Unravelling night train travel behaviour

A stated preference survey into the influence of operational and personal factors

T.C. Weisshaar

TIL M.Sc. Thesis

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A stated preference survey into the influence of operational and personal factors

by

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Preface

After exactly six and a half years of studying, with a break of one year to work, this thesis marks the end of my life's - so far - most shaping time. I want to thank wholeheartedly my committee members for guiding me on my journey over the last six months. Dear Bert, thanks for helping me shape my research focus and guiding me towards a (hopefully) coherent story line. Eric, thank you very much for helping me with the survey construction. When modelling, you reminded me that sometimes including fewer variables is more meaningful. By accidentally referring all respondents with their complaints to you, I hopefully have not let your mailbox explode. Niels, thank you very much for providing a fresh and different viewpoint to this thesis, always emphasising the practical implications and asking: What can I/operators/policymakers now do with it?

Barth, thank you very much for always supporting me within the committee. It relieves me to know that I always had a supporter in you! Thanks furthermore for the opportunity to pursue an internship at RoyalHaskoningDHV and to be my personal priority setter. Without you, it would have been way more different. I immensely enjoyed changing my working location and seeing something of the Netherlands - Utrecht, Den Haag or Amersfoort. Thanks for the freedom you provided me to work wherever and whenever I want! Thanks to all other coworkers at RHDHV and NACO for welcoming me, even though I have not always found the right words, to dive into Dutch working culture and to enjoy drinks after work!

I want to thank Jet for distributing the survey via the NS panel. Without you, I would have struggled ten times more for viable results. Thanks also to Valerie for accepting such a project, especially from the background of challenging privacy issues. I hope both of you receive at least some insights from this study! For the construction of the survey, I especially thank Klaas from MWM2. You helped me a lot with reformulating and simplifying the survey questions; for me as a non-native, formulating the survey was quite challenging!

Furthermore, I would like to thank all my fellow students in the thesis room. For their companionship, some random games in between and movie nights. You made these last six months very enjoyable! Thanks also to my roommates and friends, who I could see less over the previous months. I hope I can see you more frequently over the next few months.

Lastly, I thank my family and girlfriend for their endless support. Over the last months, when I was sometimes quite stressed, you always supported me. Thanks also for believing in me and encouraging me to pursue my goals and not retreat in difficult times. Thanks, Mom and Dad, for your financial support over the last few years. Without you, I would not be there where I am now.

Dear reader, I hope you enjoy reading this thesis. May it provide you with some insights, and may it be useful to you.

T.C. Weisshaar
Delft, February 2024

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Acronyms

BIC Bayesian information criterion

GDS global distribution system

GHG green house gases

HII hierarchical information integration

HS high speed

HSR high speed rail

LCCM latent class choice model

LL log likelihood

ML mixed logit

MNL multinomial logit

NS Nederlandse Spoorwegen

RHDHV Royal HaskoningDHV

RUM random utility maximisation

SP stated preference

WTP willingness to pay

Summary

Introduction

In recent years, night trains have enjoyed a comeback and rising popularity, mainly driven by the general public's higher importance on the environment (Danson, 2023). They become a viable option for many environmentally minded people by emitting significantly less green house gases (GHG) emissions than flying (Curtale et al., 2023). Night trains have further social benefits by improving land use efficiency and the accessibility of regions. To harness environmental benefits through an increased usage of night trains, insights are needed into people's preferences. The main research question is therefor the following:

Main research question: How do operational and personal factors influence Dutch travellers' preferences for night train services headed to European very-long-distance destinations?

Methodology

Several experiments have been used. Since conceptualising booking convenience is new and has not been done before, more attention has been attributed towards this factor. The booking experience experiment delivers insight into the booking behaviour of Dutch citizens, whereas, in the booking convenience rating experiment, factors that influence booking convenience will be determined. Lastly, a convenient booking scenario will be one factor in the mode choice experiment.

To decipher factors influencing mode choice, it was chosen for a stated preference survey. For the survey construction and distribution, the Nederlandse Spoorwegen (NS) panel, where 85,000 respondents were willing to answer NS-related questions, was chosen. For the analysis of the data, various methods have been used. The questions regarding booking experience were chosen to be answered by descriptive questions. The booking convenience was analysed through linear regression due to a simple integration into the discrete choice models used for the mode choice experiment. To detect average effects, it was chosen to analyse the data via an multinomial logit (MNL) model and an Panel mixed logit (ML) model. Afterwards, deeper insights into heterogeneity are possible through an latent class choice model (LCCM), which was used to reveal latent classes with specific demand patterns. Lastly, scenarios were created and market shares were estimated for night trains under various circumstances. For this, the LCCM was used.

Specification

The experiment is scoped to distances of 1400 to 1600 km, and people are expected for an outbound trip to Barcelona departing from the Netherlands. Furthermore, people are expected to consider the price of an additional hotel night when choosing the plane and the HS train option when travelling. Two scenarios have been chosen. Respondents currently working and occasionally travelling internationally for work purposes were expected to travel to Barcelona for a business trip. Other respondents were assigned to travel for leisure purposes.

The total travel time for the night train varies from 12 to 18 hours and is fixed for the plane option at 5 hours and for the HS option at 12 hours. The HS train option was defined as a reference alternative. Travel costs are expected to vary significantly for both the night train and the plane option. For the night train, costs from 50 EUR to 290 EUR are expected, whereas the flight expenses are 150, 250 and 350 EUR. In each attribute level, a hotel stay with a price of 100 EUR is assumed to be considered. For the night train, new rolling stock is assumed, with comfort classes thus being seating arrangement, a couchette, a mini-cabin and a sleeper. Economy class is assumed for the flight, and second class is assumed for the HS train. Access distance was conceptualised as the distance of respondents towards the closest boarding station, both for the plane and train alternative.

The booking experience is conceptualised through questions regarding the usual booking sites, pain points in booking international rail connections in Europe and whether they book multiple tickets to reach their destination. The factors mentioned in the conceptual model have been used for the booking convenience scenarios. For realistic booking horizons, one month and six months have been assumed. Regarding the average booking time, a study from Preslmayr et al. (2021) was taken as input, delivering the attribute values 5 and 20 minutes. In the mode choice experiment, it was chosen to use the reliability attribute levels 15, 30 and 45 minutes. Train travel experience was measured through three indicator variables: The usual train travel, experience with international train travel and experience with night train travel. The intention to use environmentally friendly modes is determined by finding it essential to use environmentally friendly modes, to be influenced by people important to the respondents, and to use environmentally friendly modes even under inconvenient circumstances.

After having defined the survey, choice sets have been defined by ngene. It was chosen for an orthogonal fractional factorial design, where 111 responses are necessary, considering each respondent answering nine choice situations.

Out of the invited 5,461, 1,062 respondents answered the survey, resulting in a response rate 19.5%. 1,031 answers have been used for the analysis due to a programming error. Regarding age, the survey respondents closely align with the Dutch population. However, there are slightly more males in the data set, and according to Heufke Kantelaar et al. (2022), the panel is prone to be skewed to higher educated respondents with higher salaries. This could not be validated in this survey due to privacy restrictions. On average, the HS train is selected in 23.2% of cases, while the night train is the most favoured option at 42.7%, and the plane follows closely at 34.1%. This distribution suggests that each mode represents a viable alternative.

Results

Firstly, insights are provided into the Dutch traveller’s habits and preferences regarding booking international rail connections. In the second step, the importance of booking is compared with other operational factors. Then, insights into population heterogeneity are provided and market shares are predicted under various scenarios.

Dutch citizens book their international rail tickets mainly on NS International. Predominantly, train tickets for one trip are booked on one site, while booking sites are chosen based on habit and user-friendliness. The most significant issues in booking international rail tickets are comparing travel options, ticket availability, and finding a fitting website. A convenient booking situation mainly involves booking one ticket for the whole journey and easily comparing various train and flight connections through a search engine. Respondents are willing to spend up to 31 EUR to improve their booking experience. However, while people consider booking convenience a factor for long-distance mode choice, the effect is relatively small. Accommodation, for example, is four times more important in decision-making.

