Towards Air and Rail Integration

Assessing the Preferences of Dutch Travellers for Multi-legged Journeys

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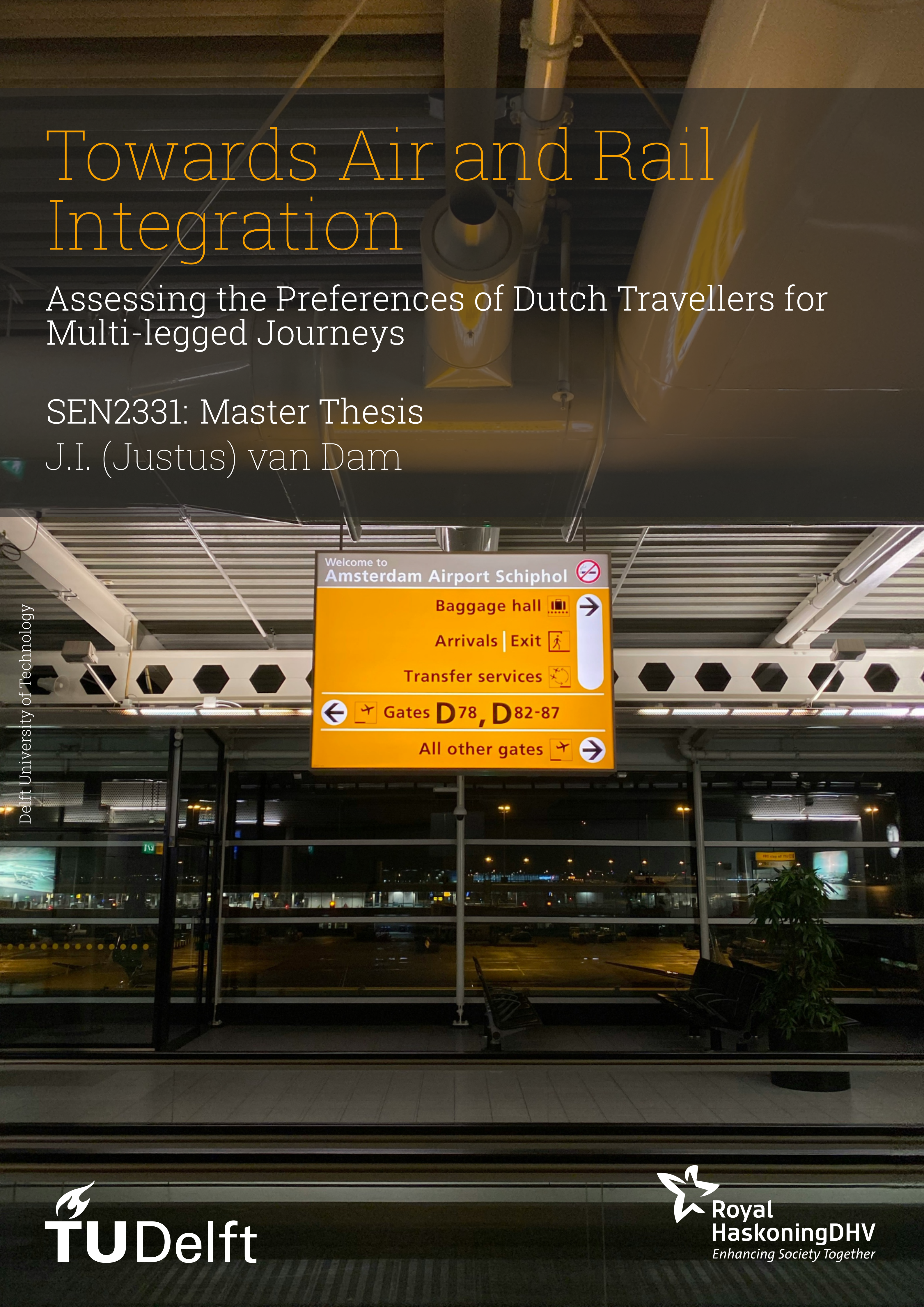
J.I. (Justus) van Dam



Delft University of Technology

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Royal HaskoningDHV
Enhancing Society Together

Towards Air and Rail Integration

Assessing the Preferences of Dutch Travellers for Multi-legged Journeys

by

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Preface

Before you lies the Master thesis ”Towards Air and Rail Integration: Assessing the Preferences of Dutch Travellers for Multi-legged Journeys”, which was written in fulfilment of the Master’s program Complex Systems Engineering and Management at Delft University of Technology. Over the past few months, I have enjoyed delving into the integration potentials of air and rail transport. The trigger for this research was an article that had come up in my Google ads by my algorithm. It was about that KLM had bought extra seats on the Thalys for transfer passengers, in order to reduce the number of flights to Brussels. That such a simple article could lead to such a research is something I could never imagine.

Through this preface, I would like to thank my graduation committee. First of all, I would like to thank Eric Molin for the guidance and feedback meetings. Never thought I would graduate in the field of stated preference, but I have appreciated it more and more during this thesis process. I would also like to thank Yilin Huang for her contributions. It was very nice to receive feedback from someone more distant from this subject, in order to avoid tunnel vision. Finally, I would like to thank Barth Donners, both for introducing me to Royal HaskoningDHV and for the always interesting insights and discussions during our meetings.

I hope you will enjoy reading this report and that it may trigger your curiosity about the field of air and rail integration,

J.I. (Justus) van Dam
Delft, August 2024

Executive Summary

Combining air and rail travel into one journey is being increasingly adopted in the network strategies of major airlines such as Air France-KLM and Lufthansa. This to reduce the amount of short-haul flights within Europe, in order to improve local air quality, reduce greenhouse gas emissions, and achieve Net Zero in 2050 (Andrejiová et al., 2020; Bory, 1999; European Commission, 2024; Givoni et al., 2012). **While literature is mainly focused on substitution of short-haul origin-destination travel, this study focuses on the integration of air and rail transport**. This is the adoption of high-speed rail, complementary to air transport, as spokes in the hub-and-spoke model of major airlines. This study is therefore not about direct origin-destination traffic, but scoped on travel itineraries involving two separate travel legs (i.e. multi-legged journeys).

Regarding air and rail integration, there is still a lack of understanding on what travellers value as important regarding potential services, comfort and other, more operational, travel determinants such as travel time and travel cost. **By quantifying the preferences of passengers, this study shows airlines, airports and other involved actors the importance of several air/rail features**. In order to explore the potentials of integrated air/rail travel, the following main research question is constructed:

How do travel decision determinants, socio-demographic characteristics and trip characteristics influence Dutch travellers' preferences for an integrated air and rail service for multi-legged journeys?

As it is currently unknown which service and comfort attributes are found important for air/rail journeys, a first-order identification is done via a comprehensive **literature review in combination with focus groups**. The focus groups were mainly used to verify the found attributes for service and comfort from literature, but as this topic is quite new, new attributes also emerged from the focus group discussions. The identified attributes for air/rail service and comfort are then introduced in **two separate rating experiments** in order to quantify the importance of those factors.

The attributes service and comfort, together with operational factors, are then introduced in a **mode choice experiment with two alternatives: air/rail vs. air/air journey**. This study used a stated preference survey as data collection technique. The survey was distributed among the Dutch Railways (NS) panel. A **multinomial logit model** has been used to analyse the data from the survey in order to estimate the beta coefficients for the utility functions, involving service, comfort, travel time of the train leg, time spend on the airport/ train station and the waiting time in case of a missed transfer. In extension to the multinomial logit model, a **latent class choice model** was estimated in order to capture unobserved heterogeneity among the response group. Based on the results of the latent class choice model, **scenarios** were created in order to estimate substitution ratios from air/air to air/rail for different classes, based on real-life cases.

The attributes considered in the **service rating experiment** were: **luggage integration**, **integrated ticketing**, **integrated information provision** and **integrated customer service** between air and rail. For the **comfort rating experiment**, the attributes included were: **priority lanes for air/rail**, **lounge availability for all air/rail passengers**, **WiFi availability** and **integrated loyalty programs** between air and rail. The respondents were faced with several configurations of these attributes and had to rate, based on a 1 to 5 scale, how attractive or comfortable the provided profile was perceived. In the end, 541 respondents fully completed the survey, including these rating experiments, but also the mode choice experiment. The response group consisted mainly of higher educated and working people, who on average, expressed a slight preference for the air/rail alternative with 53.0%.

From the service rating experiment, it is found that **integrated ticketing** for the entire air/rail journey is perceived as **most attractive**, twice as attractive as information provision and three times as attractive as luggage integration and integral customer service. Concluding from the comfort rating experiment, **travellers perceive the most comfort from having priority lanes for air/rail**. These priority lanes are considered for luggage check-in, security and passport control, in this study. This regression model is also specified for travellers with business purposes, who perceive more comfort from having priority lanes in comparison to those who travel for leisure purposes. However, this is effect is marginal, 0.1 on a total score of 5.0. Having a lounge available for all air/rail passengers also has a reasonable effect on the perceived comfort. Offering lounges in combination with integrated loyalty programs has about the same effect as introducing priority lanes. Also, people tend to perceive more comfort from free WiFi which has less quality than payed WiFi which has a good quality, but the effect is marginal.

According to the results of the mode choice experiment where all parameters are assumed to be linear, **travel cost** remains the **most crucial determinant for choosing air/rail**. Also, the waiting time at the airport/ train station in an air/rail journey is considered to be important, as the effect is almost as high as for travel cost. It is also found that people mind less staying at an airport only than both at an airport and train station within a multi-legged journey. Travel time by train, in line with results from other literature studies, also remains a decisive factor for mode choice. However, it must be nuanced that this effect less than time spend at an airport and train station. The effect of delay in case of a missed transfer has the least effect on the mode choice. People extract more disutility for waiting for the next train or flight in an air/rail journey than waiting for the next flight in an air/air journey. **Comfort has the biggest positive impact for choosing air/rail**, followed by integrated services.

The **latent class choice model** identified three distinct customer groups: waiting time disfavourites, plane lovers and air/rail service admirers. **Waiting time disfavourites**, mostly students who have less international train travel and flight experience, show nearly **equal preferences** with 53.0% for air/rail and 47.0% for air/air. This group of travellers are most susceptible for service and comfort features, as a substitution rate from air/air to air/rail of 45.0% (equalling 147 passengers) can be achieved comparing the base case with no service integration and comfort with maximum integration and comfort for air/rail travellers. This in the context of a case of introducing an air/rail terminal at Frankfurt Airport. A similar pattern is also found in a case of introducing an air/rail terminal at train station Brussels-Midi by Air France-KLM. The **plane lovers predominantly prefer air/air** (85.1%) over air/rail (14.9%). Also, concluding from the scenario analysis, this group of passengers are reluctant in choosing air/rail, as a maximum substitution ratio of 27.2% can be achieved (indicating only 33 passengers of this group). The **air/rail service admirers have a strong preference for air/rail** with 97.9%, but is also the smallest group (91 respondents). According to the scenario analysis, a maximum substitution rate of 2.7% can be achieved, indicating only two passengers.

Overall, in the case of the air/rail terminal at Frankfurt Airport, a substitution ratio of 30.2% (163 passengers) can be achieved. In the case of Air France-KLM, with their terminal at train station Brussels-Midi, this ratio is 20.7% (184 passengers). However, **the biggest shift from air/air to air/rail can be realized among younger, less experienced travellers**, according to both real-life cases.

As also **discussed** by Weisshaar (2024), integrated ticketing is the most important service feature. However, luggage integration is also commonly considered as important (Chiambaretto & Decker, 2012; Román & Martín, 2014; van Alphen & Reijenga, 1998). Opposite to these studies, this study shows that this can be nuanced. To put this in perspective, setting up a helpdesk counter at an airport or train station has about the same effect on the perceived comfort than fully integrated luggage systems, which is way more costly. Information provision is also found to be important by this study, in line with van Alphen and Reijenga (1998). Travellers need transparency from the air/rail operator in order to make thoughtful decisions regarding mode choice. For airports and airlines, according to this study, opening priority lanes and lounges for all air/rail passengers are effective policies to increase substitution rates for air/rail. Regarding operational factors, travel time and travel cost remain important in the mode choice, in line with studies as Behrens and Pels (2012), Bergantino and Madio (2017), Kantelaar et al. (2022), and Weisshaar (2024). However, this study shows that travel time for the train leg specifically is more negatively than spending time at airports and train stations, and are thus weighted differently by the respondents.

Regarding the study's **limitations**, first, the small size of the focus groups may have constrained the depth of the discussions. Also, the use of the Dutch NS panel may have given biased results, as such a panel does not fully represent the Dutch population. This limits the generalizability of the obtained results. Regarding the concepts service and comfort, some attributes such as lounge accessibility or an integrated loyalty program are multi-interpretable, being either a service or comfort feature. This could potentially lead to inconsistencies if future studies hold other definitions. Also, a stated preference survey is always subject to a hypothetical bias, not accurately reflecting the real-life choices made by respondents. And at last, due to the exclusion of a direct flight option, the substitution rates from air/air to air/rail may be overestimated.

One recommendation for **future research** should be on distributing the survey among a more diverse population. Involving the International Air Transport Association (IATA), with its wide reach among various travellers would be an option in order to get more diverse response group regarding air travel. Incorporating environmental awareness by adopting the New Ecological Paradigm scale (NEP) would provide insights into the environmental perceptions of travellers, as environmental pollution of aviation is one driver for Net Zero 2050 by the European Commission. Using the outcomes of the latent class choice model would be valuable in capturing more heterogeneity and to discover the impact on the decision towards more environmentally friendly travel modes. Extending the scope of the research by including longer rail journeys (over 800 kilometers) in combination with long-haul flights could offer new valuable opportunities as well. Including a direct flight option instead of proposing two multi-legged journeys in future studies would help assess the substitution rate for air/rail, as a direct flight is mostly favoured by air travellers. At last, discovering the potentials for air/rail in the Netherlands, similar to TGV-Air in France and Lufthansa Express Rail in Germany, could gain insights in the potentials for an national air/rail service.

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1 Introduction

We like to fly, especially after the COVID-19 period. According to the numbers of Schiphol Group (2023), passenger transport at Schiphol Airport increased almost 200% from 20.9 million passengers in 2020 to 61.9 million passengers in 2023, which is almost equal to the pre-COVID-19 level of 71.1 million passengers in 2019. In four years, Schiphol almost totally recovered from the pandemic in terms of passenger numbers. With an average of 1365 flights per day, the numbers of Schiphol further address the challenge regarding climate change, as aircrafts are major emitters of greenhouse gases (GHGs) per travel kilometer (Donners et al., 2018; Schiphol, 2024). Airlines need support of policymakers and all involved actors in the value chain in order to achieve a sustainable transition, as Net Zero emissions is targeted by 2050 (European Commission, 2024). But how? An European high-speed rail network may be one piece of the puzzle with offering travellers a sustainable alternative for flying. This study explores the range of possibilities for airlines to integrate train travel into their business models.

1.1. Environmental Effects of Aviation

Air travel is one main contributor to environmental pollution due to excessive greenhouse gas emissions. Regarding the contribution of CO2 emissions, aircrafts are emitting ten times more CO2 per travel kilometer compared to more environmentally friendly transport modes such as high-speed rail (HSR) (Donners et al., 2018). The Paris Agreement of 2015 shows that 195 countries all over the world are willing to limit global warming well below two degrees Celsius caused by excessive CO2 emissions (United Nations, n.d.). However, according to recent forecasts, the demand for air transport will also grow with 4.3% per year for the next 20 years (International Civil Aviation Organization, n.d.). This addresses the need to switch to more sustainable modes of transport even more.

Moreover, aircrafts do not only impact the environment via CO2 emissions, but also via non-CO2 related emissions (Lee et al., 2018). These emissions of aircrafts contribute twice as much to global warming as direct CO2 effects (Transport & Environment, 2023). Other greenhouse gases such as nitric oxides (NOx), methane (CH4) and fluorinated gases are also affecting the environment, and more specifically, the air quality. In 2021, 97% of the European population was exposed to poor air quality and over 230.000 Europeans faced a premature death in 2020 due to poor air quality which may cause respiratory and cardiovascular diseases (Andrejiová et al., 2020; European Environment Agency, 2023).

In order to limit climate change and achieve Net Zero, the European Commission closed the European Green Deal which implies that transport emissions (compared to 1990 levels) need to be reduced with 90% by 2050 (European Commission, 2024). Therefore, the European Commission is endorsing the importance of a trans-European transport network (TEN-T) (European Commission, 2023a). This is to enable Europeans to make the switch to rail transport, which is a more sustainable transport mode compared to air travel.

1.2. Substitution of Short-haul Air Travel by High-speed Rail

Currently, only 5.1% of passenger mobility in the EU is provided by railways (European Council, 2024; Ritchie & Roser, 2023). With a trans-European transport network, the European Commission introduced an instrument in order to develop a coherent, efficient, multimodal and high-quality infrastructural network across Europe. This policy includes the construction of railways, waterways, short sea shipping routes and roads that connect urban centers, maritime and inland ports, airports and terminals (European Commission, n.d., 2023b).

With the aim to extend the European railway network, the possibilities to substitute short-haul air travel for high-speed rail is increasing. In literature, there are multiple studies that explore the potentials of air travel substitution by rail in order to reduce GHG emissions (Behrens & Pels, 2012; Chiambaretto & Decker, 2012; Cokasova, 2003; Donners et al., 2018; Givoni, 2007a, 2007b; Zanin et al., 2012). Currently, high-speed train journeys are attractive for journeys of two hours or less. However, with TEN-T, high-speed rail could also replace European flights within a range up to 800 kilometers (Kroes & Savelberg, 2019). The estimations for Schiphol Airport show that approximately 5.600 flights within Europe can be replaced in 2030 and 11.000 flights in 2040 (Durand & Romijn, 2023). This equals 0.8 to 2.4 million passengers per year shifting from short-haul air travel to high-speed train. However, this is only taking into account direct origin-destination travellers. Transfer passengers are not considered in these studies.

1.3. Transfer Passengers

Durand and Romijn (2023) also state that, in addition to reduced travel times and more daily travel options, if convenience of train travel for transfer passengers could be increased, the shift from air to train will increase to approximately 2.4 million air journeys per year in 2030 and 3.4 million per year in 2040. With only including thirteen high-speed train destinations from Schiphol, this would account for 18% (2030) and 22% (2040) of all air travel.

Schiphol, as well with all the other major airports in Europe, has a hub function for air travellers. In 2023, 36.3% of all passengers at Schiphol Airport were transfer passengers. However, looking at the major airline of Schiphol, KLM Royal Dutch Airlines, their share of transfer passengers was already 70% in 2022 (van de Hulsbeek & van der Parre, 2022).

Reducing the barriers between train and plane for transfer passengers will lead to a significantly higher shift in passenger numbers (Durand & Romijn, 2023). Barriers that emerge in the literature is the absence of integrated ticketing and baggage handling (Chiambaretto & Decker, 2012; Coogan et al., 2015; Givoni, 2007a; Givoni et al., 2012; Zhang et al., 2018). But are these features really found important by air and train travellers? There is no statistical ground for these claims yet in literature. And what about other features that are not considered in these studies regarding service and comfort?

Addressing these transfer barriers between plane and train requires effort from both airlines and train operators. These actors need to integrate their services in order to offer passengers who transfer from plane to train (and the other way around) the same experience as transferring from plane to plane.

1.4. Intermodality between Air and Rail

Instead of substituting direct origin-destinations flights by train, this study focuses on the integration of both the transport modalities into one intermodal transport system. Intermodal transport refers to a transportation system that integrates multiple modes of transport such as road, rail, air, and barge (Reis et al., 2013).

Passengers who travel at a hub mainly transfer between two flight legs. Some of these travellers have an origin and destination inside Europe and could, via TEN-T, replace their whole journey by train (i.e. direct substitution). However, a significant fraction of people who transfer at a hub in Europe have an origin or destination outside Europe. At Schiphol, the share of intercontinental flights was 30% (Schiphol Group, 2023). These passengers have a multi-legged journey containing one short-haul leg and one long-haul flight to another continent. If the short-haul leg is within Europe, it would be possible to replace this particular leg by train (i.e. partial substitution or integration).

According to Ministerie van Infrastructuur en Waterstaat (2021), approximately 32% of the total flights from Schiphol are less than 800 kilometers, which are classified as short-haul flights (Wilkerson et al., 2010). This means that almost one-third of the flights are within the spectrum that could potentially be replaced by train.

Direct substitution implies that airlines will lose market share on the short-haul origin-destination market, as their flights have less demand because travellers shift to train. Therefore, airports and airlines are hesitant to invest in the right infrastructure and services to accommodate high-speed train travel. However, with cooperation between airlines and train operators instead of competition, an intermodal transport system may have value for both airlines and train operators as it could attract new passengers for both markets, which is not taken into account in the current exploration of air and rail integration (Royal HaskoningDHV, 2020).

1.5. Research Gap

Current literature is mainly focused on substituting short-haul origin-destination air travel by train and on how train could compete with air travel in order to reduce the greenhouse gas emissions of aircrafts. Studies done by Chiambaretto and Decker (2012), Clewlow et al. (2014), Givoni (2007a), Xia and Zhang (2017), and Zanin et al. (2012) explore the possibilities of direct substitution of flights by high-speed rail and show that there could be significant improvements regarding emission rates. However, all these studies are focused on the origin-destination market. The possibilities for the transfer market are not yet explored, while the largest proportion of passengers from legacy carriers such as KLM are transfer passengers (van de Hulsbeek & van der Parre, 2022).

Studies on the integration of air and rail address that it could have value regarding the saturation of airport hubs, environmental benefits and social welfare, but are also focused on the operational burdens on how to integrate these services. Studies as Chiambaretto and Decker (2012), Coogan et al. (2015), and Givoni (2007a) state that luggage and ticket integration are important. But the current literature lacks studies that quantify these needs for integrated services from a passenger perspective. Studies as Barreira et al. (2013), Behrens and Pels (2012), and Bergantino and Madio (2017) show with case studies that travel determinants such as price, travel time, frequency and comfort are found important. Travel attributes such as price, travel and frequency are considered as more operational attributes, other than service and comfort, which are more passenger-specific. However, these are all studies on direct substitution, while with partial substitution, passengers are not choosing between air or rail but between an air/air and an air/rail journey. There is still no understanding for the needs regarding service and comfort as well as operational factors for integrated air and rail and how it influences travellers' preferences and how these attributes impact the choice between air/air and air/rail.

1.6. Societal Relevance

Apart from scientific relevance, this study also has societal relevance. This topic of air and rail integration has relevance for airlines, airports, train operators and national governments.

By quantifying the preferences of passengers, this study shows airlines the importance of specific service and comfort factors for an integrated air and rail service. This information could be used in order to optimize the travel experience of passengers. Namely, it provides insights for airports and airlines where to invest in. For example, Air France-KLM has opened an air/rail terminal at train station Brussels-Midi. This terminal offers Flying Blue members all the benefits which KLM also offers at Schiphol: earning member points, priority check-in, access to a lounge, extra luggage options and free access to upgrades on connecting flights (Somsen, 2024). However, there is no study that confirms the importance of these features, based on statistical analysis. This study shows airlines such as KLM what factors for air/rail are actually found important by travellers and how to attract them for air/rail. Based on this study, airlines have statistical ground for their policy decisions regarding air/rail.

This study is also relevant for European major airports and railway operators. Because of TEN-T, airports need to make significant investments in their train infrastructure to enable long-distance rail connections, but they are still reluctant. For example, actors such as airports (e.g. Schiphol Group) and rail operators (e.g. NS/ ProRail) are still hesitant to make strategic (or even painful) decisions that enable air/rail to be a credible alternative for flying (Ronald Verkaaik, 2023). These actors are not yet convinced of the benefits air/rail can offer them. With the results of this study, recommendations could be given to policymakers of both airports and train operators on how best to design this service from a traveller's perspective. This to make those painful decisions that are needed in order create a credible alternative for short-haul flights and get a step closer in achieving Net Zero in 2050.

Regarding Net Zero, substituting short-haul air travel by train may be one piece of the puzzle in reducing greenhouse gas emissions, according to Chiambaretto and Decker (2012), Clewlow et al. (2014), Givoni et al. (2012), and Xia and Zhang (2017). Studies done by Wang, Sun, et al. (2020) and Zanin et al. (2012) show with their case studies that introducing a high-speed rail alternative for air travel reduces air traffic and increases rail travel. This in order to reduce the excessive emission of CO2 and other greenhouses gases by aircrafts, thereby mitigating further global warming and improving the (local) air quality for Europeans (Andrejiová et al., 2020).

The results of this study could also be used to discover if travellers are willing to substitute a short-haul flight for high-speed rail. Apart from service and comfort features, also other travel determinants such as travel time, travel cost and waiting time in case of a missed transfer may be important. By examining the choice behaviour of passengers, this study gives insights on how to attract more passengers to high-speed rail and reduce the amount of short-haul flights. This catalyses the possibilities to solve other societal challenges such as the saturation of airport hubs, airport car congestion, but most dominantly, reducing aircraft emissions.

This study also takes a closer look into the potential market segments for air/rail. By capturing unobserved heterogeneity among passengers, market segments can be identified. Based on this kind of information, actors such as airlines, airports and train operators are enabled to target specific customer groups with tailor-made policies according to their specific needs.

At last, besides scientific and social relevance, this specific study also has company relevance. This study is in collaboration with Royal HaskoningDHV (RHDHV), and with the results of this thesis, their knowledge about a relatively new topic as air and rail intermodality increases. With the results of this study, both the air as rail department of RHDHV has new statistically based data to advice clients on how to integrate air and rail travel into one intermodal transport system.

1.7. Research Questions

The general aim of this study is to quantify the passenger needs for an intermodal transport system containing air and rail, stated in one overarching main research questions with five sub-questions:

How do travel decision determinants, socio-demographic characteristics and trip characteristics influence Dutch travellers' preferences for an integrated air and rail service for multi-legged journeys?

1. What are important decision factors influencing the service level of air/rail from the perspective of Dutch travellers?
2. What are important decision factors influencing the comfort level of air/rail from the perspective of Dutch travellers?
3. What is the impact of operational travel decision determinants on the choice for an integrated air/rail service?
4. Which demand segments can be identified for an air/rail vs. air/air mode choice?
5. What are the predicted substitution rates for different choice scenarios between air/rail and air/air journeys?

1.8. Methods

The first part of this research is to estimate regression coefficients for service and comfort attributes of air/rail with a regression analysis.

The second part aims to capture individuals' preferences for an integrated air/rail product for multi-legged journeys by using a survey to allow respondents to trade-off hypothetical choice scenarios. This will be done with a discrete choice experiment (DCE), whereafter the parameters will be estimated with a multinomial logit model.

The last part is to identify market segments by using a latent class choice model and estimate substitution rates from air/air to air/rail by doing a scenario analysis. **Table 1.1** shows the used research method(s) per sub-question. The research methodology is further elaborated in **Chapter 3**.

Table 1.1: Research method(s) used per sub-question

Sub-question	Research method(s)
(1) What are important decision factors influencing the service level of air/rail from the perspective of Dutch travellers?	Rating experiment, Regression analysis
(2) What are important factors influencing the comfort level of air/rail from the perspective of Dutch travellers?	Rating experiment, Regression analysis
(3) What is the impact of operational travel decision determinants on the choice for an integrated air/rail service?	Discrete choice experiment, Multinominal logit model
(4) Which demand segments for mode choice can be identified for an air/rail vs. air/air mode choice?	Latent class choice model
(5) What are the predicted substitution rates for different choice scenarios between air/rail and air/air journeys?	Latent class choice model, Scenario analysis

1.9. Thesis Outline

This thesis is structured as follows. At first, the concept of an integrated air and rail journey will be elaborated in more detail in **Chapter 2**. **Chapter 3** explains the methodology which is applied in this study. Afterwards, the existing literature about air and rail intermodality is discussed and conceptualised in **Chapter 4**. Next, based on the conceptual model, the survey will be designed **Chapter 5**. The received data from the survey is analysed in **Chapter 6**. **Chapter 7** shows and discusses the model results. Next to the estimation of model parameters, several choice scenarios are explored in **Chapter 8**. At last, key conclusions are drawn and discussed in **Chapter 9**, next to the limitations and recommendations for future research of this study.

2

Air and Rail Integration Concept

This chapter dives into the concept of air and rail integration. In order to give some context, **Section 2.1** introduces the concept of the Trans-European Transport Network. **Section 2.2** explains the difference between substitution and integration in further detail. **Section 2.3** discusses how air/rail can be valuable for the airline business model of legacy carriers, and **Section 2.4** explains the difference between an air/air and an air/rail journey.

2.1. Trans-European Transport Network

With the environmental concerns of aviation in mind, short-haul flights within Europe are getting more criticized (Yuksel, n.d.). With the introduction of TEN-T, itineraries involving short haul flights could be replaced by rail transport. The intended plans regarding the extension of current infrastructure for TEN-T is shown in **Figure 2.1**.

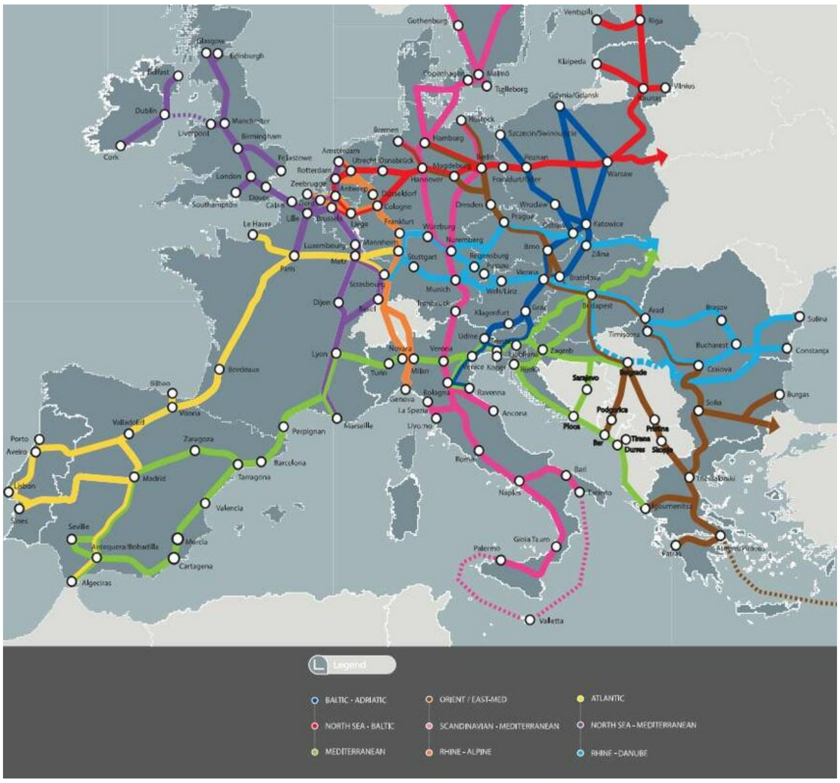


Figure 2.1: Trans-European Transport Network (Kumrić et al., 2017)

But before TEN-T can be achieved, different burdens are needed to take care of, both from the passenger as operational point of view. Besides the shortcomings from the passenger perspective regarding travel time, travel costs, transfer time, delay, service and comfort features, there are also operational shortcomings with the current infrastructure such as track characteristics, safety systems and power supply.

The problem mainly occurs when creating new corridors and networks across borders of different countries. Having a high-speed rail network inside one country is already proved to be effective, with Italy, France and Spain as examples (Bergantino & Madio, 2017; Pagliara et al., 2012; Wang, Sun, et al., 2020). However, when creating new corridors across borders, it requires coordination from different actors like municipalities, local governments and national governments from different countries that make it more complicated to set agreements (Priemus & Zonneveld, 2003). In addition, with new generations of infrastructure, the theory of corridors of Whebell (1969) come into play. New generations of infrastructure are often located near older systems and sometimes even on top of older systems. Therefore, the development of a corridor is highly path-dependent (Whebell, 1969). Decisions made in the past may have direct impact in today's development.

2.2. Substitution vs. Integration

Air and rail substitution, in this study, refers to the concept that travellers have an option to choose between air and rail travel for the same trip. Passengers are enabled to substitute one mode of transportation for the other, based on their preferences. In this study, this is classified as direct substitution where passengers' journey from origin to destination contains only one single leg of transportation. In this case, rail and air transport are two competing transport modes. The concept of substitution is shown in **Figure 2.2**.

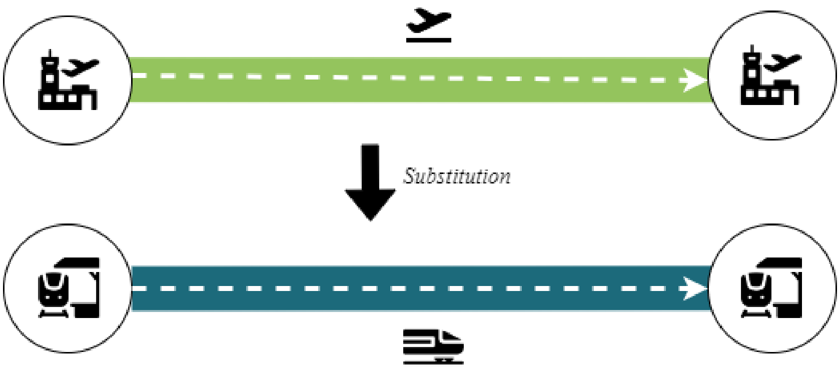


Figure 2.2: Substitution of air travel by rail, based on Bruinsma (2023)

However, the focus of this study is on integration. Air/rail integration (also known as partial substitution) refers to the idea that air and rail are both integrated in an intermodal transportation system. Rather than having competition between air and rail, there is cooperation, making it one intermodal transport system. In this case, there is will be competition between an air/air and air/rail journey. The concept of integration is shown in **Figure 2.3**

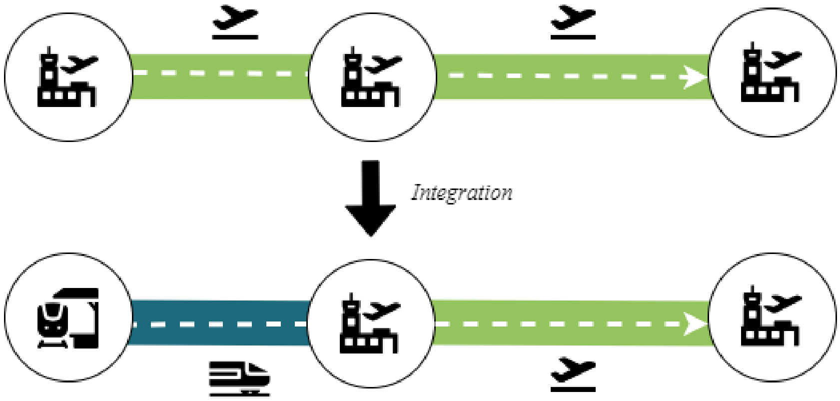


Figure 2.3: Integration of air and rail, based on Bruinsma (2023)

2.3. Air/rail and the Hub-and-spoke Model

In order to understand why a combined air and rail service may be interested for airlines to integrate in their business models, a more detailed explanation is needed about how airlines operate.

In theory, there are two types of airlines: low-cost carriers and legacy carriers. Low-cost carriers are, by the definition of Alamdari and Fagan (2005), aiming for origin-destination travellers that have a journey containing only one single flight leg. The architecture of such a network of a low-cost carrier is shown in **Figure 2.4**.

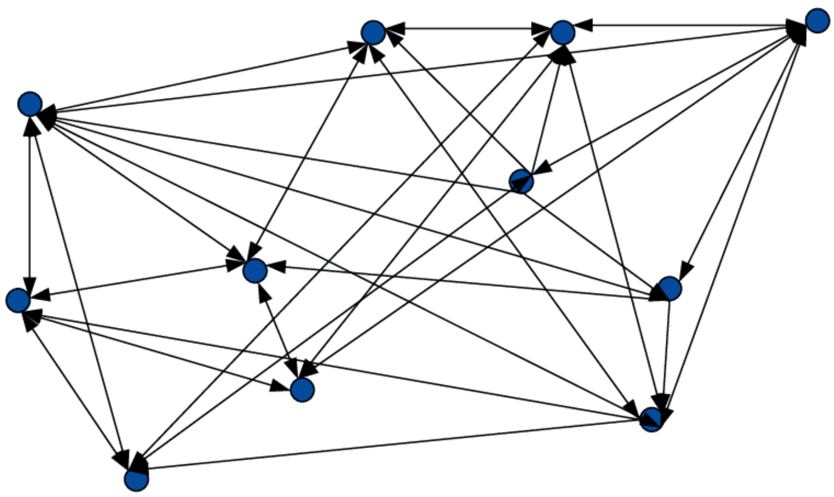


Figure 2.4: Point-to-point network (Borhani et al., 2020)

This point-to-point network is, according to the theory of Alamdari and Fagan (2005), mostly used by low-cost carriers (e.g. Ryanair, easyJet and Transavia). Low-cost carriers are focused on cutting costs by flying with high frequencies within their point-to-point network with direct flights. Now, the concepts of point-to-point network and direct substitution of air travel can be linked. If high-speed rail could substitute a certain flight leg, it suggests that one specific edge (double black arrow in **Figure 2.4**) between two nodes (blue dots in **Figure 2.4**) of the point-to-point network could be removed. This would lead to a loss of market share for the low-cost carriers operating on those edges and thereby competition between the carrier and train operator will start.

However, this is not the case for legacy carriers. Airlines such as KLM, Lufthansa and British Airways are using a different network strategy: a hub-and-spoke network. This type of network strategy is facilitating the strategy of bringing passengers from origin to destination, via a hub (which could also be a destination). This concept is shown in **Figure 2.5**.

