Air France and CDG airport could have possibly added extra insights. Yet, due to time constraints, this has not been possible.

Overall, the used methods and theory have enabled me to come to just and valid conclusions as to why an air-HSR product is currently not being offered on the Amsterdam-Paris corridor but also international short distance routes where train connections exist in general.

Reference list

Albalate, D., Bel, G., & Fageda, X. (2015). Competition and cooperation between high-speed rail and air transportation services in Europe. *Journal of Transport Geography*, *42*, 166-174.

Alderighi, M., Cento, A., Nijkamp, P., & Rietveld, P. (2005). Network competition—the coexistence of hub-and-spoke and point-to-point systems. *Journal of Air Transport Management*, *11*(5), 328-334.

Andersreizen.nu (2022). Vliegwijzer. Retrieved on 16-02-2022 from https://www.andersreizen.nu/vliegwijzers/

ATAG (2021). *Waypoint 2050.* Geneva: Air Transport Action Group.

Avogadro, N., Cattaneo, M., Paleari, S., & Redondi, R. (2021). Replacing short-medium haul intra-European flights with high-speed rail: Impact on CO2 emissions and regional accessibility. *Transport Policy*, *114*, 25-39.

Baroutaji, A., Wilberforce, T., Ramadan, M., & Olabi, A. G. (2019). Comprehensive investigation on hydrogen and fuel cell technology in the aviation and aerospace sectors. *Renewable and sustainable energy reviews*, *106*, 31-40.

Behrens, C., & Pels, E. (2012). Intermodal competition in the London–Paris passenger market: High-Speed Rail and air transport. *Journal of Urban Economics*, *71*(3), 278-288.

BNR (2022). Kabinet zet mes in Schiphol: vliegbewegingen moeten met 10 procent omlaag. Retrieved on 05-07-2022 from https://www.bnr.nl/nieuws/infrastructuur/10479888/kabinet-zet-mes-in-schiphol-vliegbewegingen-moeten-met-10-procent-omlaag

Chester, M. V., & Horvath, A. (2010). Life-cycle assessment of high-speed rail: The case of California. Environmental Research Letters, 5(1), 18.

Clewlow, R. R., Sussman, J. M., & Balakrishnan, H. (2012). Interaction of high-speed rail and aviation: exploring air–rail connectivity. *Transportation research record*, *2266*(1), 1-10.

DeLyser, D. (2010). The sage handbook of qualitative geography. SAGE.

Dobruszkes, F. (2011). High-speed rail and air transport competition in Western Europe: A supply-oriented perspective. *Transport policy*, *18*(6), 870-879.

Dobruszkes, F., & Givoni, M. (2013). Competition, integration, substitution: Myths and realities concerning the relationship between high-speed rail and air transport in Europe. In *sustainable aviation futures*. Emerald Group Publishing Limited.

Dutch Union of Airports (2018). *Visie 2020-2050.* Nederlandse Vereniging van Luchthavens.

European Comission (2020). *CEF support to North Sea – Mediterranean Corridor.* Brussels: European Comission

European Commission (2021). *Long-distance cross-border rail passenger services.* Brussels: European Commission

European court of auditors (2018). A European high-speed rail network: not a reality but an ineffective patchwork. Retrieved on 25-02-2022 from https://op.europa.eu/webpub/eca/special-reports/high-speed-rail-19-2018/en/

Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. *Journal of transport geography*, *24*, 471-482.

Geels, F. W., & Kemp, R. (2000). Transities vanuit sociotechnisch perspectief. *Maastricht, MERIT*.

Gill, P., Stewart, K., Treasure, E. & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. British Dental Journal, 204(6), 291-295.

Givoni, M. (2007). Air? rail intermodality from airlines' perspective. *World Review of Intermodal Transportation Research*, *1*(3), 224-238.

Givoni, M. (2016). Airline and railway (dis) integration. In *Sustainable Railway Futures* (pp. 117-130). Routledge.