Flight prices emerged as the most crucial determinant for choosing night trains. Total travel costs of the night train and accommodation are equally important. The population is highly willing to pay for accommodation upgrades; for example, people are willing to spend 144 EUR on average to upgrade from a traditional couchette to a mini cabin. This shows the high attractiveness of the new accommodation category. The total travel time for a night train does play a less critical role in choosing this mode of transportation. Around 13 hours is the optimal time for people on a night train. However, longer travel times are not considered a knock-out factor. Almost as crucial as travel time is booking convenience. Delay and the access distance do not affect the decision process. This indicates that the night train can capture demand from large areas around departure stations and that no buffers are needed in the timetable. People’s joint preferences vary significantly, with some disliking and others liking travelling by plane. Similar effects emerge for high speed rail (HSR) services. However, preference heterogeneity for night trains is present to a lesser extent. This high observed heterogeneity among respondents indicates that when modelling preferences for night trains, it is insufficient to rely only on average effects.

This study revealed four demand segments with various preferences. 13% of respondents can be considered environmentally conscious comfort lovers, who think when choosing for modes only the accommodation, booking convenience and the distance towards railway stations. Whereas booking convenience only influences decisions to a limited extent, accommodation has the most considerable influence. Members of this class find it essential to use environmentally friendly modes of transportation and also use them under inconvenient circumstances. They tend to be older and are less likely to travel with their partner.

The second revealed class are experienced night train travellers, who make up 29% of the population. The most crucial variable for their decision to choose the night train is flight costs. Furthermore, the accommodation and the costs of the night train are relevant decision variables. Lastly, booking convenience plays a role for this group, however, to a lesser extent. Most likely in this class are people who have travelled by night train in the last two years and travellers with their partners.

The most significant demand segment is cost-sensitive travellers, who make up 37% of the population. For them, ticket prices are the most critical determinant of mode choice, and accommodation is 20% less important. Most likely to be in this group are respondents who are less environmentally concerned and younger people.

The last observed group are flight lovers, who make up 20% of the population. They have a high initial preference for the mode aeroplane, and their most crucial operational factor to decide on is the accommodation level. The most determining personal variable is the intention to use environmental modes. Members of this class are least likely to use environmentally friendly modes under inconvenient circumstances and do not find it essential to use them.

None of the groups considers travel times or delays of night trains to be decisive variables in their choice of transportation modes. A lot of personal variables turned out not to influence class membership. Firstly, leisure and business travellers are likely to be members of each latent class, highlighting that the scenario does not influence preferences regarding night trains. Further variables that do not affect class membership are usual train frequency and experience with international train travel. Lastly, also socio-demographics vastly do not alter preferences regarding transportation modes. Gender, as well as work status, do not play a role, whereas age does.

In the base case scenario, where a mini cabin as an accommodation category is offered for 210 EUR, 40% of the respondents would choose the night train. Remarkable is the heterogeneity: Whereas 92% of flight lovers decide to fly and 80% of the environmentally-conscious comfort lovers choose the HSR, experienced night train travellers choose the night train (89%) predominantly. In the low-cost scenario, where the night train offers a couchette accommodation for 130 EUR, only a market share of 20% can be reached. In each class, the night train loses market share, with the most potent effect on experienced night train travellers, where only 60% still opt for the night train. For a luxury scenario, however, where a sleeper for 290 EUR is assumed, the night train can reach a market share of 61%. Heterogeneity among the population persists, whereas classes 1 and 2 do not fly at all; 70% of class 4 members choose to fly. The night train can capture slightly less market share if a high GHG tax is introduced compared to when night trains are subsidised (61% vs. 71%). However, this results at the expense of HSR services. Applying the base case scenario on the stretch Amsterdam - Barcelona, 240 passengers would choose to use night train services daily, with customers being predominantly experienced night train travellers (154 passengers) and 64 cost-sensitive travellers. Having answered all previous sub-questions, it is possible to answer the following main research question:

Total travel costs and accommodation are the most critical operational factors for choosing night train services on European long-distance destinations. Booking convenience and access distance are only relevant for particular parts of the population, and their importance is significantly lower. High heterogeneity is present among the population and must be considered when describing night train demand. Demand patterns vary mainly depending on peoples' intention to use environmentally friendly modes. Other factors that separate travellers are the travel group and age, however, to a lesser extent. Travel times and unreliability do not influence travel demand when opting for night trains on very long European distances. This study revealed that most customers of a hypothetical night train service are experienced night train travellers and cost-sensitive travellers.

Discussion and Conclusion

The results generally provide a representative insight into the demand for night trains. Whereas some previous studies like Heufke Kantelaar et al. (2022) estimate higher night train market shares, others like Curtale et al. (2023) estimated lower market shares. Regarding the found heterogeneity, the results of this study vary significantly from previous studies that have investigated latent classes for night train demand like Moors (2023) and Heufke Kantelaar et al. (2022). The intention to use environmentally friendly modes turned out to be the most important determinant for class membership, supporting the findings of Curtale et al. (2023). Out of the operational factors, ticket prices for both night trains and flights along with accommodation turned out to be the most important determinants, confirming the findings of Heufke Kantelaar et al. (2022). Also booking convenience turned out significant, however, this factor being way less influential than the ones previously mentioned.

Despite revealing novel insights, this thesis also contains some limitations. Firstly, it was assumed that people compare night trains with flights and a hotel stay, which incurs costs of 100 EUR. This might not be realistic and overestimates night train market shares. Furthermore, the NS panel has been used to acquire data, which is known to contain many train affine respondents, again potentially increasing the resulting market shares from night trains. Lastly, estimating market shares with stated preference surveys is challenging. The results are heavily dependent on the assumptions made in the survey.

The results of this study can be generalised to Western Europe, especially to Spain, France Italy and Benelux, where a dense HSR network is available. In other regions, HSR services might not be a relevant competitor for night trains for such long distances, there might be the potential thus slightly higher. Furthermore, results might only be valid for 10 years, since social norms, price environments and technology change.

To conclude, being able to book one ticket and to compare various train and plane connections contributes to a convenient booking scenario. Dutch citizens book mainly on NS International their train tickets and do it because of habit and the user-friendliness of the site. Main factors to consider when choosing for the night train are prices of the night train itself, the competing plane and the accommodation category that is offered. High heterogeneity prevails among respondents, expressed through four distinctive latent classes. Lastly, night trains are able to capture in the base case scenario 40% market share. When offering couchette accommodation, this value decreases to 20%. If night trains are subsidised, the share raises up to 72%.

For further research, it is recommended to explore other research methods in order to capture booking convenience differently. Furthermore, other attributes and attribute values could be explored, especially long travel times and psychological variables. Lastly, it would be interesting to explore the impact of widespread hindrances for night train travel like track capacity issues.

For night train operators, this thesis implies that in order to improve their market position, the focus should lay on cost efficiency while offering high accommodation levels. Other factors are less important. However, if booking convenience should be improved, focus should be laid on collaborating with other railway operators. This enables customers to book one ticket and facilitates comparing travel options between operators. Policy makers are able to alter market shares significantly for night trains. Therefore, a significant shift towards harnessing the societal benefits is possible. However, the question remains if the benefits outweigh the costs.

1
Introduction

International night or sleeper trains with dedicated sleeping accommodations have been part of the European transportation mix for over a century. In their prime period between the two world wars, they were typical for mostly the upper class on very long distances, where the company Compagnie Internationale des Wagon-Lits operated multiple routes across Europe (Meillassoux, 2023). After the Second World War, technological innovations such as the car and the aeroplane led to night train services losing market shares on shorter and longer distances. From the 1980s on, gradually, a lot of services were put out of operation, mainly because of high operating costs and changing social norms, with passengers demanding more privacy (Directorate General for Internal Policies et al., 2017). To add to that, the aviation industry was able to cut costs, leading to low-cost airlines.

However, in recent years, night trains have enjoyed a renaissance, with new services being introduced each year and many services planned for the upcoming years (Hughes, 2023). This development is mainly driven by a higher importance of the environment to the general public (Danson, 2023. Additionally, pressure has risen over the last years for governments to cut emissions of GHG. In the Paris Agreement, 196 countries pledged not to exceed temperatures higher than 2 degrees above pre-industrial level (United Nations, 2015). The European Union, as one of the main polluters, consequently set up the programme Fit for 55, which incorporates lowering net GHG emissions by 55% till 2030 compared to 1990 and having net zero emissions by 2050 (European Comission, 2021).