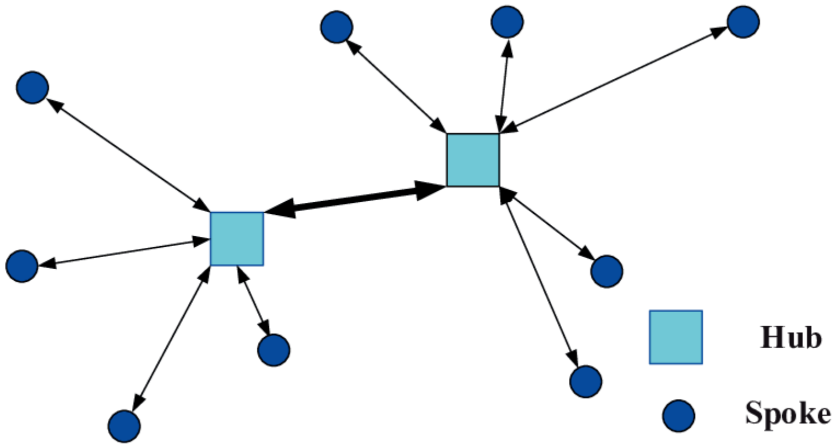


Figure 2.5: Hub-and-spoke network (Borhani et al., 2020)

The focus of legacy carriers is, opposite to low-cost carriers, not to focus on origin-destination travellers but on transfer passengers. Their focus is to bridge passengers with a high willingness to pay (WTP), commonly business travellers, to their hub and consolidate them on a long-haul flight (to another hub) in order to reduce operational costs (Dobruszkes, 2006; Kouwenhoven et al., 2014). By bringing passengers with a high WTP from more remote locations (i.e. the spokes), these carriers extract the most benefit from the economies of density (Pels, 2008). So, it can be concluded that low-cost carriers and legacy carriers are thus not in competition with each other, as they operate in different markets. Linking the hub-and-spoke model to air/rail integration, instead of having a short-haul flight as a spoke in the network of legacy carriers, the train leg could substitute the function of being a feeder for long-haul flights on the spokes.

2.4. Air/rail vs. Air/air Journey

The last part of this chapter contains an analysis that visualises the elements of a trip a traveller is facing: customer journey mapping. This analysis explores the difference between an air/rail and an air/air journey, from the perspective of a passenger. By comparing both road maps, potential challenges and focus points could be addressed. The first customer journey map is for a traveller with an air/air journey, as shown in **Figure 2.6**.

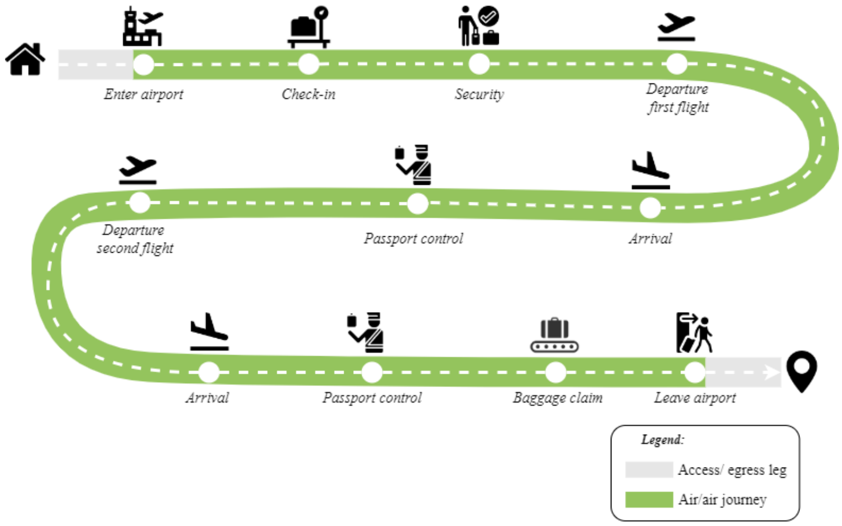


Figure 2.6: Customer journey map air/air journey

For an air/air journey, the trip starts with traveling from home to the airport. This first segment, known as the access leg, varies for each traveller because everyone has different travel distances, travel times, and modes of transportation to reach the airport. Therefore, this part of the journey is excluded from the scope of this research. The same applies to the egress leg, where the traveller goes from the airport to their final destination.

Figure 2.6 shows a so-called outbound journey, from home to destination. For example, a traveller would fly from Amsterdam to Paris and transfers on a flight to Sydney, Australia. Because the first flight is within Schengen countries, the passenger follows the general procedure of luggage check-in (if necessary) and security checks without any passport controls. After the first (short-haul) flight, the passenger needs to go through passport control in order to get on the second intercontinental (long-haul) flight to Sydney. After arrival, another passport control and possible luggage claim, the passenger leaves the airport towards the final destination.

For the way back (inbound), from destination back to home (e.g. Sydney to Amsterdam, via Paris), the traveller arrives at the departure airport and follows the general procedure of luggage check-in, security and passport control and departs back to Europe. Arriving in Paris, the passengers faces another passport check and then boards the second inter-European flight to Amsterdam. In Amsterdam, because of Schengen, the passenger only needs to claim the luggage and could leave the airport.

Important to notice is that, after the travellers pass security before the first flight, they leave the landside of the airport and enter the airside. The landside is the area of the airport which is accessible for public, where airside refers to the area accessible for only passengers and airport staff, after security. This is not the case for air/rail journeys and therefore the customer journey map looks somewhat different, as shown in **Figure 2.7**.

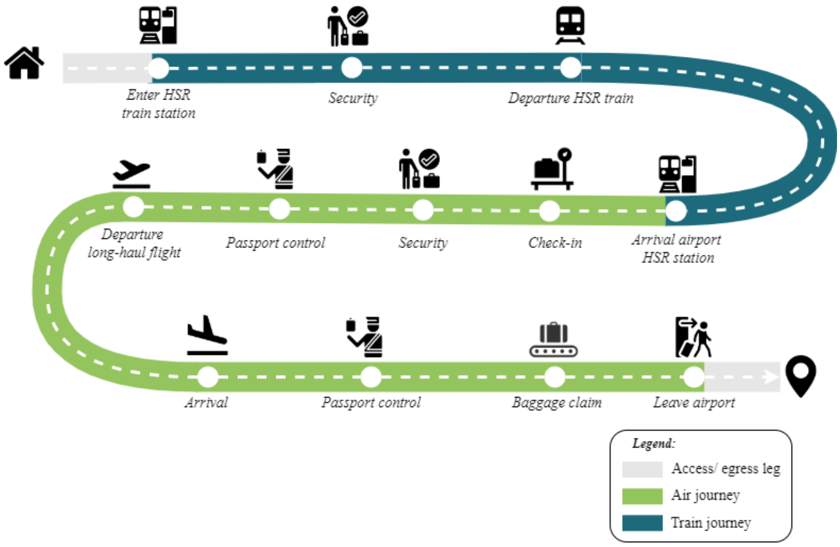


Figure 2.7: Customer journey map air/rail journey

Figure 2.6 also shows an outbound journey, the only difference here is that the first flight leg is replaced by train. For example, a traveller would travel with a high-speed train from Amsterdam to Paris and transfers on a flight to Sydney.

At first, the passenger needs to travel to the high-speed rail station (access leg). After entering the station in Amsterdam, normally, security must be passed next. However, from Somsen (2024), it is clear that KLM also invests in luggage drop-off facilities. In the future, it could be possible that, similar to air travel, that luggage drop-off could be a valuable addition. KLM also invested in facilities after security with waiting lounges for Flying Blue members. These are facilities that may improve the service and comfort levels of passengers and incentives them to take the train more often.

After arriving to the train station at the airport in Paris, the passengers leave the train and need to check-in luggage if the service is not integrated and pass security. A feature that may be interesting is to let passengers go through priority lanes regarding check-in, security and passport control on the airport in order to have accommodate the short transfer time of 50 minutes that is promised by KLM (KLM Royal Dutch Airlines, n.d.-c).

For travelling from a destination to home (inbound), it is the other way around. Passengers head to the departure airport, drop off luggage, go through security and passport control and board a long-haul flight back to Europe. After arrival, they leave airside via passport control and luggage claim and transfer to the high-speed train on landside. After security checks, passengers head back to the train station near their hometown.

Concluding from this analysis, the main difference between air/rail and air/air is the transfer that passengers need to make. When making an air/air journey, passengers always stay on the airside of the airport. While, in an air/rail journey, passengers need to transfer between landside and airside. The valuation of features such as ticket integration, luggage integration, priority lanes and loyalty programs need to be quantified in order to know how air/rail can become more attractive.

3 Methodology

This chapter explains the methodology of this study. **Section 3.1** explains how the search for relevant literature research is done. **Section 3.2** introduces another qualitative data collection method used in this research: focus groups. **Section 3.3** is about the stated preference survey, which is a quantitative way of collecting choice data. **Section 3.4** introduces the choice models that have been used for estimating attribute parameter values.

3.1. Literature Review

The purpose of doing a literature review is to identify research gaps. But in order to be able to discuss literature, relevant research papers must be derived from trustworthy sources. For this research, Google Scholar was selected as the primary platform for deriving relevant research papers. Google Scholar stands out as a reliable search engine for academic research due to its extensive database and its user-friendly interface. Also, Google Scholar covers a wide-range of both peer-reviewed research papers as (inter)national reports from, for example, the Dutch Government or the European Commission.

For identifying relevant articles, search strings are conducted to identify research papers and reports related to air/rail intermodality. Search strings are specified queries with search operators such as ”AND” and ”OR”. In this study, two separate search strings are conducted.

The first string is to identify current literature on the air/rail product. This to identify general information about environmental potentials, bottlenecks and some common passenger preferences. The specific search string used for this particular query is: (”air/rail” OR ”air-rail”) AND (”sustainability” OR ”sustainable” OR ”innovation” OR ”substitution” OR ”substitute” OR ”integration”). After abstract searching and reading several papers, the papers that are fit for reviewing are shown and discussed in **Section 4.1.1**.

The second string is more specific, focussing on the research method used in this study. In order to identify research gaps, it is necessary to see what literature on this topic already exists, using stated choice experiments. Therefore, the next search string is conducted: (”stated choice” OR ”stated preference” OR ”choice model” OR “discrete choice” OR “discrete choice experiment”) AND (”air/rail” OR ”air-rail”). This query generates many papers, but after abstract searching for identifying the relevance, several papers are extracted and discussed in **Section 4.1.2**.

However, this research also includes grey literature sources such as reports from companies, governments and newsletters. This to get access to local knowledge, understanding definitions and recent developments around air/rail intermodality. For this research, non-peer reviewed company reports, theses and other local projects are used to extract information from. These are shown and discussed in **Section 4.1.3**.

3.2. Focus Group Research

Apart from a literature review, another qualitative data collection method is employed for this research: focus groups. A focus group consists of a group of people that share similar characteristics or interests with a moderator that facilitates the conversation (Krueger, 2002). It is used as an extension to the literature review in order to get more in-depth information about travel attributes for air/rail integration.

As this study covers both air as rail modality, two separate focus groups are held. In collaboration with Royal HaskoningDHV, a company specialised in both railway as aviation consultancy, three to four experienced air and rail travellers are gathered to be in one of the focus groups. Both groups discuss which travel attributes for them are considered as important for choosing integrated air and rail transport. In this way, from two different perspectives, potential important travel attributes for air/rail are collected.

The advantage of focus groups are that they are quick and easy to set up. Also, because of the group dynamics, focus groups may provide more in-depth insights that can't be provided by individual or group interviews. With focus groups, more participants are involved that can share knowledge from their own experiences or personal perspective. And as air/rail is a relatively new topic, the more in-depth information about passenger attributes, the more value this study could have. **Table 3.1** sets out the differences between focus groups and group interviews.

Table 3.1: Differences between focus groups and group interviews (Krueger, 2002)

Method	Rationale	Interaction	Data	Depth
Focus groups	Designed to facilitate interaction	Between participants	Group discussion and debate	Topic is explored in depth
Group interviews	Quicker way to interview than using individual techniques	Between moderator and participants	Individual responses	Topic ranges widely

However, as both focus groups participants are experienced travellers for either air and rail transport, groups may be biased towards a certain travel mode. Therefore, it is important to consider focus groups complementary to a comprehensive literature review and not as a stand-alone data collection method. This in order to reduce the impact of a response bias (McGrath et al., 2010).

3.3. Stated Preference Survey

3.3.1. Stated vs. Revealed Preference

Before choice models can be estimated, quantitative data is needed on the choice behaviour of travellers. There are two ways to obtain data, either via revealed preference (RP) or via stated preference (SP). Wardman (1988) describes that using SP data has several advantages over RP data in the analysis of travel behaviour. One main advantage using SP is that non-existing transport alternatives can be evaluated in hypothetical choice scenarios. This is not possible with RP data, which relies on existing choice data. As this study considers an integrated air/rail service, there is no existing choice data available yet. Therefore, in this study, SP data will be gathered via a stated preference survey.

However, there are also drawbacks using SP data over RP data. Wardman (1988) describes that in an ideal world, a comparison could be made between stated preferences and observed choices at the right place on the right time. However, this is often not the case. Therefore, doing a SP research, the researcher must be aware of the hypothetical bias. Individuals' hypothetical preferences may not correspond to their actual preferences (Wardman, 1988). Choices made in a stated preference survey have no real consequences, while in real life, the consequences may influence the decision of an individual. In order to mitigate, nine recommendations are given by Ben-Akiva et al. (2019). Four relevant mitigation strategies for this study are addressed below.

- **Familiarity**: Subjects of the study (i.e. respondents) should be familiarized with the air/rail concept. As the air/rail modality is assumed not to be known by the respondents, a comprehensive introduction will be given before the start of the survey.
- **Sampling, Recruitment, Background**: The sample should be as representative as possible for the population. Therefore, the socio-demographic characteristics of the response group will be compared with data from the Central Bureau of Statistics (CBS) about socio-demographic characteristics of the Dutch population.
- **Attribute Formatting**: This study includes two alternatives and does not include more than six main attributes per travel mode option. Otherwise, the amount of travel attributes may be too much to trade-off for respondents.
- **Menu Design**: In order to assure orthogonality, equidistance between attribute levels is assured. Ngene (software tool) is used to construct experimental designs that maximise information about trade-offs and minimize standard errors of parameters with the same number of respondents compared to orthogonal designs.

3.3.2. Discrete Choice Experiment

This study uses a particular form of the stated preference method: discrete choice experiment (DCE). A DCE is a survey-based experimental design where respondents are presented with a series of hypothetical scenarios (Szinay et al., 2021). Important in a DCE is constructing the set of alternatives (choice sets). But before constructing, it is necessary to select travel attributes and their attribute levels. The attributes will be derived from literature and focus groups, and the attribute levels are chosen in a range in which the respondent still can relate to it. This in order to be able to construct a range of choice scenarios later on. Important to notice is that equidistance among attribute levels should be guaranteed in order to assure orthogonality (i.e. zero correlation between attributes). This results in lower standard errors and thus more reliable model estimates. This study considers three experiments: two rating experiments and one mode choice experiment.

The first rating experiment is about the services of an air/rail product and the second rating experiment is about air/rail comfort. The outcomes of both experiments are analysed using a linear regression model, assuming that the scale of both rating experiments are continuous. Both attributes (service and comfort) are complicated to determine because several determinants are expected to contribute to these attributes. These attributes may be valued differently for each individual. If all determinants of these attributes would be included in the mode choice experiment, there would be too much attributes to trade-off for the respondent (Ben-Akiva et al., 2019).

In order to overcome information overload and respondent burden, Hierarchical Information Integration (HII) is suggested by Molin and Timmermans (2009). This theory works under the premise that decision-makers, when presented with numerous attributes during a choice task, organise them into a smaller set of decision constructs. In a sub experiment, respondents trade-off the determinants of that decision construct with a rating score. In the mode choice experiment, the respondents are presented with the different scores in a so-called bridging experiment (Molin & Timmermans, 2009). This study adopts this HII concept by introducing two sub experiments.

The mode choice experiment will have a labelled form, as the choice alternatives will display different modes of transport: air/air vs. air/rail. A labelled experiment allows the researcher to estimate alternative specific parameters. A labelled form is chosen over an unlabelled form, because for unlabelled alternatives, the label does not play a role in the choice and is generalised (Rose & Bliemer, 2009). Moreover, if the respondents have to choose between air/air or air/rail in real life, they will know the labels of the travel mode options. Therefore, in this study, it is chosen to label the alternatives. How this reflects regarding the choice sets and chosen (alternative specific) attributes is discussed in **Chapter 5**.

3.4. Choice Models

3.4.1. Introduction to Choice Models

A DCE is a method for collecting data on respondents' choice behaviour and can be analysed through discrete choice modelling. Conceptually, discrete choice models are representing the econometric modelling paradigm. This holds the premise that travel behaviour is the outcome of a rational choice process. These discrete choice models are based on the assumption that people are random utility maximisers (RUM) (Ben-Akiva et al., 2019; Greene, 2009). The alternative with the highest utility will be chosen. For example, in the case of two alternatives (i.e. i and j, binary choice), person n chooses the option that maximizes the utility U, from the full set of alternatives where i is not equal to j. This is expressed in **Equation 3.1**. **Note: Equation 3.1**, **3.2** and **3.3** could also be specified for person n with a subscript.

$$U_i > U_j, \quad i \neq j, \quad \forall i, j \in Alternatives \tag{3.1}$$

Equation 3.1 holds the assumption that the decision-maker has perfect information about the alternatives and is completely rational in its decision. However, when obtaining data, only the observed choices can be analysed because there is no perfect information. In order to model the uncertainty in the data, utility functions have a deterministic, observed, part V and an error component ϵ. The error term captures the uncertainty by capturing the utility contribution of choice attributes that are not included in the choice model (Ben-Akiva et al., 1999). For alternative i, the utility function is shown in **Equation 3.2**

$$U_i = V_i + \epsilon_i, \quad \forall i \in Alternatives \tag{3.2}$$

The respondent will trade-off every single attribute of an alternative, and therefore, every attribute of an alternative (ik) gets a weight factor β_k. The deterministic part of the utility function of an alternative i is thus determined by the weighted importance of attributes in a choice set. This can be expressed as done in **Equation 3.3**.

$$V_i = \sum_{k=1}^{k} \beta_k \cdot X_{ik} \tag{3.3}$$

3.4.2. Multinomial Logit Model

One discrete choice model is the multinominal logit model (MNL), which based on maximum likelihood estimation and is one of the most used models in literature studies. The formulation of the MNL model is shown in **Equation 3.4**. It calculates the probability that a respondent n chooses alternative i in choice set C ($P(i|C)$) (also here, the subscript for identifying an individual n is left out of the equation).

$$P(i|C) = \frac{e^{V_i}}{\sum_{j=1}^{j \in C} e^{V_j}} \tag{3.4}$$

In order to obtain elegant logit probabilities, the MNL model assumes that the error term is Extreme Value Type I and independently and identically distributed (IID) across observations and alternatives (Ben-Akiva et al., 1999; Huffman & McCluskey, 2017). This means that the error term of the utility function consist of uncorrelated unobserved factors over all alternatives and observations. However, this may be unrealistic because alternatives often share unobserved factors that matter and thus correlate. Ignoring these correlations may lead to biased estimates.

Also, MNL postulates that the addition of a third alternative is irrelevant for for the substitution ratio predictions for the other two alternatives. This is also known as the independence of irrelevant alternatives (IIA) property. This means that the popularity of two alternatives does not depend on a third one. However, in real-life, the addition of a third alternative may shift the likelihood of choosing one of the other alternatives.

At last, MNL does also not account for panel effects. This means that there is correlation in the sequence of choices of the same individual. In this case, there is more data assumed in the dataset than there actually is, leading to underestimated standard errors and thus biased estimates. A more practical example, if a respondent has aversion to travelling by train, the respondent will most likely omit every alternative where train travel is involved in the choice sets, while the MNL model does not account for this effect.

Concluding, the MNL model offers, due to its assumptions, an elegant way of obtaining logit probabilities. But the researcher should always be aware of the fact that these assumptions may be unrealistic in real-life choice situations. One way to overcome the limitations of the MNL model by using the mixed logit model (ML). The ML model accounts for:

1. Unobserved utility across similar alternatives
2. Unobserved taste heterogeneity across people
3. Correlation in utilities between choice observations of the same individual

However, ML models are computationally more demanding to estimate in comparison to MNL models. ML models include parameters that have a pre-defined distribution. This means that the estimated parameters are not fixed anymore, but follow a pre-defined distribution. And as this study wants to advice policymakers on how travellers value certain attributes for the air/rail product through different scenarios, having distributions across the parameters is more difficult to estimate and explain. Mixed logit models will most likely lead to a better model fit, but it has no further added value for the purpose of this study. The goal is to quantify traveller needs for the air/rail product and show what travellers care about in order to advise airlines and train operators on how to design this product to make it attractive to travellers. Therefore, in this study, it is chosen not to estimate a ML model. Instead, to capture unobserved heterogeneity, a latent class choice model is estimated.

3.4.3. Latent Class Choice Model

Latent class choice models are able to account for unobserved heterogeneity across the response group. In this study, a latent class choice model may provide insights into which groups, with similar characteristics, are most likely to choose for an integrated air/rail alternative. In this way, tailor-made policy advice could be designed suited to the specific needs of various latent classes of travellers.

The added value of latent class choice models is the ability to explain class-membership based on observed (socio-demographic) variables. The probability of an individual belonging to a latent class is determined by the traditional MNL model. In **Equation 3.5**, the class membership function (π_{ns}) is shown, where δ_s and γ_{sq} are class-membership parameters and $\mathbf{z}_n$ covariates.

$$\pi_{ns} = \frac{e^{\delta_s + g(\gamma_{sq}, z_n)}}{\sum_{l=1}^{S} e^{\delta_l + g(\gamma_{lq}, z_n)}} \tag{3.5}$$

As this study uses panel data, the class membership allocation need to account for the fact that data is collected on the level of the individual, and not on the level of observation. In that case, the LCCM is not a probability, but a likelihood L_n. The likelihood of observing the sequences of choices ($i_1, ..i_T$), conditional on model parameters β is given in **equation 3.6**.

$$L_n(i_t, \ldots, i_T \mid \beta) = \sum_{s=1}^{S} \pi_{ns} \left(\prod_{t=1}^{T} P_n(i_t \mid \beta_s) \right) \tag{3.6}$$

Equation 3.6 shows that the individual likelihood is the product of a sequence of choice probabilities per decision maker. This is different from cross-sectional data, where the likelihood function is just the unconditional choice probabilities at the choice situation level.

After estimating the latent class choice model, the amount of classes can be defined. More classes mean that more heterogeneity is captured, however, there is a boundary. Having too much classes may result in an overfitted model. Therefore, the Bayesian information criterion (BIC) is used to select the model that best fit the data. The general rule is to prefer the model with the lowest BIC, as the BIC decreases with better log-likelihoods. The BIC is based on the log-likelihood LL, number of parameters k and the number of observations n. The BIC formula is shown in **Equation 3.7**.

$$BIC = -2 \cdot LL + k \cdot \ln(N) \tag{3.7}$$

4 Theoretical Framework

This chapter identifies the important travel attributes for air/rail based on both a literature review as focus groups in, respectively, **Section 4.1** and **Section 4.2**. The travel attributes and other factors included in the conceptual model are discussed in **Section 4.3**. These attributes and socio-demographic characteristics are both presented in the conceptual model in **Section 4.5**. This framework forms the basis for the survey design of **Chapter 5**.

4.1. Literature Review

4.1.1. Literature Studies on Air/rail

In order to be concise, a literature content table (**Table 4.1**) is used to provide insight into what aspects of air/rail are already discussed in literature. This approach is based on the theory of Wee and Banister (2016) on how to write a literature review paper. This section synthesises empirical insights in order to get a state of the knowledge and forms the basis to identify research gaps afterwards.

Table 4.1: Literature content on air/rail intermodality

Author(s)	Year	Title	Aspects
Bory, M. P.	1999	Air/rail Intermodality: Optimizing Airport Capacity	Saturation of airport hubs Air/rail as a strategic opportunity Need for infrastructure and service integration
Chiambaretto, P., & Decker, C.	2012	Air/rail intermodal agreements: Balancing the competition and environmental effects	Environmental benefits Integration levels of air/rail
Clewlow, R. R., Sussman, J. M., & Balakrishnan, H.	2014	The impact of high-speed rail and low-cost carriers on European air passenger traffic	Environmental benefits System-wide impact of air/rail substitution
Cokasova, A.	2003	Air Rail intermodality from Passenger Perspective	Air/rail as complementary transport modes Determinant(s): waiting time, attractiveness, travel expenses
Coogan, M., Brand, D., Hansen, M., Kivett, H., Last, J., Marchi, R., ... & Thompson, L.	2015	Integrating Aviation and Passenger Rail Planning	Saturation of airport hubs Service coordination Air/rail as complementary service
Givoni, M.	2007	Air rail intermodality from airlines' perspective	Cooperation instead of competition HSR to connect major airport hubs
Givoni, M. Dobruszkes, F. Lugo, I.	2012	Uncovering the Real Potential for Air/rail Substitution: An Exploratory Analysis	Saturation of airport hubs Environmental problems of flying Airport hubs & HSR integration
Wang, Y., Sun, L., Teunter, R. H., Wu, J., & Hua, G.	2020	Effects of introducing low-cost high-speed rail on air/rail competition: Modelling and numerical analysis for Paris-Marseille.	Effect of low-cost HSR on air/rail competition Less air traffic & increase in total rail traffic
Wang, Y., Lu, Q., Cao, X., Zhou, X., Latora, V., Tong, L. C., & Du, W.	2020	Travel time analysis in the Chinese coupled aviation and high-speed rail network	Determinant(s): frequency; Societal impact of high multimodal accessibility
Xia, W., & Zhang, A.	2017	Air and high-speed rail transport integration on profits and welfare: Effects of air-rail connecting time	Airport congestion Environmental impact Social welfare Determinant(s): connection time
Zanin, M., Herranz, R., & Ladousse, S.	2012	Environmental benefits of air/rail intermodality: The example of Madrid Barajas	Positive environmental impact air/rail Saturation of airport hubs
Zhang, F., Graham, D. J., & Wong, M. S. C.	2018	Quantifying the substitutability and complementarity between high-speed rail and air transport	Determinant(s): city-airport distance, transfer distance, ticketing

From **Table 4.1**, several themes are identified from the literature about what is known about air/rail.

Saturation of airport hubs
Several papers discuss the trend of saturation of major airport hubs (Bory, 1999; Coogan et al., 2015; Givoni et al., 2012; Xia & Zhang, 2017). An air/rail product in both the form of partial as complete substitution has the potential to reduce the amount of flights from congested European airports. The potentials are there, comparing the capacity between high-speed trains versus common used aircrafts for short-haul flights. To illustrate, the Intercity Nieuwe Generatie (ICNG), a high-speed train which is currently introduced in the Netherlands has a capacity of 417 seats, using an 8-wagon configuration (Wikipedia, 2024). In contrast, the newest Airbus A320neo, which is going to be used by KLM for the short-haul flights, only has a capacity between 150 to 180 seats, depending on the configuration (Airbus, 2021). These papers address that the scarcity of airport slots, due to the increasing trend of flying, may be partly solved by introducing more HSR connections between major airport hubs.

Environmental benefits of (partial) substitution
Other papers such as Chiambaretto and Decker (2012), Clewlow et al. (2014), Givoni et al. (2012), Xia and Zhang (2017), and Zanin et al. (2012) propose air/rail as opportunity to reduce GHG emissions. Givoni et al. (2012) admit that introducing air/rail may reduce emissions, but that it won't solve the environmental problems. In a case study done by Wang, Sun, et al. (2020) on the Paris-Marseille route, introducing an alternative for air travel reduced the air traffic by 39% and shows a total increase of 37% in rail traffic, leading to less emissions from aviation. In line with these results, Zanin et al. (2012) found that the introduction of a high-speed rail station at Madrid Barajas airport resulted in a 10% decrease in total emissions on this corridor. These studies indicate that air/rail has actual potential to decrease GHG emissions. However, to make a significant impact, providing an inter-European network is essential. Every bit of emissions that can be reduced due to less flights could in the end be accumulated into a significant reduction of European emissions.

Travel determinants
In the non-DCE literature, several travel attributes came to light that may affect travellers' choices for an alternative mode of transport. Cokasova (2003) identifies a couple of determinants such as waiting time, travel expenses and trip purpose. Closely related to waiting time is transfer time, which is also considered to be important by Xia and Zhang (2017). Wang, Lu, et al. (2020) adds another choice factor with frequency. This relates back to the attractiveness of rail, which could be improved when the frequency is higher, according to this study. Other travel attributes such as punctuality, comfort, arrival and departure times and availability of other travel modes are also influencing the attractiveness of rail. Apart from these, Zhang et al. (2018) concludes that other determinants more related to distance such as city-airport distance and transfer distance may also affect mode choice. At last, another noticeable determinant is integrated ticketing, which is classified as low-level integration by Chiambaretto and Decker (2012).

Air/rail as complementary service
Chiambaretto and Decker (2012) distinct three levels of integration based on service components. Services as integrated ticketing, IT systems and baggage check-in may provide a smooth integral air/rail product, rather than having competition between air and rail operators (Bory, 1999; Cokasova, 2003; Coogan et al., 2015; Givoni, 2007a; Xia & Zhang, 2017). This in order to achieve a complementary and competitive air/rail alternative for air/air journeys instead of direct substitution of air journeys by rail.

Air/rail to increase social welfare
Air/rail may also be beneficial for social welfare, linking this to the themes already introduced. By introducing a HSR network among Europe, congested corridors may be alleviated and this facilitates connectivity among European cities that could boost tourism and economic development (Wang, Lu, et al., 2020; Zanin et al., 2012). By offering an environmentally friendly travel mode for Europeans, more sustainable travel choices could be promoted which will contribute to the environmental goals set by the European Commission.

4.1.2. Discrete Choice Model Studies on Air/rail
The second part of this literature review builds on the empirical insights and provides deeper insights into method-specific papers that used discrete choice models in order to derive important travel attributes that could be valuable for passengers in the choice for an air/rail product. This in order to construct a conceptual model on how dependent and independent variables are related (Wee & Banister, 2016).

Table 4.2: Literature content on air and/or rail DCE studies

Author(s)	Year	Title	Travel Attributes (trip purpose specific)
Barreira, Á., Reis, V., & Macário, R.	2013	Competitiveness of High-Speed Rail: Analysis for Corridor Between Lisbon, Portugal, and Madrid, Spain, Based on Discrete Choice Models.	Price; Travel time; Frequency; Comfort
Behrens, C., & Pels, E.	2012	Intermodal competition in the London-Paris passenger market: High-Speed rail and air transport	Travel time; Frequency
Bergantino, A. S., & Madio, L.	2017	High-Speed Rail, Inter-Modal Substitution and Willingness-to-Pay. A Stated Preference Analysis for the 'Bari-Rome'.	Access/ egress time; Reliability (business); Travel time (business)
Jiang, Y., Timmermans, H. J., Chen, C., Sun, J., & Yao, B.	2019	Determinants of air-rail integration service of Shijiazhuang airport, China.	Frequency; Ground access time; Ticket price; Delay
Kantelaar, M. H., Molin E., Oded C., Donners B., & Van Wee, B.	2022	Willingness to use night trains for long-distance travel.	Trip time; Travel cost; Perceived comfort
Nikolaev, E.	2022	Rail-air transport competition: A discrete choice analysis along with an international empirical investigation.	Travel time; Access time to station/ airport
Pagliara, F., Vassallo, J. M., & Román, C.	2012	High-speed rail versus air transportation: Case study of Madrid–Barcelona.	Price; Service frequency; Parking facilities at train stations; Ease of check-in & security
Román, C., & Martín, J. C.	2014	Integration of HSR and air transport: Understanding passengers' preferences	Price integration; Connecting/ access time; Baggage integration (leisure); Travel time (business)
Valeri, E.	2013	Air and rail transport in the Rome-Milan corridor: competition policy implications based on a discrete choice analysis.	Total travel time; Total travel cost; Delay

In literature, there are quite some papers about the potentials of substituting air travel by high-speed rail. However, looking at method-specific studies about this topic already narrows down the amount of research. DCE studies mainly address the choice behaviour of respondents regarding a choice between either an air ticket or rail ticket (direct substitution). Actually, all studies from **Table 4.1** and **Table 4.2** including a case-study indicate scenarios that are based on direct substitution. This is where the gap in current literature occurs. As conventional airlines are using hub-and-spoke networks, their focus is to let passengers transfer at their hub. These passengers are thus making a multi-legged journey. If rail could replace the short-haul flight leg in a combined service, what do passenger value as important on these trips? This study aims to quantify the needs of those passengers by using a discrete choice experiment (DCE). The travel attributes found in the DCE studies for direct substitution may play also a role in the partial substitution, but these are not quantified yet in literature.

In order to obtain as much information as possible about the attributes that may play a role in the choice for air/rail, other "grey" sources are also used. Subsequently, two focus groups are also set up to get more information on potential important choice characteristics from the perspective of frequent air and rail travellers.

4.1.3. Grey Literature on Air/rail

In this study, alternative grey sources are also used to examine what attributes are important to investigate for air/rail. Apart from similar non peer-reviewed studies, also reports from national governments and companies such as Royal HaskoningDHV are taken to gain information. An overview is given in the **Table 4.3**.

Table 4.3: Related grey literature on air/rail travel

Author(s)	Year	Title	Aspects
Donners, B., Van Buuren, E., & Rijners, R.	2018	Steden verbonden, trein of vliegtuig, effecten van substitutie	Modal shift due to International HSR; Operational barriers; Determinant(s): ticketing, travel time, findability of information/ service
Durand, A., & Romijn, G.	2023	Substitutiemogelijkheden van luchtvaart naar spoor in 2030 en 2040	Train to partly replace flights; Determinants: distance gate-station, luggage integration, ticketing, train price
Kantelaar, M. H.	2019	Night-Time Train Travel	Night train advantages over air; Night train determinant(s): trip/ access/ egress time/ departure/ arrival/ waiting time, frequency, reliability, trip cost, comfort
Royal HaskoningDHV	2020	Potentie AirRail substitutie ZWASH-corridor	Air/rail substitution for O/D market; Potential connections in Europe
Savelberg, F., & De Lange, M.	2018	Substitutiemogelijkheden van luchtvaart naar spoor	Air/rail barriers and potentials for substituting O/D travel
Van Alphen, R., & Reijenga, A.	1998	Vluchten kan niet meer…	Prospects of substitution; Determinant(s): Travel/ transfer/ access/ egress time, travel cost, information transparency, image of train, transfer-related attributes, delay, luggage integration, frequency, comfort;
Weisshaar, T. C.	2024	Unravelling night train travel behaviour	Night train advantages; Night train determinant(s): travel time, travel cost, accommodation, booking convenience, delay, reliability, access distance

Donners et al. (2018) investigated the potentials of air to rail substitution and came to the conclusion that it is possible to establish a modal shift from air to rail, only when an international railway network is established with an increased frequency of international HSR trains. This is also acknowledged by Durand and Romijn (2023), who conclude that approximately 5.600 to 16.000 flights in Europe can be replaced by train. The focus of both studies are from the perspective of Schiphol Airport and on flights up to approximately 750 kilometers. Long haul flights are yet not substitutable by train because this modality does not have the infrastructure to be competitive. Looking at Schiphol, Donners et al. (2018) indicate 31 short-haul destinations that have potential to be connected via TEN-T (**Figure 4.1**).

Figure 4.1: Destinations from Amsterdam on short-haul distances (<750 km) (Donners et al., 2018)

This study demonstrates that, for each destination shown in **Figure 4.1**, the average travel time for train journeys within an European high-speed rail network would be shorter than the average travel time for flying to the same destination. This is due to the perceived perception on travel times (Cokasova, 2003; Donners et al., 2018; Savelberg & de Lange, 2018). Travellers commonly perceive the travel time of flying as more advantageous because they only consider the time of actual flying instead of the whole journey.

Apart from travel times, ticketing is also considered as an important determinant (Donners et al., 2018; Durand & Romijn, 2023; Royal HaskoningDHV, 2020; Savelberg & de Lange, 2018; van Alphen & Reijenga, 1998). It is described as one of the main operational barriers for TEN-T, as integrating ticketing comes with institutional burdens. In general, all studies have one question in common when discussing the potentials of air/rail: *What happens when something within the journey goes wrong?*

This is one question that summarises the bottlenecks of integrated rail, both from an operational as from the passenger perspective. Aspects such as delays, ticketing, reliability, findability of tickets and travel information (i.e. transparency) and luggage integration are well covered by the airline industry, but not in the rail industry. In essence, the travellers bear no responsibility when travelling by plane only. This in contradiction for train journeys, where travellers cannot rely on the support of train operators when something goes wrong within their journey.

However, this study won't focus in detail about the bottlenecks and how to operate an intra-European railway network. This study focuses on what happens afterwards, when TEN-T is achieved and in operation. van Alphen and Reijenga (1998) already did research about the substitution possibilities of air to rail in Northwestern Europe. Focusing on transfer passengers, in order to enable substitution in the transfer market, it is necessary for rail and airline operators to develop a complementary, rather than competitive, transport product with far-reaching cooperation that maintains the same quality standards as air travel.