Givoni, M., & Banister, D. (2006). Airline and railway integration. *Transport policy*, *13*(5), 386-397.

Givoni, M., & Chen, X. (2017). Airline and railway disintegration in China: the case of Shanghai Hongqiao Integrated Transport Hub. *Transportation letters*, *9*(4), 202-214.

Givoni, M., & Dobruszkes, F. (2013). A review of ex-post evidence for mode substitution and induced demand following the introduction of high-speed rail. *Transport reviews*, *33*(6), 720-742.

Givoni, M., & Rietveld, P. (2008). 14. Rail infrastructure at major European hub airports: the role of institutional settings. *Decision-making on mega-projects*, 281.

Goodwin, P. B. (1996). Empirical evidence on induced traffic: A review and synthesis. Transportation, 23, 35–54

Google (2022). Flights between Paris CDG and London Heathrow. Retrieved on 02-03-2022 from https://www.google.nl/travel/flights/search?tfs=CBwQAhoIagwIAhIIL20vMDRqcGwSCjIwMjItMDQtMjIyBwgBEgNDREcoAHABggELCP___________wFAAUgBmAEC&tfu=EgYIAxAAGAA&hl=nl&gl=nl&curr=EUR

GÓRECKA, A., & HORÁK, T. (2014). Ineffective but Reasonable-Why do European Airlines Operate Short-haul Flights?. In *Paper Presented at the International Conference on Logistics & Sustainable Transport*.

Gössling, S. (2020). Risks, resilience, and pathways to sustainable aviation: A COVID-19 perspective. *Journal of Air Transport Management*, *89*, 101933.

ICAO (n.d.). The world of air transport in 2019. Retrieved on 22-02-2022 from https://www.icao.int/annual-report-2019/Pages/the-world-of-air-transport-in-2019.aspx#:~:text=According%20to%20ICAO's%20preliminary%20compilation,a%201.7%20per%20cent%20increase.

Jiang, C., & Zhang, A. (2014). Effects of high-speed rail and airline cooperation under hub airport capacity constraint. *Transportation Research Part B: Methodological*, *60*, 33-49.

Jiang, Y., Timmermans, H. J., Chen, C., Sun, J., & Yao, B. (2019). Determinants of air-rail integration service of Shijiazhuang airport, China: analysis of historical data and stated preferences. *Transportmetrica B: Transport Dynamics*, *7*(1), 1572-1587.

KiM (2018). *Substitutiemogelijkheden van Luchtvaart naar Spoor.* The Hague: Kennisinstituut voor Mobiliteitsbeleid.

KiM (2020). *Op de groene toer. De bijdrage van gedragsinterventies aan het verduurzamen van de luchtvaart.* The Hague: Kennisinstituut voor Mobiliteitsbeleid.

KLM (2020). *Het belang van mainport Schiphol.* Amstelveen: KLM.

KLM (2022a). Timetable Schiphol airport to Charles de Gaulle. Retrieved on 28-06-2022 from https://www.klm.nl/search/offers?pax=1:0:0:0:0:0:0:0&cabinClass=ECONOMY&activeConnection=0&connections=AMS:A:20221021%3ECDG:A-CDG:A:20221026%3EAMS:A&bookingFlow=LEISURE

KLM. (2022b). KLM en Thalys maken trein aantrekkelijker voor intercontinentale en Europese transferpassagiers. Retrieved on 22-06-2022 from https://nieuws.klm.com/klm-en-thalys-maken-trein-aantrekkelijker-voor-intercontinentale-en-europese-transferpassagiers/

Köhler, J., Whitmarsh, L., Nykvist, B., Schilperoord, M., Bergman, N., & Haxeltine, A. (2009). A transitions model for sustainable mobility. *Ecological economics*, *68*(12), 2985-2995.

Loorbach, D. (2010). Transition management for sustainable development: a prescriptive, complexity-based governance framework. *Governance*, *23*(1), 161-183.