Night trains emit significantly lower GHG emissions per passenger than flights. They could lead in an optimistic scenario to a 9% reduction in GHG emissions in the long-distance transportation sector in Europe, as Curtale et al. (2023) pointed out. Besides this, night trains benefit society in multiple other ways. For users, night trains are pleasant and, for some, even adventurous. The main advantage from a user's perspective is that the travel time can be used for sleeping. The lower value of time lets passengers accept higher travel times for reaching their destination, which increases the catchment area of night trains and, thus, the accessibility of regions. For society, benefits emerge mainly through increased land use efficiency. In general, new night train connections do not rely on constructing dedicated new tracks, which destroys natural habitats and human settlements (Danson, 2023). Furthermore, the accessibility of regions can be improved through additional travel options.

By accommodating passenger needs in policy and the operational design of night trains, the attractiveness of night trains increases. Furthermore, some connections might be profitable that would not have been if people's preferences had not been taken into account (Danson, 2023). By incorporating the preferences of night train users, the societal benefits associated with this mode can be harnessed to a greater extent. Therefore, this thesis focuses on deciphering people's preferences regarding night trains destined for an improved policy- and operational design of night trains.

1.1. Research gaps

Three previous studies have investigated respondents' preferences for night trains. Heufke Kantelaar et al. (2022) pioneered by estimating the willingness to use night trains instead of flights for Dutch travellers. He focused on comfort, a variable highly relevant for night train travellers but less so for other modes. Curtale et al., 2023 also followed suit by estimating the flight replacement potential for

Swedish travellers, varying the starting location and travel distances. Furthermore, attitudes have been included to increase the realism. Lastly, Moors (2023) conducted a stated choice experiment of Belgian customers, revealing various classes with different preferences regarding night train interior design.

However, these previous studies have limitations when identifying factors influencing demand for night trains. Firstly, they do not cover all available alternatives. Heufke Kantelaar et al. (2022) and Curtale et al. (2023) aim to estimate the replacement potential of night trains towards short-haul flights. They do not include other relevant alternatives like private cars, buses and high-speed trains, which are competitors on long distances, as Van Goeverden (2009) pointed out. Moors (2023) even considers only night train to determine preferences for this mode. In the three available papers estimating night train demand, various factors have been included, such as comfort, price, travel time (Heufke Kantelaar et al., 2022), the fear of flying, pro-environmental attitudes (Curtale et al., 2023) and various contexts (Moors, 2023) like travel purpose and group size.

Despite the broad variety of factors covered in previous analyses, some potential influencing factors are missing in earlier analyses. For 43.2% of the respondents, booking convenience was important for long-distance mode choice in a study conducted by Curtale et al. (2023). Currently, booking international trains is tedious in Europe (Donners, 2016 and Garrod et al., 2021). Preslmayr et al. (2021) conducted a study in 2021 where respondents had to book international train connections. Whereas just 3% of all flight bookings were not completed, this was the case for a third of all train tickets. Curtale et al. (2023) acknowledges this by including easy booking as a scenario but fails to analyse a tedious booking scenario.

Similarly, night trains in Europe are unreliable (Ehrbar, 2023), significantly hampers customer satisfaction and impacts the company brand. For over a quarter of customers, unreliability is essential when choosing modes on long distances (Curtale et al., 2023). Lastly, the influence of experience on mode choice for night trains was not studied before. Also, it might be attractive to research night train demand for different attribute levels. Longer running times of night trains towards more remote destinations would utilise the rolling stock more efficiently and increase the catchment area. A study from DB International GmbH (2013) confirms the potential of night trains on very long distances under reduced track access charges.

All previously mentioned factors missing in the last analysis are described in this study as operational factors (in technical terms attributes), which can be influenced by operators of night trains and policymakers. However, some insights into personal factors (in technical terms covariates), which describe heterogeneity among respondents, are missing in previous studies. Firstly, nesting effects between night trains and other modes are neglected in earlier research. Nesting effects describe the joint preferences of respondents for a specific group of modes. Here, it is not known from previous research if night trains are more similar to HSR services or flights. Due to the more similar departure and arrival times, people might consider night trains more comparable to a flight instead of a day-long HSR service. Secondly, heterogeneity regarding attribute preferences is missing in previous analyses. Whereas Moors (2023) divides the population into latent classes, he refers only to night train users. Heufke Kantelaar et al. (2022) also divides the population into latent classes, describing only their composition and not varying attribute preferences. However, insights are needed into which type of passengers are more likely to use night trains instead of other modes and how the preferences for operational factors vary among respondents. The three previous studies have studied various factors determining night train demand. However, missing relevant alternatives, attributes, and attribute levels and neglecting heterogeneity makes it difficult to precisely estimate the importance of factors and night train market demand.

1.2. Research questions

The previously mentioned research gaps have been addressed by answering the following main research question:

How do operational and personal factors influence Dutch travellers' preferences for night train services headed to European very-long-distance destinations?

This thesis assumes very long distances at around 1500km (driving distance), as pointed out in chapter 2. To answer the main research question, various sub-research questions are used. Firstly,

Table 1.1: Research sub-questions and applied methods

How do operational and personal factors influence Dutch travellers' preferences for night train services headed to European very-long-distance destinations?

Sub-question	**Method**
What comprises a convenient booking, and to what extent does it influence night train demand on average?	Descriptive analysis, Regression, ML
How do other operational factors influence travellers' night train preferences on average?	ML
Which night train demand segments can be identified, how do personal factors influence them, and what are their preferences regarding operational factors?	LCCM
What are the predicted market shares of night train services for various demand segments in different scenarios?	LCCM, Scenario analysis

convenient booking situations are conceptualised through a rating experiment. Then, the average importance of choosing the mode night train of several operational factors like booking convenience, long travel times, costs, comfort, reliability and access is revealed. Thirdly, the market environment of night trains is revealed by detecting relevant competitors. Fourthly, further insights into heterogeneity are provided. Several demand segments are revealed through latent classes. Personal factors describe these and vary in their preferences regarding operational factors. Lastly, market segments explore and differentiate night train market shares for various scenarios. An overview of the used sub-research questions and the used methods is provided in Table 1.1.

1.3. Methods

The sub-questions are answered through various methods as visualised in Table 1.1, where only the analysis methods are presented. Firstly, a literature review is conducted to derive a conceptual model. This model showcases a relation between factors relevant to the decision process. In the second step, a survey is used to acquire data. Since booking convenience is complex to conceptualise, it was chosen to unravel its factors twofold. Firstly, respondents were asked directly about their booking experience, and secondly, it was selected to conduct a booking convenience rating experiment. A mode choice experiment has been performed to answer the other research questions. Respondents were asked various questions in the booking experience experiment. A stated preference (SP) survey was chosen to obtain data for the booking convenience rating and mode choice experiments.

Descriptive analysis and regression have been used to answer the first part of research question 1. The methods model the data generated from the booking experience experiment and the booking convenience rating experiment, respectively. MNL, ML, LCCM, and scenario analysis have been used to analyse the mode choice experiment, all having different purposes. Firstly, average impacts of factors are determined with the MNL and ML model, whereas only the ML model has been used due to a better model fit. This is because the ML model is able to incorporate heterogeneity regarding mode preferences. Incorporating this heterogeneity greatly improves the realism and thus the reliability of the estimates. An LCCM divides the population into segments with their preferences, answering subquestion 3. Lastly, scenarios are created, and an estimated LCCM is applied to determine market shares for various segments.

1.4. Relevance

This thesis is relevant to night train operators, policymakers, the commissioner of this thesis, the scientific community and society. Firstly, international and night train operators can harness the importance of convenient booking factors to optimise their booking systems. Secondly, by analysing the significance of long travel times and access distance towards night train services, general assumptions about the capture area of night trains are possible. By revealing respondents' preferences regarding accommodation categories, the rolling stock design of night trains can be improved. Insights into the importance of delays are essential for timetabling night train services. Furthermore, the main competitors of night train services are revealed, which enables night train operators to delimit the market better. Moreover, heterogeneity among respondents is revealed, enabling night train operators to target specific customer groups.