One alternative which has been explored in this study is a dedicated shuttle train carrying passengers exclusively for one airline. With such a shuttle, schedules between air and rail could seamlessly merge, creating one integrated product. Seems to be a viable outcome, however, more than 20 years later, Royal HaskoningDHV (2020) did another study about such a dedicated shuttle. In line with van Alphen and Reijenga (1998), they found that there is enough demand for air/rail for direct substitution on the origin-destination (OD) market. While for the transfer market, they found that there is not enough demand to operate dedicated shuttle trains. However, this study also acknowledges that the potential of substitution for the transfer market may be bigger than indicated. This because latent demand is not incorporated in this study, only the modal shift of the current pool of passengers. Therefore, it is necessary to quantify the passenger needs of air/rail in order to say something about the the willingness to use such an intermodal product for potential new users. What the latent demand for air/rail will be is still unknown, but by quantifying the needs for specific potential user-groups, tailor-made recommendations can be given to both national policymakers as rail- and airline operators on how to manifest users on the air/rail product.

Relating to the topic of air/rail, Kantelaar et al. (2022) and Weisshaar (2024) already investigated the potentials of night-train travel. They both conclude that night trains can have additional value for substitution. Night trains could, in this regard, also be valuable for air/rail. For example, by travelling to an airport by a night train and take an early morning intercontinental flight. Kantelaar (2019) conclude that privacy is a major component in choosing for night trains. Weisshaar (2024) states that for booking convenience, the ability to book a single ticket for the whole journey is found important by train travellers.

Both studies examined which attributes are important to choose night time travel, and this study continues on these findings, but only in the context of air/rail. Therefore, the night train is also left out of the scope of this research.

4.2. Focus Group Outcomes

4.2.1. Results Focus Group Air

This focus group, from the perspective of experienced air travellers, contained three participants. They were asked about what determinants they would find important travelling with air/rail. The following attributes were considered as important, based on results from **Appendix A** for the focus group air:

- Transfer/ connection time
- Reliability/ punctuality
- Frequency of service
- Integrated services (ticketing, luggage, lounge availability)
- Comfort
- Loyalty program

These attributes are also described in literature. However, the focus group came to specific attributes which are less common in literature. For example, frequent business travellers for KLM are able to save so-called Flying Blue miles. With these points, travellers are able to get discount on tickets or other services such as free upgrade to economy comfort instead of economy. The focus group stated that if these points could be used in the same way for air/rail, they are more likely to use this transport mode. This is one specific example for the common attribute of ”integrated services”. The same holds for availability of lounges at train stations.

The members of the focus group often experience that there is less flexibility in booking last-minute train tickets. For them, the service of ticketing should be as dynamic as for airline tickets. For example, last-minute adjustments about seats and free last-minute cancellations should also be part of future air/rail services. At last, with respect to transfer time, when switching from to train from air, coming from an intercontinental flight, another passport control is mandatory. This is also perceived as inconvenient for choosing air/rail.

4.2.2. Results Focus Group Rail

The question *What happens when something within the journey goes wrong?* is a common thread through both the literature review and the focus groups. The focus group from the rail department of RHDHV, consisting of four participants, also addressed this question in depth from their perspective on air and rail integration. The following travel attributes were considered as important, based on results from **Appendix A** for the focus group rail:

- Reliability/ punctuality
- Guarantee to arrive at destination
- Delay (with compensation)
- Integrated services (ticketing, information, luggage)
- Travel time
- Booking flexibility/ convenience (re-booking)
- Comfort

Reliability and punctuality are considered as a must for travellers with business purposes, while for people who travel for leisure, the guarantee to arrive at the destination is already enough. Therefore, trip purpose is an important element to consider. Here, the focus group also considered attributes such as booking flexibility.

In general, the main takeaway of this focus group was that the current railway operations are more focused from the operators' perspective instead of the travellers' perspective. Services of airlines are more oriented on how to enhance the overall journey experience of its passengers in order to meet diverse passenger needs. In this way, airlines create attraction. When their needs are satisfied, passengers are more likely to choose for a certain mode of transportation.

4.3. Travel Attributes Included in Model

Both the literature and the focus groups mention possible travel attributes that may influence travellers' choice behaviour in the air/rail context. All potential attributes for the conceptual model are shown and grouped in **Table 4.4**.

Table 4.4: All considered travel attributes per attribute group from literature and focus groups

Attribute category	*Total travel time*	*Total travel cost*	*Performance*	*Distance*	*Services air/rail*	*Comfort air/rail*
Attributes	Transfer time	Ticket price	Punctuality/ reliability	City-airport distance	Integrated ticketing	Security
	Access/ egress time		Frequency of service	Transfer distance	Luggage integration	Lounge availability
	Transportation time		Arrival certainty/ delay		Integrated information (findability)	WiFi availability
	Waiting/ lead time				Integrated customer service	Integrated loyalty programs
					Booking convenience	Catering on board

Total travel time

Travel time is always a major component in mode choice studies such as Barreira et al. (2013), Behrens and Pels (2012), Bergantino and Madio (2017), Jiang et al. (2019), Nikolaev (2022), and Valeri (2013). However, different studies address time in a different way by taking either the total journey time or only the time spend in the actual mode of transportation (transportation time). In this study, the total travel time is considered because the **transportation time** for air versus rail may differ such that the choice may be influenced by the perceived travel time instead of the total travel time of the whole trip. To avoid this, the total travel time of the whole journey is taken, not only the time spend in the mode of transport.

The total travel time for air/rail can be divided in three parts: access and egress times, transportation time, and the time spend on the airport/ train station. The **time spend at the airport/ train station** is defined as the time spend for security, waiting, walking, and boarding. In this study, **transfer time** is included in this attribute, as transfer time is part of the total time not being in a transport mode within a journey. According to Cokasova (2003), transfer time may be an important attribute when choosing for an air/rail alternative. Therefore, this attribute is taken into account by integrating into the time spend at the airport/ train station. For the air/air alternative, travellers only spend time at the airport, as rail is only included in the air/rail alternative. **Access and egress times** are not considered in this study. As Reis et al. (2013) does not consider these travel times within their definition of intermodal transport and are traveller-specific. Also, Weisshaar (2024) explored the influence of access distance to the airport and to the station on night train travel and found that access distance to the airport has a negative influence on the mode choice. This is also expected for the mode choice for air/rail. The further a person lives away from the airport, the less likely the person would choose to fly. The parameter about access distance to the train station is found insignificant, and can thus not be aggregated to the population.

Total travel cost
Ticket price, like the time attribute, also a major component in mode choice studies (Barreira et al., 2013; Behrens & Pels, 2012; Pagliara et al., 2012; Román & Martín, 2014; Valeri, 2013). It is also already known that business travellers are less price sensitive than leisure travellers, but more time sensitive (Kouwenhoven et al., 2014). However, air/rail as it may be with TEN-T does not exist, and therefore, it is crucial to know how travel costs do affect travellers' mode choice.

Performance
Performance attributes, especially addressed by focus group rail, are considered as important. According to them, the current high-speed rail network and services within Europe are not reliable enough to attract more passengers. Attributes such as punctuality, reliability, frequency of service, arrival certainty and delay are addressed as indicators for performance.

Punctuality is often quantified in percentages, but for respondents, this may be hard to interpret. Therefore, in order to minimize the possibility of a response bias, punctuality is left out of scope. The same rationale also holds for **reliability**, which is hard to quantify. As reliability is also hard to capture within an already extensive survey for respondents, this attribute is left out of the scope of this research.

It is important to choose attributes that respondents can relate to. Therefore, in this study, performance is captured based on the **frequency of service**. But as time schedules may be hard to grasp as well, it is approached differently. **Certainty of arrival** was also considered as important according to both focus groups. Travellers want certainty of arrival to get at their destination. They need to rely on the fact that they actually arrive at their destination. Therefore, frequency of service and arrival security are encompassed by the following question: "How long do I have to wait for replacement transport in case of a missed transfer or defective train or plane?". This is based on the overlapping question of both focus groups: *What happens when something within the journey goes wrong?* This could be related to transfer time, however, transfer time is already included in the time spend at the airport/ train station. Therefore, another attribute is introduced which captures the extra waiting time in case of an unexpected event: **delay in case of missed transfer**.

It should be noted that this parameter also does not perfectly encompass the concept of performance. Namely, it is the waiting time in the case of when something goes wrong in journey causing a passenger to be delayed. However, the question is: What is the probability of such an event that causes a delay? To express this, using percentages is the most obvious. Only again, the question is how well respondents can interpret these probabilities. That is why it is chosen to keep the interpretation of this attribute with the respondent, which is also the limitation of this attribute. Because this could lead to a response bias as well, as every respondent will interpret this parameter differently.

Distance
Distance is also considered as potential attribute in literature. Zhang et al. (2018) addresses that **city-airport distance** could influence the mode choice. However, this would be part of either the access or egress leg of the travel journey, and these are left out of scope in this study. Also, **transfer distance** may influence the choice behaviour of passengers. Because the distance between the train station and the terminal differs per airport. However, TEN-T aims for a HSR connection at every airport where every major hub would have a HSR connection directly from the airport. Therefore, under this assumption, this distance is not considered in this study.

Services
The attribute group services is defined as the offered integrated air/rail features. The services of air/rail is a more abstract concept to grasp because it consists of several elements that define the overall service level. Therefore, a rating experiment held in order to estimate regression coefficients for every single attribute being part of the overall service level. Afterwards, it is possible to say something about the importance of these attributes, from a passenger perspective.

In both literature as the focus groups, **integrated ticketing** is considered as one important aspect (Bory, 1999; Donners et al., 2018; Durand & Romijn, 2023; Royal HaskoningDHV, 2020; Zhang et al., 2018). Integrated tickets could also have different degrees based on interlining, co-operation or even a joint-venture of air and rail operators. However, before going into operational strategies, the value of integrated ticketing from a passenger perspective should be quantified. The operational side of integrated ticketing is left out of the scope.

The same holds for **integrated luggage** services. As this concept is already discussed widely in literature by Chiambaretto and Decker (2012), Durand and Romijn (2023), and Román and Martín (2014), but not quantified for air/rail, this attribute will be considered in the conceptual model.

Other elements such as **helpdesk integration** is also considered, mainly addressed by the focus groups. Rail operators do not offer the same services as airline operators. Airlines do offer compensation for delays, missed flights and arrange accommodations if the next flight leaves the next day. There are service desks where passengers can ask for help and also their luggage will be taken care of when it needs to be transported to the next flight. Most of these services are not offered by rail operators. Therefore, helpdesk integration of air/rail is considered in order to have an easier access to help when necessary.

Regarding information provision, airlines are transparent in their disclosure. Many airlines such as KLM have an app where up-to-date travel information is shared. As a result, passengers are always aware of developments around their flights. This creates a familiar feeling with the traveller, a feeling that is lacking with railway operators. Delays or other disruptions are often announced late and rail operators are often not transparent in the provision of information. From the rail focus group, this was also a major point of discussion. Therefore, for air/rail, **integrated information** provision is also considered as attribute. Having all the information about a passengers' trip on one platform (website/ app) may be found valuable.

The last considered attribute for the services is **booking convenience**, which is also an attribute that is defined by multiple other attributes (Weisshaar, 2024). This study did an in-depth research into booking convenience for night train travel bookings. The conclusion is that having a search engine available, booking the trip in one ticket, high early booking time and availability of digital ticket increase the convenience of booking. These results could also be aggregated for future air/rail booking systems and is, therefore, not considered in this study. Also, it is concluded that having a single ticket is considered as most important among the booking convenience parameters. And this factor is also integrated in the rating experiment for potential air/rail services.

Comfort
Comfort does also play a role in mode choice behaviour (Barreira et al., 2013), but, what is comfort? Comfort is traveller-specific and is thus perceived differently. There are several attributes that could, together, define the level of comfort. Kantelaar et al. (2022) describe this as the perceived comfort, where attributes such as accommodation type, privacy, catering, number of stops, inside environment, facilities and staff are considered for determining night train comfort. However, these attributes are also mode-specific. Therefore, the focus groups are taken as main source for defining air/rail comfort.

According to the focus groups of air and rail, comfort is perceived by the following attributes: priority lanes for air/rail, lounge availability, WiFi availability and integrated loyalty program and catering.

Priority lanes for air/rail is an attribute that indicates if passengers have priority for luggage check-in, security and passport control. With regular air/air journeys, passengers stay on the airside of the airport. However, for making an international train journey, another passport check is needed because passengers leave landside and enter airside. This extra check adds up to the time spend at the airport/ train station and thus could influence the decision whether to take alternative mode of transportation.

Lounge availability, **WiFi availability** and **integrated loyalty programs** are features addressed by experienced air travellers who would like to have more degrees of comfort for train travelling. Therefore, these attributes are taken into account for determining the comfort level for air/rail as well. One point to note is that WiFi on trains is usually free, but not of the best quality. It is commonly slow and it is difficult to download, stream a movie or have a call, for example. In planes, internet can nowadays be obtained for a fee. Therefore, this experiment does not consider the presence of WiFi, but its quality. This is summarised in two options: paid but good WiFi and free but poor WiFi. It is expected that people are that price-sensitive that they will choose the free but poor WiFi. Also because people have their own internet bundles available which generally provide better quality than the WiFi in the train.

Catering is not considered in this study, as Kantelaar et al. (2022) already concluded that travellers associate utility with the possibility to get food or drinks on board, but upgrading the services from a kiosk to a full restaurant car does not pose a higher rating for comfort. As this is already discussed by Kantelaar et al. (2022), this study does not consider catering on board for air/rail. As these conclusions could also be aggregated to international high-speed trains. And for air, this study assumes long-haul flights and there passengers get multiple meals included. Therefore, catering for air/rail is not included in this conceptual model.

4.4. Other Factors Included in Model

4.4.1. Socio-demographics and Travel Experience

Other than travel attributes, also socio-demographics are included in order to gain insight into the composition of the response group. Also, in extension to the regression analysis and the multinomial logit model, a latent class choice model is estimated that incorporate those socio-demographics in order to identify customer segments. In this study, the following socio-demographic characteristics are included: **age**, **gender**, **educational level** and **occupation**. These variables were made available by the NS panel background data. This panel is used to recruit respondents for the survey of this study. Income is not included in this study because this variable was not available from the NS panel.

Other factors that also may vary across different groups is the travel experience for both air and rail transport. People who often do travel with the train may be biased for choosing rail as their favourable mode of transportation. This choice is then made not based on rational consideration, but based on habits. The same holds for plane lovers, people who often fly may be biased towards air transport. In order to capture these preferences, their travel experience is incorporated in the conceptual model in two separate factors: **travel experience air** and international **travel experience rail** in the past five years.

In addition to the regular travel experience, also parameters are included indicating how often in the past five years a respondent has had an unpleasant experience, for both train and air travel. The hypothesis is if individuals have had an unpleasant experience with one of the two modes of transport, it will be chosen less often in the mode choice experiment. Two extra parameters are included in the conceptual model: **unpleasant travel experience air** and **unpleasant travel experience rail** in the past five years.

4.4.2. Trip Characteristics

Trip purpose may be quite an important determinant for the mode choice. In this study, two kinds of trips are distinguished, either travelling for leisure purposes or for business purposes. As passengers who travel for business purposes commonly value time over cost, it could be expected that these respondents are more likely to choose for the faster alternative. And travellers who travel for leisure tend to choose the cheaper alternative, based on their willingness to pay (Kouwenhoven et al., 2014).

Other travel characteristics included in this study are **travel company** and **check-in luggage**. Travel company is included in the latent class choice model in order to see if travelling alone, with colleagues or with family has an impact on the mode choice. The hypothesis is that when people travel with colleagues, for a business trip, that they tend to choose for the air/air alternative, which is commonly the faster alternative. Keeping in mind that this travel characteristic could be correlated to trip purpose. Check-in luggage is also included for the regression analysis, for testing the interaction effect if having check-in luggage may modify the weight of having luggage integration.

Another considered attribute in literature is the **time of departure and arrival**, especially in the case of night trains (Kantelaar, 2019; Weisshaar, 2024). They found, the earlier the arrival time, the more convenient. As this is already statistically proven and quantified, this attribute won't be included in the conceptual model of this study.

At last, the **number of transfers** is also considered in literature, but not in this study. Because, in this study, it is assumed that there is only one transfer. The attribute level would be the same for both alternatives in the mode choice experiment and is therefore left out of the conceptual model.

4.5. Conceptual Model

In the conceptual model, shown in **Figure 4.2**, the mode choice attributes, trip characteristics and background information are shown. The mode choice attributes are divided in several other attributes, where service and comfort are two separate experiments. Also, a factor for the latent classes is shown. Membership in latent classes is assumed to be influenced by socio-demographic variables and previous travel experiences (i.e. background information). These latent classes, along with alternative attributes, collectively influence the utility of an alternative.

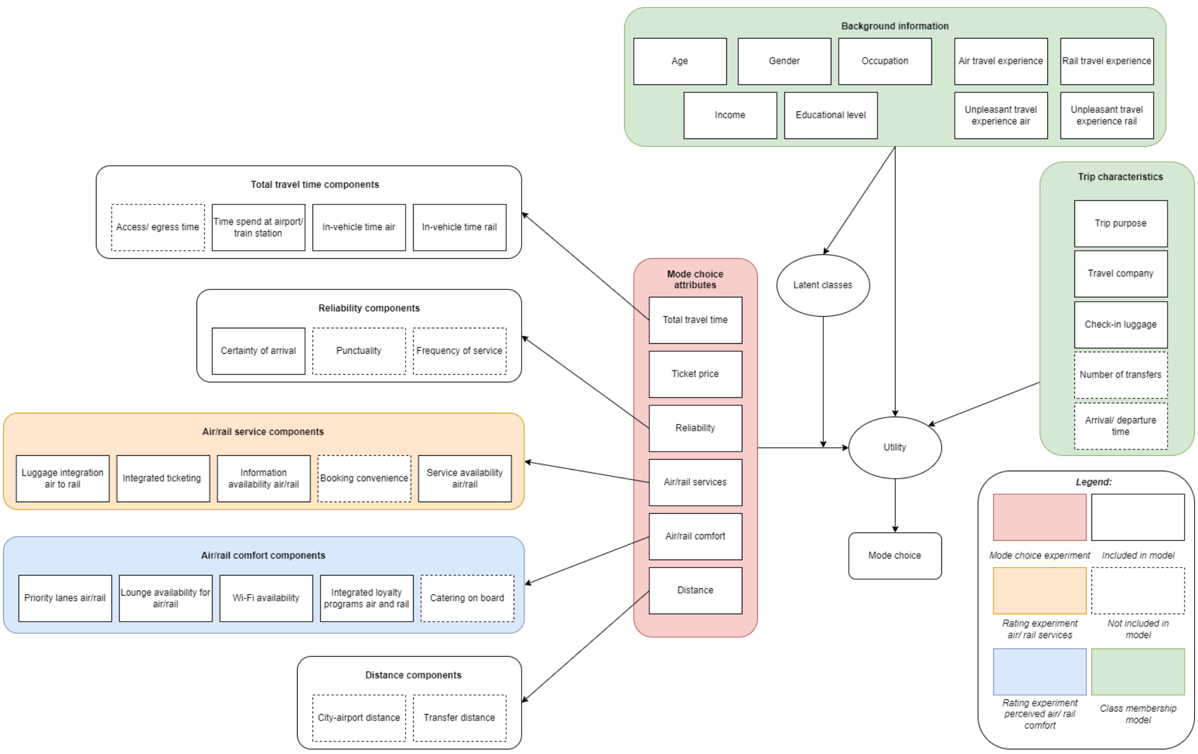


Figure 4.2: Conceptual model

4.6. Expectations

4.6.1. Expectations Service Attributes

The main attributes for the service rating experiment are: luggage integration, integrated ticketing, information integration and integrated customer service. Regarding the expectations of the parameter signs, all main attributes for this experiment are expected to have positive parameter signs, as integration of luggage, tickets, information and helpdesk ensure that travelling is smoother compared to the case where air and rail are not integrated. These service features are thus expected to increase the overall service rating by respondents.

However, it is not only the main attributes that are estimated with the regression analysis. Regarding the socio-demographics, it is expected that students generally rate the level of service higher, because students are assumed to be satisfied more quickly with lower service levels which is expected to result in higher general ratings for the integrated service features. This would implicitly mean that people with age rate the general service level lower and is thus expected to have a negative sign. It is also expected that people who have travel experience with international trains give a higher rating because they are more familiar with travelling by train and thus already satisfied with the current service levels. This would mean that experienced flight travellers rate the general service level of air and rail lower, as they are used to the offered service standards of airlines, which already have integrated luggage, ticketing, information and helpdesk for air/air journeys.

However, these are all generic effects. In order to be able to advice policymakers regarding air/rail more specifically, some interaction effects are added to the model. As already introduced in **Chapter 1**, KLM opened a new terminal at station Brussels-Midi for travellers to drop-off luggage, similar to what Lufthansa did at Frankfurt Airport (Frankfurt Airport, n.d.-a). As the business models of these type of carriers are mainly focussing on travellers who travel for business purposes, it is therefore interesting to find out how these travellers rate luggage integration specifically. Also, it is expected that people with check-in luggage value luggage integration higher than people who don't. Because of the full integration feature, people with luggage are enabled to travel hands-free for the whole trip. At last, it is expected that elderly are more likely to use a physical helpdesk when having problems or questions about their journey. Therefore, this interaction effect is also considered in the linear regression model.

4.6.2. Expectations Comfort Attributes

For the comfort rating experiment, the main attributes are: priority security, lounge availability for air/rail passengers, WiFi availability and the existence of an integrated air and rail loyalty program. Security, lounge availability and an integrated loyalty program are expected to have positive signs. However, regarding WiFi, there are two levels: ”slow + free WiFi” and ”fast + paid WiFi”. It is therefore expected that people rather have slow, but free WiFi over paid WiFi which is fast. This because people generally have their own internet bundles as well. Therefore the sign is expected to be negative.

Regarding other included variables, it is expected that younger people (i.e students) positively rate extra comfort, as their comfort standards are generally lower than people who are older. This in line with the reasoning of service level standards. Also, regular train users are expected to give a higher rating, because of their familiarity with train travel. It is also expected that people who travel for leisure purpose generally rate the comfort level higher than people who travel for business purposes, as business travellers are generally more demanding with what they expect from the comfort levels.

Because the socio-demographics only says something about the general perceived comfort level, interaction effects are added in order to specify the preferences of specific customer groups. In this case, it is interesting to see how business travellers rate certain comfort attributes. In this regard, policymakers can specify their policy based on their preferences.

Regarding those interaction effects, it is expected that business travellers rate extra comfort features higher. This because travellers who travel for business purposes are commonly more time sensitive compared to people who travel for leisure (Kouwenhoven et al., 2014). And with the availability of smoother travel with priority lanes, which is most time-saving, lounges, the availability of fast WiFi and gaining points from both air as rail travel for the personal loyalty program, the air/rail alternative may become more appealing. Therefore, interaction effects for all main attributes and trip purpose are included.

4.6.3. Expectations Mode Choice Attributes

The attributes included and varied in the mode choice experiment are: transportation time by train, time spend at the airport/ train station, ticket price, delay in case of a missed transfer, service and comfort. The expectation is that parameters regarding travel time and travel costs are expected to have negative signs, as this relation is generally found in literature (Bergantino & Madio, 2017; Kantelaar et al., 2022; Pels, 2008). This reasoning could also be applied for the delay people may have when missing a transfer. The journey becomes longer and are expected to be perceived negatively by travellers. These parameters are also assumed to be linear, as the longer travel times, costs and delays, the less people extract positive utility. However, this may not hold for the time spend at the airport and/ or train station. Travellers want enough time to check in, walk to the gate and board, but this should not be too short or too long. Therefore, this parameter will also be included quadratic, and is expected to be negative.

Regarding the parameters comfort and service, it is questionable if these attributes can be assumed linearly. It could also be the case that there is a saturation level regarding service and comfort and that the effect flattens out afterwards. The same line of reasoning holds for waiting time at airports or railway stations. People want enough time to go through security, passport control and walking to the gate. However, having too much time just adds up to being waiting and waiting is often associated with disutility (Cokasova, 2003; Kantelaar et al., 2022). Therefore, with these parameters included, a second multinomial logit model will be estimated where the quadratic components are also included and estimated.

When comparing an air/air with an air/rail journey, the total travel time can be distinguished in separate time elements. It is expected that these separate time elements are negative and have different weights, meaning that the travel time elements are perceived differently by the respondents.

Unlike both the rating experiments, the mode choice experiment does not consider any background or interaction effects. Not that no relationships can be expected between different background characteristics and the main parameters. It is because only the basic MNL model is estimated in this study, and this model does not consider unobserved heterogeneity and cannot account for different segments within the population. And with a Latent Class Choice Model, this shortcoming of the MNL model can be captured. These models estimate separate parameters for each latent class, allowing for different responses within each class. Also, with the class membership function, the model is able to provide class-specific choice probabilities. It was therefore chosen to not include background characteristics in the MNL model and introduce them in the latent class choice model. Regarding the latent class choice model, as it is, in essence, a MNL model, there is no reason to expect that the parameter signs for the main parameters included in the mode choice experiment are different. Therefore, for the estimation of the latent class choice model, the same parameter directions are expected for each parameter, for each class.

5

Survey Design

Section 5.1 describes the context in which the survey is held. **Section 5.2** is about the survey specification. **Section 5.3** dives into the generation of choice sets. **Section 5.4** explains the structure of the survey. **Section 5.5** discusses how the survey is tested and distributed and, at last, **Section 5.6** calculates the minimum number of respondents necessary for the experiments.

5.1. Survey Context

The aim of giving the survey a context is to reduce the occurrence of a response bias, which may lead to less representative or inaccurate responses (Ben-Akiva et al., 2019; McGrath et al., 2010). The aim of the survey context of this study is to introduce the respondent with the topic by giving examples of journeys possible by air/rail. By asking relatively simple questions about travel experience, trip purpose, travel company and luggage, the respondent may emphasize better with the choices made while travelling.

The first questions are about travel experience. As this study considers both a travel legs by rail as by air, the respondents are asked about their experience of each of the transport modes. They are asked about how many trips they made with international trains in the past five years. The same is asked for air travel.

Afterwards, respondents are asked about their trip purpose. Respondents will be asked if they ever travelled for business before. If so, there are asked to fill in the survey from that perspective and make choices between air/air and air/rail when travelling for business purposes. Also, respondents are asked for their travel company, whether they travelled alone, with family, friends or colleagues on their last (business) trip. This is in order to examine if travelling alone, with family or with colleagues does affect the preferences for air/rail or mode choice.

The respondents are also asked about check-in luggage. This may affect their preferences for certain service such as luggage integration. Because no check-in luggage means that passengers make no use of check-in luggage services. Having luggage, opposite to Kantelaar et al. (2022) and Weisshaar (2024), is included in this study because luggage integration is part of the offered services in air/air journeys, and not by air/rail.

For both the rating experiments about air/rail services and comfort, the respondents are introduced with personalised travel conditions, based on their trip purpose, travel company and having check-in luggage. Moreover, two examples are given in order to give the respondent an idea of what is possible with air/rail as an integrated service:

- **Home to destination:** From Amsterdam to Frankfurt by train en from Frankfurt to Bangkok by plane (i.e. outbound journey)
- **Destination to home:** From New York to Paris by plane and from Paris to Amsterdam by train (i.e. inbound journey)

For the mode choice experiment, the respondents get the same introduction on their travel conditions as with the rating experiments. But here, an example of a choice is given in order for the respondent to understand the difference between an air/rail journey and an air/air journey: From Amsterdam to Paris by plane and transfer to another flight to Miami *OR* from Amsterdam to Paris by high speed train and transfer to a flight to Miami.

In this study, it is not chosen to give respondents a specific case study, but rather giving them examples where they can relate to. This is intended so that later, with the scenario analysis, a range of scenarios can be tested which represent different types journeys. This keeps the complexity away from the respondent and is drawn to the analysis of the experiments.

5.2. Survey Specification

5.2.1. Alternatives

The first alternative is the **air/air journey**. Legacy carriers like KLM, Lufthansa and British Airways build their business model around transfer passengers. Combining a short-haul leg with a long-haul intercontinental leg and let passengers transfer at their hub is the way of conventional airlines to exploit economies of density (Pels, 2008). In this study, the short-haul leg is always considered within Europe and the long-haul leg is always considered to be an intercontinental flight. The second alternative is the **air/rail journey**, where travellers replace the short-haul air leg by train within Europe.

Other alternatives like a long-distance rail leg in combination with a long-haul air leg or having a direct flight alternative are excluded from this study. Long distance (night) trains are not considered because the scope of this study is within 750 km. And direct flights are excluded because air/rail is only competing with air/air, because they both focus on letting people transfer at a hub and consolidate them on a flight. Direct point-to-point flights are only competing with other direct flights. Therefore, for this stated preference survey, two alternatives are distinguished.

5.2.2. Attribute Levels Rating Experiments

This section explains the attributes and the attribute levels for both the rating experiments about air/rail services and air/rail comfort. The attributes used for both rating experiments are based on the conceptual model of **Figure 4.2**.

The first rating experiment is about air/rail services: How do people value different service features for air/rail? According to literature and the focus groups, there are several determinants that, together, define the air/rail services: ticket integration, luggage integration, integrated information provision and integrated customer service.

Luggage integration is an attribute that is distinguished into two levels:

- **No air/rail luggage integration**. No integration is the current situation where travellers need to pick-up their luggage from the luggage belt at the airport and carry it with them into the train, in case of an inbound journey. They need to go through passport control, exit airside, pick up luggage and go to the train on landside, along with all other passengers. For outbound journeys, passengers take their luggage with them on the high-speed train, drop-off at an airport check-in desk and enter airside via airport customs. Luggage is collected at the conveyor belt at the place of destination.
- **Full air/rail luggage integration**. Full integration means that for both outbound as inbound journeys, full luggage integration is offered as a service by the air/rail operator. Travellers are enabled to travel the entire journey without check-in luggage. Cabin luggage must be carried by their own, if not checked-in.

Integrated ticketing is an attribute named relatively often in literature about integrated services between air and rail. In this study, it is distinguished into two attribute levels:

- **Separate tickets**. Travellers have to book separate tickets for both the air as rail part of their journey. In case of a missed transfer, there is no compensation guaranteed by the operators. Rebooking a flight or train ticket is not free of charge.
- **Single integrated ticket**. The traveller is able to book one integrated ticket for the entire journey and will get compensation from the air/rail operator in case of a missed transfer, which is free of charge.

This attribute is also discussed by Weisshaar (2024), but only in the context of night train travel. This study concluded that having a single ticket for multi-legged train journeys has a significant impact on the booking convenience. This may also apply for multi-legged air/rail journeys. However, integrated ticketing is not only about the convenience of booking, it is also about the convenience of travelling. By involving a form of code-share agreement between the airline and rail operators, operators are able to allocate a dedicated booking number to an integrated trip (Chiambaretto & Decker, 2012). Passengers may benefit, due to the integration of IT systems, through offered guarantees in case of delays at a segment of their journey. These code-share agreements and integration of IT systems also enable operators to coordinate integrated baggage handling, according to (Chiambaretto & Decker, 2012).

Integrated information provision is more difficult to define in attribute levels. Because what is meant with integrated information provision? In this study, it is about the degree of integration between information platforms offered by the air/rail operator. Donners et al. (2018) addressed that passengers have difficulty with the findability of information at these kinds of trips. Based on these findings, two levels are distinguished:

- **No air/rail information integration**. This level indicates that the information provision to travellers such as schedules, routing, up-dates on delays and gate changes is done separately by rail operators and airlines. The travellers must consult both websites or apps in order to be fully up to date with the latest developments regarding the journey.
- **Full air/rail information integration**. The air/rail operator provides an integrated information platform with all the information needed for the traveller. There is no need to consult separate apps or websites of different operators, everything is located in one information platform.

Integrated customer service is about the integrated customer services by air/rail operators. Two attribute levels are distinguished:

- **No integrated customer service**. Both the air as the rail operator offer separate helpdesk services and customer service lines in order to assists passengers.
- **Integrated air/rail customer service**. The air/rail operator offers integrated services such as an air/rail helpdesk and an air/rail customer service helpline.

Summarizing, all the attributes used for the air/rail service rating experiment, with their attributes levels are shown in **Table 5.1**.

Table 5.1: Attribute levels for air/rail service rating experiment

Attribute	Levels
Luggage integration	1. No air/rail luggage integration 2. Full air/rail luggage integration
Ticketing	1. Separate tickets 2. Single integrated ticket
Information integration	1. No air/rail information integration 2. Full air/rail information integration
Integrated customer service	1. No integrated customer service 2. Integrated air/rail customer service

The second rating experiment is about the perceived air/rail comfort: What attributes do travellers value as important, regarding comfort, for a future air/rail product? Comfort is, as explained earlier, traveller-specific and may be determined by different determinants. From literature and focus groups, the following comfort components for a potential air/rail product are derived: security, lounge availability, WiFi availability and the existence of a loyalty program.

Security is one attribute that was addressed in the focus group from the perspective from frequent air travellers. They stated that, if rail transport want to be complementary to air travel, the comfort levels should match. This especially for travellers with business purposes who like to have a time-efficient and comfortable journey. In this study, two different attribute levels are distinguished:

- **No priority**. For outbound journeys, the air/rail traveller pass the regular security checks in order to enter the high-speed train and also passes security and passport control in order to get on the intercontinental flight. For inbound journeys, passengers pass security and passport control at the departure airport before getting on the flight. For the second leg, travellers need to exit airside via an extra passport security and enter landside for travelling with the high-speed train, and have security checks again.
- **Air/rail priority**. This attribute does indicate that air/rail travellers have private lanes in security procedures. This holds for both inbound as outbound journeys.

Lounge availability is a feature of airlines offered at airports for passengers of certain loyalty programs. NS international also offers dedicated lounges at certain train stations such as the DB, TGV or ÖBB lounge for members of those loyalty programs. These attributes (lounge availability and loyalty program) are linked because having a certain status of a loyalty program may give access to lounges. However, in this rating experiment, the attributes are treated separately because of two reasons:

1. Lounge availability is only one feature of being member of a loyalty program, especially highlighted by the focus group air.
2. Lounge availability for loyalty members, for airlines like KLM, is only limited to members of higher tiers (KLM Royal Dutch Airlines, n.d.-b). In this study, it is assumed that every air/rail passenger has access to such a premium lounge. As the first focus of this study is to quantify the passenger needs, and not about the operational challenges that may occur afterwards.

This study considers two levels of lounge availability:

- **No air/rail lounge availability**. There are no dedicated lounges or waiting areas available at the European train stations. Passengers must wait at the station and wait on public benches without any extra services.
- **Air/rail lounge availability**. Only air/rail passengers have access to premium lounge facilities at the train station, offering amenities such as comfortable seating, free drinks and snack, newspapers and phone charging facilities.

WiFi availability is also an attribute that was discussed during both focus groups. Especially for passengers who travel for business purposes would it be convenient to have the possibility to work from the train. This study considers two attribute levels, based on the amenities offered by KLM Royal Dutch Airlines (n.d.-d):

- **Free & limited WiFi**. For this level, the train operator offers free WiFi, while on the plane there is no free WiFi available at all. The WiFi on the train is also limited, meaning that travellers can only receive or send text messages or surf on the internet with rather slow internet. Having online meetings or streaming audio, series or movies is not possible with the free WiFi.
- **Paid & unlimited WiFi**. The air/rail operators offers a paid WiFi option that enables passengers to surf on the internet, send and receive text messages and stream audio, series and movies. Due to the fast internet access, it would be also possible to have online meetings.

One attribute which was highlighted by the focus group air is about an integrated **loyalty program**, but is this also valued by passengers? In order to find out, the loyalty program attribute is divided into two attribute levels:

- **Separate loyalty programs**. In this case, both the air as rail operator offer a separate loyalty program. For example, KLM offers Flying Blue membership with different tiers (Air France-KLM, n.d.). Train operators such as Deutsche Bahn also offer a loyalty program (BahnBonus) which also offers benefits to frequent train travellers (Deutsche Bahn, n.d.).

- **Integrated air/rail loyalty program**. This attribute level suggest one integrated loyalty program where earned points with, for example, KLM could also be spend for features on train rides (e.g. Thalys) and the other way around. The points could thus be exchanged between the two modes of transport.

Summarizing, all the attributes used for the air/rail comfort rating experiment, with its attributes levels, are shown in **Table 5.2**.

Table 5.2: Attribute levels for perceived air/rail comfort rating experiment

Attribute	**Levels**
Security	1. No priority 2. Air/rail priority
Lounge availability	1. No air/rail lounge availability 2. Air/rail lounge availability
WiFi availability	1. Free & limited WiFi 2. Paid & unlimited WiFi
Loyalty program	1. Separate loyalty programs 2. Integrated air/rail loyalty program

5.2.3. Attribute Levels Mode Choice Experiment

Concluding from the conceptual model of **Figure 4.2**, five main attributes are considered for the mode choice experiment: total travel time, ticket price, performance (i.e. delay in case of missed transfer), air/rail service and air/rail comfort.

The **total travel time** for air/air and air/rail journeys consist of several time elements that, together, make up the total travel time. The analysis on how the levels are determined is explained in **Appendix B.1**.

- **Flight time short-haul flight**. The alternative-specific attribute is only for air/air journeys, as the short-haul leg is replaced by train for air/rail journeys. There is only attribute level: **1 hour**.
- **Flight time long-haul flight**. The flight time for the long-haul intercontinental flight is kept the same for both alternatives: **10 hours**.
- **Transportation time train**. This attribute is alternative-specific for air/rail and is distinguished in three levels: **2 hours**, **4 hours** and **6 hours**.
- **Time spend at airport/ train station**. This is the total time spend at an airport or train station, including transfer time. This differs per alternative. For air/air, these are split into three levels: **2.5 hours**, **4 hours** and **5.5 hours**. For air/rail, also three levels are distinguished; **1.5 hours**, **3 hours** and **4.5 hours**.