Ministry of I&W (2020a) *Verantwoord vliegen naar 2050. Luchtvaartnota 2020-2050.* The Hague: Ministry of Infrastructure and Water Management.

Ministry of I&W (2020b) *Uitvoeringsagenda luchtvaartnota.* The Hague: Ministry of Infrastructure and Water Management.

Ministry of I&W (2020c) *State Action Plan for the Reduction of CO2 emissions from aviation* The Hague: Ministry of Infrastructure and Water Management.

MPIRPT (2022) *Better rail connections for Europe's passengers. A common agenda.* 2nd progress report 2022. Ministerial Platform on International Rail Passenger Transport.

NHnieuws (2019): Londen populairste bestemming vanaf Schiphol, kamer wil van Brusselvluchten af. Retrieved on 26-11-2021 from https://www.nhnieuws.nl/nieuws/241554/londen-populairste-bestemming-vanaf-schiphol

NOS (2022). KLM lost laatste deel coronalening af dankzij herstel luhctvaartsector. Retrieved on 05-07-2022 from https://nos.nl/artikel/2434663-klm-lost-laatste-deel-coronalening-af-dankzij-herstel-luchtvaartsector

NSinternational (2022). Treintickets. Retrieved on 25-02-2022 from https://www.nsinternational.com/nl/treinticketsv3/#/search/NLSHL/FRMLW/20220528/0704/1013?pax=A

Nykvist, B., & Whitmarsh, L. (2008). A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden. *Technological forecasting and social change*, *75*(9), 1373-1387.

Odyssee-Mure (2022). *Specific consumption.* Retrieved on 14-07-2022 from https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/specific-consumption.html

Parkhurst, G., Kemp, R., Dijk, M., Sherwin, H., 2012. Intermodal personal mobility: a niche caught between two regimes. In: Geels, F.W., Kemp, R., Dudley, G., Lyons, G. (Eds.), Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport. Routledge, New York, pp. 308–334

Peeters, P., Higham, J., Kutzner, D., Cohen, S., & Gössling, S. (2016). Are technology myths stalling aviation climate policy?. *Transportation Research Part D: Transport and Environment*, *44*, 30-42.

Prorail (2020). De international trein krijgt vleugels. Retrieved on 25-02-2022 from https://www.prorail.nl/nieuws/internationale-trein-krijgt-vleugels

Rijksoverheid (2020). Actieagenda trein en luchtvaart. Retrieved on 21-03-2022 from https://open.overheid.nl/repository/ronl-d37c462c-0506-4dd2-ba17-d888d65a9e50/1/pdf/bijlage-1-actieagenda-trein-vliegtuig.pdf

RLI (2020). *Verzet de wissel. Naar beter internationaal reizigersvervoer per trein.* The Hague: Raad voor de Leefomgeving en Infrastructuur.

Román, C., & Martín, J. C. (2014). Integration of hsr and air transport: understanding passengers' preferences. *Transportation Research Part E*, *71*, 129–141.

Royal HaskoningDHV (2020). *Potentie AirRail substitutie ZWASH corridor.* Amersfoort: Royal HaskoningDHV

Royal Schiphol Group (2020). *Vision 2050 storyline.* Royal Schiphol Group.

RTLnieuws (2019). Een derde van vliegreizen niet verder dan 750 kilometer. Retrieved on 18-01-2022 from https://www.rtlnieuws.nl/economie/artikel/4935031/vluchten-schiphol-kort-750-kilometer-trein-emissie-milieu-co2

Schiphol (2016). Schiphol tweede hub-luchthaven ter wereld. Retrieved on 26-11-2021 from https://www.schiphol.nl/nl/adverteren/nieuws/schiphol-tweede-hub-airport-van-de-wereld/

Takebayashi, M. (2015). Multiple hub network and high-speed railway: connectivity, gateway, and airport leakage. *Transportation Research Part A: Policy and Practice*, *79*, 55-64.