With the results of this thesis, policymakers can assess policies regarding changing the price environment of the long-distance transportation sector. Subsidies for night trains are possible to determine, as well as additional taxes for flights. Furthermore, policymakers might access the distribution of accessibility benefits through the results of this thesis. Royal HaskoningDHV (RHDHV), the commissioner of this thesis, acclaims itself as a leading consultancy in sustainable long-distance mobility. This thesis is relevant for RHDHV by extending the knowledge of general long-distance mobility and night trains. This enables higher-quality consultancy services for policymakers and night train operators.

This thesis is also relevant to the scientific community. To the author's knowledge, this thesis is the first study to include booking convenience and train experience in a long-distance mode choice model. Furthermore, this is the first study to conceptualise booking convenience through individual components in a rating experience. Additionally, these factors were included in a case study for night trains, which have not been studied extensively. As one of the first studies about night trains, this study adds to understanding people's preferences regarding this mode. Lastly, this thesis is also relevant for the general public. By aligning night train services more with people's choices, demand for night train connections might increase. The societal benefits of this mode can be harnessed more through additional services. Night trains increase land use efficiency and the accessibility of regions while being environmentally friendly.

1.5. Thesis outline

This thesis is organised like the following. Firstly, in chapter 2, the methods used are explained for this thesis. In chapter 3, through a literature review, a conceptual model was derived. This states which attributes, background variables and contexts might influence business and leisure travellers' night train use. The specification of the used experiments is highlighted in chapter 4. Furthermore, the questionnaire, the factor coding, the model specification and the scenario design are shown. Various models will be estimated and used to answer the sub-research questions in chapter 5. Starting with highlighting the booking experience of Dutch travellers, various factors are determined that cause a convenient booking scenario. Then, the average influence of operational factors on the willingness to use night trains is explored before diving deeper into heterogeneity. Closer competitors of night trains are revealed before diving deeper into demand segments. Lastly, night train market shares are explored for various scenarios. This thesis will be rounded off with the discussion in chapter 6. It comprises the key findings of this thesis, some implications for night train operators and policymakers, a section reflecting on the generalisability of this thesis, limitations, future research recommendations and the conclusion.

2 Methodology

The following methodology chapter outlines the methods used for this thesis. Firstly, a model framework is presented in section 2.1, highlighting the relation of the various models used in this thesis. Additionally, it is argued why it was chosen to apply these models. In the following, the used models are presented more in detail in section 2.2, section 2.3 and section 2.4.

2.1. Model framework

The sub-research questions are answered through various methods for which an overview is provided in Figure 2.1. Firstly, it was chosen to conduct a literature review. It aims to determine relevant alternatives, attributes, background variables and specific contexts that might influence travel demand for night trains. A conceptual model was derived through a literature review. This model showcases a relation between factors relevant to the decision process. Using a conceptual model enables the selection of relevant attributes and methods for analysis.

In the second step, a survey was applied to gather data. In the survey, three different experiments were used. Since booking convenience is complex to conceptualise, it was chosen to unravel its factors twofold. Firstly, respondents were asked directly about their booking experience in a questionnaire. This enables an overview of the current booking behaviour of Dutch citizens and potential difficulties that could emerge. The analysis took place through descriptive analysis using plots for visualisation to detect current booking problems more efficiently.

Secondly, it was chosen to conduct a booking convenience rating experiment. Rating booking situations has the advantage that people do not have to mention the importance of various factors comprising a difficult booking situation themselves but rather reveal their preferences indirectly. This is preferred since people are often unaware of how they weigh multiple factors (Chorus, 2022). Furthermore, it is possible to easily integrate a rating experiment into a choice experiment through a hierarchical information integration (HII) approach. In the context of this thesis, this enables the detection of factors that comprise difficult booking situations and relevant factors for night train mode choice while not leading to fatigue among respondents (Louviere, 1984).

For an analysis, it was chosen for a linear regression. On the one hand, this is a standard method for analysing rating experiments and on the other hand, it leads to intuitive results. Ordinal regression reflects the Likert-scale question more closely, but the linear regression method is well-known and commonly used in HII experiments when using rating experiments. It was, therefore, decided to use the linear regression method. All research questions besides the first part of research question 1 are answered by a mode choice experiment comparing the night train with competitors. This enables highlighting respondents' preferences for night trains - respective to other modes. Various models for analysis were chosen. For sub-research question 3, potentially, two models are suitable for modelling - a Panel ML model and a nested logit model. For sub-research questions 1 and 2, also, a traditional MNL model is possible.

Because of its known superior model fit respective to the MNL model and the nested logit model when incorporating heterogeneity respective to mode preferences, a Panel ML model was chosen. However, an MNL model was also estimated and compared with the Panel ML model regarding model

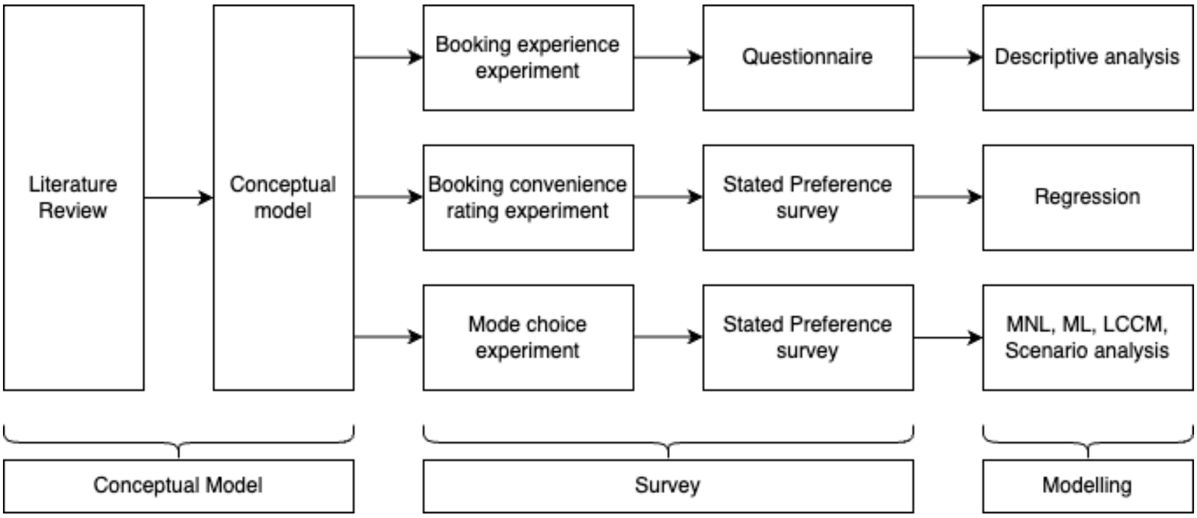


Figure 2.1: Model framework

Table 2.1: Search terms and retrieved papers for scientific literature review

Search Term	Initially Found	Analysed	Snowballed
mode AND choice AND high AND speed AND rail	184	12	9
mode AND choice AND long AND distance	471	5	
mode AND choice AND long AND distance AND railways	43	4	
mode AND choice AND long AND distance AND bus	58	1	
mode AND choice AND long AND distance AND aviation OR aircraft OR plane	34	1	
Mode AND choice AND night AND trains	8	2	

fit. The MNL model was included in the analysis of this thesis because of its simplicity, speed, and widespread usage in the choice modelling community. To detect segments in the population, it was decided to apply a LCCM instead of a Panel ML model and a latent class model. This provides deep insights into heterogeneity while still not being too computationally demanding. Additionally, it connects random utility maximisation (RUM) theory with other modelling paradigms, which the latent class model does not. Lastly, it was chosen to apply the fitted LCCM model on various scenarios to highlight market shares of night trains under different circumstances. Applying scenario analysis enables insights into market shares under well-defined circumstances and makes it possible to derive implications for both night train operators and policymakers.

2.2. Conceptual Model

2.2.1. Literature review

Scientific literature review regarding mode choice The scientific literature review focused only on mode choice. It is assumed that people compare night train services with competing modes and decide afterwards. Other choices, like the destination choice and time of day choice, are out of the scope of this literature review. The literature review was conducted through Scopus in a three-step procedure. Firstly, it focuses on the long-distance passenger market to derive general variables before focusing specifically on the mode of night trains.