The **total travel cost** is derived by looking at the air/rail product of Air France. They already offer air/rail tickets where the train leg is within France, in collaboration with the French railway operator SNCF (AirFrance, n.d.). These prices are compared to the prices of air/air journeys for the same journey as for air/rail, in order to see if those prices are substantially different from each other. The analysis of determining the total travel costs is shown in **Appendix B.2**. The attribute levels used in this study are: **1050 euro**, **1250 euro** and **1450 euro** for air/rail and only **1250 euro** for air/air.

The **delay in case of missed transfer** attribute is in this study explained as the answer to the following question: "How long do I need to wait for the next flight or train in case of a missed transfer?". The attribute levels are derived by having a deeper look into the frequencies of both transport modalities for several destinations, shown in **Appendix B.3**. For this attribute, the levels for air/air are set to **2 hours**, **4 hours** and **6 hours** and for air/rail to **1.5 hours**, **2.5 hours** and **3.5 hours**.

The **service** attribute is alternative-specific for air/rail and can be perceived differently per respondent. In this experiment, the range of attribute levels for this attribute is from 1 to 5, in terms of attractiveness. However, because most of the attributes consider three attribute levels, also three levels are considered for this attribute in the mode choice experiment: 1, 3 and 5. For the respondent, it could be hard to recall what a score expressed by a number represents. Therefore the corresponding labels for those scores are used: **very unattractive (1)**, **not unattractive but not attractive either (3)** and **very attractive (5)**.

For air/air, this is different. In order to determine attribute levels for the total cost of a trip, economy tickets were assumed. Therefore, **economy class** service is taken as service level for air/air. This entails full luggage integration between flights, a single ticket, all travel information located in one app and the availability of a customer service.

The **air/rail comfort** attribute is considered similarly as the service attribute. In the rating experiment, respondents are asked to rate the comfort level from 1 to 5. For the mode choice experiment, three levels are used because of orthogonality: 1, 3 and 5. Also here, for the respondents' understanding, the corresponding labels are used: **Very uncomfortable (1)**, **not uncomfortable but not comfortable either (3)**, and **very comfortable (5)**.

For the air/air alternative, the regular comfort levels for **economy class** tickets are assumed, as economy tickets are assumed when determining the ticket price. This entails no priority lanes, no lounge available, free and limited WiFi and one loyalty program for air/air journeys.

At last, it is expected that respondents do not value a minute travel time on a plane the same as in the train. Therefore, alternative specific coefficients are estimated for the parameters regarding travel time. The same holds for the delay in case of a missed transfer attribute. Waiting on an airport could be perceived differently than waiting on a train station, so for this attribute, the coefficients are estimated alternative specific. In the mode choice experiment, comfort and service are also estimated alternative specific because the services and comfort features offered by air/rail may be perceived differently than for air/air as well. Travel cost is a point of discussion, because from an economical perspective, every spend euro is the same. However, it could also be that an euro spend on either train or air travel may have different weights for travellers. Therefore, travel cost is also estimated alternative specific.

Summarizing, all the attributes used for the mode choice experiment, with its attributes levels, are shown in **Table 5.3**.

Table 5.3: Attribute levels mode choice experiment

Attribute	Levels air/air alternative	Levels air/rail alternative
Total travel time [hh:mm]:		
Flight time short-haul flight	[01:00]	
Flight time long-haul flight	[10:00]	[10:00]
Transportation time train		[02:00]; [04:00]; [06:00]
Time spend at airport/ train station	[02:30]; [04:00]; [05:30]	[01:30]; [03:00]; [04:30]
Total travel cost [€]	1250	1050; 1250; 1450
Delay due to missed transfer [hh:mm]	[02:00]; [04:00]; [06:00]	[01:30]; [02:30]; [03:30]
Service level	Economy class	Very unattractive; not unattractive but not attractive either; very attractive.
Comfort level	Economy class	Very uncomfortable; not uncomfortable but not comfortable either; very comfortable.

5.3. Choice Sets Generation

After defining the attributes with its attribute levels, choice sets are generated by using Ngene, a software tool to generate experimental designs for stated choice surveys. The Ngene user manual is held as source for defining the computer syntax (ChoiceMetrics, 2018). The syntax for both the rating experiments as the mode choice experiment are shown in **Appendix C**.

For this study, the determination of choice sets is based on traditional designs. Since full factorial design grows exponentially with the number of attributes, such a design explodes quickly. Therefore, a fractional factorial design is used, which results in an orthogonal design with uncorrelated attributes.

The rating experiment about air/rail services is considered to be an unlabelled experiment, because the alternative names do not represent a characteristic. Therefore, the choice sets can be generated sequentially, where the alternatives are randomly placed in the choice sets. For this experiment, Ngene is able to find an orthogonal fractional factorial design with eight rows, indicating eight choice situations. With eight choice sets, there are seven degrees of freedom. And with four attributes, there are enough degrees of freedom to estimate the included service parameters.

However, as there is also a rating experiment and a mode choice experiment included in this study, blocking is applied for the air/rail service rating experiment. This in order to prevent the respondent for having too much choice sets to trade off. A new design is generated using two blocks. This means that, for this experiment, every respondent gets four choice sets to rate the service level of air/rail. Within these blocks, it is essential to have every attribute level represented, otherwise some respondents have no attribute to trade off, which leads to less reliable estimates.

The same reasoning also holds for the rating experiment about perceived air/rail comfort. This is also considered to be an unlabelled experiment, because here the alternative names also do not represent a characteristic. Ngene is able to find an orthogonal fractional factorial design with eight rows for four attributes. Also here, blocking is applied. A new design is generated using two blocks, meaning that every respondent gets four choice sets. Also here, every attribute level is represented in every block at least ones.

For the mode choice experiment, Ngene is able to find an orthogonal fractional factorial design with 27 rows, so 27 choice sets. However, as there are already eight choice sets per respondent due to the rating experiments, blocking is also applied for the mode choice experiment. A design using three blocks of nine choice sets is generated. In total, in the survey, every respondent is now presented with seventeen choice sets. With 27 choice sets, every attribute level occurs equally often in each block.

With 27 choice sets for the, there are 26 degrees of freedom. With only eight parameters and one constant, there are seventeen degrees of freedom left. So, it is also be possible to estimate quadratic parameters for time spend at airport/ train station, service level and comfort.

5.4. Survey Construction

The choice sets generated by Ngene, per experiment, are used as basis for the survey. The survey is created in collaboration with MWM2, a market research company specialising in online research, including surveys. As they are in charge of the Dutch NS panel, the survey is held in Dutch.

The survey is divided in the following five parts:

1. Context questions about travel experience and trip purpose
2. Rating experiment air/rail service
3. Rating experiment air/rail comfort
4. Mode choice experiment air/air vs. air/rail
5. Questions on unpleasant travel experiences and socio-demographic characteristics

After introducing the respondent with a informed consent form and the air/rail topic, context questions about travel experience, trip purpose, travel company and check-in luggage are asked.

The second part of the survey consists of the rating experiment about potential air/rail service features. For every row in the experimental design created by Ngene, a choice situation is made. One example of a choice set is shown in **Figure 5.1**. All profiles for the service rating experiment are shown in **Section D.1** in **Appendix D**.

Vraag: Als u kijkt naar het onderstaande scenario, hoe aantrekkelijk zou u de volgende services vinden van de gecombineerde trein-vliegtuig reis?

	Voor uw treinrit kunt u uw ruimbagage **niet** afgeven; voor uw vlucht kunt u **wel** uw ruimbagage afgeven
TICKET	U moet **losse tickets** boeken voor uw vlucht en treinrit; omboeken kost extra geld
	De treinvervoerder en luchtvaartmaatschappij hebben **aparte apps/ websites** voor hun informatievoorziening
HELP DESK	Voor vragen moet u naar de **aparte klantenservice** van of de luchtvaartmaatschappij of treinvervoerder

- Heel onaantrekkelijk
- Onaantrekkelijk
- Niet onaantrekkelijk, maar ook niet aantrekkelijk
- Aantrekkelijk
- Heel aantrekkelijk

Figure 5.1: Example choice set for air/rail service rating experiment

The third part consists of the comfort rating experiment. Respondents are asked to score the proposed set of attribute levels in terms of comfort. One example is shown in **Figure 5.2**. All profiles for the comfort rating experiment are shown in **Section D.2** in **Appendix D**.

Vraag: Als u kijkt naar het onderstaande scenario, hoe comfortabel zou de volgende kenmerken van een gecombineerde trein-vliegtuig reis vinden?

	U kunt **met priority** door de security voor uw gehele reis
	Voor uw reis is er **geen lounge beschikbaar** op het vliegveld/treinstation
4G	De Wi-Fi in de trein en vliegtuig is **gratis maar gelimiteerd**; u kunt alleen tekstberichten of e-mails sturen
	Er is **één loyaliteitsprogramma** beschikbaar waarbij de punten tussen trein en vliegtuig **wel uitwisselbaar** zijn

- Heel oncomfortabel
- Oncomfortabel
- Niet oncomfortabel, maar ook niet comfortabel
- Comfortabel
- Heel comfortabel

Figure 5.2: Example choice set for air/rail comfort rating experiment

The fourth part is the mode choice experiment between an air/air and an air/rail alternative. One example of a choice set for the mode choice experiment is shown in **Figure 5.3**. All choice sets used in the mode choice experiment are shown in **Section D.3** in **Appendix D**.

Als u onderstaande reismogelijkheden beschouwd, welke zou u kiezen?

	Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
	Service niveau	Economy class	Heel onaantrekkelijk
	Comfort niveau	Economy class	Heel oncomfortabel
	Totale reistijd, waarvan:	**13:30**	**13:30**
	Vluchttijd korte afstand:	01:00	
	Vluchttijd lange afstand:	10:00	10:00
	Voertuigtijd korte afstand trein:		02:00
	Tijd op vliegveld/ treinstation:	02:30	01:30
	Totale reiskosten	€1250	€1050
	Wachttijd in geval van gemiste overstap	02:00	01:30

- Vliegtuig + Vliegtuig
- Trein + Vliegtuig

Figure 5.3: Example choice set for air/air vs. air/rail mode choice experiment

The last part of the survey are questions about unpleasant travel experiences of travellers and socio-demographic characteristics. These demographics are received from the already existing dataset of the Dutch NS panel.

5.5. Survey Testing and Distribution

As already introduced, this survey makes use of the Dutch NS panel. The benefit of such a panel is that it offers a large pool of potential respondents, opposite to recruiting respondents from own networks. Another benefit is that a panel increases the possibility of having a sample that is more representative for the population.

As this study makes use of this Dutch NS panel, the survey is held in Dutch and therefore are all the questions and choice sets of this survey translated into Dutch. This is also one disadvantage, since this study does not only focus on the Dutch population. It would also be valuable to quantify the traveller needs of other European residents, as TEN-T will also connect their countries. But with an Dutch panel, that is not possible.

Another drawback of this panel is that most respondents are biased towards rail travel, as they are part of a railway panel and helps NS improving their services via their opinion.

Before the actual survey could be distribution among the NS panel, the first draft will be tested among test respondents. These respondents consist of persons from various backgrounds: study friends with similar interest in transport studies and family and friends who have no affinity with transport-related studies. Their feedback will be taken into account for designing the final survey.

5.6. Necessary Number of Respondents

The last part of this chapter is determining the number of respondents for both the rating experiments as the mode choice experiment. Orme (2006) presents a formula to calculate the minimum number of respondents needed for these kind of experiments. The formula is shown in **Formula 5.1**.

$$\frac{n \cdot t \cdot a}{c} \geq 500 \tag{5.1}$$

In this formula, n is the number of respondents, t the number of choice sets, a the number of alternative and c the maximum number of attribute levels used in the experiment. Rewriting this equation for n and putting in the values for the rating experiments and mode choice experiment, the following number of respondents are needed per experiment:

- **Rating experiment air/rail service**. In this experiment, t is equal to eight, a is equal to two and c is equal to two. For n, approximately 63 respondents is found. However, using two blocks, 126 respondents are needed in total.
- **Rating experiment air/rail comfort**. In this experiment, t is equal to eight, a is equal to two and c is equal to two. For n, approximately 63 respondents are needed. Using two blocks of four, 126 respondents are needed as well.
- **Mode choice experiment air/air vs. air/rail**. In this experiment, t is equal to 27, a is equal to two and c is equal to three. For n, approximately 28 respondents are needed. With using blocks of three, 84 respondents are needed for this experiment as well.

6
Data Analysis

This chapter examines the data sample by showing the socio-demographic characteristics in **Section 6.1** and travel characteristics in **Section 6.2**. Also, an overview is given on the mode choice split in **Section 6.3**. **Section 6.4** explains the aggregation potentials of this study. And, at last, **Section 6.5** shows how the variables are coded for the experiments.

6.1. Socio-demographic Composition

In the survey, several socio-demographic characteristics are asked from the Dutch respondents of the NS panel. With these background variables, knowledge about the composition of the response group can be derived. The results are shown in **Table 6.1**. In total, the dataset contains 553 responses. However, after exclusion of non-answered questions, 541 complete responses were left in the dataset.

For the background variables gender and age, a comparison is made with data from the Dutch population (Centraal Bureau voor de Statistiek, n.d.-a, n.d.-b; Kantelaar, 2019). As can be concluded from this data, the distribution of gender between the response group and the Dutch population is quite similar. However, CBS makes no separate categories for people who identify themselves as an other gender. Also, in this research, people were able to not reveal their gender by answering ”prefer not to say”.

Regarding age, for this research, age is divided in several age groups. The received data from Centraal Bureau voor de Statistiek (n.d.-a) uses other categories for age groups compared to what is used in this survey. But still, it can be observed that the group size people older than 65 years old is quite similar between the Dutch population (20%) and the response group (18.3%). This is often not found in literature studies.

Comparing the response group with the Dutch population on the background variables variables education and occupation, it can be concluded that this response group is highly educated, as almost 40% of the group holds a master’s degree or higher. And regarding occupation, the main majority of the sample is a salaried employee (65.1%), followed by the group of retired people (15.9%).

Table 6.1: Demographic composition of respondents

Variable	Category	Number	Percentage	Dutch population
Gender	Male	264	47.7%	49.7%
	Female	282	51.0%	50.3%
	Other	4	0.7%	0.0%
	Prefer not to say	3	0.5%	0.0%
	Total	**541**	**100%**	**100%**
Age	18-24	51	9.4%	21% (< 20)
	25-34	112	20.7%	26% (20-40)
	35-44	88	16.3%	33% (40-65)
	45-54	88	16.3%	15% (65-80)
	55-64	103	19.0%	5% (80+)
	65-74	99	18.3%	
	Total	**541**	**100%**	**100%**
Education	Preschool	3	0.6%	10.3 %
	VBO, MAVO, VMBO, MBO1	45	8.3%	21.3 %
	HAVO, VWO, MBO2-4	80	14.8%	38.7%
	HBO, WO Bachelor	195	36.0%	18.9 %
	WO Master or higher	207	38.3%	10.8 %
	Other	11	2.0%	
	Total	**541**	**100%**	**100%**
Occupation	Salaried employee	352	65.1%	57.3 %
	Entrepreneur w/ employees	5	0.9%	
	Entrepreneur w/o employees	21	3.9%	
	Unemployed/looking for work	8	1.5%	2.2 %
	Unfit for work	11	2.0%	
	Retired	86	15.9%	28.6 %
	Pupil or student	51	9.4%	11.9 %
	Other	7	1.3%	
	Total	**541**	**100%**	**100%**

6.2. Travel Experience and Trip Characteristics

Apart from socio-demographic characteristics, the survey respondents were also asked about their general travel experience of the past five years for both the international train as for flying. According to **Table 6.2**, more than 25% of the respondents admit that they never used an international train in the past five years. In contrast, every respondent in this dataset has flown one or more times in the past five years.

Also, respondents were asked about their unpleasant travel experiences for both train as air travel. The hypothesis is that unpleasant experiences in the past could influence the decision whether to take the train or plane in the future. **Table 6.2** shows that 73.6% of this sample has had one or more unpleasant experiences with train travel. This in contrast to air travel, where 42.2% had one ore more experiences which were undesirable.

The last table is about trip characteristics. As shown in **Table 6.3**, 71% of the respondents were completing the survey from the perspective of travelling for leisure purposes. The respondents were also asked if they ever travelled for business purposes, and 29% did complete the survey from this perspective. Regarding travel company, most of the trips were either alone (37.5%) or with a partner (27.7%) and the majority of the respondents (56.4%) had check-in luggage with them.

The main conclusion, based on the socio-demographic composition, travel experience and trip characteristics, is that there is heterogeneity in this dataset. This heterogeneity can't be captured by the multinomial logit model, as this model assumes that all estimated betas are equal across all people of the population. In order to capture this heterogeneity, a latent class choice model is used where these variables could be included in the membership function.

Table 6.2: Travel experience of respondents

Variable	Category	Absolute number	Percentage
General travel experience			
International train experience past 5 years	0 times	144	26.6%
	1 time	45	8.3%
	2-3 times	121	22.4%
	4-5 times	81	15.0%
	6-10 times	69	12.8%
	> 10 times	78	14.4%
	I don't know	3	0.6%
	Total	**541**	**100%**
Flight experience past 5 years	0 times	0	0.0%
	1 time	88	16.3%
	2-3 times	156	28.8%
	4-5 times	91	16.8%
	6-10 times	102	18.9%
	> 10 times	103	19.0%
	I don't know	1	0.2%
	Total	**541**	**100%**
Unpleasant travel experience(s) past 5 years			
Train travel	0 times	104	19.2%
	1 time	88	16.3%
	2-3 times	133	24.6%
	4-5 times	60	11.1%
	6-10 times	46	8.5%
	> 10 times	71	13.1%
	I don't know	39	7.2%
	Total	**541**	**100%**
Flight travel	0 times	286	52.9%
	1 time	148	27.4%
	2-3 times	71	13.1%
	4-5 times	7	1.3%
	6-10 times	1	0.2%
	> 10 times	1	0.2%
	I don't know	27	5.0%
	Total	**541**	**100%**

Table 6.3: Trip characteristics of respondents

Variable	Category	Absolute number	Percentage
Trip purpose	Business	157	29.0%
	Leisure	384	71.0%
	Total	**541**	**100%**
Travel company	Alone	203	37.5%
	With colleagues	73	13.5%
	With children	16	3.0%
	With partner	150	27.7%
	With partner and children	31	5.7%
	With friends	68	12.6%
	Total	**541**	**100%**
Check-in luggage	Yes	305	56.4%
	No	236	43.6%
	Total	**541**	**100%**

6.3. Mode Choice Split

This section explores the choices that respondents made during the survey. As already discussed in **Section 5.3**, the mode choice experiment follows a design of 27 choice sets. **Figure 6.1** shows the distribution of the choices between air/rail and air/rail for all choice sets in percentages. On average, over all choice sets, the air/rail alternative (i.e. train + plane) is chosen 53% of the times, which indicates that this alternative is found slightly more favourable than the air/air alternative (i.e. plane + plane), according to the respondents.

The air/rail alternative is mostly chosen in choice set 9 with 89%. In this choice task, the service level was very attractive, the comfort level very comfortable, the total travel time was as long as compared to the air/air alternative and was also as expensive. Also the delay in case of missed transfer was lower. Therefore this option was most likely to be chosen. But still, there is no dominance, as 11% of the respondents chose the other alternative.

The air/rail alternative is chosen the least in choice set 26 with 14%. In this choice task, the air/air alternative was cheaper and also much faster. The service and comfort levels of air/rail were also not really appealing and the waiting time in case of missed transfer was slightly longer. But this alternative is not fully dominated, as 14% still chose this option.

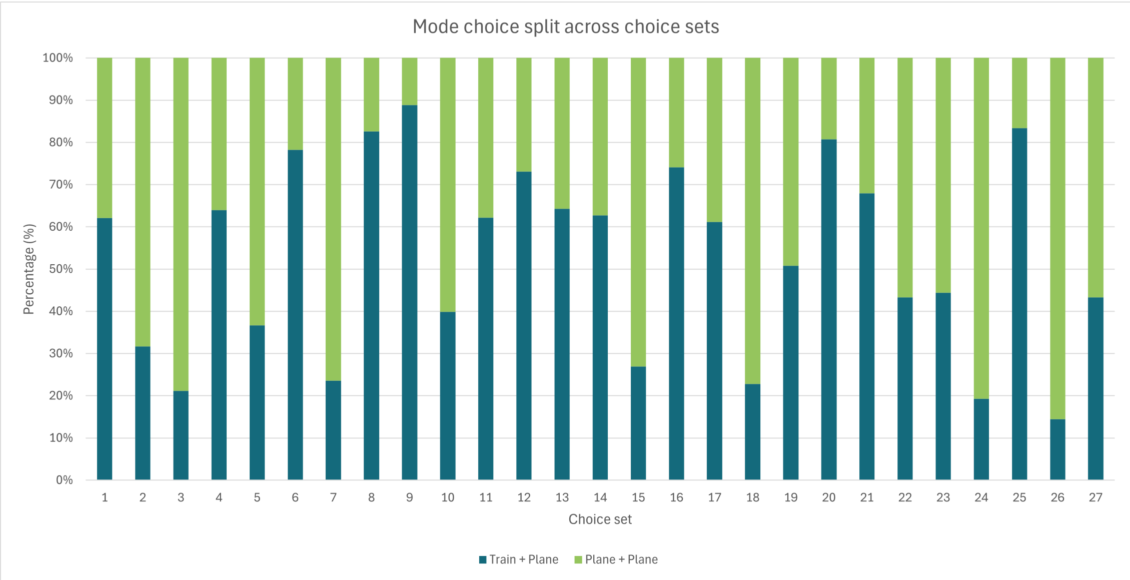


Figure 6.1: Mode choice percentages per choice task

6.4. Data Aggregation Potentials

The population targeted by this study is basically the entire Dutch population. The survey did not ask any questions to exclude people from this study. This was chosen in order to get the sample size as large as possible, in order to get more reliable parameters with the estimated models.

However, it should be mentioned that the sample of this study is not a random sample of the Dutch society. Since all respondents are part of the NS panel, this may yield biased estimates. Namely, it is quite plausible that people who are part of the NS panel may have a stronger preference for train travel compared to the Dutch population. The same holds for using the train for domestic travel. However, this does not necessarily mean that respondents of the NS panel do favour international train travel over air travel as well. But this is something to keep consider, interpreting the outcomes of the models.

After all, there are two alternatives: air/rail and air/air. Since the members of the NS panel may prefer the alternative including train travel, those parameters may be overestimated, showing a stronger preference towards the air/rail alternative than what the population would actually have.

This does not mean that the estimated parameters lose their value in this study. If significant parameters are found, it means they can be aggregated to a population which is highly educated and mostly working and where individuals may have a slight preference for train travel. If parameters are not found significant, the parameter values still say something about the response group, although the effects will be marginal. This is one of the limitations of this study because the response group was not randomly selected from the Dutch population.

About the bias towards rail travel, is the response group, recruited from the NS panel, actually slightly biased towards air/rail? Well, in the previous section, it is mentioned that, on average, 53% of the response group chose air/rail. In addition, the air/air alternative dominates in twelve of the 27 choice sets. If the response group were truly biased towards rail, this was expected to be less. Also, looking at the travel experience, over 25% admitted that they did not take an international train in the past five years. Even, 57.3% of the respondents have used the international train less than three times in the last five years. Comparing to flight experience, 54.7% has made four or more journeys in the past five years. So with respect to travel experience, it could even be argued that this response group may be even biased towards flying.

6.5. Data Coding

6.5.1. Coding Rating Experiments

The main variables that are used for both the service rating as the comfort rating experiment are shown in **Table E.1** in **Appendix E**. The main variables for both experiments are measured on a nominal scale. There is no reason to believe that these variables are having linear effects, and therefore are these variables effects coded. The average utility contribution of all levels is always zero in this case. From this, the utility contribution of each attribute level can be determined.

Every main attribute of both the rating experiments has two levels, so using effects coding is quite straightforward. But this is not the case for the socio-demographic characteristics, travel experience and trip characteristics. For example, the variable education has six categories. With effects coding, there would be too many variables. Therefore, it is chosen to recategorise the variables by merging different categories. The new parameter for education is categorized in two levels: HBO Bachelor or higher and Else. Every single respondent is still placed in one of the two categories. How each variable is coded regarding socio-demographics, travel experience and trip characteristics is shown in **Table E.3** in **Appendix E**.

6.5.2. Coding Mode Choice Experiment

For the mode choice experiment, every variable is on either a ratio or an interval scale and do not have to be coded explicitly. The travel attribute about cost is scaled to improve estimation. Special attention for the attributes service level and comfort level, these are included as linear variables because linearity is also assumed in both the rating experiments. **Table E.2** in **Appendix E** shows the main attributes included in the mode choice experiment with its levels and variable name.

7 Results

This chapter contains the model results for the experiments. **Section 7.1** discusses the regression results for the the service rating experiment and **Section 7.2** for the comfort rating experiment. **Section 7.3** dives into the multinomial logit model results and interpret the estimated parameters. At last, **Section 7.4** gives insight into the different customer segments for air and rail integration by looking into the latent class choice model.

7.1. Results Service Rating Experiment

7.1.1. Linear Regression Results

In order to answer the research question on how integrated service features influence the service level rating of air/rail, a linear regression model is chosen as research method. This is because respondents were asked to rate the service, based on a 1 to 5-scale. This could be considered as an continuous scale, where level 2 is twice as more attractive compared to level 1. Therefore, a linear regression model is estimated, using IBM SPSS Statistics 29.0.2.0.

The service level rating is used as the dependent variable in this linear regression. The independent variables are: Luggage, Ticket, Info and Helpdesk. These nominal variables are effects coded. Also, some background variables are included: Age, Student, TrainExp, FlightExp, Purpose and Checkin, based on the introduced expectations. These variables are coded as shown in **Table E.1** and **Table E.3** in **Appendix E**.

The parameter value, t-value and significance level (95% interval) of the linear regression models are shown in **Table 7.1**. There are three estimated models, one with the main effects only, one including background and interaction effects and one final model with stepwise regression. Stepwise regression involves adding or removing potential explanatory variables after each iteration, based on its statistical significance.

Table 7.1: Linear regression results service rating experiment

Model	**Main effects**			**Background & Interactions**			**Final model**		
Parameter	**Value**	**t**	**Sig.**	**Value**	**t**	**Sig.**	**Value**	**t**	**Sig.**
Constant	3.273	165.627	<0.001	3.536	51.333	<0.001	3.531	51.408	<0.001
Luggage	0.185	9.340	<0.001	0.178	8.289	<0.001	0.185	9.486	<0.001
Ticket	0.554	28.012	<0.001	0.553	28.410	<0.001	0.554	28.451	<0.001
Info	0.213	10.758	<0.001	0.213	10.921	<0.001	0.213	10.926	<0.001
Helpdesk	0.177	8.981	<0.001	0.157	2.619	0.009	0.177	9.121	<0.001
Age				-0.006	-4.289	<0.001	-0.006	-4.180	<0.001
Student				0.219	3.784	<0.001	0.230	4.028	<0.001
Purpose				-0.025	-1.082	0.280			
TrainExp				0.090	3.178	0.002	0.087	3.079	0.002
FlightExp				-0.080	-3.127	0.002	-0.083	-3.310	<0.001
Checkin				0.035	1.699	0.089	0.040	1.985	0.047
LuggagePurpose				-0.015	-0.668	0.504			
HelpdeskAge				0.000	0.369	0.712			
LuggageCheckin				0.005	0.226	0.822			
R-square	0.332			0.354			0.354		
Adj. R-square	0.330			0.350			0.351		

7.1.2. Parameter Interpretation

Looking at the adjusted (adj.) R-square of all three estimated models, it can be concluded that the final model performs better than the base model with main effects only and slightly better than the model with background and interactions. The final model explains 35.1% of the variance in the dependent variable. This percentage is adjusted for the number of predictors in the model.

Looking at the direction of the parameters of the final model, all of them have the expected sign (see **Section 4.6.1**). All main effects are positive. Ticketing has the largest positive effect on the overall rating (0.554) and is found about three times more attractive than luggage (0.185) and helpdesk integration (0.177). And an integral information platform (0.213) for an air/rail journey is perceived as slightly more attractive than both luggage as helpdesk integration.

Looking at the background variables, age is indeed found to be negative (-0.006). This means if a person ages one year, it gives a 0.006 lower rating to the general service level. The effect seems to be marginal, but can have quite some impact. For a person of 20 years old is the effect 0.120, for 50 years 0.300 and for someone who is 80 years old 0.480.

In the final model, it is found that students generally give higher ratings (0.230), strengthening the hypothesis that this group is more likely to be satisfied with lower service levels. In the model with background and interactions it is found that the parameter purpose is negative, but also found insignificant, meaning that there is not enough evidence to believe that travellers with business purposes are rating the general service level differently than people who travel for leisure purposes in the population.

The expectations for the parameter signs of train experience (0.087) and flight experience (-0.083) also hold, but the effect is marginal. Noticeable is that the variable Checkin becomes significant in the final model (0.040). So this means that people who carry a check-in suitcase give a higher rating to the overall service level.

Regarding the interaction effects in the final, none of the expectations hold, as all parameters are found to be insignificant. There is not enough evidence to believe that there is a relation between trip purpose and luggage, helpdesk and age and checkin and luggage in the population. However, because none of the interaction effects are significant, the model can be applied to anyone without specific conditions about trip purpose, age or having check-in luggage. This increases the generalisability of this linear regression model.

Regarding the sample, there are small effects found in the model with background and interactions for the interaction between luggage and purpose (-0.015) and between luggage and check-in (0.005). Regarding luggage and purpose, a negative parameter indicates that people with leisure purposes slightly rate luggage integration higher. There is also a very small relation found between luggage integration and check-in luggage, indicating that people with check-in luggage rate luggage integration higher than people that don't. But, this is only for the people in the sample, not for the population.

Now, with the linear regression results of the service rating experiment, different integration scenarios can be constructed. Chiambaretto and Decker (2012) introduced several levels of integration between air and rail. These levels can now be quantified. **Table 7.2** shows the integration levels, the associated parameter values (effects coded) and the predicted ratings. The predicted service rating ($Rservice$) for every scenario is calculated with the regression formula, shown in **Equation 7.1**.

$$Rservice = 3.531 + 0.185 \cdot Luggage + 0.554 \cdot Ticket + 0.213 \cdot Info + 0.177 \cdot Helpdesk \quad (7.1)$$

Table 7.2: Air/rail integration level scenarios and predicted service level ratings

Scenario	Luggage	Ticketing	Information	Helpdesk	Predicted rating
No integration	-1	-1	-1	-1	2.4
Low integration	-1	1	-1	-1	3.5
Moderate integration	-1	1	1	-1	3.9
High integration	1	1	1	1	4.7

Concluding from **Table 7.2**, as expected, full integration is perceived as most attractive and no integration as the least attractive. However, it is still worth notifying that the step from low integration to moderate integration, based on the definition of Chiambaretto and Decker (2012), is only perceived as 0.4 points more attractive by the respondents. Also, the step from no integration to low integration, with only the integration of tickets, is perceived as way more attractive with a difference of 1.1 points. This is almost equal to the effect going from low integration to full integration. However, adding luggage integration is operationally quite challenging.

7.2. Results Comfort Rating Experiment

7.2.1. Linear Regression Results

The second research question of this study is about travel attributes influencing the comfort rating of air/rail from the perspective of Dutch travellers. The same method is applied as for the service rating experiment, a linear regression model. This with the same consideration about the scale on which respondents had to answer. The rating is representing a continuous scale, and therefore a linear regression can be used. The data is prepared in Microsoft Excel and estimation is done using IBM SPSS Statistics 29.0.2.0.

In this regression, the comfort level rating is the dependent variable. The independent variables are: Security, Lounge, PaidWifi and Loyalty. These nominal variables are effects coded. Here, based on the expectations, also other background variables are included: Age, Student, Retired, Purpose and TrainExp. Other socio-demographic characteristics are not included because there is no valid reason to say anything about the direction of those parameters. The coding of the included variables is shown in **Table E.1** and **Table E.3** in **Appendix E**.

The estimated coefficients of the regression model are shown in **Table 7.3**. There are three estimated models. One with only the main effects, one including the background and interaction variables and the final model with stepwise regression. Per estimated model, the parameter estimates, t-value and significance level is shown. For the significance level, a 95% interval level is taken.

Table 7.3: Linear regression results comfort rating experiment

Model	Main effects			Background & Interactions			Final model		
Parameter	Value	t	Sig.	Value	t	Sig.	Value	t	Sig.
Constant	3.109	160.646	<0.001	3.274	39.478	<0.001	3.158	114.903	<0.001
Security	0.394	20.335	<0.001	0.417	19.661	<0.001	0.417	19.659	<0.001
Lounge	0.313	16.155	<0.001	0.314	14.776	<0.001	0.313	16.222	<0.001
PaidWifi	-0.056	-2.913	0.004	-0.060	-2.826	0.005	-0.056	-2.927	0.003
Loyalty	0.111	5.731	<0.001	0.113	5.347	<0.001	0.111	5.759	<0.001
Age				-0.003	-1.638	0.102			
Student				0.063	0.920	0.358			
Retired				0.145	2.400	0.016			
Purpose				-0.016	-0.747	0.455			
TrainExp				0.079	2.835	0.005	0.079	2.868	0.004
SecurityPurpose				0.056	2.642	0.008	0.056	2.639	0.008
LoungePurpose				0.002	0.112	0.911			
PaidWifiPurpose				-0.009	-0.402	0.688			
LoyaltyPurpose				0.006	0.283	0.777			
R-square	0.243			0.253			0.251		
Adj. R-square	0.241			0.249			0.248		

7.2.2. Parameter Interpretation

Looking at the adjusted R-square of all the models, the model with background and interactions explains the most variance with 24.9%, slightly more than the final model which explains 24.8% of the total variance. Both models, however, perform better than the initial base model with main effects only. For the interpretation of the parameters, the second model with background and interactions is hold, because it best fits the data.

All estimated parameters have the expected sign direction (see **Section 4.6.2**). Security, lounge and loyalty are found to be positive, meaning that travellers rate the overall comfort level higher when these comfort features are present. The variable regarding WiFi is found to be negative, which means that people rather have free and slow WiFi than paid and good WiFi. However, with a parameter value of -0.056, the effect is marginal. Security has the biggest positive effect on the general comfort rating (0.417), followed by the availability of a lounge (0.314) and loyalty program (0.113). Security is perceived almost four times more comfortable than an integrated loyalty program. As for lounges, they are nearly three times more comfortable. These two parameters are the primary factors influencing the perceived comfort of air/rail.

Looking at the background variables, age, student, retired and purpose are found to be insignificant, so the expectations do not hold regarding these variables. However, people who have quite some experience with travelling by international trains do rate the general comfort level higher (0.079), so this expectation holds. However, the effect is approximately half as compared to the group of retired people (0.145), who perceive more comfort from the proposed combination of comfort level features in the rating experiment.

The interaction effect of purpose and security is found to be positive and significant (0.056). This means that the impact of priority security lanes on the overall comfort rating depends on the trip purpose. With business coded positively (purpose = 1), meaning that business travellers rate the general comfort level higher when having priority security lanes. This is an outcome on which specific policies can be implemented by airlines, airports and train operators

Regarding the other interaction effects, there is not enough evidence to claim that trip purpose modifies the weight of the parameters Lounge, PaidWifi and Loyalty in the population. Also, in the response group, the effects are extremely small. Travellers with business purposes perceive more comfort from having a lounge, but the effect is found 28 times smaller with respect to priority lanes. For loyalty, this is almost ten times as small.

But still, it is difficult to say something about the magnitudes, because of the effects coded parameters. For example, regarding the interaction of trip purpose and lounge, if half of the respondents perceive more comfort from having a lounge, and the other half doesn't, the effect cancels out. While if you would interview groups of travellers if they perceive more comfort when having access to a lounge with all kinds of extra amenities, they would probably say yes at all times. But in general, not specified for trip purpose, travellers perceive more comfort from having access to a lounge. This also makes sense because if passengers get lounge access with their air/rail ticket without having to pay for it, then people will appreciate this more quickly.

Also in this experiment, several scenarios can be tested. Here, four scenarios are constructed. As this model must be specified for trip purpose, so it is less generelisable, but more specific. Therefore, the scenarios for the minimum and maximum comfort features are tested for dedicated trip purposes. **Table 7.4** shows the comfort scenarios and predicted ratings. The predicted comfort rating ($Rcomfort$) for each scenario is calculated with the regression formula shown in **Equation 7.2**.

$$\begin{aligned} Rcomfort = 3.158 + 0.417 \cdot Security + 0.313 \cdot Lounge - 0.056 \cdot PaidWifi \\ +0.111 \cdot Loyalty + 0.056 \cdot Security \cdot Purpose \end{aligned} \quad (7.2)$$

Table 7.4: Air/rail comfort scenarios and predicted comfort level ratings

Scenario	Security	Lounge	PaidWifi	Loyalty	Purpose	Predicted rating
Min. comfort; leisure	-1	-1	1	-1	-1	2.3
Min. comfort; business	-1	-1	1	-1	1	2.2
Max. comfort; leisure	1	1	-1	1	-1	4.0
Max. comfort; business	1	1	-1	1	1	4.1

As can be concluded from **Table 7.4**, business travellers experience the minimum comfort scenario as slightly less comfortable compared to people who travel for leisure purposes. But, people travelling for business do perceive the included comfort features as slightly more comfortable, with respect to leisure travellers. But both effects are very minimal, as the predicted ratings only differ 0.1 on a scale of 5.0 between the two trip purposes.