Thalys (2021). Meer comfort, meer ruimte en minder CO2. Dat is mogelijk! Retrieved on 14-03-2022 from https://www.thalys.com/sites/thalys.com/files/2021-10/Persdossier%20Thalys%20NL.pdf

Thalys (2022a). Timetable Amsterdam central – Paris Nord. Retrieved on 14-03-2022 from https://www.thalys.com/be/nl/infos-diensten/dienstregeling/amsterdam/parijs?date=2022-03-19

Thalys (2022b). Timetable Paris Nord-Amsterdam central. Retrieved on 07-07-2022 from https://www.thalys.com/nl/nl/infos-diensten/dienstregeling/parijs/amsterdam?date=2022-07-26

Trainline (2022a). Brussels Midi to Paris Charles de Gaulle airport. Retrieved on 28-06-2022 from https://www.thetrainline.com/en/train-times/brussels-midi-to-paris-charles-de-gaulle-airport

Trainline (2022b). Brussels to Disneyland Paris Marne la Vallee chessy. Retrieved on 28-06-2022 from https://www.thetrainline.com/en/train-times/brussels-to-disneyland-paris-marne-la-vallee-chessy

Trouw (1999). minder binnenlandse vluchten, klm heft binnenlandse lijnen op. Retrieved on 26-11-2021 from https://www.trouw.nl/nieuws/minder-binnenlandse-vluchten-klm-heft-lijnen-met-groningen-en-enschede-op~b27b7a6a/?referrer=https%3A%2F%2Fwww.google.nl%2F

Van der Brugge, R., Rotmans, J., & Loorbach, D. (2005). The transition in Dutch water management. *Regional environmental change*, *5*(4), 164-176.

Wittmer, A., & Bieger, T. (2011). Fundamentals and structure of aviation systems. In *Aviation systems* (pp. 5-38). Springer, Berlin, Heidelberg.

Xia, W., & Zhang, A. (2017). Air and high-speed rail transport integration on profits and welfare: effects of air-rail connecting time. *Journal of Air Transport Management*, *65*, 181–190.

Appendices

Appendix 1: Codebook used for coding documents

Code Group	Code
Actor's goals	Airline goals
	Airport goals
	EU goals
	Government goals
	Railway operator goals
	User Goals
	Other actors goals
Barriers to integration	Competition
	Conflicting interests
	Difference in working practices
	Higher financial costs
	Infrastructure barriers
	Lack of dominant integration actor
	Legislative barriers
	Limited benefits
	Limited demand for integrated products
	Necessity for international action
	Negative environmental impact aviation
	Negative environmental impact HSR
	Promising other niches general
	Promising other transport modes
	Promising sustainable aviation fuel niches
	Reinforcing regime practices
	Service barriers
	Uncertainties for actors
	Other Barriers
Definition or airrail integration	Definition
Drivers for integration	Ability to accomodate increasing passenger demand
	Airport congestion
	Environmental benefits
	Financial benefits operators
	Financial benefits users
	Other niches failing
	Public pressure
	Service drivers
	Suitability Amsterdam-Paris
	Other drivers/benefits
Solutions to barriers	Different practice solution
	Environmental solution
	Financial solution
	Infrastructure solution
	Legislative solution
	Other solution

Appendix 2: Codebook used for coding interviews

Code Group	Code
Corridor	Corridor characterization
Effects	Effects of integration
Driver	Driver for integration
	Potential for integration
Need for attractive product	International competition & Profit
	Legislation
	Other need for attractive product
Barrier to integration	Code share and IT integration barrier
	Global different practice barrier
	Lack of driver
	Luggage barrier
	Promising other niches
	Quick transfer barrier
	Railway
	Train frequency/schedule barrier
	Other barrier
Opportunity for integration	Code share and IT integration opportunity
	Failing other niches
	Luggage opportunity
	Quick transfer opportunity
	Railway infrastructure
	Train frequency/schedule opportunity
	Other opportunity

Appendix 3: Interview guides

Interview guide: Knowledge institute for Mobility policy

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What does air-rail integration ideally look like in the future and what is your organization's goal regarding air-rail integration at the Amsterdam-Paris corridor

3. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
4. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
5. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
    b. Environment
6. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
7. What is needed to take away those barriers?
8. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
9. Is there anything else that is needed to stimulate air-rail integration?