For this, three search terms have been used, the first being ”mode” AND ”choice”. The second search term denotes ”long-distance” transportation since most papers analysing mode choices refer to short and middle distances. Lastly, the various modes are added to the search string since, in studies, the preferences for one specific mode relative to other modes are compared. The particular mode terms used are ”high-speed rail”, ”railways”, ”car”, ”bus”, ”plane”, ”aviation”, and ”aircraft”. Lastly, the literature covering night train mode choices is analysed using the search term ”night trains”.

By applying these search terms, various documents were initially retrieved. All of them have been screened for relevance, and a smaller portion of the document was analysed. Some other papers were discovered through snowballing from these analysed papers. The number of analysed papers are presented in Table 2.1. Whereas some papers turned out to add insightful information, three of the

Table 2.2: Search terms and retrieved papers for grey literature review

Search Term	Retrieved	Analysed
factors AND night AND trains	25	5
mode AND choice AND night AND trains	25	0
Faktoren AND Nachtzüge	25	4
Verkehrsmittelwahl AND Nachtzüge	25	1

documents were crucial and central in understanding the state of the literature.

Grey literature review regarding mode choice Similar to the scientific literature review, a grey literature review was conducted. Here, the search engine "Google" was used. As shown in Table 2.2, two different search terms have been used. Since most night trains in Europe are operated by the Austrian railways ÖBB and night trains are very popular in German-speaking countries, it was decided to search the same terms in German as well. Lastly, employees from RHDHV were contacted for Dutch sources, which led to the retrieval of one source.

Literature review regarding booking convenience This thesis defines booking as searching for and acquiring tickets for international travel using transportation modes. The author mainly defines booking convenience as the absence of booking problems. These booking problems can emerge in various phases of the booking process, which consists of finding the right website, having tickets available at the desired time, comparing travel options, entering contact details, paying for the ticket and receiving a ticket. Since scientific literature is missing regarding factors comprising booking convenience or difficulty on international travel, a grey literature review was conducted using Google. The search was restricted to flying and using trains since these two modes are most popular and bookable on long distances. Seven articles have been analysed in total.

2.2.2. Behavioural modelling paradigms

Various behavioural modelling paradigms have been developed to explain travel behaviour. Under a modelling paradigm, a distinct set of methods, postulates and standards for a legitimate contribution to a field is understood (Kroesen, 2023). Each paradigm explains and predicts travel behaviour in a specific way and has particular reasons for it. This thesis aims to evaluate the importance of factors influencing night train demand and to estimate market shares under various scenarios. The econometric modelling paradigm is best suited (Kroesen, 2023). It assumes travellers choose the transportation option with the maximal utility. The RUM family is the most famous mathematical model family that follows the econometric modelling paradigm. Whereas the econometric modelling paradigm is the primary paradigm used in this study, mobility styles are expected to influence mode choice. Under this concept, discrete latent groups emerge that differ through various experiences, attitudes, motivations, needs and others. LCCM combines the econometric modelling and mobility styles paradigms. Here, travellers are expected to choose an alternative depending on their probability of belonging to specific classes.

Lastly, the psychological modelling paradigm is also assumed to apply to decision-makers' choices. In this modelling paradigm, people's decisions are determined by psychological factors such as habits, social norms and attitudes (Kroesen, 2023). The reason for including this paradigm is the study's results of Curtale et al. (2023), which highlight that psychological factors greatly influence mode choice for night trains. To simplify, it was not chosen for a hybrid choice model but rather to include the psychological factors as a covariate influencing the probability of selecting modes.

Regarding environmental protection, this might be the extent to which essential people like family or friends influence the respondent to behave more environmentally friendly. Lastly, the control beliefs influence the perceived behavioural control. In the example, a control belief describes to which extent the respondent is willing to behave environmentally friendly, even though it is more inconvenient (Ajzen, 2006). Whereas in psychological studies, multiple indicators are usually used, it was decided to apply only one indicator for each aspect of planned behaviour, attitude, subjective norm, and perceived behavioural control. This simplifies the model and prevents respondents from becoming fatigued.

2.2.3. Conceptual model

The conceptual model was designed using draw.io. Here, a concept that aims to capture long-distance mode choice for night trains with all factors is presented. In the following survey, not all conceptual model elements were used due to practicality, privacy, and potential fatigue of respondents.

Within the conceptual model, conceptualising booking convenience was particularly new, which is why a small survey was conducted after pursuing the literature review. Firstly, scientific and grey literature was analysed to determine possible influential factors. People surrounding the author were asked to rank the importance of these factors. Employees in the same business unit of RHDHV and the personal environment were contacted for this. Through this, a subset of factors became the most relevant. In the last step, one employee of RHDHV was contacted to derive insights from a night train expert. The most important factors for a convenient website could be derived using all these methods.

2.3. Survey

2.3.1. Scope

The introduction states that the European Union is ambitious in its climate policy. In combination with the extensive existing railway network and favourable public opinion towards railways (Eurostat, 2023 and McClanahan, 2022), Europe has advantageous conditions for the introduction of new night train services as a replacement for more environmentally damaging modes like flights and driving private vehicles. Therefore, this continent is selected as a destination area.

Regarding night train demand, just the substitution effect is considered. For practical reasons, the generation effect of new modes of transportation is neglected.

Furthermore, the passenger is assumed to adhere to the classical four-step transportation planning model (Ortúzar and Willumsen, 2011). In particular, the activity and destination choices are believed to precede the mode choice. The route choice is considered to be less critical. This thesis focuses solely on mode choice.

To simplify, this thesis assumes no capacity issues regarding the rolling stock and infrastructure. A theoretical demand potential of night trains was thus computed. There are severe night train rolling stock shortages and track capacity, especially in the morning peak hours. (De Kemmeter, 2022 and Posaner and Cokelaere, 2023)

Night trains, which are also sometimes called sleeper trains, can be categorised for Europe into standard day, classic night, and tourist journey trains (DB International GmbH, 2013)

Standard day trains consist of rolling stock that has not particularly been adapted to let passengers sleep. A prominent example is German ICE high-speed trains operating during the night. Touristic journey trains operate mainly for consecutive days and might feature luxurious interiors like the Venice Simplon Orient Express. Touristic journey trains operate more irregularly than standard day and classical night trains.

Besides the categorisation mentioned above, there are seasonal charter night trains. They operate as traditional night trains except running at specific times of the year, primarily for touristic purposes (Kok, 2023).

This thesis focuses on classical night trains comprising different accommodation types. Furthermore, it focuses on night trains that operate just one night and not multiple nights.

This thesis assumes that the population is Dutch citizens aged 18 and older. This is because all population groups are possible night train users and not only those who travel regularly. Furthermore, defining the population broadly makes it possible to conclude that people living in various parts of the Netherlands have different socio-demographic backgrounds. The potential generation effects of these groups are not considered to simplify the model.

As will be shown later in the report, the group is envisioned to be split into two scenarios: business and leisure travellers. For business travellers, the population is narrowed down to working people who have to travel to foreign countries for business purposes. For leisure travellers, the population is not narrowed down.

2.3.2. HII approach

The HII theory of Louviere (1984) was applied conceptually to connect the mode choice experiment and the booking convenience experiment. The theory declares that when decision-makers encounter numerous attributes in a decision-making scenario, they categorise them into what is referred to as "decision constructs". In a sub-experiment, individuals initially weigh the attributes associated with each specific decision construct before assigning a rating to that particular decision construct. Subsequently, in the comprehensive choice task, individuals are presented with the various scores assigned to the decision constructs in a "bridging experiment." In this thesis, only booking convenience is conceptualised in the mode choice experiment as a decision construct.

2.3.3. Stated Preference survey

Using a SP survey for the primary choice experiment and the booking rating experiment, it is possible to include hypothetical alternatives. As shown in chapter 4, night trains are introduced on a leg not served in the scenario. This non-existing alternative would not have been possible to include using a revealed preference study. Furthermore, it also allows one to perceive choices for rare situations where attribute values are in such a way that they would usually not occur in reality.

In addition, using SP surveys enables one to observe multiple choices per respondent and perceive individual preference differences. This also allows the data set to deliver reliable estimates, even though the sample size is not too big (Molin, 2023). Lastly, revealed preference data would have enabled only insights into why passengers already use night trains. Insights regarding potential night train passengers would not have been possible. This would not be desirable, especially for the mode night trains, which is still a niche mode. Due to the night train being a niche mode, receiving enough revealed preference respondents would have been difficult.