7.3. Results Mode Choice Experiment

7.3.1. Model Results Mode Choice Experiment

This section discusses the model results of the mode choice experiment. In order to answer the research question about which (operational) travel determinants are significantly impacting the mode choice, discrete choice modelling is applied. The used coding is shown in **Table E.2** in **Appendix E**. The data is prepared in Microsoft Excel and the models are estimated using PandasBiogeme (Bierlaire, 2018). The syntax code for estimating the multinominal logit models can be found in **Appendix F**.

Before the MNL models can be estimated, utility functions must be constructed. The equations for the utility functions for the air/rail and air/air alternative, including quadratic components, are shown in **Equation 7.3** and **Equation 7.4**, respectively.

$$\begin{aligned} V_{\text{train\_plane}} = ASC_{\text{train\_plane}} \\ + \beta_{\text{tt\_train\_train\_plane}} \cdot \text{tt\_train\_train\_plane} \\ + \beta_{\text{wt\_train\_plane}} \cdot \text{wt\_train\_plane} \\ + \beta_{\text{del\_train\_plane}} \cdot \text{del\_train\_plane} \\ + \beta_{\text{tc\_train\_plane}} \cdot \text{tc\_train\_plane\_scaled} \\ + \beta_{\text{serv\_train\_plane}} \cdot \text{serv\_train\_plane} \\ + \beta_{\text{comf\_train\_plane}} \cdot \text{comf\_train\_plane} \\ + \beta_{\text{comf\_train\_plane\_Q}} \cdot (\text{comf\_train\_plane} \cdot \text{comf\_train\_plane}) \\ + \beta_{\text{wt\_train\_plane\_Q}} \cdot (\text{wt\_train\_plane} \cdot \text{wt\_train\_plane}) \\ + \beta_{\text{serv\_train\_plane\_Q}} \cdot (\text{serv\_train\_plane} \cdot \text{serv\_train\_plane}) \end{aligned} \tag{7.3}$$

$$\begin{aligned} V_{\text{plane\_plane}} = ASC_{\text{plane\_plane}} \\ + \beta_{\text{wt\_plane\_plane}} \cdot \text{wt\_plane\_plane} \\ + \beta_{\text{del\_plane\_plane}} \cdot \text{del\_plane\_plane} \\ + \beta_{\text{wt\_plane\_plane\_Q}} \cdot (\text{wt\_plane\_plane} \cdot \text{wt\_plane\_plane}) \end{aligned} \tag{7.4}$$

The model with only the main effects is considered as basic model. In the second model, the expected quadratic parameters are added. The effect of adding quadratic parameters for service, comfort and time spend at airport/ train station is tested against the base model. Both models are shown in **Table 7.5**.

Table 7.5: Parameter estimates for base model and base model with quadratic components

Model:	Base model			Base model & Quadratic components		
Parameter	**Value**	**t**	**Sig.**	**Value**	**t**	**Sig.**
ASC_train_plane	4.615	13.858	<0.001	4.178	6.958	<0.001
Beta_comfort_train_plane	0.212	10.751	<0.001	0.446	4.304	<0.001
Beta_del_plane_plane	-0.082	-4.191	<0.001	-0.078	-3.973	<0.001
Beta_del_train_plane	-0.158	-4.067	<0.001	-0.160	-4.115	0.478
Beta_service_train_plane	0.172	8.717	<0.001	0.073	0.710	<0.001
Beta_tc_train_plane	-0.368	-18.236	<0.001	-0.367	-18.154	<0.001
Beta_tt_train_train_plane	-0.241	-12.164	<0.001	-0.239	-12.116	<0.001
Beta_wt_plane_plane	-0.227	-8.559	<0.001	-0.429	-1.758	0.079
Beta_wt_train_plane	-0.317	-12.126	<0.001	-0.364	-1.991	0.404
Beta_comfort_train_plane_Q				-0.039	-2.282	0.023
Beta_service_train_plane_Q				0.016	0.987	0.327
Beta_wt_plane_plane_Q				0.025	0.835	0.404
Beta_wt_train_plane_Q				0.007	0.244	0.807
Rho-square	0.228			0.229		
Adjusted Rho-square	0.226			0.226		

The first thing to notice is that the adjusted Rho-square is the same for both models. Both models have similar explanatory power, adjusted for the number of predictors in the model. Regarding the interpretation of the parameters, this is further discussed in **Section 7.3.4**.

7.3.2. Model Comparison

This sections compares both the estimated models. **Table 7.6** shows the estimated parameters, Rho-square, initial and final log-likelihood for both multinominal logit models.

Table 7.6: Model comparison linear MNL model and MNL model including quadratic components

Model	#Parameters	Rho-square	Initial LL	Final LL
MNL base	9	0.228	-3754.417	-2896.605
MNL base & Quadratic components	13	0.229	-3754.417	-2893.017

In order to compare both models, the likelihood ratio test (LRS) is used. This test can be used to test the hypothesis that the model with quadratic components is statistically better than the base model. The calculation of the LRS is shown in **Equation 7.5**.

$$\begin{aligned} LRS &= -2 \cdot (LL_{\text{MNL\_base}} - LL_{\text{MNL\_base, quadratic}}) \\ &= -2 \cdot (-2896.605 + 2893.017) \\ &= 7.176 \end{aligned} \tag{7.5}$$

The critical value (χ^2) for a parameter difference of four and a significance level at 95% is 9.488. Therefore, according to the likelihood ratio test, the hypothesis that the model with quadratic parameter fits the data better than the base model must be rejected. The chance that the model with quadratic parameters better fits the data due to the randomness of the sample is bigger than 5%. However, with a significance level of 80%, the hypothesis can be assumed (critical value = 7.29).

Based on the results that the model with quadratic parameters does not better fit the data than the base model, with a confidence interval of 95%, it is chosen to only use the parameters of the linear base model for the calculation of the utility contributions and the latent class choice model.

7.3.3. Utility Contribution

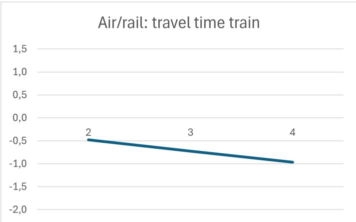
In order to answer the research question about the impact of travel decision determinants on the choice for an integrated air and rail service, a closer look into the utility contributions of the estimated parameters must be taken. **Table 7.7** shows the estimates for the parameters, the minimum (min.) utility contribution and the maximum (max.) utility contribution, based on the used ranges of the attribute levels. Regarding the travel cost attribute, the levels are scaled by dividing those by 100 in order to get an estimate which is more interpretation-friendly.

Table 7.7: Estimates and utility contributions linear base model for air/rail and air/air alternatives

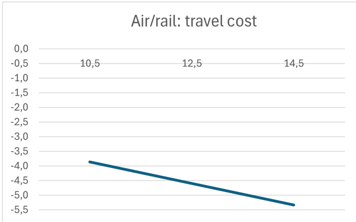
Attributes	Linear estimate	Attribute range	Min. utility contribution	Max. utility contribution
Attributes air/rail alternative				
Travel time train	-0.241	2 - 4 (hrs)	-0.964	-0.482
Travel cost	-0.368	10.5 - 14.5 (€/ 100)	-5.336	-3.864
Time at airport/ train station	-0.317	1.5 - 4.5 (hrs)	-1.427	-0.476
Waiting time missed transfer	-0.158	1.5 - 3.5 (hrs)	-0.553	-0.237
Service level	0.172	1 - 5 (score)	0.172	0.860
Comfort level	0.212	1 - 5 (score)	0.212	1.060
Attributes air/air alternative				
Time at airport	-0.277	2.5 - 5.5 (hrs)	-1.524	-0.693
Waiting time missed transfer	-0.082	2 - 6 (hrs)	-0.492	-0.164

From **Table 7.7**, it can be concluded that the largest negative effect for travelling with integrated air and rail is caused by the travel cost, with a maximum utility contribution of -3.864 and a minimum contribution of -5.336, which is quite significant comparing to the other utility contributions. The largest positive effect for air/rail travel is caused by the comfort level (1.060). Comparing to service, comfort can add 0.490 more utility points when both having a score of 5.

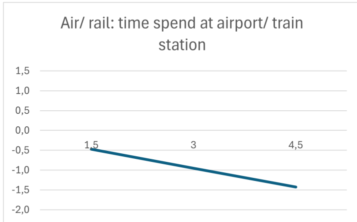
In order to give a more structural overview of the effects of all parameters on the total utility for the linear base model, for both alternatives, the utility contribution of the attribute level within the ranges of all parameters are shown. **Figure 7.1** shows them for the air/rail alternative, while **Figure 7.2** shows them for the air/air alternative.



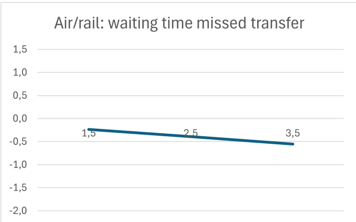
(a) Travel time train



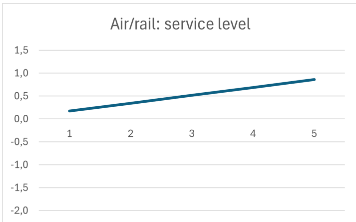
(b) Travel cost



(c) Time spend at airport/ train station



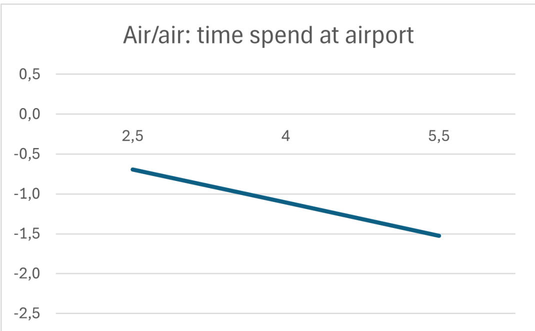
(d) Waiting time missed transfer



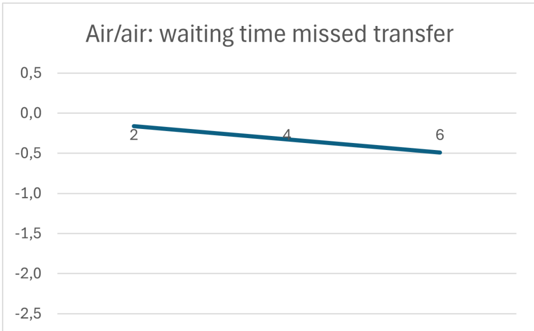
(e) Service level

(f) Comfort level

Figure 7.1: Utility contribution graphs of air/rail attributes



(a) Time spend at airport



(b) Waiting time missed transfer

Figure 7.2: Utility contribution graphs of air/air attributes

7.3.4. Parameter Interpretation

Regarding the alternative specific constant of both models in **Table 7.5**, this is the utility when all the attributes have the value of zero. This would mean that both the travel time as the travel cost would be zero, and is in this study not considered as a valid travel alternative. If all attributes are set to zero, the non-varied attributes are still present in the hypothetical choice set. Leaving out the varied attributes, the air/rail has no price and an hour less total travel time. With no price and less travel time, it makes sense that people would choose the air/rail option. But interpreting the ASC remains complicated.

It can first be concluded that, in accordance with the expectations, respondents do indeed perceive the separate time elements differently. Based on the estimates of the base model of **Table 7.5**, where all parameters are found significant, it can be concluded that for air/rail journeys people extract more disutility from time spending at the airport/ train station (-0.317) than the actual travel time (-0.241). Another interesting finding from the base model is that, in case of a missed transfer, people do not extra more disutility from waiting for the next flight or train (-0.158) with respect to the other time elements. This may be explained by the fact that, for this parameter, it was assumed that there is always a next flight or train available and therefore passengers were always secured to get to their destination. It could also be the case that this parameter was hard to interpret by the respondents because this parameter indicated a non-defined chance by stating ”in case of a missed transfer”. Respondents may have not be able to imagine how this would reflect to a real-life situation and is therefore less considered compared to the other parameters which were more easy to interpret.

Comparing the air/rail with the air/air alternative, it can be concluded from the base model of **Table 7.5** that waiting on the airport only (-0.227) is related to less disutility compared to waiting on both an airport and a train station in the air/rail journey (-0.317). Also, it is found that waiting on the next plane in an air/air journey (-0.082) is related to less disutility than waiting on a next plane/ train in an air/rail journey (-0.158). This could be explained by the fact that in an air/rail transfer, people need to leave airside and transfer to rail on the landside, which could be more stressful than transferring on the airside only. In this case people don't have to go through passport control and pickup luggage at the luggage belt, which takes time while there is a limited transfer time.

There are multiple ways to create more attraction for air/rail based on the utility contributions of the linear base model. By either reducing the transportation time by train or reducing the total travel cost of the journey. Also, more attraction for air/rail can be achieved by focusing on comfort. This has more effect than service. These effects are further explored in **Chapter 8** with a scenario analysis.

Looking at the base model including the quadratic components from **Table 7.5**, the first thing to notice is that the non-quadratic parameters for delay in case of a missed transfer for air/rail and the time spend at the airport for both air/rail as air/air are found insignificant in this model. Also found is that the effect of comfort more than doubles from 0.212 in the base model to 0.446 in the base model including quadratic parameters. Respondents, according to this model, extract more than twice as much utility from comfort compared to the base model. Where the effect of comfort increases, decreases the effect of service for air/rail from 0.172 to 0.073. Regarding the other significant parameters, the effects are approximately the same for both models.

When considering the base model including quadratic parameters, only the quadratic parameter for comfort is found significant. The effect of comfort weakens as the comfort level goes up. Increasing the perceived comfort level from 1 to 3 brings more utility (0.580 points) than from 3 to 5 (0.268 points).

The quadratic parameters for service and time spend at airport and train station for both air/rail as air/air are found insignificant. The effects only hold for the response group, and are marginal. But only looking at the direction of the signs, opposite to the quadratic component of comfort, these are found positive. For service, this means that people extract more utility when the perceived service level goes from 3 to 5, than from 1 to 3. For the response group, this means that people are not saturated with a certain perceived service level, but are gaining utility exponentially from more services.

Considering the base model with quadratic components, the respondents don't like to spend time at the airport, as the linear parameter for time spend at the airport for the air/air alternative is negative, but not found significant. Which means this effect is also marginal. With a positive quadratic component, this effect weakens increasing the time spend on the airport. People associate waiting time at the airport with negative utility, but it does not scale linearly. Intuitively, this could also make sense as more time at the airport only adds up to being waiting and above a certain threshold, waiting is waiting and people just accept that the journey takes longer than expected. This same line of reasoning also holds for waiting at the airport/ train station for air/rail journeys.

7.4. Results Latent Class Choice Model

7.4.1. Model Results Latent Class Choice Model

In order to answer research questions (4) and (5), introduced in **Table 1.1**, a latent class choice model is estimated. Latent GOLD 6.0 was used for model estimation (Vermunt & Magidson, 2021). In order to prevent the iteration from being stuck in local minima, ten random sets of starting values are used to start the iterative estimation algorithm. The covariates included in the choice model are: Student, Working, Retired, Gender, Age, Edu, TrainExp, FlightExp, Checkin, Purpose, Alone, Colleagues, UnpleasantTrainExp and UnpleasantFlightExp. These variables are coded as shown in **Tables E.3** in **Appendix E**. All included attributes are consistent with the base MNL model including quadratic parameters from **Table 7.5**.

Determining the amount of classes is based on the Bayesian Information Criterion (BIC). **Table 7.8** shows the loglikelihood, BIC (based on the loglikelihood) and Rho-square for different latent class models.

Table 7.8: Loglikelihood, BIC and Rho-square for different latent class models

Model	Loglikelihood (LL)	BIC (based on LL)	Rho-square
1-class	-2999.6534	6049.6541	0.1444
2-class	-2550.8699	5328.3029	0.3776
3-class	-2381.9758	5166.7305	0.4936
4-class	-2321.9604	5220.9154	0.5630
5-class	-2253.6494	5262.5091	0.5943
6-class	-2231.4639	5394.3539	0.6061

As can be seen from **Table 7.8**, with increasing the amount of classes, the model fit (Rho-square) increases as well. However, looking at the BIC, the 3-class model has the lowest value and, therefore, it is chosen to work with the 3-class model. All raw output of the 3-class choice model are shown in **Appendix G**.

7.4.2. Identifying Consumer Segments

Based on the results of **Table 7.8**, it can be concluded that three customer segments can be identified based on the input parameters. Based on the results of **Table 7.9**, looking at the class sizes, respondents have a probability of 60.3% belonging to class 1, 23.0% of belonging to class 2 and 16.7% of belonging to class 3. This corresponds to an absolute class size of 326, 124 and 91 respondents, respectively.

Table 7.9: Class sizes and absolute class sizes for the 3-class model

	Class 1	Class 2	Class 3
Class size	60.3%	23.0%	16.7%
Absolute class size	326	124	91

In order to label the consumer segments, a closer look into the relative importance (RI) of the included parameters is taken. The relative importance for all attributes, for each alternative, per class, is shown in **Table 7.10**. The identified segments are also further explained based on the choices made per alternative and the class profiles, where the share of each background characteristic per class can be derived. The choices per class, and overall, for each alternative are shown in **Table 7.11**. The percentages for class profiles on the background characteristics are shown in **Table 7.12**.

Table 7.10: Relative importance, in percentages, for included attributes regarding air/air and air/rail alternative

	Attribute	Class 1	Class 2	Class 3
Air/air alternative	Time spend at airports	18.9%	13.5%	0.8%
	Delay in case of missed transfer	10.3%	15.3%	8.8%
Air/rail alternative	Transportation time train	10.2%	22.4%	11.8%
	Time spend at airport/ train station	12.8%	10.0%	2.3%
	Total travel cost	12.3%	12.8%	11.6%
	Service level	16.0%	15.5%	26.2%
	Comfort level	17.6%	8.1%	18.6%
	Delay in case of missed transfer	1.9%	2.5%	19.9%

Table 7.11: Choices per alternative, per class and overall, in percentages

Alternative	Class 1	Class 2	Class 3	Overall
Air + Rail	53.0%	14.9%	97.9%	51.8%
Air + Air	47.0%	85.1%	2.1%	48.2%

Table 7.12: Class profiles based on background characteristics, in percentages

	Level	Class 1	Class 2	Class 3
Age	19 – 30	26.0%	12.9%	10.1%
	31 – 41	20.7%	21.4%	9.8%
	42 – 53	19.5%	28.9%	12.5%
	54 – 63	18.2%	19.2%	23.0%
	64 – 74	15.6%	17.6%	44.6%
Education	HBO bachelor or higher	72.5%	77.6%	76.3%
	Else	27.5%	22.4%	23.7%
Occupation	Student	13.9%	3.0%	2.2%
	Working	69.6%	81.0%	55.6%
	Retired	12.3%	9.4%	37.8%
International train experience	More than 10 times in past 5 years	15.1%	11.9%	15.5%
	Less than 10 times in past 5 years	84.9%	88.1%	84.5%
Flight experience	More than 10 times in past 5 years	18.6%	31.8%	3.1%
	Less than 10 times in past 5 years	81.4%	68.2%	96.9%
Trip purpose	Business	30.4%	29.1%	24.0%
	Leisure	69.6%	70.9%	76.0%

Class 1: waiting time disfavourites
People in this class put the most attention on the time spend at the airports, considering the air/air alternative, with a RI of 18.9%. Regarding the air/rail alternative, people put most attention to service and comfort level, with a RI of 16.0% and 17.6% respectively. This group does not necessarily has a strong preference for one of the two alternatives, as 53.0% chooses air/rail and 47.0% chooses air/air. People in this group are likely to be younger than 41 years old (46.7%) and highly educated (72.5%). Also, comparing to the other classes, most of the students are within this group (13.9%). This relatively young group also doesn't have a lot of experience with travelling by international train (15.1%) or plane (18.6%) in the past five years.

Class 2: plane lovers
The people in this group have a strong preference for travelling by plane, with choosing the air/air alternative 85.1% of the time. For this group, transportation time by train is considered as most important (22.4%), which explains the preference for air/air, as this option is commonly faster. They also pay quite some attention to the service (15.5%) and travel cost (12.8%) of air/rail. People in this group are mostly between 31 and 53 years old (50.3%), are working (81.0%) and have quite some flight experience (31.8%) in the past five years.

Class 3: air/rail service admirers
The smallest group (16.7%) chooses the air/rail alternative 97.9% of the times. They pay the most attention to the air/rail service level (26.2%), delay in case of missed transfer (19.9%) and comfort level (19.9%). People in this group are likely to be above 54 years old 67.6%, retired (37.8%), and have not much flight experience (3.1%) in the past five years. This group also mostly travel for leisure purposes (76.0%).

Other than identifying the consumer segments, the latent class choice model also estimates attribute parameters per class and class membership parameters, based on background information. With the parameter estimates per class, scenarios can be created to study the degree of substitution from air/air to air/rail for the different classes. The attribute values, class membership parameters, Wald statistic and significance (sig.) of the latent class choice model for each class are shown in **Table 7.13**. The exploration of the air/rail market for different scenarios is done in **Chapter 8**.

Table 7.13: Parameters latent class choice model

Parameters	Class 1	Class 2	Class 3	Wald	Sig.
Alternative specific constant					
ASC_train_plane	1.504	-0.407	-1.912	22.926	<0.001
Attributes air/air alternative					
del_plane_plane	-0.229	-0.374	-0.252	91.756	<0.001
wt_plane_plane	-0.561	-0.440	-0.032	234.981	<0.001
Attributes air/rail alternative					
tt_train_train_plane	-0.227	-0.547	-0.338	99.981	<0.001
wt_train_plane	-0.380	-0.322	0.088	113.547	<0.001
tc_train_plane_scaled	-0.273	-0.311	0.333	240.491	<0.001
serv_train_plane	0.355	0.378	0.753	195.978	<0.001
comf_train_plane	0.390	0.197	0.533	187.864	<0.001
del_train_plane	0.083	-0.122	-1.144	6.023	0.110
Background information					
Student	1.002	-0.424	-0.578	68.357	<0.001
Working	-1.792	1.428	0.364	73.887	<0.001
Retired	-0.887	0.648	0.239	0.000	1.000
Gender	0.036	0.173	0.137	3.866	0.140
Age	-0.016	-0.002	0.017	6.600	0.037
Edu	-0.066	0.057	0.009	0.618	0.730
TrainExp	-0.023	-0.177	0.200	2.415	0.300
FlightExp	0.137	0.631	-0.768	20.616	<0.001
Purpose	0.180	-0.376	0.196	5.894	0.052
Checkin	0.049	0.031	-0.080	0.837	0.660
Alone	-0.995	0.925	0.069	220.675	<0.001
Colleagues	-2.777	1.863	0.913	0.000	1.000
UnpleasantTrainExp	0.100	-0.100	0.000	1.818	0.400
UnpleasantFlightExp	-0.025	0.017	0.008	0.123	0.940

The first thing to notice, according to **Table 7.13**, is that the delay in case of a missed transfer for the air/rail alternative is insignificant when estimating for different classes. This in contrast with the outcome of the linear base MNL model of **Table 7.5**. Generally it can be concluded, looking at the background information, that many parameters turn out to be insignificant. Only *Student*, *Working*, *Age*, *FlightExp* and *Alone* are found significant for determining the class membership.

Comparing the alternative specific constants (ASCs) of the three classes, it can be seen that, when all variables have the parameter value of zero, that class 1 obtains the most utility for air/rail. This is contrast with the other two classes, where the ASC is negative, indicating a preference for air/air when all the attributes have the value of zero.

From the background information, the parameter value of 1.002 for *Student* suggests that students are more likely to belong to class 1. This is further addressed by the parameter *Working* (-1.792), which indicates that if a person is working that this person is way less likely to belong to the first identified class. It is also found that when someone is travelling alone, it is not likely to be member of this class (-0.995), compared to the parameters of class 2 (0.925) and class 3 (0.069).

Opposite to class 1, the parameter *Working* suggests that employed people are very likely to be member of class 2 (1.428). Also if travellers have a lot of flight experience (more than 10 times) in the past five years (0.631) and travel alone (0.925), they are much likely to belong to class 2.

Looking further into the flight experience parameter, it can be concluded that travellers who have a lot of flight experience, are having a higher probability of belonging to class 3 (-0.768). Also, considering the parameter *Age*, opposite to class 1 and class 2, this parameter is found positive for class 3. This indicates that when people are older, they are more likely to be member of class 3, which makes sense, as most of the elderly are member of this group, considering the class profile of **Table 7.12**. For example, when a traveller is 70, the parameter value for *Age* is 1.190, indicating a significant probability of belonging to class 3.

8
Exploring the Air/rail Market

From the multimonimal logit model, it is clear which travel attributes are affecting the total utility of air/rail the most, and from the latent class choice model it is clear which consumer segments can be identified. Now the bridge needs to be built between the outcomes of the statistical analyses on air/rail mobility and the societal application of this study. What can different actors such as legacy carriers, airports and governments do with the results found? To put the results into practice, several scenarios are tested, based on real-life cases. **Section 8.2** introduces and dives into the potentials for air/rail based on the introduction of Lufthansa Express Rail, **Section 8.3** explores the potentials for Air France-KLM and **Section 8.4** compares the effect of an air/rail subsidy against service and comfort improvements for air/rail. But first, **Section 8.1** discusses the significance of the estimated parameters of the latent class choice model.

8.1. Significance of Latent Class Choice Model Estimates

Based on the attribute parameters found for the different latent classes in **Table 7.13**, the substitution rate from air/air to air/rail can be derived. But in order to significantly say something about this substitution ratio, the parameters were first checked for their significance using the Wald test. The Wald test tests the restriction that a parameter estimate in the set of estimated betas equals zero. Thus, a non-significant p-value associated with this Wald statistic indicates that the indicator does not differ across classes in a statistically significant way (Vermunt & Magidson, 2021).

It can be concluded from **Table 7.13** that each mode choice attribute has a significant Wald statistic, which means that the effect differs per class, except for the parameter on waiting time in case of a missed transfer for the air/air alternative. Thus, for this specific parameter, it cannot be said with certainty that this parameter differs per class. However, since the effect of different scenarios will be indicated per class, it was chosen to still include this insignificant parameter, as this is the best predictor estimated in this study. However, when interpreting the results of the different scenarios for the cases, this is something to keep in mind.

8.2. Case 1: Lufthansa Express Rail

8.2.1. Scenario Description

In collaboration with Deutsche Bahn (DB), Lufthansa introduced Lufthansa Express Rail, which allows travel from 28 train stations in Germany to Frankfurt Airport with one boarding pass for both the train journey as the connecting flight. Also, at Frankfurt Airport, a special air/rail terminal is opened with all kinds of features for the air/rail traveller.

In this case, a trip from Amsterdam Schiphol Airport to Singapore Airport, via Frankfurt Airport, is held as context. This involves travelling from Schiphol to Frankfurt by train (or plane) and continuing on to Singapore with a long-haul flight from Frankfurt. In order to quantify the effect of the offered features regarding service and comfort by this air/rail terminal, several scenarios are constructed.

Base case scenario

This is the base case scenario where there is no integration regarding services and no comfort features for air/rail. This in order to check the effect of the extra amenities of other scenarios. Regarding the operational travel attributes, the travel time from going from Schiphol to Frankfurt Airport by train is set to 4.5 hours and the total travel cost for this scenario is set to 1050 euro. The waiting time in case of a missed transfer for air/rail is equal for all scenarios and set to 2 hours. The time spend at the airport/ train station is set to 2.5 hours for air/rail, assuming an one hour presence in advance before departing with a high-speed train and a transfer time of 90 minutes.

Current scenario: Lufthansa Express Rail

According to Frankfurt Airport (n.d.-b) and Lufthansa (n.d.), the advantages of Lufthansa Express Rail are that a seamless transfer is guaranteed, there is one integrated ticket and loyalty points can also be earned for the train journey. There is also a lounge for status customers and a luggage drop-off directly at the new-opened air/rail terminal at the long-distance train station at Frankfurt Airport. Pictures of this terminal are shown in **Figure 8.1**.

(a) Air/rail terminal Frankfurt Airport

(b) Luggage drop-off area for air/rail passengers

(c) Luggage claim area air/rail passengers

(d) Luggage claim area, sorted per destination

Figure 8.1: Pictures of new air/rail terminal Frankfurt Airport, made by Donners (2024)

As can be seen from the pictures, Frankfurt Airport introduced separate luggage drop-off counters and a dedicated luggage claim area for air/rail passengers. With these new services of being able to drop off luggage directly from the train and having a dedicated pick-up point, waiting at the baggage claim is avoided. Travellers can go straight through the luggage claim for air/rail, reducing the total time spend at the airport/train station, and is therefore assumed to be 2 hours instead of 2.5 hours. Although, for air/rail passengers, this means that luggage still has to be carried on the train, so there is no full luggage integration. Lufthansa Express Rail also allows online or mobile check-in from 30 hours to 15 minutes before departure. This also reduces the total time spend at the airport/train station. The amount of time saved by this feature is assumed to be included in the 30 minutes time reduction for the time spend at the airport.

Regarding other service features, information is assumed not to be integrated, as DB and Lufthansa still have separate apps and websites for their information provision. An integrated helpdesk is assumed to be available at the train station. Regrading comfort, there are no separate security lanes, there is no lounge available for air/rail passengers, WiFi is assumed to be free and the points of the loyalty programs are exchangeable.

Current + lounge + TEN-T scenario
The previous scenario examines the effects of improving services and perceived comfort by introducing an air/rail terminal at Frankfurt Airport. In this scenario, this is extended by assuming that TEN-T is also operational and assumed to decrease the total travel time by train by 1.5 hours. As the distance between Amsterdam Schiphol to Frankfurt Airport is similar to that from Schiphol to Paris Charles de Gaulle, the same travel time by high-speed rail is assumed. According to Trainline (2024), the journey takes 3 hours, and is therefore also assumed for this scenario. Other than introducing TEN-T, this scenario also improves the comfort features by opening up the lounge for all air/rail passengers, which increases the comfort rating by air/rail passengers.

Maximum integration + comfort scenario
The last scenario, similar to the one of the Lufthansa Express Rail case, examines the effect of introducing full service integration between air and rail, together with introducing all comfort features included in this study. Because both priority lanes for air/rail and luggage integration is assumed in this scenario, the total time spend at the airport/ train station is assumed to be 30 minutes shorter than in the previous scenarios. This sets the parameter time spend at the airport/ train station to 1.5 hours. This would suggest a 30 minutes presence in advance for the train ride and an transfer time of one hour.

This scenario assumes luggage to be fully integrated between air and rail, suggesting that passengers can drop off their luggage at the train station of Schiphol Airport and collect it back at Singapore Airport. It is also assumed that integrating luggage is saving time spend at the airport/ train station. Therefore, this parameter is set to 1.5 hours instead of 2 hours. Also, information is assumed to be fully integrated, where all train and flight information is located in one app or website. Regarding comfort, priority lanes are assumed to be available for all air/rail travellers for check-in, security and passport control. The rest of the included features are the similar to the previous scenario.

Concluding from the rating experiment for comfort, the difference in ratings between business and leisure travellers for comfort is found to be minimal. Therefore, for the scenarios, it is chosen to include the rating based on the business traveller, as this type of passenger is the primary focus of legacy carriers such as Lufthansa. The scores associated with the including service and comfort features for air/rail per scenario are shown in **Table 8.1**. These ratings are calculated with **Equation 7.1** for service (**Section 7.1.2**) and **Equation 7.2** for comfort (**Section 7.2.2**). The parameter values for the attributes per scenario, with the changes in bold, are shown in **Table 8.2**. These are the parameters that are used as input per scenario.

Table 8.1: Included service and comfort features per scenario Lufthansa Express Rail case

Scenario	Base case	Current	Current + lounge + TEN-T	Max. integration + comfort
Service				
Luggage	x	x	x	✓
Ticketing	x	✓	✓	✓
Info	x	x	x	✓
Helpdesk	x	✓	✓	✓
Service rating	2.4	**3.9**	3.9	**4.7**
Comfort				
Security	x	x	x	✓
Lounge	x	x	✓	✓
PaidWifi	x	x	x	x
Loyalty	x	✓	✓	✓
Comfort rating	2.3	**2.5**	**3.2**	**4.1**

Table 8.2: Different scenarios with associated attribute parameters for both alternatives Lufthansa Express Rail case

Scenario	Base case	Current	Current + lounge + TEN-T	Max. integration + comfort
Air/rail alternative				
Travel time train (hrs)	4.5	4.5	**3.0**	3.0
Time at airport/train station (hrs)	2.5	2.5	**2.0**	**1.5**
Travel cost (€)	1050	1050	1050	1050
Delay in case of missed transfer (hrs)	2.0	2.0	2.0	2.0
Service rating	2.4	**3.9**	3.9	**4.7**
Comfort rating	2.3	**2.5**	**3.2**	**4.1**
Air/air alternative				
Delay in case of missed transfer (hrs)	2.0	2.0	2.0	2.0
Time at airports (hrs)	3.0	3.0	3.0	3.0

8.2.2. Scenario Results

This section applies the introduced scenario regarding Lufthansa Express Rail for predicting the different shares for air/rail, based on the found classes. **Table 8.3** shows the shares of air/rail and absolute class sizes per class for the air/rail alternative, per scenario.

Given the rates from the table, the same trend for all three classes can be seen. Compared to the base scenario, as services and comfort features are added per scenario, the shares of air/rail with respect to air/air increase.

Regarding the first class, waiting time disfavourites, approximately 30% chooses to take the air/rail option when no service or comfort features are offered. With the current features offered by Lufthansa and Frankfurt Airport for the air/rail passenger, a significant increase is realized compared to the base case, from 31.4% in the base case to 45.7% in the current scenario. When introducing TEN-T, which decreases the travel time by train, in combination with opening a lounge for all air/rail passengers, a further increase of 19.6% can be realised under the assumptions of this study. When offering all service and comfort features, a potential 76.4% substitution from air/air to air/rail can be realized, representing 249 out of the 326 members of this class choosing for air/rail. This is an increase of 101 passengers that will choose air/rail compared to the current scenario.

The effect of offering more features for air/rail passengers is much less for the plane lovers. In the base case, hardly anyone chooses for the air/rail option, with 3.4% (4 people). With the current offered features at Frankfurt Airport, the market shares do increase, but not much (about 3%). Offering those passengers a travel time decrease of 1.5 hours by train, via TEN-T, is more effective. An increase from 10.4% to 16.5% (13 people) can be realized, but comparing this to the first class, the substitution rate to air/rail remains rather low. Offering maximum comfort in combination with full integration results in a share of 23.1% for air/rail, which equals a substitution rate of 17.0% compared to the current scenario. However, this group of travellers remain persistent in choosing the air/air option.

The complete opposite holds for the air/rail service admirers. Without any features offered, almost everyone of this class chooses for the air/rail option. Adding service and comfort features does help increasing the shares of air/rail, but those are already that high that the increase does not have much effect on the substitution rates anymore. The same holds for introducing shorter travel times and offering full service integration and all comfort amenities. Also concluding from the absolute share choosing for air/rail, comparing the base case with the maximum integration and comfort scenario, only two passengers more of this class will choose the air/rail option.

Overall, looking at the total share for air/rail, an increase of 22.5% can be realized comparing the maximum integration and comfort scenario with the current situation. In absolute numbers, this is equal to 126 passengers, based on the response group of this study.

Table 8.3: Air/rail shares and absolute passenger numbers per scenario Lufthansa Express Rail case

Scenario	Base case	Current	Current + lounge + TEN-T	Max. integration + comfort
Waiting time disfavourites (N = 326)				
Share air/rail	31.4%	45.7%	65.3%	76.4%
Absolute share air/rail	102	148	212	249
Plane lovers (N = 124)				
Share air/rail	3.4%	6.1%	16.5%	23.1%
Absolute share air/rail	4	7	20	28
Air/rail service admirers (N = 91)				
Share air/rail	97.2%	99.2%	99.6%	99.9%
Absolute share air/rail	88	90	90	90
Total share (N = 541)				
Share air/rail	35.9%	45.3%	59.5%	67.8%
Absolute share air/rail	194	245	322	367

8.2.3. Policy Application

This section bridges the gap between the outcomes of the scenarios about the substitution potentials from air/air to air/rail and what this could mean for different actors involved in the development of air/rail.

As already concluded from **Table 8.3**, the shares of air/rail increase comparing the current scenario with the base case. This means that, according to the findings of this study, the cooperation of Lufthansa and Deutsche Bahn, with opening an air/rail terminal at Frankfurt Airport, is an effective policy to attract more air/rail passengers.

Especially the first class, containing mostly members which are younger and less experienced in travelling by plane or international train, are eager to switch from air/air to air/rail in multi-legged journeys with the offered service and comfort features from Frankfurt Airport, Lufthansa and Deutsche Bahn. This effect is smaller for the second class, but an increase in the share of air/rail is still noticeable. The effect is even less for the third class.

The prospect is that the share of air/rail can be even further increased when looking at the third and fourth scenario. But what can involved actors do? According to **Table 7.13**, Lufthansa, Frankfurt airport and Deutsche Bahn can either increase service, comfort or reduce the time spend at the airport/ train station for air/rail. Reducing travel time must be accomplished by TEN-T, which is more European oriented. For the short term, especially for class 1 and class 2, the focus should be on these three aspects.