10. Are there any questions you did expect me to ask, but that I did not ask?
11. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
12. Would you like to receive my research after it is finished?

Interview guide: KLM

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. How important is KLM's aerial connection between Amsterdam and Paris?
3. What does air-rail integration ideally look like in the future and what is KLM's goal regarding air-rail integration at the Amsterdam-Paris corridor?

4. What is KLM's experience with the air-rail product for Brussels-Amsterdam and Antwerp-Amsterdam?
5. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
6. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
7. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
8. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
9. What is needed to take away those barriers?
10. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration?
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
11. Is there anything else that is needed to stimulate air-rail integration?

12. Are there any questions you did expect me to ask, but that I did not ask?
13. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
14. Would you like to receive my research after it is finished?
15. Do you have any questions for me?

Interview guide: NS international

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What is NS international her role at the Amsterdam-Paris corridor?
3. What does air-rail integration ideally look like in the future and what is NS international's goal regarding air-rail integration at the Amsterdam-Paris corridor?

4. Is NS international involved with the air-rail product for Brussels-Amsterdam and Antwerp-Amsterdam and if yes, what are your experiences?
5. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it? How much does the train company profit?
6. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
7. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
8. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
9. What is needed to take away those barriers?
10. Within what time frame can the train schedule be adapted to better serve the air-rail product?
11. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
12. Is there anything else that is needed to stimulate air-rail integration?

13. Are there any questions you did expect me to ask, but that I did not ask?
14. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
15. Would you like to receive my research after it is finished?
16. Do you have any questions for me?

Interview guide: Council for the living environment and infrastructure

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What does air-rail integration ideally look like in the future and in what way has the council for the living environment and infrastructure researched air-rail integration at the Amsterdam-Paris corridor

3. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
4. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
5. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
6. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
7. What is needed to take away those barriers?
8. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
9. Is there anything else that is needed to stimulate air-rail integration?

10. Are there any questions you did expect me to ask, but that I did not ask?
11. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
12. Are there other people who I should approach to aid my research?
13. Would you like to receive my research after it is finished?
14. Do you have any questions for me?

Interview guide: Royal Schiphol Group

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What does air-rail integration ideally look like in the future and what is Schiphol's goal regarding air-rail integration at the Amsterdam-Paris corridor?

3. In what way is Schiphol involved with air-rail integration at the Amsterdam-Paris corridor?
4. What are Schiphol's experiences with the air-rail product for Brussels-Amsterdam and Antwerp-Amsterdam?
5. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
6. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
7. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
8. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
9. What is needed to take away those barriers?
10. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
11. Is there anything else that is needed to stimulate air-rail integration?

12. Are there any questions you did expect me to ask, but that I did not ask?
13. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
14. Would you like to receive my research after it is finished?
15. Do you have any questions for me?

Interview guide: Consultancy firm with expertise in air-rail integration

1. Can you tell something about yourself and how you are involved with air-rail integration

2. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
3. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
4. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
5. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
6. Where lies the main conflict of interest?
7. What is needed to take away current barriers?
8. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
9. Is there anything else that is needed to stimulate air-rail integration?

10. Are there any questions you did expect me to ask, but that I did not ask?
11. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
12. Would you like to receive my research after it is finished?
13. Do you have any questions for me?

Interview guide: Prorail

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What does air-rail integration ideally look like in the future and what is Prorail's goal regarding air-rail integration at the Amsterdam-Paris corridor?