However, SP surveys are inclined to include a hypothetical bias. Under this concept, it is understood that due to several shortcomings, people do not behave as they communicated in the SP research in real life. These shortcomings include, among others, that the consequences of choices are not felt; in SP surveys, perfect information is available, and new alternatives and levels are not yet experienced (Molin, 2023). To mitigate this shortcoming, Heufke Kantelaar et al. (2022) from Ben-Akiva et al. (2019) recommended raising attention to five issues.

Firstly, respondents are required to be familiar with the alternatives used. Therefore, the new interior of the night train variant was described in detail. It was tried as much as possible not to manipulate respondents by describing the alternative neutrally. Secondly, the sample has to represent the population as closely as possible regarding socio-demographic background data. Care was taken to ensure representability as closely as possible during the survey construction and distribution. Thirdly, the survey has to be well-designed regarding the alternatives used, socio-demographics, and other background variables. The survey construction and distribution subsection will explain the tools used to ensure a high-quality survey. Fourthly, the number of alternatives and attributes has to be limited to prevent respondents' fatigue and retrieve reliable results. Rules of thumb regarding the number of other options and variables were applied, leading to three alternatives with five attributes in both choice experiments. Because not all of the indicators for booking convenience could be added to the main experiment, a HII approach was used (Louviere, 1984). According to Johnson and Orme (1996), people are only able to consider seven factors at the same time. Lastly, it is suggested that the data from the SP survey be calibrated and tested with RP data. This thesis revealed that preference questions enable some initial validation for some variables. However, accurate calibration was not possible due to the limited scope.

2.3.4. Survey construction and distribution

After defining a conceptual model, the choice sets have been created using ngene because of its availability and the author's experience with the tool. For more detailed information on the choice set generation and the consideration of the minimum number of respondents, it is referred to chapter 4. The survey was distributed via the NS panel. The NS panel comprises 85,000 possible respondents willing to answer NS-related questions. Through this, it is possible to achieve a large number of respondents. Furthermore, respondents not in the author's age group or region can also be contacted. This dramatically raises the probability of representing the population through a sample that is as good as possible.

However, this approach has also some disadvantages. First of all, the panel is skewed regarding age. Many pensioners signed up for the panel and are more likely to complete the survey. Additionally, most respondents are expected to have a favourable opinion of railways since a reason to join the panel is to help NS improve its services.

To mitigate these disadvantages, more respondents from younger age groups were interviewed to represent the Dutch population as closely as possible.

Because the survey was distributed via the NS panel, it was constructed in collaboration with MWM2. As a subcontractor of NS, MWM2 manages the panel using its own Crowdtech platform.

2.4. Modelling

The three experiments were analysed using different methods. In this section, the discrete choice models, which have been used to analyse the mode choice experiment, are highlighted. Firstly, an overview of discrete choice models is provided. In the second step, the MNL model, the Panel ML model and the LCCM are provided. Lastly, some metrics that have been used for model comparison are presented.

2.4.1. Overview of discrete choice models

Discrete choice models represent the econometric modelling paradigm based on utility maximisation (McFadden, 1972). Here, people are assumed to choose one alternative i if the utility of this alternative exceeds the utility of other options ($U_i > U_j, i \neq j \forall i, j \in Alternatives$). To include uncertainty in the model, the utility of an alternative is split up in a deterministic part V and an error component ϵ_i: $U_i = V_i + \epsilon_i \forall i \in Alternatives$. The utility of each alternative i is determined by the weighted importance of attributes in the choice set, as described by Equation 2.1. All models conceptualise the utility similarly. However, they differ in determining the choice probability for one alternative.

$$V_i = \sum_{k=1}^{k} \beta_k \cdot X_{ik} \tag{2.1}$$

2.4.2. Multinomial logit model

To calculate the probability of choosing a particular alternative i, the MNL model assumes the following formula:

$$P(i|C) = \frac{e^{V_i}}{\sum_{j=1}^{j \in C} e^{V_j}} \tag{2.2}$$

The probability of choosing the alternative i depending on the choice set C can be calculated in a closed form when assuming that error terms are independent and identical Gumbel distributed (i.i.d) (Ben-Akiva and Bierlaire, 1999) and that the probability of one alternative is independent of irrelevant alternatives. Furthermore, the importance of attributes b_k is homogeneous among individuals, and decisions are independent of each other if one respondent has collected multiple observations.

2.4.3. panel mixed logit model

Since most assumptions do not hold if some alternatives are more similar, respondents answer multiple times and differ in their preferences; the ML model has been developed. By incorporating variables for heterogeneous tastes and preferences, it is possible to acquire higher model fits (Chorus, 2022). These variations are assumed to follow specific distributions. Accounting for a Panel effect increases the overall model fit even further. The observation is now the sequence of all choices, which means that integrals are now necessary for all variations that have been modelled. These integrals are open-form, so simulations are necessary, leading to high computational effort. In Equation 2.3, v_n denotes the variance of a taste parameter β_n

$$P(n,i) = \int_{v_n,\beta_n} (\prod_{t=1}^{T} (P_{ni}^{t} | v_n, \beta_n) \cdot f(v_n, \beta_n)) dv_n d\beta_n \tag{2.3}$$

This thesis specifies a ML model to detect nests between alternatives. Furthermore, the Panel version was used to increase the model fit further.

2.4.4. Latent Class choice model

One drawback of the Panel ML model is that respondents' preferences are assumed to follow specific distributions. LCCM think that the population has various latent classes with different tastes. In a class-membership function, the probability of one individual belonging to one latent class is determined. This probability is determined by a traditional MNL model, where γ_{sq} and δ_S denote the class membership parameters and z_n the covariates that determine the class. In this thesis, it was assumed that the context, the train travel experience, the intention to use environmentally friendly modes and socio-demographics influence the class. In Equation 2.4, the class membership model is presented.

$$\pi_{ns} = \frac{e^{\delta_S + g(\gamma_{sq}, z_n}}{\sum_{l=1...S} e^{\delta_l + g(\gamma_{lq}, z_n}} \quad (2.4)$$

This approach has the advantage that it is a mixture between the mobility styles modelling paradigm and the econometric modelling paradigm. Various groups with different preferences can be targeted while receiving some information on the characteristics of the groups. The LCCM is provided in Equation 2.5, where S denotes the classes and π_{ns} the class membership function (Magidson and Vermunt, 2002)

$$P(n, i) = \sum_{s=1}^{S} \pi_{ns} (\prod_{t=1}^{T} P_n(i_t | \beta_s)) \quad (2.5)$$

2.4.5. Metrics for model comparison

Various metrics have been used to compare the model performance. This thesis uses the R^2 value, the F-test, the likelihood ratio test, the Ben-Akiva and Swait test, and the Bayesian Information Criterion.

For the evaluation of regression models, the R^2 value was used. It represents the proportion of the variance in the dependent variable that is predictable from the independent variables. In simpler terms, R^2 indicates how well the regression predictions approximate the data points. An R^2 value ranges from 0 to 1, where 0 indicates that the model explains none of the variability of the response data around its mean, and 1 indicates that the model explains all the variability around its mean.

To statistically determine the superiority of booking convenience rating models, an F-test was used. It compares the variances of two or more groups to verify if they come from populations with equal variances. At its core, the F-test calculates an F-statistic, which is the ratio of the variance estimates from the groups being compared. Specifically, the larger variance is divided by the smaller variance, resulting in the F-value. This F-value is then compared to a critical value from the F-distribution table, which is determined by the degrees of freedom for the numerator and denominator and the chosen significance level (usually 0.05). If the calculated F-value exceeds the critical value, the null hypothesis that the variances are equal is rejected.

To compare discrete choice models statistically, a likelihood ratio test is suited. It also compares the goodness of fit of two competing statistical models using the likelihood. The null hypothesis of the likelihood ratio test is that a more restrictive model represents the data adequately. The test statistic can be computed by subtracting the log-likelihood values of the models: $\lambda = -2 \cdot LL_0 - LL_1$, where LL_0 denotes the Log-likelihood value of the more restrictive model, thus comprising fewer parameters.