At first, Lufthansa, in collaboration with Deutsche Bahn, could increase the perceived service rating by developing an integrated information platform where all the information for a multi-legged air/rail journey is gathered. This can be done via Mobility as a Service (MaaS) apps (Rijksoverheid, 2019). These kinds of apps provide tailored multimodal travel advice to passengers about their whole journey. For example, such an app could create insights on CO2 savings of the trip, crowded security lanes, walking routes and gate changes. This technology can be used to provide air/rail travellers full transparency on their travel itinerary. With the development of such an technology, it is important for the German government to be an intermediary in order to assure the standardization of service, security and privacy for the travellers.

Second, according to the results of this study, improving the perceived comfort for all classes can be done with opening a lounge for all air/rail passengers. As the lounge are located on the airports, the airport operator is responsible for this feature. In this case this is Frankfurt Airport. Air/travellers should then be enabled to enter a dedicated air/rail lounge with their ticket. As mainly younger, less experienced travellers are willing to change, they should be encouraged to choose air/rail. One way for Frankfurt Airport, but actually also for Lufthansa and Deutsche Bahn, is to reach this passenger group via influencer partnerships. With promoting such a lounge via influencers who have a wide reach among young people on TikTok and Instragram, popularity of air/rail can be further increased.

The last option to increase the attractiveness of air/rail is to reduce the time spend at the airport/ train station for the passengers, especially for class 1 and class 2. In this study, this can be achieved via luggage integration and having priority lanes for air/rail travellers. As full luggage integration may have some operational burdens, asking a direct transfer from suitcases from a plane into the right train, priority lanes are more realistic to realize on a shorter term. However, luggage check-in is operated by the airline, so there is a responsibility there for Lufthansa to open priority lanes for air/rail passegers. While for security and passport control, this is commonly operated by the airport operator (Frankfurt Airport) and is thus responsible for facilitating air/rail priority at these operations.

In general, air/air to air/air substitution for the short-haul flights in the hub-and-spoke network will also lead to empty slots at airports. These slots could then be used by legacy carriers to operate more long-haul flights, as these flights are the main source of profit. A cap on the amount on flight movements is difficult to implement on the short term because the higher court said that this could only be implemented through a long European procedure (Luchtvaartnieuws, 2024a).

From a Dutch perspective, the Ministry of Infrastructure and Water management (IW) created an action plan (**Table 8.4**) for air/rail on what should be explored for air/rail on the Amsterdam - Frankfurt corridor (Ministry of Infrastructure and Water management, 2020a). However, what still lacks, is a further collaboration between the Dutch and German air and rail operators in order to accommodate cross-border air/rail journeys. Everything on this agenda is still on a national level.

Table 8.4: Action agenda and involved actors for Amsterdam - Frankfurt corridor

Destination	Action	Responsible actors
Frankfurt	Investigate increasing train frequency	NS and ProRail
	Investigate reducing journey times	NS, ProRail and IW
	Investigate docking at Amsterdam Zuid	ProRail, NS and IW
	Investigate possibilities for AirRail product	KLM and NS
	Investigate adaptations for AirRail product	KLM and Schiphol

8.3. Case 2: AirFrance-KLM Air/rail Terminal Brussels-Midi

8.3.1. Scenario Description

The second case focuses on the renovated air/rail terminal at Brussels-Midi train station of Air France-KLM. This case also introduces a hypothetical journey from Brussels-Midi to Los Angeles, via Amsterdam Schiphol Airport. As the journey between Brussels-Midi and Amsterdam Schiphol is already made by high-speed train, TEN-T has no further significant role in this case. The pure effect of the integrated services and offered comfort features are tested. Also in this case study, several scenarios are constructed, described below.

Base case scenario

This is basically the same scenario as explained for the Lufthansa Express Rail case in **Section 8.2.1**. In this scenario, there is no integration regarding service and there are no comfort features for air/rail. The total travel time from Amsterdam Schiphol to Brussels-Midi is set to 2 hours, as this is approximately the travel time and is also the boundary of tested range of the attribute levels for this parameter. A faster travel time was not presented to the respondents in this study. The rest of the parameters are the same as with the Lufthansa Express Rail base case scenario.

Current scenario: Air France-KLM air/rail terminal at Brussels-Midi

As already introduced, Air France-KLM opened an air/rail terminal at train station Brussels-Midi (KLM Royal Dutch Airlines, 2024; Somsen, 2024). With this new terminal, the high-speed train must become an increasingly attractive alternative for short-haul flights.

With Air France-KLM Air&Rail, travellers can combine their train ride and flight in the same booking and can rebook free of charge, in case of a missed transfer. So, there is integrated ticketing, but no luggage integration is available from this station to final destinations, via Schiphol. According to KLM Royal Dutch Airlines (2024), teams from Air France and KLM are also present to help travellers, so an integrated helpdesk is available. And since everything is available within one booking in the KLM app, there is also information integration assumed.

Regarding comfort, AirFrance and KLM customers have all the benefits associated with their status. According to Luchtvaartnieuws (2024b), travellers can save miles when travelling by train and have access to the Eurostar Lounge at Brussels-Midi station if they are from a certain status of the loyalty program. In this case, the lounge is not available for every air/rail travellers, and is thus not considered in this scenario.

Current + lounge + priority lanes scenario
In this scenario, a lounge and priority lanes are available for all air/rail travellers. When transferring at Schiphol Airport, KLM customers could benefit by giving them priority with luggage check-in, security, and immigration KLM Royal Dutch Airlines (2024). With priority lanes, time spend at the airport could be reduced. In this scenario, it is assumed to be 30 minutes, so the total time spend at the airport/ train station is set to 2 hours. Priority lanes are not available for all the travellers in the air/air alternative, so therefore the time spend at the airports is not varied in this alternative.

Current + lounge + luggage scenario
In order to see the effect of potential different policies of KLM, this scenario does not consider priority lanes for all air/rail passengers, but instead, full luggage integration is assumed. In this case, people can drop their luggage before entering the train at Brussels-Midi and collect it at Los Angeles Airport, so they can travel hands-free for the whole journey. Therefore, it is also assumed that this will save 30 minutes compared to the current situation. In order to calculate the effect of luggage integration versus priority lanes, the rest of the parameters are kept the same. So also in this scenario, a lounge is available for all air/rail passengers.

Maximum integration scenario
The last scenario, similar to the one of the Lufthansa Express Rail case, examines the effect of introducing full service integration between air and rail, together with introducing all comfort features included in this study. Also in this scenario, priority lanes and full luggage integration are assumed to save one hour of time spend at the airport/ train station, setting this parameter to 1.5 hours. Because priority lanes are included, the comfort rating in this scenario is also higher. The rest of the parameters are the same as in the previous scenario.

In all the considered scenarios in this Air France-KLM case, the ratings are based on the business traveller, similar to what is done with the Lufthansa Express Rail case. The ratings are estimated with **Equation 7.1** for service (**Section 7.1.2**) and **Equation 7.2** for comfort (**Section 7.2.2**). What is considered per scenario for service and comfort is shown in **Table 8.5**. The parameter values for the mode choice attributes, with changes per scenario in bold, are shown in **Table 8.6**.

Table 8.5: Included service and comfort features per scenario Air France-KLM case

Scenario	Base case	Current	Current + lounge + priority lanes	Current + lounge + luggage	Max. integration + comfort
Service					
Luggage	x	x	x	✓	✓
Ticketing	x	✓	✓	✓	✓
Info	x	✓	✓	✓	✓
Helpdesk	x	✓	✓	✓	✓
Service rating	2.4	**4.3**	4.3	**4.7**	4.7
Comfort					
Security	x	x	✓	x	✓
Lounge	x	x	✓	✓	✓
PaidWifi	x	x	x	x	x
Loyalty	x	✓	✓	✓	✓
Comfort rating	2.3	**2.5**	**4.1**	**3.2**	**4.1**

Table 8.6: Different scenarios with associated attribute parameters for both alternatives Air France-KLM case

Scenario	Base case	Current	Current + lounge + priority lanes	Current + lounge + luggage	Max. integration + comfort
Air/rail alternative					
Travel time train (hrs)	2.0	2.0	2.0	2.0	2.0
Time at airport/train station (hrs)	2.5	2.5	**2.0**	2.0	**1.5**
Travel cost (€)	1050	1050	1050	1050	1050
Delay in case of missed transfer (hrs)	2.0	2.0	2.0	2.0	2.0
Service rating	2.4	**4.3**	4.3	**4.7**	4.7
Comfort rating	2.3	**2.5**	**4.1**	**3.2**	**4.1**
Air/air alternative					
Delay in case of missed transfer (hrs)	2.0	2.0	2.0	2.0	2.0
Time at airports (hrs)	3.0	3.0	3.0	3.0	3.0

8.3.2. Scenario Results

Table 8.7 shows the air/rail shares per class for each tested scenario regarding the case about the Air France-KLM air/rail terminal at Brussels-Midi.

For the first class, containing mostly younger, less experienced travellers, the majority of travellers chooses for air/rail in the current scenario, with 63.1%. When introducing a dedicated air/rail lounge and priority for air/rail travellers, the amount of passengers choosing for air/rail increases with 16.3% (53 people). Comparing this to the effect of introducing a lounge with full luggage integration, the overall effect is less than with priority lanes. When introducing both in a scenario with maximum integration and comfort, a maximum air/rail share of 84.3% can be realized, for this class.

For the plane lovers, in every scenario, the majority is still hesitant to choose for air/rail. In the maximum integration and comfort scenario, 39.3% chooses for air/rail, which is significantly less compared to the first class. But still, a substitution rate of 16.6% for air/rail can be realized, compared to the current scenario.

The last group, the air/rail service admirers, shows the same trend compared to the Lufthansa Express Rail case. Even with no service and comfort features offered, 89 out of 91 passengers in this group chooses for air/rail. Comparing this to the maximum integration and comfort scenario, only an absolute increase of 1 can be realized. People in this class are almost always chooses air/rail over air/air travel.

Overall, this case of the renewed air/rail terminal at Brussels-Midi station shows with the current scenario that, comparing to the base case, an increase in air/rail travel can be realized (13.7%). Based on the results of this response group, 323 people choose for air/rail instead of 249. And if Air France-KLM decide to integrate more service and offer more comfort amenities, an overall air/rail share of 76.2% can be realized, which is 15.5% more compared to the current scenario.

Table 8.7: Air/rail shares and absolute passenger numbers per scenario Air France-KLM case

Scenario	Base case	Current	Current + lounge + priority lanes	Current + lounge + luggage	Max. integration + comfort
Waiting time disfavourites (N = 326)					
Share air/rail	44.7%	63.1%	79.4%	75.8%	84.3%
Absolute share air/rail	145	205	258	247	274
Plane lovers (N = 124)					
Share air/rail	12.1%	22.7%	32.2%	31.6%	39.3%
Absolute share air/rail	15	28	39	39	48
Air/rail service admirers (N = 91)					
Share air/rail	98.8%	99.7%	99.9%	99.9%	99.9%
Absolute share air/rail	89	90	90	90	90
Total share (N = 541)					
Share air/rail	46.0%	59.7%	71.5%	69.5%	76.2%
Absolute share air/rail	249	323	387	376	412

8.3.3. Policy Application

The three ways for increasing the attractiveness of air/rail by Air France-KLM are similar as for the Lufthansa Express Rail case. However, there is one major difference between the cases. The air/rail terminal is now located at a train station, instead of an airport. This means that travellers are now also enabled to choose for air/rail when departing from a train station which is not located near an airport. This is similar to the concept of TGVair where, within France, passengers can choose for a combined plane and high-speed rail ticket from or to assigned SNCF (French railway operator) stations. But in the case of the air/rail terminal at Brussels-Midi station, people would also get the possibility to use air/rail cross border.

As can be concluded from **Table 8.7**, increasing attractiveness by offering more integrated services and comfort features has the most impact on the first class, containing mostly younger, less experienced travellers. But also for the second class, the plane lovers, despite the fact that these are middle-aged and frequent flyers, a significant shift can be realized. The question is now what actors as KLM, Schiphol, Thalys and maybe even the Dutch government could practically do.

In the current scenario at Brussels-Midi station, but also at Schiphol, there is no lounge available where every air/rail passenger could enter. Currently, only higher-tier passengers can make use of the Eurostar Lounge at Brussels-Midi station when choosing air/rail. However, to increase attractiveness, KLM should negotiate with Eurostar for the possibilities to explore extra features for regular air/rail passengers as well. Otherwise, KLM could explore the possibility, in discussion with SNCB (the Belgium railway operator), to open a dedicated air/rail lounge at Brussels-Midi station. However, this is not all, regarding the availability of an air/rail. When making a trip from Brussels-Midi station to Los Angeles, with a transfer a Schiphol, Schiphol should then also facilitate an air/rail lounge in order to standardize the comfort facilities.

The third scenario introduced in **Section 8.3.1** is the current scenario including priority lanes for all air/rail travellers. This in order to reduce the time spend at the airport and train station, which increases the share of substitution from air/air to air/rail. However, regarding priority lanes, this should be further nuanced. In general, there are three elements where the passenger transit time can be delayed: luggage check-in, security checks and passport control. For introducing separate lanes for air/rail travellers, in this KLM case, a closer look into Schiphol must be taken because the airport is responsible for these operations. Schiphol offers premium passengers benefits for luggage check-in, security checks and passport control with two programmes: SkyPriority and Privium. This is shown in the picture below. On the left part of the sign, below Priority, a separate lane for SkyPriority is created. On the far right side of this sign, a separate lane for Privium members is shown.

Figure 8.2: Picture of SkyPriority and Privium entrance at Amsterdam Schiphol Airport, made by Troquete (2024)

Concluding from this picture, there are separate lanes for the security checks, for both SkyPriority as Privium members. But what is the difference? Privium is a subscription where members can benefit from, for this study most relevant, fast lanes for security and passport checks and have access to Privium lounges, offered by the airport. SkyPriority is a service from the airline, in this case KLM. With SkyPriority, passengers have separate check-in desks, priority with luggage claim and boarding and there are thus fast lanes for security.

In this study, it is considered that in case of separate security lanes, air/rail passengers have priority at all three introduced operations. This means that, for these services, SkyPriority and Privium lanes should be integrated for air/rail in order to accommodate the full range of benefits. In this case, air/rail passengers could then check-in their luggage via SkyPriority, go through security via either SkyPriority or Privium and go through passport control via Privium. However, as Privium is an exclusive subscription offered by Schiphol, one could also think of creating a separate priority lane for air/rail at immigration en emigration only.

Since such an integration could significantly increase the number of users of these fast lanes, it could lead to operational problems, delays on these lanes and current users may start complaining. Therefore, there is another possible alternative to air/rail on the short term. This particularly relates to security control at Schiphol Airport. Currently, it is possible to book a time slot for the security control at Schiphol. This policy measure could also be used in the future when accommodating air/rail passengers. Promoting it among these travellers will only increase its use. In this case, the air/rail passengers will be among the other travellers who booked the same slot, but can still get through security faster. Therefore, this can also be considered a short-term solution. In the long term, KLM and Schiphol could consider an integration of SkyPriority and Privium at Schiphol for air/rail.

With regard to security at train stations, it is similar. Air/rail travellers could be given priority, along with frequent high-speed rail travellers, or book time slots. In this way, KLM can standardise and improve their services across the board. As a lot of the high-speed train travel (except for the United Kingdom) is within Schengen countries, passport control is not required. And as luggage is currently is not fully integrated, priority lanes at luggage check-in counters are not required as well.

However, according to the scenario including full luggage integration, there are some potentials for substitute air/rail for air/air as well. However, as this is operationally a challenge to develop, this measure should be more of a long term policy. Besides, according to **Table 8.7**, including priority lanes together with a lounge has more effect than introducing lounge and full luggage integration. Therefore it is recommended to first focus on opening a lounge and introducing priority lanes for air/rail passengers.

What holds for Frankfurt Airport, also holds for Schiphol. When the substitution rate from air/air to air/rail increases, there is less need for short-haul flights. It could then be the case that Schiphol also gets empty slots. According to Ministry of Infrastructure and Water management (2020b), the aim of the Dutch government is to fill these slots with long-haul flights which are more valuable for the Dutch prosperity and well-being. However, this sounds contradicting with the aim to be Net Zero in 2050, as long-haul flights are also polluting.

Another way of reducing emissions is to downsize Schiphol. However, according to Luchtvaartnieuws (2024a), the supreme court decided that Schiphol can only downsize via a long European procedure. So for the short term, it is rather difficult to decrease the amount of emissions from Dutch aviation drastically. However, it is still valuable to promote air/rail as part of substitution to the train. Therefore it is important for the Dutch government to create a long-term plan, together with Schiphol and KLM, on how to downsize Schiphol in a way which is acceptable for all stakeholders involved.

In order to do so, the Dutch government (i.e. the Ministry of Infrastructure and Water management) also introduced an action agenda for air/rail, specifically for the Amsterdam - Brussels corridor (Ministry of Infrastructure and Water management, 2020a). In **Table 8.8**, the action points and the involved actors are shown. Here it can be seen that improving the rail connection responsible for both the Dutch as the Belgium rail operator. However, in order to make big steps in the development of air/rail, national air and rail operators must also go in conversation, or even collaboration, to achieve cross-border air/rail travel.

Table 8.8: Action agenda and involved actors for Amsterdam - Brussels corridor

Destination	Action	Responsible actors
Brussels	Reduce flight frequency	KLM
	Investigate customised baggage solutions	KLM and Schiphol
	Investigate digital combi-ticket solutions	KLM and NS
	Improving rail connection	NS and SNCB
	Improving performance	NS, ProRail and IW
	Providing up-to-date travel information	NS and KLM
	Measuring and evaluating transfer AirRail travellers	Schiphol, NS, ProRail and KLM
	Investigate trains at day borders	NS and ProRail

8.4. Case 3: Subsidy for Air/rail

8.4.1. Scenario Description

The last case about an air/rail subsidy is more hypothetical because this case is not based on a real-life case. A price reduction for air/rail is introduced in this case instead of a price increase for airline tickets, as this parameter is not varied in the mode choice experiment and latent class choice analysis, so there is no estimate for this parameter to construct scenarios around. Therefore, in this case, the effect of either increasing attractiveness for air/rail by reducing the ticket price or improving the perceived service and comfort levels by respondents is tested with different scenarios.

The base case scenario is tested with a subsidy of 0%, with a ticket price of 1250 euros. In the other two scenarios about ticket price policies, a subsidy of 5% and 10% are considered. In the case of air/rail, reducing the overall ticket price is also questionable because flying is still involved in both alternatives. In both alternatives, a long-haul flight is made. By introducing a subsidy for air/rail, flying is eventually made more attractive. Nevertheless, this case just shows the pure effect of such a policy, as it may have significant effect on the substitution rates for air/rail.

In order to compare these scenarios with the effect of full integration of service and offering all comfort features, a last scenario is added. However, this case also considers an increase in ticket price. Introducing features such as priority lanes and full luggage integration is not only decreasing time spend at the airport/ train station, however, the air/rail operator is also facing more operational cost. Because it is unclear what the effect of establishing full luggage integration will be on the ticket price, the price is assumed to be 1450 euros, the highest attribute level tested in the mode choice experiment.

The included service and comfort features per scenario for the air/rail subsidy case are shown in **Table 8.9**, calculated with **Equation 7.1** for service (**Section 7.1.2**) and **Equation 7.2** for comfort (**Section 7.2.2**). The input parameters for the mode choice attributes, with changes per scenario in bold, are outlined in **Table 8.10**.

Table 8.9: Included service and comfort features per scenario air/rail subsidy case

Scenario	Base case	Base case + 5% subsidy	Base case + 10% subsidy	Max. integration + comfort
Service				
Luggage	x	x	x	✓
Ticketing	x	x	x	✓
Info	x	x	x	✓
Helpdesk	x	x	x	✓
Service rating	2.4	2.4	2.4	**4.7**
Comfort				
Security	x	x	x	✓
Lounge	x	x	x	✓
PaidWifi	x	x	x	x
Loyalty	x	x	x	✓
Comfort rating	2.3	2.3	2.3	**4.1**

Table 8.10: Different scenarios with associated attribute parameters for air/rail alternatives with varying subsidy levels

Scenario	Base case	Base case + 5% subsidy	Base case + 10% subsidy	Max. integration + comfort
Air/rail alternative				
Travel time train (hrs)	3	3	3	3
Time at airport/train station (hrs)	2.5	2.5	2.5	**1.5**
Travel cost (EUR)	1250	**1187.50**	**1125**	**1450**
Delay in case of missed transfer (hrs)	2	2	2	2
Service rating	2.4	2.4	2.4	**4.7**
Comfort rating	2.3	2.3	2.3	**4.1**
Air/air alternative				
Delay in case of missed transfer (hrs)	2	2	2	2
Time at airport (hrs)	3	3	3	3

8.4.2. Scenario Results

Table 8.11 shows the shares in percentages and absolute shares for air/rail per class for this case. As can be seen from the table, for the first class (waiting time disfavourites) and second class (plane lovers), people tend to choose air/rail more often when a price reduction can be realized.

However, looking at the third class (air/rail service admirers), it can be concluded that less people are choosing air/rail instead of air/air when prices are reduced. These travellers are not price sensitive, which makes sense looking at the negative parameter for travel cost for this class in **Table 7.13**. It is also worth notifying, for this class, that a 100% substitution ratio (91 persons for this class) to air/rail can be realized with a maximum integration and comfort scenario, while the price is 200 euros more expensive than the base case. It can thus be a point of discussion whether in real-life these decisions would still be present and that these respondent were susceptible for the hypothetical response bias. Because a negative parameter for travel cost is something not often found in literature.

Comparing the scenarios, it can be concluded from the overall total share that implementing a subsidy of either 5% or 10% does not have the same significant impact as what maximum service and comfort can realize. A subsidy of 10% increases the share of air/rail by 7.3% compared to the base. But the effect of maximum service and comfort, while the price is 200 euros higher, is increasing the substitution ratio of air/air to air/rail with 31.9%.

Table 8.11: Air/rail shares and absolute passenger numbers per scenario air/rail subsidy case

Scenario	Base case	Base case + 5% subsidy	Base case + 10% subsidy	Max. integration + comfort
Waiting time disfavourites (N = 326)				
Share air/rail	27.1%	30.6%	34.4%	59.0%
Absolute share air/rail	88	99	112	192
Plane lovers (N = 124)				
Share air/rail	4.1%	5.0%	5.9%	9.8%
Absolute share air/rail	5	6	7	12
Air/rail service admirers (N = 91)				
Share air/rail	99.1%	98.9%	98.7%	100.0%
Absolute share air/rail	90	89	89	91
Total share (N = 541)				
Share air/rail	33.8%	35.9%	38.4%	54.5%
Absolute share air/rail	183	194	208	367

8.4.3. Policy Application

The main conclusion of this case for policymakers is that a subsidy for air/rail, considering a 5% and 10% decrease in ticket price, has less effect on the substitution rate than improving the service and comfort levels.

Introducing subsidies are rather expensive, while improving service by integrating ticketing, information and a helpdesk or improving comfort by opening priority lanes or an air/rail lounge or integrating loyalty programs are relatively less difficult policies to implement. These are policies actors can undertake themselves, which do not require governmental involvement. Full luggage integration can have some operational burdens, so that would be more of a long-term focus.

This case shows that with a maximum integration and comfort scenario, even when the price is 200 euros more expensive for the passengers, the substitution rate from air/air to air/rail is significantly higher than having a 10% decrease in ticket price for air/rail. Therefore it is recommendable for airlines, airports, but also governments, to invest time and money in the development of air/rail from a passenger perspective rather than trying to artificially lower the ticket prices for air/rail.

Reducing the ticket price will always be an effective measure, as travellers tend to be price-sensitive. The question is whether the benefits outweigh the costs. And according to the results of these scenarios, under the assumptions of the introduced parameters, it is more attractive to invest in service and comfort features which ensure passengers to spend less time at the airport and train station.

9
Conclusion and Discussion

9.1. Conclusion

Air and rail intermodality is on the rise. The latest developments show that combining rail with air travel is being taken increasingly seriously by various actors in the rail and aviation industry, as pressure increases from the European Commission to drastically reduce short-haul flights in order to achieve Net Zero by 2050. The aim is to make air/rail increasingly attractive in order to substitute air/air for air/rail journeys. While the literature mainly focuses on the direct substitution of origin-destination travel within point-to-point networks, is this research focussing on how integrated air and rail services could be valuable for multi-legged journeys within a hub-and-spoke network, from a passenger perspective. The question is how travel decision determinants, socio-demographic characteristics and trip characteristics influence travellers' preferences for an integrated air and rail service for multi-legged journeys.

This study addressed this research question with a stated-preference survey, where 541 Dutch respondents of the Dutch Railways (NS) panel indicated their preferences regarding air/rail. With rating experiments for both service as comfort attributes, respondents had to determine the degree of attractiveness for different service and comfort configurations. The attributes service and comfort, together with other operational factors such as travel time and travel cost, were then included in the mode choice experiment. Afterwards the data was analyzed with several choice models, such as the multinomial logit model and the latent class choice model, in order to estimate model parameters and identify different consumer groups for air/rail.

One key finding, based on the service rating experiment, is that respondents find integrated ticketing by far the most attractive (0.554), more than twice as attractive as integrated information provision (0.213) and three times more attractive than integrated luggage handling (0.185) and integral customer service (0.177). In other words, if an air/rail operator offers luggage integration, an integral information platform and integral customer service, it has about the same effect on the perceived attractiveness than only offering integrated ticketing. When considering no integration of services at all, the perceived rating by respondents is 2.4 out of 5.0. Having full integration of all the considered services in the experiment, the perceived rating regarding attractiveness is 4.7 out of 5.0. Based on this experiment, air/rail travellers perceive maximum integrated services almost twice as attractive as having no integrated services at all.

The key finding from the comfort rating experiment is that respondents perceive the possibility of having priority lanes for air/rail passengers as most comfortable (0.417). The perceived comfort is also higher when a lounge is available on the airport or train station (0.313), accessible with an air/rail ticket. But this effect should be put into perspective. Having a lounge for air/rail passengers and an integrated loyalty program (0.111) has about the same effect on the perceived comfort as having priority lanes only. Also concluding from this experiment is that travellers prioritise free and slow WiFi over fast but paid WiFi. But the overall effect on the perceived comfort rating is marginal (0.056), almost eight times less than priority lanes for air/rail. It is also found that passengers who travel for business purposes perceive more comfort from having priority lanes for air/rail in comparison to passengers who travel for leisure, but the impact is rather small, about 0.1 out of 5.0. When having no comfort features for air/rail at all, together with paid WiFi, the perceived rating for leisure travellers is 2.3 (and 2.2 for business travellers). When offering maximum comfort, the perceived rating increases to 4.0 for leisure and 4.1 for business.

Regarding the operational factors for air/rail, according to the multinomial logit (MNL) model where all attributes are assumed to be linear, the total travel cost has the biggest negative effect (-0.368) on the choice between an air/air journey and an air/rail journey. When the ticket price for air/rail increases, travellers tend to choose for the air/air option more often. Travel time by train (-0.241), time spend at the airport and train station (-0.317) and delay in case of a missed transfer (-0.158) also have a negative effect on the choice for air/rail. On the other hand, comfort (0.212) and service (0.172) both have a positive influence for choosing air/rail, where comfort has more positive impact on the utility function when both having a maximum score of 5.0, concluding from the utility contributions. Another conclusion from the multinomial logit model is that travellers do perceive the separate time elements differently. Other than done commonly in literature, this study divided the total travel time for air/rail in the transportation time by train, flight time and the time spend on the airport and train station. Travellers extract more disutility from time spending at the airport/ train station than the actual travel time by train. Therefore, it is important to not only focus on reducing the actual in-vehicle travel time, but also on the time travellers spend at an airport or train station.

The latent class choice model provided insights into three different customer groups for air/rail: waiting time disfavourites (class 1), plane lovers (class 2) and air/rail service admirers (class 3). The first class find waiting time on the airport and train station for air/rail highly important and are mostly young adults with less travel experience. They choose in 53.0% of the cases for air/rail. The plane lovers are middle-aged, experienced plane users and favour air/air in most cases over air/rail, with 85.1%. The air/rail service admirers are mostly elderly, retired and find the service of air/rail relatively important. They almost always choose air/rail over air/air, in 97.9% of the cases.

The estimated parameter results of the latent class choice model are used to predict substitution rates from air/air to air/rail per class, based on real-life cases with several scenarios. One main conclusion from the first case about an air/rail terminal at Frankfurt Airport is that the biggest shift towards air/rail travel can be achieved among the first class with younger, less experienced travellers. What Frankfurt Airport, in collaboration with Lufthansa, currently offers to their air/rail passengers (pax) is increasing the air/rail share from 31.4% (i.e. 102 pax) in the case of having no integration of services and no comfort features at all, to 45.7% (148 pax) to what they offer now with integrated ticketing, loyalty programs and a helpdesk. This equals a substitution rate of 14.3%. However, when exploring more scenarios, with more integrated services and comfort features, it can be concluded that, for the first class, a maximum air/rail share of 76.4% (249 pax) can be achieved. The share for air/rail for the other two classes are much less when comparing the maximum integration and comfort scenario with the current scenario. The second class is more persistent in choosing air/rail over air/air, as a maximum substitution rate of 17.0% can be achieved, equalling only 21 respondents in this class. And as the third class already favours air/rail over air/air, no absolute increase can be achieved in passenger numbers. At last, concluding from the overall shares, a maximum air/rail share of 76.2% can be achieved. This equals a substitution rate of 30.2% and an increase of 163 in passenger numbers, based on the response group of this study.

The same trend can be concluded from the a case where Air France-KLM introduced an air/rail terminal at train station Brussels-Midi. The most impact can be made on the first class, where 60 passengers more choose air/rail over air/air comparing the current scenario with the case of having no integration and comfort at all, equalling an substitution rate of 18.4%. With offering maximum integration and comfort, this number increases to 274 passengers, equalling an increase of 21.2% comparing to the current scenario. For the second class, a maximum air/rail share of 39.4% can be achieved, equalling 48 passengers in this class. Offering more service integration and comfort features has no effect on the substitution rate of the third class, who already favour air/rail over air/air. Another conclusion that can be drawn from the scenario analysis, is that introducing priority lanes for air/rail travellers has more effect than offer full luggage integration among the whole journey, equalling 11 passengers (2.0%) based on the total shares.

The last case is about a subsidy policy for air/rail tickets. From this analysis, with a 10% subsidy (equalling a 125 euro decrease in ticket price), an overall share of 38.4% (208 pax) for air/rail can be achieved. However, when offering maximum integrated services and comfort features, an overall share of 54.5% (367 pax) can be reached. It can thus be concluded that a subsidy on air/rail tickets has less effect than increasing the integrated services and comfort standards, under the assumptions on parameter values used in this study.

9.2. Policy Recommendations

From case studies done in this study, several actor-specific policy recommendations regarding air/rail can be proposed. The first case about introducing an air/rail terminal at Frankfurt Airport involves actors such as Lufthansa, Deutsche Bahn, Frankfurt Airport and the (local) government. From the scenario analysis based on this case, it can be concluded that such a dedicated air/rail terminal does increase attractiveness. By introducing more integrated services, introducing more comfort features and by reducing the time at the airport and train station, these actors can make air/rail more appealing. But how?

Currently, Lufthansa and Deutsche Bahn do not offer a full integrated information platform for air/rail journeys. With new technologies such as Mobility as a Service (MaaS), actors are able to give travellers full transparency regarding their trip, which is also emphasized by both focus groups of this study. MaaS also enables these actors also to standardize the services across their operations, as also done in the aviation industry. For more comfort, a dedicated air/rail lounge could be opened. But in order to create awareness among travellers, Frankfurt Airport and Lufthansa could hire influencers on TikTok and Instagram to promote these lounges, as these platforms are mostly used by younger people, who are the main segment to focus on according to the results of this study. The last way to make air/rail more appealing is to introduce full luggage integration and priority lanes for air/rail, this in order to save time spend at the airport and train station. Luggage integration should be handled by Lufthansa, Frankfurt Airport and Deutsche Bahn together, while for priority lanes, the responsibility lies with Frankfurt Airport and Lufthansa.

For the Amsterdam - Frankfurt corridor, air/rail could also be made more attractive by reducing the travel time by train. With TEN-T, a shift from air/air to air/rail can be realized, but the overall effect is less than offering integrated services and comfort features. It is therefore recommendable for policymakers not to only focus on reducing travel times but also focus on the journey around the travellers.

The second real-life case about Air-France KLM shows the same patterns as for the Frankfurt case. With increasing service, comfort and decreasing time spend at the airport/ train station, Air-France KLM can with their terminal at Brussels-Midi increase the share of air/rail. At Brussels-Midi, there is already an Eurostar lounge available, but only for higher-tier loyalty passengers. It is recommended for KLM to explore the possibility to open this lounge for all air/rail passengers as well. For standardization, lounge facilities should also be opened at Schiphol Airport. Regarding priority lanes, SkyPriority (offered by KLM) could be used to create separate lanes for air/rail at the luggage drop-off and security. The Privium lanes (offered by Schiphol Airport) could then be used to have priority at the passport control at Schiphol, as Privium members should still benefit from their privileges. And for the short term, it could be promoted among air/rail travellers to book time slots at the security check at Schiphol. These measures all to reduce the time spend at the airport and train station.

9.3. Discussion

Studies as Bory (1999), Clewlow et al. (2014), and Zanin et al. (2012) discuss how high-speed trains can directly substitute short-haul flights in order to reduce greenhouse gas emissions and prevent airport hubs from being saturated, this to increase societal welfare. However, these studies focuses on substitution instead of integration, while van Alphen and Reijenga (1998) already concluded that the rail product should be complementary to the air product in order to make air/rail more attractive. This study builds further on that claim from van Alphen and Reijenga (1998), by quantifying the potential integration benefits of air/rail in a hub-and-spoke network, from a passenger perspective.

When it comes to the services offered, ticketing emerges as the most important factor, in line with Weisshaar (2024), who found this result in a rating experiment on booking night train tickets. Travellers consider having a single ticket for an integrated journey way more important than luggage integration. Opposite to Chiambaretto and Decker (2012), Román and Martín (2014), and van Alphen and Reijenga (1998), who claim that the focus should be on luggage integration, this study shows that this effect can be nuanced. Luggage integration is considered just as important as having an integrated customer service. In other words, setting up a helpdesk counter at an airport or train station where travellers can ask all their questions about their air/rail journey has the same effect on the perceived service level as full luggage integration between train and plane, with all its associated costs. Based on the results of this research, it is a point of discussion why Frankfurt Airport, Lufthansa, and Air France-KLM are investing so much in luggage integration, while focussing on integrating customer service is as effective.

In line with van Alphen and Reijenga (1998), travellers also find the provision of information important. If the necessary information cannot be found because it is spread over multiple websites or apps, mode choices may be based on incorrect travel information. Regarding lounges, opening a lounge for all air/rail passengers is considered as such important that it could become a point of discussion why operators are not facilitating such a feature, as lounges are currently only available to higher-tier loyalty customers. One implication of such a policy intervention is that those lounges may become crowded, which decreases the comfortability of such a feature.

Opening priority lanes for all air/rail passengers seems to be an effective policy. According to this study, this is perceived as most comfortable, more by business travellers than leisure travellers. This policy could also shorten the total lead time at Schiphol, which significantly increases the likelihood that air/rail will be chosen over air/air.

Travel time and travel costs remain important elements in mode choice, as already concluded by studies as Behrens and Pels (2012), Bergantino and Madio (2017), Kantelaar et al. (2022), and Weisshaar (2024). However, these studies only consider the time of actual transportation. Donners et al. (2018) claims that travellers consider the concept of travel time, when comparing air and rail travel, differently. This means that travellers are making mode choices, only based on the actual time of transport and do not consider the total travel time of the journey. However, the results of this study show that time spend in a vehicle is valued differently than time spend at the airport/train station.

There are two ways to reduce the amount of travel time for air/rail in this study, by either reducing the in-vehicle time for train travel or reducing the time spend at the airport/ train station. Reducing the in-vehicle time for the train can be achieved by building new infrastructure in order to achieve TEN-T. However, this study shows that spending a lot of money on infrastructure is not the only way to make air/rail attractive. Offering features such as luggage integration and priority lanes for air/rail can shorten the time spend at the airport/ train station as well. This research shows that the effect of reducing the time spend at the airport is almost as big as reducing the in-vehicle time for train.

This study shows that air/rail could be a valuable alternative for air/air journeys. But how may this look like in practice? Well, van Alphen and Reijenga (1998) recommended dedicated shuttle trains for air/rail passengers. And based on the outcomes of Kantelaar et al. (2022), this may a valuable policy, as privacy and comfort are valued as highly important. However, a study by Royal HaskoningDHV (2020) shows that this would not be operationally feasible, as there would be not enough demand to make these trains cost-effective. Therefore, a balance must be found between cost-effectiveness, privacy and comfort for long-distance train travel, and thus also for air/rail. A middle way for making an exclusive trip by train might be buying or renting first-class seats for air/rail passengers on existing high-speed trains from Eurostar, Thalys, TGV or Deutsche Bahn which may be more convenient regarding privacy than second class tickets.

9.4. Limitations

As every other study, this research contains limitations which should be taken into account considering the results. At first, the group size of the focus groups. Focus groups are used to derive unknown travel attributes, from the perspective of both experienced air as rail travellers. However, it must be noted that the group size was rather small, consisting three or four persons per session. In this case, the host had to keep the conversation going, making it more like a group interview at times. With multiple participants, there could have been more of a discussion where different attributes could have been approached from different perspectives, and then weighted according to how important they might be for air/rail. With more people, also other attributes that were not considered in this study could also have come to the surface, which leads to different results in the experiments.