3. Is Prorail involved with the development of the air-rail product for Amsterdam-Paris and if yes, what does Prorail do or is Prorail going to do?
4. What are Prorail's experiences with the air-rail product for Brussels-Amsterdam and Antwerp-Amsterdam?
5. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
6. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
    a. Passenger numbers → chance of success
    b. Is this (air-rail integration) going to be able to fully replace flights?
    c. How large do you estimate the environmental and climate profits?
7. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
    a. Is air-rail integration a good development?
8. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
    a. Lacking infrastructure
    b. Cooperation
    c. Lack of demand
    d. Lack of driver
9. What is needed to take away those barriers?
10. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
    a. Cleaner aircraft
    b. Hyperloop
    c. Other niches
11. Is there anything else that is needed to stimulate air-rail integration?

12. Are there any questions you did expect me to ask, but that I did not ask?
13. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
14. Would you like to receive my research after it is finished?
15. Do you have any questions for me?

Interview guide: Thalys

1. Can you tell something about yourself and about how you are involved with the air-rail integration subject on the Amsterdam-Paris corridor
2. What role does Thalys play on the Amsterdam-Paris Corridor
3. How do you foresee an integrated air rail journey, and what is Thalys's goals regarding air-rail integration

4. Are you involved with the air-rail product on Brussels-Amsterdam and Antwerp-Amsterdam and if yes, what are your experiences?
5. What are the main benefits originating from air-rail integration? Who benefits the most? How much does Thalys benefit from the air-rail product?
6. How large do you consider the potential of air-rail integration on the Amsterdam Corridor?
   - Passenger numbers, will it succeed?
   - Will it be able to fully replace flights?
   - How large do you estimate the eventual environmental benefit?
7. Do you see any negative consequences arise as a result from air-rail integration??
   - Is air-rail integration a good development?
8. What are the biggest barriers for air-rail integration on the Amsterdam Paris corridor?
   - Infrastructure
   - Cooperation with other parties
   - Limited demand
   - Lack of incentive
9. What is needed to take away those barriers?
10. Is it easy to change train schedules so that air-rail integration becomes easier?
11. Are there, apart from previously mentioned barriers, other developments that prohibit air-rail integration?
    - Clean aircraft
    - Hyperloop
    - Other niches
12. What else is needed to stimulate air-rail integration?

13. Are there questions I have not asked but that you did expect to get?
14. Are there any other things that have not been mentioned in this interview, but which are important for my research?
15. Would you like to receive my research after it is finished?
16. Do you have questions for me?

Interview guide: Ministry of Infrastructure and Water management

1. Can you tell something about yourself and about how you are involved with air-rail integration?
2. What does air-rail integration ideally look like in the future and what is the ministry's goal regarding air-rail integration at the Amsterdam-Paris corridor?

3. Wat are, from your perspective, the main drivers for air-rail integration at the Amsterdam-Paris corridor? What are the main benefits and who profit from it?
4. How large is the potential for air-rail integration at the Amsterdam-Paris corridor?
   a. Passenger numbers → chance of success
   b. Is this (air-rail integration) going to be able to fully replace flights?
   c. How large do you estimate the environmental and climate profits?
5. Do you see any negative effects that could emerge from air-rail integration at the Amsterdam-Paris corridor?
   a. Is air-rail integration a good development?
6. Wat are the main barriers to air-rail integration at the Amsterdam-Paris corridor?
   a. Lacking infrastructure
   b. Cooperation
   c. Lack of demand
   d. Lack of driver
7. What is needed to take away those barriers?
8. Are there, apart from the already mentioned barriers, other developments in the (aviation) transport industry that prohibit and/or slow down the development of air-rail integration
   a. Cleaner aircraft
   b. Hyperloop
   c. Other niches
9. Is there anything else that is needed to stimulate air-rail integration?

10. Are there any questions you did expect me to ask, but that I did not ask?
11. Are there any other matters that have not been discussed in this interview, but which are important to the subject of air-rail integration?
12. Do you know other people whom I could approach for an interview regarding air-rail integration at the Amsterdam-Paris corridor?
13. Would you like to receive my research after it is finished?
14. Do you have any questions for me?