However, the likelihood ratio test demands that the same decision rules have been used. Therefore, the likelihood ratio test is not feasible for comparing the MNL and the Panel ML model with each other. For this, the Ben-Akiva & Swait test (Ben-Akiva and Swait, 1986) is used. It provides a conservative estimate for the probability that although model B fits the data better than A, A is the better model in the population Equation 2.6. N denotes the number of observations, and j is the number of alternatives in the choice set.

$$p = NormSDist(-\sqrt{2 \cdot N \cdot ln(j) \cdot \frac{LL(B) - LL(A)}{LL(0)}}) \quad (2.6)$$

As it is good practice in estimating LCCM to determine the number of optimal classes, the Bayesian Information Criterion (BIC) has been used. It is defined through Equation 2.7, where k denotes the number of alternatives, and N is the number of observations. By comparing BIC values, it is possible to determine superiority quickly. However, this is also not statistically valid.

$$BIC = -2 \cdot LL + k \cdot ln(N) \quad (2.7)$$

3
Conceptual Model

After having presented the methods that have been used in this thesis, this section develops a conceptual model as a basis for further analysis. Firstly, relevant alternatives in the long-distance transportation sector are determined in section 3.1. In the second step, influential factors for long-distance transportation are discovered in section 3.2. Each of them was evaluated if they were added to the conceptual model. The conceptual model is presented in a third step in section 3.3, showcasing the relation between alternatives and factors and highlighting expectations for further analysis.

3.1. Alternatives in the long-distance transportation sector

Maier (2022) cites Association negaWatt (2018), summarising current market shares in the European long-distance transportation market. The mode car is predominant for trip distances from 600km to 1499km, accounting for over 57% of the trips made. Other relevant modes are the train with 22% of all trips made, flights with 16% and using a long-distance bus with 4%. On distances longer than 1500, using flights becomes dominant with a mode share of 85%, using a car with 11% and trains and buses having a share of 2%. Disagreeing on the specific numbers, Donners (2016) concludes that the previously mentioned modes are the most relevant in the long-distance sector.

However, many studies have only examined parts of the modes mentioned above. Prevalent in literature is comparing HS trains with flights, such in Román et al. (2010), Park and Ha (2006) and Li et al. (2020). Other studies cover other sub-sets of the modes as mentioned earlier, like comparing HSR with driving by car in González□Savignat (2004), Cascetta et al. (2011) and Yang et al. (2022). Including long-distance buses seems particularly popular in research conducted in China by Li et al. (2020) and Li et al. (2021). Also, mode choice within modes is analysed by researchers, such as between HSR and conventional rail in Ku et al. (2023).

Previous studies have very seldom covered night trains. However, both Heufke Kantelaar et al. (2022) and Curtale et al. (2023) aim to estimate the replacement potential of night trains towards short-haul flights. Moors (2023) covers exclusively night trains.

To adequately cover the long-distance transportation market, this research decided to include the modes of night train, HS train, and aeroplane. The modes of car and bus are not included in this analysis. Car was not chosen because of its conceptual difference from other modes. Whereas all other modes are public transportation modes, cars are generally owned by their users and not shared with others. Furthermore, it was chosen not to use the bus as an alternative due to its minor relevance on very long distances, its long travel times and only competition ability with night trains only regarding seating comfort (Walther et al., 2017).

3.2. Influential factors for long-distance mode choice

3.2.1. Total travel time

For long-distance transportation mode choice, the total travel time is crucial and included in almost all researches (Cascetta et al., 2011, Ku et al., 2023, Li et al., 2020, Ren et al., 2020, Givoni and Dobruszkes, 2013, Avogadro and Redondi, 2023 and Van Goeverden, 2009). In Steer Davies Gleeve

(2006), it even explains up to 84% of the modal split on seven European routes. Increasing travel times are always associated with disutility; travel time is generally perceived as worse for flying compared to using trains (Román et al., 2010, Park and Ha, 2006 and Dällenbach, 2020). Travel time is essential for all modes and often the most critical factor in long-distance mode choice, as stated by Van Goeverden (2009). Furthermore, travel time is mainly conceptualised linearly (González□Savignat, 2004).

However, this assumption might not hold for night trains since travel time is used for sleeping, and thus, it is perceived differently (Savelberg, 2019). Respondents mention efficient use of the travel time by 29% as a factor in choosing night trains (Buh and Peer, 2022).

Furthermore, an interrelation with departure and arrival times is persistent for night trains, which deviates from other modes. This is mainly confirmed by non-scientific sources (Gardner and Kries, 2022 and Cerny, 2021). The importance of the travel time might be reduced for night trains as the ÖBB, operator of the largest night train fleet in Europe, states in Cerny (2021). Demand might depend more on the arrival time, which is deeply connected with the travel time, emphasising the importance of defining a scenario. However, some previous studies confirm the importance of travel time for choosing night trains (Curtale et al., 2023, Moors, 2023, Heufke Kantelaar et al., 2022 and Savelberg, 2019. However, this importance might be altered by psychological factors like the expectation of a longer sleeping time, as stated by Curtale et al. (2023). As the scientific community agrees that travel times greatly influence mode choice on long distances, it was decided to include this factor for all chosen modes in the conceptual model.

3.2.2. Departure and arrival time

For long-distance transport, the departure and arrival times were insignificant in some studies, and others like Li et al. (2020) significant. However, night trains play a more prominent role as scientific sources like Heufke Kantelaar et al. (2022) and grey literature like Cerny (2021) confirm. Therefore, they were added to the conceptual model.

3.2.3. Total travel distance

Mainly, Chinese studies include additionally the total travel distance as a deciding factor in travel mode choice (Li et al., 2020 and Li et al., 2021). In all studies, this variable was significantly different from 0, thus influencing travellers' mode choice. However, this factor was not included in the conceptual model. Decision makers are assumed to care about the time spent travelling in various modes and not how long the detour of each mode is to reach the destination. Furthermore, the correlation between travel time and distance is expected to be too high, so multicollinearity issues emerge.

3.2.4. Total travel cost

Besides the total travel time, travel costs are considered by most researchers to be decisive in choosing travel modes on long distances. Yang et al. (2022), Avogadro and Redondi (2023), Wang et al. (2017), and others highlight the importance of travel costs for choosing HSR services. Van Goeverden (2009) confirms this and adds the importance of flying. González□Savignat (2004) adds on that by highlighting differences regarding the assumed trip purpose, with business travellers having a lower price sensitivity.

These findings are also valid for the mode night train, as Heufke Kantelaar et al. (2022) and Curtale et al. (2023) state. Also, non-scientific sources confirm the importance of the costs of using night trains, such as Sonnenberg (2023) and Walther et al. (2017). Also, leisure travellers seem to be more price-sensitive than business travellers, which leads to the conclusion that regarding pricing, the night train is not significantly different compared to other modes (Hödl, 2006).

Hödl (2006) states that in 2006, for 79% of night train users, the price was an essential factor. However, the design of the price system also seems to play a role, with 63% mentioning that they consider a simple price system necessary. Buh and Peer (2022) defines night train total travel costs, not as a pull factor like short-haul flights but as a push factor that keeps people away from using it. 77.8% of respondents mentioned the price as a factor that could potentially stop them from using the night train. DB International GmbH (2013) even included only travel costs in their model to describe mode choice between the night train and other modes. Because of its widespread significance - not only for night trains particularly but also different modes - it was chosen to include travel costs in the conceptual model.

3.2.5. Comfort

Besides the travel time and travel costs, the comfort of travelling determines the mode choice. In different studies, different definitions of comfort are applied, ranging from rudimentary definitions including only classes (Cascetta et al., 2011) to more sophisticated definitions including multiple explanatory variables and heterogeneity of perceptions (Heufke Kantelaar et al., 2022). Most studies agree on the significance of this variable for various modes, under which are Cascetta et al. (2011), Román et al. (2010), Ren et al. (2020), Mándoki and Lakatos (2017) and Wang et al., 2017.

Comfort seems more important for night trains than other modes, as Heufke Kantelaar et al. (2022) states. The comfort requirements for sleeping are significantly higher than for sitting. Hödl (2006) confirms the importance of comfort in using night trains, with 80% of respondents stating it. Into this variable, also psychological aspects are playing a role, with Buh and Peer (2022) mentioning a lousy night of sleep as a factor. A high correlation is expected between this factor and comfort. Sharing of cabins is furthermore mentioned as a related factor, also contributing to comfort. Heufke Kantelaar et al. (2022) mentions various factors contributing to comfort in a night train: the accommodation type, privacy, catering, stops, the inside environment, facilities and the staff. Gardner and Kries (2022) also mentions catering through a restaurant car and Cerny (2021) WiFi facilities. In Cerny (2021), the operator ÖBB mentions a higher dislike of sharing the cabin with strangers, leading to innovations such as mini cabins. Due to its particularly high relevance for the mode night train, comfort was added to the conceptual model; however, in this thesis, comfort was conceptualised as accommodation. Through this, it is possible to simplify the vague attribute.