Another possible limitation is the use of the Dutch Railways (NS) panel. The preferences of only members of this panel are examined. Therefore, the shares of choosing air/rail over air/air may be overestimated, as the response group might be biased towards train travel. It is plausible to assume that people who are part of this panel may have a stronger preference for train travel compared to the Dutch population, but it is hard to say if those people are then biased towards rail and thus choose air/rail over air/air more often. Also, as with every other stated preference research, the limitation of the hypothetical bias might be present. Indicating that the hypothetical choice made in the survey may not correspond with the choices made in real-life.

Another limitation is about the scope of the air/rail journeys. In this study, it is assumed that the rail leg within an air/rail journey is always within Europe. Also, it is assumed that within air/air journeys, there is only a passport control when having a transfer from a Schengen country to a non-Schengen country. However, this policy is based on that from Schiphol Airport and may differ for other airports where there is an extra security point.

About the concepts of service and comfort, it depends on the definition on how to interpret them. For instance, integrated loyalty programs is now considered as a comfort feature, but could also be considered as a service from the air/rail operator. The same holds for the availability of WiFi, lounge and security, they could also be defined as service features. One solution would have been to integrate all those attributes into one single rating experiment, however this would lead to an information overload and more difficult to trade-off for respondents.

The last discussed limitation of this study is about the proposed alternatives. In the survey, only the alternatives air/rail and air/air are introduced, which are multi-legged journeys. However, imaging a journey from Amsterdam to Singapore, one could also take a direct flight if this route is offered from Schiphol. Adding this to the already introduced indirect travel options may seriously affect the substitution rates from air/air to air/rail, as a direct flight is always faster than an indirect journey. Also the scope of this study, for air/rail, is within the range of 800 kilometers, which approximately equals a flight of one hour.

9.5. Recommendations for Future Research

The potentials of air and rail intermodality are examined in this study, but it does not mean that research about air/rail is finished. Therefore, several recommendations for future research are proposed.

The first is about the response group of this study, recruited from the Dutch NS panel. In order to be able to aggregate results to a wider population, the survey must be held among more varied response group. But still, in order to generalise the results to the European population, a survey must be held among Europeans, but this will be quite challenging. One recommendation would be to recruit respondents from the International Air Transport Association (IATA) in order to grasp upon a wider varied public, but this may result in biased results towards flying.

Air/rail is introduced in order to reduce the amount of short-haul flights within Europe in order to achieve Net Zero in 2050. However, environmental awareness is not included in this study. A recommendation for future research is adopt the New Ecological Paradigm (NEP) scale of Dunlap (2008), which could be used to measure the environmental perception of travellers.

For future research, it would be interesting to examine the potentials of air/rail for rail journeys over 800 kilometer. Perhaps adopting an alternative where a night train is combined with a long-haul flight, combining this study with the studies done by Kantelaar et al. (2022) and Weisshaar (2024).

For follow-up research, one could also include a direct travel option, instead of offering two indirect alternatives. It would be interesting to what happens with air/rail market shares when a direct flight is added in the choice options.

The last recommendation for future research is to look into the possibilities of air and rail intermodality in the Netherlands. In France, there is TGV-Air. In Germany, there is Lufthansa Express Rail. But in the Netherlands there is nothing like this existing. Therefore, it would be interesting to look into the potentials of a far-reaching cooperation between the Dutch railway operator NS and KLM Royal Dutch Airlines.

References

Air France-KLM. (n.d.). Status & XP - The Programme. Retrieved March 27, 2024, from https://www.flyingblue.us/en/programme/more-info/status

Airbus. (2021). A320neo | A320 | Aircraft | Airbus Aircraft. Retrieved March 13, 2024, from https://aircraft.airbus.com/en/aircraft/a320-the-most-successful-aircraft-family-ever/a320neo

AirFrance. (n.d.). Combined plane + train tickets | Air France. Retrieved March 21, 2024, from https://wwws.airfrance.nl/information/prepare/voyages-combines-avion-train

Alamdari, F., & Fagan, S. (2005). Impact of the adherence to the original low cost model on the profitability of low cost airlines. *Transport Reviews*, *25*(3), 377–392. https://doi.org/10.1080/01441640500038748

Andrejiová, M., Grincova, A., & Marasová, D. (2020). Study of the Percentage of Greenhouse Gas Emissions from Aviation in the EU-27 Countries by Applying Multiple-Criteria Statistical Methods [Number: 11 Publisher: Multidisciplinary Digital Publishing Institute]. *International Journal of Environmental Research and Public Health*, *17*(11), 3759. https://doi.org/10.3390/ijerph17113759

Barreira, Á., Reis, V., & Macário, R. (2013). Competitiveness of High-Speed Rail: Analysis for Corridor Between Lisbon, Portugal, and Madrid, Spain, Based on Discrete Choice Models. *Transportation Research Record: Journal of the Transportation Research Board*, *2374*(1), 9–16. https://doi.org/10.3141/2374-02

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.

Ben-Akiva, M., Bierlaire, M., Hall, R. W., & Hillier, F. S. (1999). Discrete Choice Methods and their Applications to Short Term Travel Decisions. In *Handbook of Transportation Science* (pp. 5–33, Vol. 23). Springer US.

Ben-Akiva, M., McFadden, D., & Train, K. (2019). Foundations of stated preference elicitation: Consumer behavior and choice-based conjoint analysis. *Foundations and Trends® in Econometrics*, *10*(1-2), 1–144.

Bergantino, A. S., & Madio, L. (2017). High-Speed Rail, Inter-Modal Substitution and Willingness-to-Pay. A Stated Preference Analysis for the'Bari-Rome'.

Bierlaire, M. (2018). PandasBiogeme: A short introduction.

Borhani, M., Akbari, K., Matkan, A., & Tanasan, M. (2020). A multicriteria optimization for flight route networks in large-scale airlines using intelligent spatial information.

Bory, M.-P. (1999). Air-rail intermodality: Optimizing airport capacity. *Japan Railway & Transport Review*, *19*, 28–29.

Bruinsma, N. (2023). Een overstap per trein of per vliegtuig: Barrières bij de integratie van hogesnelheidstreinen in de luchtvaart.

Centraal Bureau voor de Statistiek. (n.d.-a). Leeftijdsverdeling. Retrieved June 4, 2024, from https://www.cbs.nl/nl-nl/visualisaties/dashboard-bevolking/leeftijd/bevolking

Centraal Bureau voor de Statistiek. (n.d.-b). Mannen en vrouwen. Retrieved June 4, 2024, from https://www.cbs.nl/nl-nl/visualisaties/dashboard-bevolking/mannen-en-vrouwen

Chiambaretto, P., & Decker, C. (2012). Air–rail intermodal agreements: Balancing the competition and environmental effects [Publisher: Elsevier]. *Journal of Air Transport Management*, *23*, 36–40.

ChoiceMetrics. (2018). Ngene User Manual.

Clewlow, R. R., Sussman, J. M., & Balakrishnan, H. (2014). The impact of high-speed rail and low-cost carriers on European air passenger traffic [Publisher: Elsevier]. *Transport Policy*, *33*, 136–143.

Cokasova, A. (2003). Air rail intermodality from passenger perspective. *Eurocontrol Research Centre*.

Coogan, M., Brand, D., Hansen, M., Kivett, H., Last, J., Marchi, R., Ryerson, M. S., Taylor, M. J., & Thompson, L. (2015). Integrating Aviation and Passenger Rail Planning. *ACRP Report*, (118).

Deutsche Bahn. (n.d.). BahnBonus Vorteilsprogramm: Bei jeder Fahrt Punkte sammeln. Retrieved March 28, 2024, from https://www.bahn.de/service/bahnbonus

Dobruszkes, F. (2006). An analysis of European low-cost airlines and their networks. *Journal of Transport Geography*, *14*(4), 249–264. https://doi.org/10.1016/j.jtrangeo.2005.08.005

Donners, B. (2024). Pictures of new AirRail terminal Frankfurt Airport.

Donners, B., van Buuren, E., & Rijniers, R. (2018). Steden verbonden, trein of vliegtuig, effecten van substitutie.

Dunlap, R. E. (2008). The New Environmental Paradigm Scale: From Marginality to Worldwide Use. *The Journal of Environmental Education*, *40*(1), 3–18. https://doi.org/10.3200/JOEE.40.1.3-18

Durand, A., & Romijn, G. (2023). *Substitutiemogelijkheden van luchtvaart naar spoor in 2030 en 2040* (nieuwsbericht). Kennisinstituut voor Mobiliteitsbeleid.

European Commission. (n.d.). Trans-European Transport Network (TEN-T) - European Commission. Retrieved May 17, 204, from https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

European Commission. (2023a). Mobility and Transport. Retrieved January 11, 2024, from https://transport.ec.europa.eu/index_en

European Commission. (2023b). Trans-European Transport Network TENTEC - Maps - European Commission. Retrieved May 22, 2024, from https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/en/maps.html

European Commission. (2024). Reaching 'net zero' CO2 emissions by 2050. Retrieved April 3, 2024, from https://ec.europa.eu/commission/presscorner/detail/en/ip_24_585

European Council. (2024). Rail transport policy. Retrieved January 11, 2024, from https://www.consilium.europa.eu/en/policies/rail-transport-policy/

European Environment Agency. (2023). Europe's air quality status 2023 — European Environment Agency. Retrieved January 11, 2024, from https://www.eea.europa.eu/publications/europes-air-quality-status-2023

Eurostar. (n.d.). Hoe laat moet ik in het station zijn? - Eurostar Help Centre. Retrieved March 29, 2024, from https://help.eurostar.com/faq/nl-nl/vraag/Wanneer-moet-ik-inchecken-voor-de-Eurostar

FlightConnections. (n.d.). FlightConnections - All flights worldwide on a flight map! Retrieved March 26, 2024, from https://www.flightconnections.com

Frankfurt Airport. (n.d.-a). AiRail Check-in. Retrieved March 21, 2024, from https://www.frankfurt-airport.com/en/airport-guide/check-in-and-luggage/airail-check-in.html

Frankfurt Airport. (n.d.-b). Lufthansa Express Rail. Retrieved June 15, 2024, from https://www.frankfurt-airport.com/en/transport-and-parking/by-train/lufthansa-express-rail.html

Givoni, M. (2007a). Air rail intermodality from airlines' perspective. *World Review of Intermodal Transportation Research*, *1*(3), 224. https://doi.org/10.1504/WRITR.2007.016271

Givoni, M. (2007b). Environmental Benefits from Mode Substitution: Comparison of the Environmental Impact from Aircraft and High-Speed Train Operations. *International Journal of Sustainable Transportation*, *1*(4), 209–230. https://doi.org/10.1080/15568310601060044

Givoni, M., Dobruszkes, F., Lugo, I., Inderwildi, O., & King, S. D. (2012). Uncovering the Real Potential for Air–Rail Substitution: An Exploratory Analysis. In *Energy, Transport, & the Environment* (pp. 495–512). Springer London. https://doi.org/10.1007/978-1-4471-2717-8_27

Greene, W. (2009). Discrete Choice Modeling. In T. C. Mills & K. Patterson (Eds.), *Palgrave Handbook of Econometrics: Volume 2: Applied Econometrics* (pp. 473–556). Palgrave Macmillan UK. https://doi.org/10.1057/9780230244405_11

Huffman, W. E., & McCluskey, J. J. (2017). Using Stated Preference Techniques and Experimental Auction Methods: A Review of Advantages and Disadvantages for Each Method in Examining Consumer Preferences for New Technology. *International Review of Environmental and Resource Economics*, *10*(3-4), 269–297. https://doi.org/10.1561/101.00000088

International Civil Aviation Organization. (n.d.). Future of Aviation. Retrieved January 11, 2024, from https://www.icao.int/Meetings/FutureOfAviation/Pages/default.aspx

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. https://doi.org/10.1080/21680566.2019.1670117

Kantelaar, M. H. (2019). *Night-Time Train Travel* (Thesis).

Kantelaar, M. H., Molin, E., Cats, O., Donners, B., & van Wee, B. (2022). Willingness to use night trains for long-distance travel. *Travel Behaviour and Society*, *29*, 339–349.

KLM Royal Dutch Airlines. (n.d.-a). Disruption information - KLM Netherlands. Retrieved March 28, 2024, from https://www.klm.nl/en/information/travel-alerts/operational-issues-schiphol

KLM Royal Dutch Airlines. (n.d.-b). Flying Blue membership levels and Experience Points - KLM Netherlands. Retrieved March 28, 2024, from https://www.klm.nl/en/information/flying-blue/membership-levels

KLM Royal Dutch Airlines. (n.d.-c). Transfer to a connecting flight with KLM - KLM Netherlands. Retrieved March 30, 2024, from https://www.klm.nl/en/information/airport/transfers

KLM Royal Dutch Airlines. (n.d.-d). WiFi aan boord om te surfen, streamen en berichten te sturen - KLM Nederland. Retrieved April 10, 2024, from https://www.klm.nl/information/travel-class-extra-options/inflight-wifi

KLM Royal Dutch Airlines. (2024). Air France en KLM nemen vernieuwde Air&Rail Terminal in Brussel-Zuid in gebruik. Retrieved June 17, 2024, from https://klmf.ly/3Trg12K

Kouwenhoven, M., de Jong, G. C., Koster, P., van den Berg, V. A., Verhoef, E. T., Bates, J., & Warffemius, P. M. (2014). New values of time and reliability in passenger transport in The Netherlands [Publisher: Elsevier]. *Research in Transportation Economics*, *47*, 37–49.

Kroes, E., & Savelberg, F. (2019). Substitution from Air to High-Speed Rail: The Case of Amsterdam Airport. *Transportation Research Record: Journal of the Transportation Research Board*, *2673*(5), 166–174. https://doi.org/10.1177/0361198119839952

Krueger, R. (2002). Designing and Conducting Focus Group Interviews.

Kumrić, O., Šimunović, D., & Puž, G. (2017). Transport Network Development in South-East Europe. *4th International Conference on Road and Rail Infrastructure*.

Lee, D. S., Building, J. D., & Street, C. (2018). The current state of scientific understanding of the non-CO2 effects of aviation on climate.

Luchtvaartnieuws. (2024a). Hoge raad: Kabinet moet europese regels volgen bij eventuele krimp schiphol. Retrieved July 12, 2024, from https://luchtvaartnieuws.nl/nieuws/categorie/3/airports/hoge-raad-kabinet-moet-europese-regels-volgen-bij-eventuele-krimp-schiphol

Luchtvaartnieuws. (2024b). Schiphol wil vliegtaks afhankelijk van de afstand maken [Publisher: Reismedia]. Retrieved June 17, 2024, from https://www.luchtvaartnieuws.nl/nieuws/categorie/3/airports/schiphol-wil-vliegtaks-afhankelijk-van-de-afstand-maken

Lufthansa. (n.d.). Lufthansa Express Rail. Retrieved June 15, 2024, from https://www.lufthansa.com/ao/en/lufthansa-express-rail

McGrath, R. E., Mitchell, M., Kim, B. H., & Hough, L. (2010). Evidence for response bias as a source of error variance in applied assessment. [Publisher: American Psychological Association]. *Psychological bulletin*, *136*(3), 450. Retrieved May 22, 2024, from https://psycnet.apa.org/record/2010-07936-009

Ministerie van Infrastructuur en Waterstaat. (2021). Bestemmingen - Vliegverkeer Schiphol - Staat van [Last Modified: 2022-03-04T09:51 Publisher: Ministerie van Infrastructuur en Waterstaat]. Retrieved February 19, 2024, from https://magazines.ilent.nl/staatvan/2021/01/bestemmingen

Ministry of Infrastructure and Water management. (2020a). Actieagendatrein en luchtvaart november 2020. https://www.rijksoverheid.nl/documenten/rapporten/2020/11/20/bijlage-1-actieagenda-trein-vliegtuig

Ministry of Infrastructure and Water management. (2020b). Verantwoord vliegen naar 2050. https://www.rijksoverheid.nl/onderwerpen/luchtvaart/ontwikkeling-luchtvaart#:~:text=De%20Rijksoverheid%20maakt%20een%20actieplan,Er%20zijn%20minder%20nachtvluchten%20toegestaan.

Molin, E., & Timmermans, H. (2009). Hierarchical Information Integration Experiments and Integrated Choice Experiments. *Transport Reviews*, *29*, 635–655. https://doi.org/10.1080/01441640902829470

Nikolaev, E. (2022). Rail-air transport competition: A discrete choice analysis along with an international empirical investigation. Retrieved March 19, 2024, from https://www.diva-portal.org/smash/record.jsf?pid=diva2:1730799

Orme, B. K. (2006). Getting started with conjoint analysis: Strategies for product design and pricing research. *(No Title)*. Retrieved April 4, 2024, from https://cir.nii.ac.jp/crid/1130282271624104832

Pagliara, F., Vassallo, J. M., & Román, C. (2012). High-Speed Rail versus Air Transportation: Case Study of Madrid–Barcelona, Spain. *Transportation Research Record: Journal of the Transportation Research Board*, *2289*(1), 10–17. https://doi.org/10.3141/2289-02

Pels, E. (2008). Airline network competition: Full-service airlines, low-cost airlines and long-haul markets. *Research in Transportation Economics*, *24*(1), 68–74. https://doi.org/10.1016/j.retrec.2009.01.009
Priemus, H., & Zonneveld, W. (2003). What are corridors and what are the issues? Introduction to special issue: The governance of corridors [Publisher: Elsevier]. *Journal of transport geography*, *11*(3), 167–177.
Reis, V., Meier, J. F., Pace, G., & Palacin, R. (2013). Rail and multi-modal transport [Publisher: Elsevier]. *Research in Transportation Economics*, *41*(1), 17–30.
Rijksoverheid. (2019). Mobility as a service (maas): Multimodaal reisadvies op maat. Retrieved July 15, 2024, from https://www.rijksoverheid.nl/onderwerpen/mobiliteit-nu-en-in-de-toekomst/mobility-as-a-service-maas
Ritchie, H., & Roser, M. (2023). Which form of transport has the smallest carbon footprint? *Our World in Data*. Retrieved February 13, 2024, from https://ourworldindata.org/travel-carbon-footprint
Román, C., & Martín, J. C. (2014). Integration of HSR and air transport: Understanding passengers' preferences [Publisher: Elsevier]. *Transportation Research Part E: Logistics and Transportation Review*, *71*, 129–141.
Ronald Verkaaik. (2023). KLM air/rail-product.
Rose, J. M., & Bliemer, M. C. J. (2009). Constructing Efficient Stated Choice Experimental Designs. *Transport Reviews*, *29*(5), 587–617. https://doi.org/10.1080/01441640902827623
Royal HaskoningDHV. (2020). *Potentie AirRail substitutie ZWASH-corridor* (tech. rep.).
Savelberg, F., & de Lange, M. (2018). *Substitutiemogelijkheden van luchtvaart naar spoor* (tech. rep.).
Schiphol. (2024). Schiphol | Schiphol as a neighbour. Retrieved May 16, 2024, from https://www.schiphol.nl/en/schiphol-as-a-neighbour/
Schiphol Group. (2023). Schiphol | Annual Traffic Reviews. Retrieved May 16, 2024, from https://www.schiphol.nl/en/schiphol-group/page/traffic-review/
Skyscanner. (n.d.). Goedkope vliegtickets: Vergelijk goedkope vluchten | Skyscanner. Retrieved March 30, 2024, from https://www.skyscanner.nl/
Skyteam. (n.d.). Our Members | SkyTeam. Retrieved April 1, 2024, from https://www.skyteam.com/en/about/our-members/
Somsen, R. (2024, March). KLM neemt vernieuwde Air&Rail Terminal in Brussel-Zuid in gebruik [Publisher: Reismedia]. Retrieved May 20, 2024, from https://www.luchtvaartnieuws.nl/nieuws/categorie/22/spoorwegen/klm-neemt-vernieuwde-airrail-terminal-in-brussel-zuid-in-gebruik
Szinay, D., Cameron, R., Naughton, F., Whitty, J. A., Brown, J., & Jones, A. (2021). Understanding Uptake of Digital Health Products: Methodology Tutorial for a Discrete Choice Experiment Using the Bayesian Efficient Design. *Journal of Medical Internet Research*, *23*(10), e32365. https://doi.org/10.2196/32365
Trainline. (2024). Trein Eurostar & Thalys Luchthaven Schiphol - Paris Gare du Nord vanaf € 149. Retrieved March 29, 2024, from https://www.thetrainline.com/nl/treintijden/luchthaven-schiphol-naar-paris-gare-du-nord
Transport & Environment. (2023). Airplane pollution. Retrieved February 13, 2024, from https://www.transportenvironment.org/challenges/planes/airplane-pollution/
Troquete, R. (2024). Picture of skypriority and privium entrance at amsterdam schiphol airport.
United Nations. (n.d.). The Paris Agreement [Publisher: United Nations]. Retrieved May 17, 2024, from https://www.un.org/en/climatechange/paris-agreement
Valeri, E. (2013). *Air and rail transport in the Rome-Milan corridor: Competition policy implications based on a discrete choice analysis* [PhD Thesis]. Università degli studi di Trieste.
van de Hulsbeek, J., & van der Parre, H. (2022, May). Omwonenden: Schiphol kan 100 bestemmingen missen. Retrieved March 12, 2024, from https://nos.nl/artikel/2428784-omwonenden-schiphol-kan-100-bestemmingen-missen
van Alphen, R., & Reijenga, A. (1998). *Vluchten kan niet meer....* (Thesis).
Vermunt, J. K., & Magidson, J. (2021). LG-syntax users's guide: Manual for latent GOLD syntax module version 6.0.
Wang, Y., Lu, Q., Cao, X., Zhou, X., Latora, V., Tong, L. C., & Du, W. (2020). Travel time analysis in the Chinese coupled aviation and high-speed rail network [Publisher: Elsevier]. *Chaos, Solitons & Fractals*, *139*, 109973.

Wang, Y., Sun, L., Teunter, R. H., Wu, J., & Hua, G. (2020). Effects of introducing low-cost high-speed rail on air-rail competition: Modelling and numerical analysis for Paris-Marseille [Publisher: Elsevier]. *Transport Policy*, *99*, 145–162.

Wardman, M. (1988). A comparison of revealed preference and stated preference models of travel behaviour [Publisher: JSTOR]. *Journal of transport economics and policy*, 71–91.

Wee, B. V., & Banister, D. (2016). How to write a literature review paper? [Publisher: Taylor & Francis]. *Transport reviews*, *36*(2), 278–288.

Weisshaar, T. C. (2024). *Unravelling night train travel behaviour* (Thesis).

Whebell, C. F. J. (1969). Corridors: A theory of urban systems. *Annals of the Association of American Geographers*, *59*(1), 1–26. https://doi.org/10.1111/j.1467-8306.1969.tb00655.x

Wikipedia. (2024). Intercity Nieuwe Generatie. Retrieved March 13, 2024, from https://nl.wikipedia.org/w/index.php?title=Intercity_Nieuwe_Generatie&oldid=67141471#cite_note-factsheet-5

Wilkerson, J. T., Jacobson, M. Z., Malwitz, A., Balasubramanian, S., Wayson, R., Fleming, G., Naiman, A. D., & Lele, S. K. (2010). Analysis of emission data from global commercial aviation: 2004 and 2006 [Publisher: Copernicus GmbH]. *Atmospheric Chemistry and Physics*, *10*(13), 6391–6408.

World Aviation Flight Academy. (2023, August). What's the speed of an airplane? - World Aviation ATO [Section: News]. Retrieved March 28, 2024, from https://worldaviationato.com/en/airplane-speed/

Xia, W., & Zhang, A. (2017). Air and high-speed rail transport integration on profits and welfare: Effects of air-rail connecting time [Publisher: Elsevier]. *Journal of air transport management*, *65*, 181–190.

Yuksel, Y. (n.d.). Short-haul flights emit more carbon than long-haul flights. https://www.aa.com.tr/en/environment/short-haul-flights-emit-more-carbon-than-long-haul-flights/2920623

Zanin, M., Herranz, R., & Ladousse, S. (2012). Environmental benefits of air–rail intermodality: The example of Madrid Barajas [Publisher: Elsevier]. *Transportation Research Part E: Logistics and Transportation Review*, *48*(5), 1056–1063.

Zhang, F., Graham, D. J., & Wong, M. S. C. (2018). Quantifying the substitutability and complementarity between high-speed rail and air transport [Publisher: Elsevier]. *Transportation Research Part A: Policy and Practice*, *118*, 191–215.

A

Focus Group Results

This appendix shows the mentioned attributes by the members of both the focus group air **Table A.1** as the focus group rail **Table A.2**. The question asked is also shown for both focus groups.

Which attributes would you find important in choosing air/rail, based on your experiences with air transport?

Table A.1: Attributes mentioned focus group air

Attribute	#Mentioned
Total travel time	2
Travel cost	1
Reliability/ punctuality	3
Comfort	2
Frequency	2
Transfer/ connection time	3
Loyalty program	3
Integrated luggage	1
Integrated tickets	1
Security	1
Availability of a lounge	1

Which attributes would you find important in choosing air/rail, based on your experiences with rail transport?

Table A.2: Attributes mentioned focus group rail

Attribute	#Mentioned
Total travel time	2
Reliability/ punctuality	5
Integrated tickets	4
Integral services	2
Booking convenience	2
Frequency	1
Arrival certainty	1
Environment	1
Travel cost	1
Comfort	3

B

Attribute Level Analyses

This appendix discusses how the attribute levels for the attributes total travel time, total travel cost and delay in case of missed transfer were determined.

B.1. Total Travel Time

The **total travel time** for air/air and air/rail journeys consist of several time elements that, together, make up the total travel time. In this study, the total travel time is distinguished in the following elements:

Flight time short-haul flight
This attribute is only applicable for the air/air alternative, as for air/rail journeys, this leg is replaced by train. Therefore, this attribute is alternative specific for air/air journeys. The flight time for the short-haul flight is considered to be **1 hour**, because the average cruising speed is approximately 850 km/h (World Aviation Flight Academy, 2023). So, within approximately 1 hour, a flight is able to cover the full range of approximately 750 km, which is the focus of this study.

Flight time long-haul flight
Wilkerson et al. (2010) defines a long-haul flight leg when the in-vehicle time is over 6 hours. But this is, according to this study, the shortest long-haul leg possible. In order to determine the longest long-haul leg from Schiphol, FlightConnections (n.d.) has been consulted in order to identify all the destinations from Amsterdam Schiphol Airport. According to this source, Buenos Aires is the furthest destination with a flight time of almost 14 hours. This attribute has a significant impact on the total travel time and could thus also be important in determining the choice between air/rail and air/air. However, the focus of this study is not to trade-off this specific travel attribute, and therefore, this attribute has only one level: **10 hours**. This is the median flight time of a long-haul leg from Schiphol.

Transportation time train
This attribute is alternative specific for air/rail journeys. In order to determine the transportation time for this attribute, the average speed of a high-speed train should be known. However, the average speed is leg-dependent, based on factors such as the infrastructure and the amount of stops. For example, the Eurostar from Schiphol Airport to Paris Nord lasts 3 hours and 10 minutes according to the fastest schedule (Trainline, 2024). The distance is, according to Trainline (2024), 417 kilometers. This would suggest an average speed of approximately 132 km/h. For a distance of 750 kilometers, the in-vehicle travel time for train is approximately 5 hours and 40 minutes. However, for the route from Amsterdam Schiphol Airport to Brussels Airport, the average speed is approximately 90 km/h (Trainline, 2024). The attribute levels are more difficult to distinguish because it is unknown what the average speed, and thus in-vehicle times, of high-speed trains could be with TEN-T. And still, these will be leg-dependent. Therefore, in order to capture a range of travel legs, three attribute levels are taken for the transportation time for train legs: **2 hours**, **4 hours** and **6 hours**. With an average speed of 132 km/h, the high-speed train could cover the entire distance of 750 km within 6 hours.

Time spend at airport/ train station

In this study, the total waiting/ lead time is the accumulation of the time spend at the airport or the train station before departure and transfer time between two flight legs. It could basically be explained as the time at the airport or train station without being in the transport mode. Security checks, passport controls, walking time and waiting time are all included in this attribute. This to give the respondent the perception that travelling is not only the transportation time, but also the dwell time, as described by Cokasova (2003), Donners et al. (2018), and Savelberg and de Lange (2018).

For air/air journeys, KLM Royal Dutch Airlines (n.d.-a) their advice for intercontinental flights is to be 3 hours in advance at the airport. For Schengen flights, this is 90 minutes. Based on these recommendations, three levels are distinguished: 90 minutes, 120 minutes and 180 minutes.

Transfer time is flight-dependent, based on data from **Table B.1**, three levels are distinguished: 1 hour, 2 hours, 3 hours. The data is received from Skyscanner (n.d.) at one point in time: 24 to 31 May 2024. The considered journey is an indirect trip from Amsterdam to New York with KLM or SkyTeam partners (Skyteam, n.d.). In total, there were 65 indirect flights available, but only eight flights are shown in the table. This because this table is just to get an idea of possible transfer times that are offered by airlines. Among the 57 other flights, there are also transfer times up to 19 hours, but these are considered as such inconvenient transfer times that these are left out of scope.

Table B.1: Transfer times from KLM and SkyTeam partners from Schiphol to New York via indirect journeys

Departure time [hh:mm]	Airline	Transfer time [hh:mm]	Transfer city
06:45	KLM/ Delta	01:35	Paris
08:05	KLM/ AirFrance	03:20	Paris
08:30	Delta	04:59	Detroit
09:30	AirFrance	01:55	Paris
10:40	Delta	02:29	Detroit
10:40	Delta	04:39	Detroit
11:45	Delta	03:25	Boston
13:35	Delta	01:44	Detroit
14:30	Delta	02:43	Boston

The table shows just a few possibilities of transfer times, and from this data, there is no reason to believe that there is a standard range of transfer times offered. Therefore, the proposed transfer times by KLM Royal Dutch Airlines (n.d.-c) are held as indication for the transfer times. For Schengen flights, the minimum required transfer time is 50 minutes and for non-Schengen it is more because of the extra security protocols. But how much longer? This study holds on to the following values for transfer times: 1 hour, 2 hours and 3 hours. The 50 minutes is rounded up because it is easier to hold on to equidistance without getting odd attribute values that need to be interpreted by respondents. Adding the transfer times to the dwell times for air/air journeys, the total dwell time levels are: **2.5 hours**, **4 hours**, **5.5 hours**.

For air/rail journeys, the transfer times are kept the same as for air/air trips because there is no obvious reason to assume that the transfer time would be different because in both alternatives, passengers must cross extra security checks because of the intercontinental flight. However, the dwell time before departure differ. The advantage of rail journeys is that travellers generally need to be present less in advance. Eurostar (n.d.) recommends passengers to be present 30 minutes in advance before departure when travelling between Schengen countries. For travelling to non-Schengen countries, this is 90 minutes because of the extra security protocols. Based on these recommendations, three attribute levels are distinguished: 30 minutes, 60 minutes and 90 minutes. Adding these to the transfer times gives the following attribute levels for air/rail: **1.5 hours**, **3 hours** and **4.5 hours**.

B.2. Total Travel Cost

The air/rail product of AirFrance is representative for the potential European air/rail product because the range of services are comparable to what it could potentially be with TEN-T. In order to illustrate, **Table B.2** indicates some examples of the rail leg distances between origins within France and Paris Charles de Gaulle Airport that are possible with the AirFrance air/rail product (AirFrance, n.d.; Trainline, 2024).

Table B.2: Train distances to Paris Charles de Gaulle from several places in France

Origin	Distance by train (km)
Champagne-Ardenne	106
Le Mans	208
Rennes	328
Nantes	364
Lyon	400
Avignon	590
Aix-en-Provence	652
Marseille	670
Perpignan	702

In order to get to attribute levels for the total cost of the journeys, for every origin of **Table B.2**, the air/rail and air/air ticket prices are indicated. However, not every origin has its own airport, so for those trips, the air/air journey is not possible (indicated with an [x]). Also, as multi-legged journey prices are also dependend on the distance of the long-haul leg, in accordance with the long-haul travel leg attribute, which is set on 10 hours. Miami is one destination from Paris Charles de Gaulle which has an in-vehicle flight time of approximately 10 hours. This destination is taken in order to get insights into air/air and air/rail prices.

Table B.3 indicates ticket prices for air/rail and air/air to Miami. The ticket prices are retrieved from AirFrance (n.d.), all for the same dates: 24 to 31 May 2024. For all tickets, economy class is assumed for one adult. The average price for outbound and inbound journeys are taken and added up in order to get the total price (rounded up to integer numbers). Regarding ticket options, light-class prices are chosen, so travellers are only allowed to carry one cabin luggage item with them. However, since this study also incorporates the possibility that respondents had check-in luggage on their last trip, an extra fee for luggage is considered. According to AirFrance (n.d.), the extra fee for upgrading a light ticket to a standard ticket including check-in luggage is, on average, **120 euros** for a round trip. This extra fee is later used to determine the range of attribute levels.

Table B.3: Air/rail and air/air round-trip ticket prices to Miami

Origin	Round-trip price air/rail (€)	Round-trip price air/air (€)
Champagne-Ardenne	1077	x
Le Mans	1116	x
Rennes	1139	1206
Nantes	1086	1236
Lyon	1037	1126
Avignon	1216	x
Aix-en-Provence	1287	x
Marseille	1036	1005
Perpignan	1186	x
Average	1131	1143

From **Table B.3**, it could be concluded that the prices between air/rail and air/air tickets do not substantially differ. On average, air/rail is a bit more expensive that air/air. However, since this is a snapshot in time, it is hard to assume that air/rail tickets are always more expensive than air/air tickets. For example, travelling to Miami from Lyon or Nantes is cheaper for air/rail compared to air/air. And for the destinations Champagne-Ardenne, Le Mans, Avignon, Aix-en-Provence and Perpignan, an air/air journey is not even possible.

Since there is no significant reason to believe that prices differ substantially, it is concluded that the price ranges should not differ per alternative. The price for air/rail tickets varies from 1036 euros to 1287 euros, depending on the origin. These prices are rounded to the nearest 50 because for the convenience of equidistance without getting odd price ranges to interpret for respondents. Also, taking into account the 120 euro extra fee for a standard ticket, the following price range with three attributes is derived: **1050 euro**, **1250 euro** and **1450 euro** for air/rail journeys. This varying on having the cheapest trip possible without check-in luggage to having the most expensive trip possible with check-in luggage. For air/air journeys, the attribute only has one level because the focus is about the trade-off for air/rail, not for air/air. Therefore, the middle price of this range is taken: **1250 euro**.

B.3. Delay in Case of Missed Transfer

For the air/air alternative, four short-haul and four long-haul destinations from Schiphol Airport are looked into: Paris, Frankfurt, Zurich and Brussels for short-haul and New York, Atlanta, Bangkok and Buenos Aires for long-haul. The amount of flights a day are based on one point in time: May 24th 2024. Only the direct flights from KLM and its SkyTeam partners are taken into account, because these airlines have agreements to exchange passengers in case of disruptions (Skyteam, n.d.). The flight for short- and long-haul are shown in **Table B.4** and **Table B.5** respectively. In these tables, the amount of flights and the time span in which the flights take place is presented. All data is retrieved from Skyscanner (n.d.).

Table B.4: Flight frequency for 4 short-haul destinations from KLM and SkyTeam partners from Schiphol Airport

Destinations	Flights per day	Time span
Brussels	4	06:45 - 21:30
Paris	8	08:05 - 17:55
Frankfurt	6	08:25 - 20:35
Zurich	6	07:05 - 21:00

Table B.5: Flight frequency for 4 long-haul destinations from KLM and SkyTeam partners from Schiphol Airport

Destinations	Flights per day	Time span
New York	8	12:10 - 17:05
Atlanta	8	07:55 - 17:05
Bangkok	1	17:05 - 17:05 (+1)
Buenos Aires	1	20:35 - 20:35 (+1)

For short-haul flights, it depends per destination what the frequency of flights a day is. From Amsterdam to Brussels, approximately every 4 hours there is a flight available, for Paris every hour, for Frankfurt every 2 hours and for Zurich approximately every 2.5 hours if uniformity between flights is assumed. However, sometimes two flights have the same departure time, but for simplicity, this is not taken into account. This analysis is just to get a feeling for the flight frequencies of flights to several destinations that are easy for respondents to assess.

For long-haul flights, a small remark can be made. To destinations such as Bangkok and Buenos Aires, there is only one flight a day according to (Skyscanner, n.d.). For flights to New York and Atlanta, there are much more flights a day. This mainly because KLM has an alliance with Delta, allowing more flights a day without having extra cost for flying a plane on its own. For New York, approximately every 37 minutes there is a flight and for Atlanta every hour.

This attribute is so specific on date, time and destination, that, according to the analysis, no substantial range of flight frequencies can be concluded.

This attribute is so specific regarding date, time, and destination that, according to the analysis, it's not possible to substantially say something about the average flight frequency of air/air journeys. However, in order for the respondent to grasp upon several frequency times, the following range is determined: **2 hours**, **4 hours**, **6 hours**.

One element in this analysis is not taken into account for this study. If passengers, in any case, miss their last transfer possibility, they have to wait until the first flight of the next day. Especially for destinations such as Bangkok and Buenos Aires this would be inconvenient, as the waiting time would be 24 hours. For the rest of the flights, the waiting time would be about 10 to 14 hours. Including these waiting times also includes less likely cases where the traveller needs an overnight stay. However, having an overnight hotel stay also affects mode choice, proven by Kantelaar (2019) and Weisshaar (2024). Therefore, these circumstances are excluded as this aspect is not within the scope of this study.

For the air/rail alternative, the assumption of Royal HaskoningDHV (2020) is held as a standard for determining the frequency. This study considers 18 operational hours with trains on an 1-hour frequency (16 times a day) or a 2-hour frequency (8 times a day). The attribute levels are: **1.5 hours**, **2.5 hours**, **3.5 hours**.

One element in this analysis is not taken into account for this study. If passengers, in any case, miss their last transfer possibility, they have to wait until the first flight of the next day. Especially for destinations such as Bangkok and Buenos Aires this would be inconvenient, as the waiting time would be 24 hours. For the rest of the flights, the waiting time would be about 10 to 14 hours. Including these waiting times also includes less likely cases where the traveller needs an overnight stay. However, having an overnight hotel stay also affects mode choice, proven by Kantelaar (2019) and Weisshaar (2024). Therefore, these circumstances are excluded as this aspect is not within the scope of this study.

C

Syntax for Ngene

This appendix contains the syntax used in Ngene that was used to generate the choice sets for both the rating experiments and the mode choice experiment. **Section C.1** shows the syntax for the service rating experiment, **Section C.2** for the comfort rating experiment and **Section C.3** for the mode choice experiment.

C.1. Syntax Ngene air/rail service rating experiment

```
? Design air/rail service rating experiment

design
;alts = alt1,alt2
;rows = 8
;orth = seq
;block = 2
;model :

U(alt1) =
Bluggage * luggage[0,1,2] +
Bticket * ticket[0,1,2] +
Binfo * info[0,1,2] +
Bservice * service[0,1,2]
$
```

C.2. Syntax Ngene air/rail comfort rating experiment

```
? Design air/rail comfort rating experiment

design
;alts = alt1,alt2
;rows = 18
;orth = seq
;block = 6
;model :

U(alt1) =
Bsecurity * security[0,1,2] +
Blounge * lounge[0,1,2] +
Bwifi * wifi[0,1,2] +
Bloyaltyprogram * loyaltyprogram[0,1]
$
```

C.3. Syntax Ngene air/rail mode choice experiment

```
? Design air/rail mode choice experiment

design
;alts = airrail, airair
;rows = 27
;orth = sim
;block = 3
;model:
U(airair) =
Blt * LT_airair[150,240,330]
+ Bdelay * DELAY_airair[120,240,360]
/
U(airrail) = ASC_airrail
+ Btt_trainleg * TT_trainleg[2,4,6]
+ Blt * LT_airrail[90,180,270]
+ Btc * TC_airrail[1050,1250,1450]
+ Bserv * SERV_airrail[1,3,5]
+ Bcomf * COMF_airrail[1,3,5]
+ Bdel * DELAY_airrail[90,150,210]
```

D

Survey Construction

This appendix shows the introductions, all the profiles and choice sets used in the survey for both the rating experiments and the mode choice experiment. **Section D.1** shows the introduction and all profiles for the service rating experiment. **Section D.2** shows the introduction and all profiles used for the comfort rating experiment and **Section D.3** shows the introduction and all the choice sets used for the mode choice experiment.

D.1. Service Rating Experiment

Stel u gaat een intercontinentale reis maken, met daarin een overstap binnen Europa met de trein. Voorbeelden van zo'n reis kunnen zijn:

- U reist van Amsterdam naar Bangkok. U gaat vanaf Amsterdam eerst met de **trein** naar Frankfurt. Vervolgens **vliegt** u vanaf Frankfurt naar Bangkok.
- U reist van New York naar Amsterdam. U **vliegt** van New York naar Parijs. Vervolgens gaat u vanaf Parijs met **de trein** naar Amsterdam.

Stel u maakt zo'n intercontinentale reis. U reist voor **(reisdoel)** en u reist met **(reisgezelschap).** U heeft hierbij **(wel/geen)** bagage.

U krijg hierna 4 verschillende situaties voorgelegd hoe de services van u reis eruit kan zien. In de volgende vragen is het aan u om te beoordelen hoe **aantrekkelijk** (heel onaantrekkelijk tot heel aantrekkelijk) u de services zou ervaren.

Hierbij verschillen de servicemogelijkheden op onderstaande kenmerken die elk twee opties bevatten:

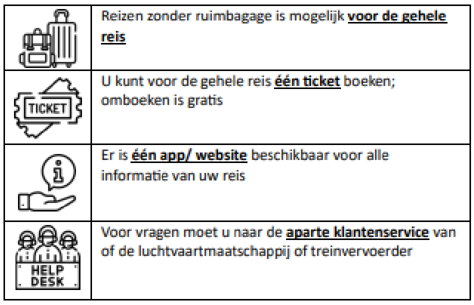
Kenmerk:	**Uitleg:**
Integrale bagage afhandeling	De mogelijkheid om de gehele reis **zonder** bagage te reizen. U geeft het af op een treinstation of luchthaven en haalt het op de plek van bestemming op. Als dit niet kan, dan moet u **alleen tijdens de treinrit** uw bagage zelf vervoeren. Voor uw vlucht kunt u de ruimbagage wel afgeven.
Integraal ticket	De mogelijkheid om **één ticket** te kunnen boeken, geldig voor zowel de treinrit als de vlucht. Als dit niet kan, moet u **losse tickets** boeken. Mist u de overstap? Dan moet u omboeken en daar extra voor betalen.
Integraal informatieplatform	Er is **één platform** *(bijvoorbeeld een app of website)* beschikbaar voor de informatievoorziening van uw reis. Alle updates worden hierop geplaatst. Is dit niet beschikbaar? Dan hebben de treinvervoerder en luchtvaartmaatschappij beide een **apart platform** voor hun informatievoorziening.
Integrale klantenservice	De aanwezigheid van **één klantenservice** voor vragen over uw reis. Is dit niet aanwezig? Dan moet u naar de **aparte klantenservice** van of de luchtvaartmaatschappij of de treinvervoerder voor uw specifieke vraag. *(Onder klantenservice wordt ook een helplijn verstaan die u kunt bellen).*

Figure D.1: Introduction service rating experiment

(a) Block 1: Profile 1

(b) Block 1: Profile 2

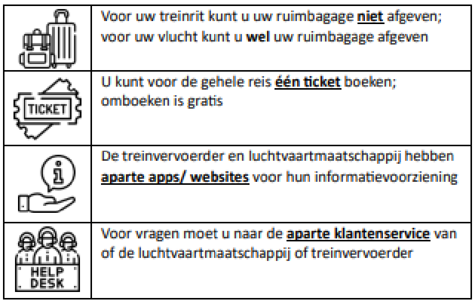
(c) Block 1: Profile 3



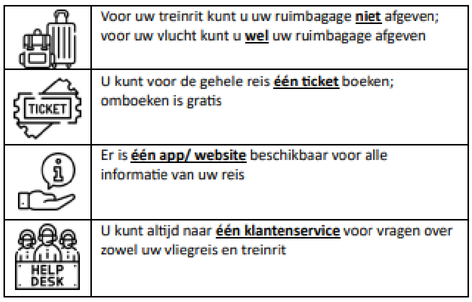
(d) Block 1: Profile 4

(e) Block 2: Profile 5

(f) Block 2: Profile 6



(g) Block 2: Profile 7



(h) Block 2: Profile 8

Figure D.2: All profiles service rating experiment

D.2. Comfort Rating Experiment

Stel u gaat een intercontinentale reis maken, met daarin een overstap binnen Europa met de trein. Voorbeelden van zo'n reis kunnen zijn:

- U reist van Amsterdam naar Bangkok. U gaat vanaf Amsterdam eerst met de **trein** naar Frankfurt. Vervolgens **vliegt** u vanaf Frankfurt naar Bangkok.
- U reist van New York naar Amsterdam. U **vliegt** van New York naar Parijs. Vervolgens gaat u vanaf Parijs met **de trein** naar Amsterdam.

Stel u maakt zo'n intercontinentale reis. U reist voor **(reisdoel)** en u reist met **(reisgezelschap).** U heeft hierbij **(wel/geen)** bagage.

U krijg hierna 4 verschillende situaties voorgelegd hoe de services van u reis eruit kan zien. In de volgende vragen is het aan u om te beoordelen hoe **comfortabel** (heel oncomfortabel tot heel comfortabel) u de combinatie van kenmerken zou ervaren.

Hierbij verschilt de mate van comfort van de reis op onderstaande kenmerken die elk twee opties bevatten:

Kenmerk:	**Uitleg:**
Security	De mogelijkheid om **met priority** door de security en paspoortcontrole te gaan via aparte wachtrijen. Is dit niet mogelijk? Dan moet u door de security en paspoortcontrole via de **reguliere wachtrijen**.
Beschikbaarheid lounge	De beschikbaarheid om als reiziger met een gecombineerde vliegtuig-trein ticket in een **lounge op het treinstation** te kunnen verblijven terwijl u wacht. Hier heeft u toegang tot hapjes, drankjes, kranten en oplaadpunten. Is dit er niet? Dan moet u wachten **op het perron**.
Wi-Fi	De beschikbaarheid van **gratis maar gelimiteerde Wi-Fi** waarmee u alleen kunt tekstberichten en e-mails sturen. Of u heeft **betaalde en ongelimiteerde Wi-Fi** waarmee u ook audio, series of films kunt streamen of online meetings kunt houden.
Loyaliteitsprogramma	De beschikbaarheid van **één uitwisselbaar** loyaliteitsprogramma. Punten verdiend tijdens het vliegen kunnen worden ingezet voor voordelen in de trein en andersom. Is dit er niet? Dan zijn er **aparte** loyaliteitsprogramma's en zijn de punten **niet** uitwisselbaar.

Figure D.3: Introduction comfort rating experiment

U kunt **met priority** door de security voor uw gehele reis
Voor uw reis is er **geen lounge beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **gratis maar gelimiteerd**; u kunt alleen tekstberichten of e-mails sturen
Er is **één loyaliteitsprogramma** beschikbaar waarbij de punten tussen trein en vliegtuig **wel uitwisselbaar** zijn

(a) Block 1: Profile 1

U kunt **met priority** door de security voor uw gehele reis
Voor uw reis is er **geen lounge beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **betaald maar ongelimiteerd**
Er zijn **aparte loyaliteitsprogramma's** en de punten zijn **niet uitwisselbaar** tussen vliegtuig en trein

(b) Block 1: Profile 2

U heeft **geen priority**; u moet door de controles via de reguliere wachtrijen
Voor uw reis is er **wel** een lounge **beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **gratis maar gelimiteerd**; u kunt alleen tekstberichten of e-mails sturen
Er zijn **aparte loyaliteitsprogramma's** en de punten zijn **niet uitwisselbaar** tussen vliegtuig en trein

(c) Block 1: Profile 3

U heeft **geen priority**; u moet door de controles via de reguliere wachtrijen
Voor uw reis is er **wel** een lounge **beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **betaald maar ongelimiteerd**
Er is **één loyaliteitsprogramma** beschikbaar waarbij de punten tussen trein en vliegtuig **wel uitwisselbaar** zijn

(d) Block 1: Profile 4

U heeft **geen priority**; u moet door de controles via de reguliere wachtrijen
Voor uw reis is er **geen lounge beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **gratis maar gelimiteerd**; u kunt alleen tekstberichten of e-mails sturen
Er zijn **aparte loyaliteitsprogramma's** en de punten zijn **niet uitwisselbaar** tussen vliegtuig en trein

(e) Block 2: Profile 5

U heeft **geen priority**; u moet door de controles via de reguliere wachtrijen
Voor uw reis is er **geen lounge beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **betaald maar ongelimiteerd**
Er is **één loyaliteitsprogramma** beschikbaar waarbij de punten tussen trein en vliegtuig **wel uitwisselbaar** zijn

(f) Block 2: Profile 6

U kunt **met priority** door de security voor uw gehele reis
Voor uw reis is er **wel** een lounge **beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **gratis maar gelimiteerd**; u kunt alleen tekstberichten of e-mails sturen
Er is **één loyaliteitsprogramma** beschikbaar waarbij de punten tussen trein en vliegtuig **wel uitwisselbaar** zijn

(g) Block 2: Profile 7

U kunt **met priority** door de security voor uw gehele reis
Voor uw reis is er **wel** een lounge **beschikbaar** op het vliegveld/treinstation
De Wi-Fi in de trein en vliegtuig is **betaald maar ongelimiteerd**
Er zijn **aparte loyaliteitsprogramma's** en de punten zijn **niet uitwisselbaar** tussen vliegtuig en trein

(h) Block 2: Profile 8

Figure D.4: All profiles comfort rating experiment

D.3. Mode Choice Experiment

Stel, u gaat een intercontinentale reis maken met daarin een overstap binnen Europa. Hieronder worden enkele voorbeelden gegeven:

Voorbeelden van intercontinentale reizen vanaf Amsterdam Schiphol naar een bestemming:

- Vanaf Amsterdam, via Parijs, naar Miami
- Vanaf Amsterdam, via Frankfurt, naar Singapore

Voorbeelden van intercontinentale reizen vanaf een bestemming terug naar Amsterdam Schiphol:

- Vanaf New York, via Parijs, naar Amsterdam
- Vanaf Tokio, via Brussel, naar Amsterdam

De vraag is nu of u voor de reis binnen Europa liever **de trein** of **het vliegtuig** zou nemen.

Stel, u reist voor **(reizigersmotief)** en u reist **(met gezelschap).** U heeft hierbij **(wel/geen)** bagage die moet worden ingecheckt.

We leggen u 9 keer een keuze voor, waarbij de kenmerken per vervoermiddel steeds verschilt. U hoeft alleen uw keuze te baseren op de volgende kenmerken:

Figure D.5: Introduction mode choice experiment (part 1)

Totale reistijd	De totale reistijd wordt opgesplitst in de volgende onderdelen: *Vluchttijd korte afstand:* Tijd in vliegtuig voor de korte afstand van de reis. *Vluchttijd lange afstand:* Tijd in vliegtuig voor de lange afstand van de reis. *Voertuigtijd korte afstand trein:* Tijd in trein voor de korte afstand van de reis. *Tijd op vliegveld/ treinstation:* De tijd die u heeft voor inchecken, bagage afgeven, security, wachten en boarding. Hierin zit ook de tijd voor het overstappen.
Totale reiskosten	De prijs per persoon voor de gehele reis.
Wachttijd in geval van gemiste overstap	De tijd die u moet wachten als u de overstap in uw reis mist.
Service niveau	Het niveau van de service die wordt aangeboden door de vervoerder. Voor de **trein + vliegtuig** reis is het uitgedrukt in de schaal die eerder is gebruikt in uw beoordeling van de verschillende service situaties. Het is dus uw eigen beoordeling van het service niveau. Voor de **vliegtuig + vliegtuig** reis wordt economy class service verondersteld. Dit houdt in: integrale bagageafhandeling, één integraal ticket, integrale informatie en klantenservice.
Comfort niveau	Het niveau van comfort die wordt aangeboden door de vervoerder. Voor de **trein + vliegtuig** reis is het uitgedrukt in de schaal die eerder is gebruikt in uw beoordeling van de verschillende comfort situaties. Het is dus uw eigen beoordeling van het comfort niveau. Voor de **vliegtuig + vliegtuig** reis wordt economy class comfort verondersteld. Dit houdt in: geen priority, geen lounge beschikbaar, gratis maar gelimiteerde WiFi en één loyaliteitsprogramma.

Figure D.6: Introduction mode choice experiment (part 2)

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**13:30**	**13:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	02:30	01:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	02:00	01:30

(a) Block 1: Choice set 1

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**13:30**	**19:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	02:30	03:00
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	06:00	02:30

(b) Block 1: Choice set 2

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**13:30**	**18:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	02:30	04:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	04:00	03:30

(c) Block 1: Choice set 3

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**16:30**	**17:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	05:30	03:00
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	06:00	01:30

(d) Block 1: Choice set 4

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**16:30**	**16:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	05:30	04:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	04:00	02:30

(e) Block 1: Choice set 5

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**16:30**	**17:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	05:30	01:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	02:00	03:30

(f) Block 1: Choice set 6

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**15:00**	**20:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	04:00	04:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	04:00	01:30

(g) Block 1: Choice set 7

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**15:00**	**15:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	04:00	01:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	02:00	02:30

(h) Block 1: Choice set 8

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**15:00**	**15:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	04:00	03:00
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	06:00	03:30

(i) Block 1: Choice set 9

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**15:00**	**20:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	04:00	04:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	02:00	01:30

(j) Block 2: Choice set 10

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**15:00**	**15:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	04:00	01:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	06:00	02:30

(k) Block 2: Choice set 11

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**15:00**	**15:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	04:00	03:00
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	04:00	03:30

(l) Block 2: Choice set 12

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**13:30**	**13:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	02:30	01:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	06:00	01:30

(m) Block 2: Choice set 13

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**13:30**	**19:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	02:30	03:00
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	04:00	02:30

(n) Block 2: Choice set 14

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**13:30**	**18:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	02:30	04:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	02:00	03:30

(o) Block 2: Choice set 15

Figure D.7: Choice sets 1-15 mode choice experiment

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**16:30**	**17:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	05:30	03:00
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	04:00	01:30

(a) Block 2: Choice set 16

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**16:30**	**16:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	05:30	04:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	02:00	02:30

(b) Block 2: Choice set 17

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**16:30**	**17:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	05:30	01:30
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	06:00	03:30

(c) Block 2: Choice set 18

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**16:30**	**17:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	05:30	03:00
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	02:00	01:30

(d) Block 3: Choice set 19

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**16:30**	**16:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	05:30	04:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	06:00	02:30

(e) Block 3: Choice set 20

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel comfortabel
Totale reistijd, waarvan:	**16:30**	**17:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	05:30	01:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	04:00	03:30

(f) Block 3: Choice set 21

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**15:00**	**20:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	04:00	04:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	06:00	01:30

(g) Block 3: Choice set 22

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**15:00**	**15:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	04:00	01:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	04:00	02:30

(h) Block 3: Choice set 23

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Heel oncomfortabel
Totale reistijd, waarvan:	**15:00**	**15:00**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	04:00	03:00
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	02:00	03:30

(i) Block 3: Choice set 24

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**13:30**	**13:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		02:00
Tijd op vliegveld/ treinstation:	02:30	01:30
Totale reiskosten	€1250	€1250
Wachttijd in geval van gemiste overstap	04:00	01:30

(j) Block 3: Choice set 25

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Heel onaantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	13:30	19:00
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		06:00
Tijd op vliegveld/ treinstation:	02:30	03:00
Totale reiskosten	€1250	€1450
Wachttijd in geval van gemiste overstap	02:00	02:30

(k) Block 3: Choice set 26

Kenmerken:	Vliegtuig + Vliegtuig	Trein + Vliegtuig
Service niveau *(Integrale bagageafhandeling, integraal ticket, integraal informatieplatform, integrale klantenservice)*	Economy class	Niet onaantrekkelijk, maar ook niet aantrekkelijk
Comfort niveau *(Security, beschikbaarheid lounge, Wi-Fi, loyaliteitsprogramma)*	Economy class	Niet oncomfortabel, maar ook niet comfortabel
Totale reistijd, waarvan:	**13:30**	**18:30**
Vluchttijd korte afstand:	01:00	
Vluchttijd lange afstand:	10:00	10:00
Voertuigtijd korte afstand trein:		04:00
Tijd op vliegveld/ treinstation:	02:30	04:30
Totale reiskosten	€1250	€1050
Wachttijd in geval van gemiste overstap	06:00	03:30

(l) Block 3: Choice set 27

Figure D.8: Choice sets 16-27 mode choice experiment

E

Data Coding

This appendix provides the coding for the service and comfort rating experiment (**Section E.1**), the mode choice experiment (**Section E.2**) and other variables included in the models (**Section E.3**).

E.1. Coding Rating Experiments

Table E.1: Coding of included main variables in service as comfort rating experiment

Attribute	Level	Variable & Coding
Main variables service rating experiment		
Luggage integration		Luggage
	Travelling without check-in baggage is possible for the entire journey	1
	For your train journey, you cannot drop off your big luggage; for your flight, however, you can drop off your big luggage	-1
Integrated ticket		Ticket
	You can book one ticket for the entire journey; rebooking is free of charge	1
	You must book separate tickets for your flight and train journey; rebooking brings extra costs	-1
Information integration		Info
	One app/website is available for all information on your journey	1
	The train operator and airline have separate apps/websites for their information provision	-1
Integrated customer service		Helpdesk
	You can always go to one customer service for questions about both your air and train journey	1
	For questions you have to go to the separate customer service of either the airline or train operator	-1
Main variables comfort rating experiment		
Security		Security
	You can go through security with priority for your entire journey	1
	You do not have priority; you must go through security via the regular queues	-1
Lounge availability		Lounge
	A lounge is available at the airport/railway station for your journey	1
	There is no lounge available at the airport/railway station for your journey	-1
Wi-Fi availability		PaidWifi
	Wi-Fi on trains and planes is paid but unlimited	1
	The Wi-Fi on the train and plane is free but limited; you can only send text messages or e-mails	-1
Loyalty program		Loyalty
	There is one loyalty program available where points are exchangeable between train and plane	1
	There are separate loyalty programmes and points are not exchangeable between plane and train	-1

E.2. Coding Mode Choice Experiment

Table E.2: Coding main attributes mode choice experiment

Attribute	Level	Variable
Main attributes		
Travel time train		tt_train_train_plane
	2	Real values
	4	
	6	
Waiting time train		wt_train_plane & wt_train_plane_Q
	1.5	Real values
	3	
	4.5	
Travel cost train	10.5	tc_train_plane
	10.5	Real values divided by 100
	12.5	
	14.5	
Waiting time plane		wt_plane_plane & wt_plane_plane_Q
	2.5	Real values
	4	
	5.5	
Delay in case of missed transfer train		del_train_plane
	1.5	Real values
	2.5	
	3.5	
Delay in case of missed transfer plane		del_plane_plane
	2	Real values
	4	
	6	
Service		serv_train_plane & serv_train_plane_Q
	Very unattractive	1
	Not unattractive but not attractive either	3
	Very attractive	5
Comfort		comf_train_plane & comf_train_plane_Q
	Very uncomfortable	1
	Not uncomfortable but not comfortable either	3
	Very comfortable	5

E.3. Coding Other Included Variables

Table E.3: Coding socio-demographics, travel experience and trip characteristics

Attribute	Level	Variable & Coding		
Socio-demographics				
Gender		Gender		
	Female	1		
	Male & Other	-1		
Education		Edu		
	HBO Bachelor or higher	1		
	Else	-1		
Occupation		Student	Working	Retired
	Student	1	0	0
	Working	0	1	0
	Retired	0	0	1
	Else	-1	-1	-1
Age		Age		
	Complete range	Real values		
Travel experience				
Travel experience train past 5 years		TrainExp		
	> 10 times in past 5 years	1		
	Else	-1		
Travel experience plane past 5 years		FlightExp		
	> 10 times in past 5 years	1		
	Else	-1		
Unpleasant train experience past 5 years		UnpleasantTrainExp		
	Once or more in past 5 years	1		
	Never	-1		
Unpleasant flight experience past 5 years		UnpleasantFlightExp		
	Once or more in past 5 years	1		
	Never	-1		
Trip characteristics				
Trip purpose		Purpose		
	Business	1		
	Leisure	-1		
Travel company		Alone	Colleagues	
	Alone	1	0	
	With colleagues	0	1	
	Else	-1	-1	
Check-in luggage		Check-in		
	Yes	1		
	No	-1		

F

Multinominal Logit Model: PandasBiogeme Syntax

This appendix provides coding that is used to estimate the MNL models with the package PandasBiogeme. The code is written in Jupyter Notebook 6.5.2, via Anaconda Navigator.

```
#Import packages
import pandas as pd
import biogeme.database as db
import biogeme.biogeme as bio
import biogeme.models as models
from biogeme.expressions import Variable
from biogeme import models
from biogeme.expressions import Beta, Variable

read_file = pd.read_excel('C:/Users/vanda/Documents/TU␣Delft/Thesis␣TU/NEW_CHECKED_DATASET_MODECHOICE_MODEL.xlsx', sheet_name = 'ModeChoiceData_MNL_Python')
read_file.to_csv('C:/Users/vanda/Documents/TU␣Delft/Thesis␣TU/Mode_choice_dataset_NEW.csv', index = None, header=True)
data = pd.read_csv('C:/Users/vanda/Documents/TU␣Delft/Thesis␣TU/Mode_choice_dataset_NEW.csv')
database = db.Database('Mode_choice_data', data)
globals().update(database.variables)

#observations
database.getSampleSize()

print(database)

#Define betas
##ASCs

ASC_train_plane = Beta('ASC_train_plane',0,None,None,0)
ASC_plane_plane = Beta('ASC_plane_plane',0,None,None,1) # not estimated

##betas for alternative V1: train + plane
Beta_tt_train_train_plane = Beta('Beta_tt_train_train_plane',0,None,None,0)

Beta_wt_train_plane = Beta('Beta_wt_train_plane',0,None,None,0)
Beta_wt_train_plane_Q = Beta('Beta_wt_train_plane_Q',0,None,None,0) #quadratic

Beta_tc_train_plane = Beta('Beta_tc_train_plane',0,None,None,0)

Beta_del_train_plane = Beta('Beta_del_train_plane',0,None,None,0)

Beta_serv_train_plane = Beta('Beta_service_train_plane',0,None,None,0)
Beta_serv_train_plane_Q = Beta('Beta_service_train_plane_Q',0,None,None,0) #quadratic

Beta_comf_train_plane = Beta('Beta_comfort_train_plane',0,None,None,0)
Beta_comf_train_plane_Q = Beta('Beta_comfort_train_plane_Q',0,None,None,0) #quadratic
```

```
## betas for alternative V2: plane + plane
Beta_wt_plane_plane = Beta('Beta_wt_plane_plane',0,None,None,0)

Beta_wt_plane_plane_Q = Beta('Beta_wt_plane_plane_Q',0,None,None,0) #quadratic

Beta_del_plane_plane = Beta('Beta_del_plane_plane',0,None,None,0)

#Utility functions
#MNL model.
V1 = (ASC_train_plane
+ Beta_tt_train_train_plane * tt_train_train_plane
+ Beta_wt_train_plane * wt_train_plane

+ Beta_del_train_plane * del_train_plane
+ Beta_tc_train_plane * tc_train_plane_scaled
+ Beta_serv_train_plane * serv_train_plane
+ Beta_comf_train_plane * comf_train_plane

+ Beta_comf_train_plane_Q * (comf_train_plane * comf_train_plane)
+ Beta_wt_train_plane_Q * (wt_train_plane * wt_train_plane)
+ Beta_serv_train_plane_Q * (serv_train_plane * serv_train_plane))

V2 = (ASC_plane_plane
+ Beta_wt_plane_plane * wt_plane_plane
+ Beta_del_plane_plane * del_plane_plane

+ Beta_wt_plane_plane_Q * (wt_plane_plane * wt_plane_plane))

#associate utility functions with numbering of alternatives
V = {1: V1, 0: V2} #set alternatives

#associate availability conditions with the alternatives
av = {1: 1, 0: 1} #set conditions

#contribution to the log likelihood function is logarithm of a logit model
logprob = models.loglogit(V,av,Choice)

#biogeme
biogeme = bio.BIOGEME(database,logprob)
biogeme.modelName = 'Air_Rail_MNL_model'

#estimation
results = biogeme.estimate()

#read results
pandasResults = results.getEstimatedParameters()
pandasResults

print(results)
```

G
Raw Data Latent Class Choice Model

This appendix shows the raw output data of Latent GOLD 6.0 for the latent class choice model. Based on these outputs, the customer segments are identified and the market shares are determined.

		LL	BIC(LL)	AIC(LL)	AIC3(LL)	Npar	L^2	df	p-value	VLMR	p-value	Class.Err.	Entropy R^2	$R^2(0)$	R^2
Model1	1-Class Choice	-2999,6534	6049,6541	6015,3067	6023,3067	8	5976,0795	533	1,5e-905			0,0000	1,0000	0,1465	0,1444
Model2	2-Class Choice	-2550,8699	5328,3029	5173,7398	5209,7398	36	5078,5126	505	2,7e-743	897,5669	0,0000	0,0263	0,8856	0,3792	0,3776
Model3	3-Class Choice	-2381,9758	5166,7305	4891,9516	4955,9516	64	4740,7244	477	2,9e-691	337,7881	0,0000	0,0566	0,8492	0,4949	0,4936
Model4	4-Class Choice	-2321,9604	5222,9154	4827,9208	4919,9208	92	4620,6936	449	7,6e-682	120,0308	0,0000	0,1018	0,8066	0,5661	0,5650
Model5	5-Class Choice	-2253,6494	5262,5091	4747,2988	4867,2988	120	4484,0716	421	2,7e-669	136,6220	0,0000	0,0891	0,8447	0,5954	0,5943
Model6	6-Class Choice	-2231,4639	5394,3539	4758,9278	4906,9278	148	4439,7006	393	4,2e-675			0,1157	0,8223	0,6072	0,6061

Figure G.1: Overview of estimated choice models for different classes

	Class1	Class2	Class3	Overall	Observed	StdResid	UniResid
Class Size	0,6031	0,2297	0,1672				
Set Average (n=4869)							
Choice 1	0,5302	0,1490	0,9785	0,5175	0,5266	0,8777	1,5968
2	0,4698	0,8510	0,0215	0,4825	0,4734	-0,9091	

Figure G.2: Mode choice for each class (1 = air/rail alternative)

	Class1	Class2	Class3
Maximum			
wt_plane_plane	1,6823	1,3190	0,0964
del_plane_plane	0,9152	1,4955	1,0078
tt_train_train_plane	0,9074	2,1897	1,3509
wt_train_plane	1,1388	0,9667	0,2640
tc_train_plane	1,0933	1,2447	1,3308
serv_train_plane	1,4210	1,5111	3,0106
comf_train_plane	1,5598	0,7858	2,1332
del_train_plane	0,1657	0,2438	2,2878
Relative			
wt_plane_plane	0,1894	0,1352	0,0084
del_plane_plane	0,1030	0,1533	0,0878
tt_train_train_plane	0,1021	0,2244	0,1177
wt_train_plane	0,1282	0,0991	0,0230
tc_train_plane	0,1231	0,1276	0,1159
serv_train_plane	0,1600	0,1549	0,2622
comf_train_plane	0,1756	0,0805	0,1858
del_train_plane	0,0187	0,0250	0,1993

Figure G.3: Maximum and relative importance of each mode choice attribute

	Class1	Class2	Class3
Class Size	0,6031	0,2297	0,1672
Attributes			
wt_plane_plane			
2,5	0,6184	0,5604	0,3495
4	0,2666	0,2898	0,3331
5,5	0,1150	0,1498	0,3174
Mean	3,2449	3,3842	3,9518
del_plane_plane			
2	0,4918	0,5891	0,5078
4	0,3112	0,2789	0,3068
6	0,1969	0,1320	0,1854
Mean	3,4102	3,0859	3,3551
tt_train_train_plane			
2	0,4905	0,6913	0,5656
4	0,3116	0,2313	0,2879
6	0,1979	0,0774	0,1465
Mean	3,4149	2,7722	3,1618
wt_train_plane			
1,5	0,5302	0,5007	0,2904
3	0,3000	0,3088	0,3314
4,5	0,1698	0,1905	0,3782
Mean	2,4594	2,5346	3,1316
tc_train_plane			
1050	0,5225	0,5480	0,1486
1250	0,3025	0,2941	0,2891
1450	0,1751	0,1579	0,5623
Mean	1180,5252	1171,9653	1332,7452
serv_train_plane			
1	0,1393	0,1305	0,0388
3	0,2836	0,2779	0,1746
5	0,5771	0,5916	0,7866
Mean	3,8755	3,9220	4,4958
comf_train_plane			
1	0,1260	0,2139	0,0810
3	0,2747	0,3168	0,2353
5	0,5993	0,4693	0,6837
Mean	3,9467	3,5108	4,2054
del_train_plane			
1,5	0,3061	0,3747	0,7042
2,5	0,3326	0,3317	0,2243
3,5	0,3613	0,2936	0,0715
Mean	2,5552	2,4189	1,8673

Figure G.4: Class profiles (part 1)

Covariates			
Student			
-1	0,0420	0,0667	0,0444
0	0,8192	0,9038	0,9335
1	0,1388	0,0296	0,0221
Working			
-1	0,0420	0,0667	0,0444
0	0,2621	0,1232	0,4000
1	0,6959	0,8102	0,5556
Retired			
-1	0,0420	0,0667	0,0444
0	0,8347	0,8398	0,5777
1	0,1233	0,0936	0,3779
Gender			
-1	0,4875	0,5410	0,4280
1	0,5125	0,4590	0,5720
Age			
19 - 30	0,2600	0,1289	0,1006
31 - 41	0,2071	0,2139	0,0977
42 - 53	0,1954	0,2891	0,1251
54 - 63	0,1819	0,1918	0,2303
64 - 74	0,1556	0,1763	0,4463
Mean	44,4416	47,7262	56,8140
Edu			
-1	0,2748	0,2245	0,2369
1	0,7252	0,7755	0,7631
TrainExp			
-1	0,8491	0,8812	0,8452
1	0,1509	0,1188	0,1548
FlightExp			
-1	0,8141	0,6816	0,9695
1	0,1859	0,3184	0,0305
Purpose			
-1	0,6961	0,7090	0,7604
1	0,3039	0,2910	0,2396
Checkin			
-1	0,4401	0,4233	0,4399
1	0,5599	0,5767	0,5601
Alone			
-1	0,4985	0,4431	0,5228
0	0,1445	0,1526	0,0760
1	0,3570	0,4043	0,4012
Collegues			

Figure G.5: Class profiles (part 2)

-1	0,4985	0,4431	0,5228
0	0,3570	0,4043	0,4012
1	0,1445	0,1526	0,0760
UnpleasantTrainExp			
-1	0,2272	0,3153	0,3284
1	0,7728	0,6847	0,6716
UnpleasantFlightExp			
-1	0,5899	0,5283	0,6067
1	0,4101	0,4717	0,3933

Figure G.6: Class profiles (part 3)

Model for Choices								
	Class1	Class2	Class3	Overall				
R^2	0,2883	0,1745	0,0527	0,4936				
$R^2(0)$	0,2931	0,5731	0,9249	0,4949				
Attributes	Class1	Class2	Class3	Wald	p-value	Wald(=)	p-value	
wt_plane_plane								
	-0,5608	-0,4397	-0,0321	234,9811	1,2e-50	2,1288	0,34	
del_plane_plane								
	-0,2288	-0,3739	-0,2520	91,7545	9,2e-20	2,5289	0,28	
tt_train_train_plane								
	-0,2268	-0,5474	-0,3377	99,9894	1,6e-21	11,2012	0,0037	
wt_train_plane								
	-0,3796	-0,3222	0,0880	113,5474	1,9e-24	0,8694	0,65	
tc_train_plane								
	-0,0027	-0,0031	0,0033	240,4917	7,4e-52	10,8452	0,0044	
serv_train_plane								
	0,3553	0,3778	0,7526	195,9781	3,1e-42	1,2490	0,54	
comf_train_plane								
	0,3899	0,1965	0,5333	187,8636	1,8e-40	4,3725	0,11	
del_train_plane								
	0,0829	-0,1219	-1,1439	6,0225	0,11	5,2929	0,071	
Model for Classes								
Intercept	Class1	Class2	Class3	Wald	p-value			
	1,8389	-0,2616	-1,5772	29,0244	5,0e-7			
Covariates	Class1	Class2	Class3	Wald	p-value			
Student								
-1	-0,9556	0,5572	0,3984	15,5467	0,0037			
0	0,2477	0,3269	-0,5747					
1	0,7078	-0,8842	0,1763					
Working								
-1	0,5815	-0,1766	-0,4049	5,7547	0,22			
0	-0,0968	0,2390	-0,1423					
1	-0,4848	-0,0624	0,5472					
Retired								
-1	0,1720	0,4029	-0,5749	0,0000	1,00			
0	0,0544	0,3397	-0,3941					
1	-0,2264	-0,7427	0,9691					
Gender								
-1	-0,0360	0,1733	-0,1373	3,8664	0,14			

Figure G.7: Model for choices (part 1)

1	0,0360	-0,1733	0,1373					
Age								
	-0,0158	-0,0016	0,0174	6,5998	0,037			
Edu								
-1	0,0657	-0,0573	-0,0085	0,6175	0,73			
1	-0,0657	0,0573	0,0085					
TrainExp								
-1	0,0226	0,1773	-0,1998	2,4154	0,30			
1	-0,0226	-0,1773	0,1998					
FlightExp								
-1	-0,1367	-0,6312	0,7679	20,6161	3,3e-5			
1	0,1367	0,6312	-0,7679					
Purpose								
-1	-0,1803	0,3758	-0,1955	5,8944	0,052			
1	0,1803	-0,3758	0,1955					
Checkin								
-1	-0,0489	-0,0307	0,0796	0,8372	0,66			
1	0,0489	0,0307	-0,0796					
Alone								
-1	-0,0790	-0,3976	0,4766	22,2525	0,00018			
0	0,5088	0,1139	-0,6227					
1	-0,4298	0,2838	0,1460					
Collegues								
-1	0,3049	0,0408	-0,3458	0,0000	1,00			
0	0,2765	-0,2858	0,0092					
1	-0,5815	0,2449	0,3365					
UnpleasantTrainExp								
-1	-0,0995	0,0997	-0,0002	1,8180	0,40			
1	0,0995	-0,0997	0,0002					
UnpleasantFlightExp								
-1	0,0248	-0,0166	-0,0082	0,1229	0,94			
1	-0,0248	0,0166	0,0082					

Figure G.8: Model for choices (part 2)