3.2.6. Booking convenience

Booking convenience has not drawn widespread attention in long-distance mode choice. Only twice, in Li et al. (2020) and Yang et al. (2022), has this factor been included in the respondent's decision-making. Both authors conclude that ticketing is relevant when opting for HSR services and flying. Curtale et al. (2023) asked respondents which factors they consider important when choosing between modes on long distances. While numerous answers were possible, for 43.2% of the respondents, easy booking was essential, this factor being the 4th most important one after the price, the total travel time and the number of transfers.

Despite the importance of easy booking, booking trains in Europe is tedious (Donners, 2016). Garrod et al. (2021) mentions that this fact hinders a lot of customers from using night trains. Preslmayr et al. (2021) conducted a study where respondents had to book international train connections. Out of 152 bookings in 20 ticket shops, respondents completed 102 train and 147 flight bookings. Whereas just 3% of all flight bookings were not completed, this was the case for a third of all train tickets. Curtale et al. (2023) acknowledges this by including easy booking as a scenario. This comprises booking night trains as quickly as stated in the survey. However, it would also be interesting to investigate specific components of a problematic booking process and evaluate which ones are challenging and which are less.

Firstly, the booking process was divided into several steps that the customer has to go through if he would like to book a ticket. It is assumed that the right website that offers tickets for a chosen origin-destination pair has to be found. Secondly, tickets have to be available for this leg. Consequently, the customer compares the travel options and enters the contact details after deciding. Lastly, he pays for the ticket and receives it.

A grey literature review was conducted to derive current problems in international rail connections in Europe for all these steps. It was focused on railways since this mode is particularly prone to difficult booking situations on international connections and as the scope is Europe because of the scope of this thesis. Ten factors that could contribute to respondents' perception of difficulty booking have been determined.

1. **Search Engine comparing international train connections with flights**: According to the 4-step model of Ortúzar and Willumsen (2011), people choose the transportation mode after selecting the destination. However, comparisons are only possible between flights or train connections on most booking sites. Furthermore, booking platforms, including both options, are unknown to the broader public. Especially night train services are not included in these booking platforms (Danson, 2023).

2. **Search Engine comparing various train connections**: Besides small booking platform opera-

tors like Omio, the incumbent railway operators like NS do not cooperate with other operators to an extent where seamless booking across Europe would be possible (Sonnenberg, 2023). Therefore, the potential passenger has to look on various booking sites to find the optimal connection, unlike in the past (Lindner, 2023).

3. **Possibility to book one ticket for the whole journey**: Furthermore, this missing collaboration between railway operators leads to the fact that some connections crossing multiple borders cannot be booked at all (Sonnenberg, 2023). In aviation, a global distribution system (GDS) system has been implemented for years (Amadeus), which enables the booking connections of multiple airlines in one ticket (Garrod et al., 2021). A similar system, the Open Sales Distribution Model, is planned for railways in Europe as well and is to be introduced by 2030 (van den Bogaard, 2021 and Cerny, 2021).
4. **Earliest possible booking date**: The period between booking day and departure day influences ticket prices significantly during dynamic pricing. Wen and Chen (2017) concluded in their research that most people start booking flights four months in advance (Tanner, 2023). However, some European railways, like the Polish Railways, allow bookings one month in advance.
5. **Modern website with easy-to-follow steps**: In Cerny (2021), it is mentioned that the booking options have to be more customer-friendly. However, this is difficult to conceptualise in an experiment and entirely subjective. It might be thus measured through another indicator variable.
6. **Short time needed to have an overview of different possible connections**: This indicator defines the time required to get an overview of the other booking options. It serves as an indicator of the website design and convenience. While the time could be short for a centralistic booking platform comparing multiple transportation options, it could be longer when comparing various options.
7. **Possibility to choose the exact seat/bed for the whole journey**: In the aviation sector, it is expected to be able to book specific seats. While over the last years, it has been made possible for train journeys, especially for night trains, booking specific seats is still a rarity (Probst and Kunze, 2014).
8. **Time needed to book after choosing a connection**: This indicator measures the ease of use of the booking site and the time required to complete the booking, including adding personal details and payment.
9. **Coherent comfort level for the whole journey**: For flights, it is usually possible to book a coherent comfort level across the entire travel distance since most flights are direct flights. No first class is offered for short-haul flights, but most Legacy carriers still offer business class. For international train connections, however, sometimes different tickets have to be booked, leading to the possibility that the first class is already booked out for one leg and people have to switch to the second class.
10. **Free rebooking on the following train in case of missed transfer**: Presumably, more relevant seems to be a free rebooking in case of a missed transfer. In the aviation sector, tickets are usually booked together, and passengers are therefore eligible for compensation in case of delays and a missed transfer. As mentioned, railway connections in Europe can often not be booked in one ticket. This means passengers are no longer eligible anymore for delays and missed transfers (Lindner, 2023 and Danson, 2023). Furthermore, through this measure, connection times between services could potentially be reduced (Heufke Kantelaar et al., 2022).

A two-step procedure was applied to determine the most relevant factors for a convenient booking scenario. Firstly, employees from RHDHV and the network of the author were asked to rate the importance of the abovementioned factors. The results of this survey with n = 23 respondents (4 Royal Haskoning Employees and 19 contacts in the own network) are provided in Table 3.1. The five factors that turned out to be the most relevant are reported in bold.

In the second step, these factors were rearranged to derive the final factors for the conceptual model.

Table 3.1: Important Booking factors for international trains

Booking aspect	RHDHV	O. N.	Total
Search Engine comparing international train connections with flights (yes/no)	1	2	3
Search Engine comparing various train connections (yes/no)	**2**	**10**	**12**
Possibility to book one ticket for the whole journey (yes/no)	**2**	**5**	**7**
Earliest possible booking date (9 months, 6 months, 3 months)	**1**	**14**	**15**
Modern website with easy-to-follow steps (yes/no)	**2**	**11**	**13**
Time needed to have an overview of different possible connections (1, 5, 10 min)	1	3	4
Possibility to choose the exact seat/bed for the whole journey (yes/no)	0	2	2
Time needed to book after having chosen a connection (<1, 2, 5 min)	1	4	5
Coherent comfort level for the whole journey (yes/no)	0	1	1
Free rebooking on the following train in case of missed transfer (yes/no)	**2**	**6**	**8**

Firstly, both factors describing the search engine were merged, leading to a factor describing a search engine comparing train and flight connections. Secondly, the possibility of booking one ticket was chosen, and the fact that in case of a missed transfer, free rebooking was applied was included in this factor. The third factor, the earliest booking date, is used in the conceptual model in an unchanged way. The fourth relevant factor, a modern website with easy-to-follow steps, is challenging to measure. Therefore, it was decided to use the two-time indicators - The time needed to have an overview of different possible connections - and the time required to complete the booking. Both factors were merged into one indicator. Lastly, after speaking with an employee of RHDHV and a night train expert, the factor digital ticket was added. Even though this factor is standard in the aviation industry, particularly for night trains in Europe, it is not.

All booking convenience factors are assumed to be relevant for all alternatives and thus included in the conceptual model. Furthermore, the factors comprising booking convenience are added to the conceptual model.

3.2.7. Reliability

Besides problematic booking, international train connections are pretty unreliable in Europe (Ehrbar, 2023 and Heeg, 2015), which significantly hampers customer satisfaction and significantly impacts the company brand. However, the scientific literature concludes that reliability is a relevant factor while choosing modes on long distances (Román et al., 2010, Cascetta et al., 2011, Mándoki and Lakatos (2017) and Burgdorf et al., 2018). This is also the case for night trains, as Hödl (2006) states, with 75% of respondents stating that punctuality is essential for them when choosing a night train. This is supported by a study from the De Graeff et al. (2020). In Curtale et al. (2023), however, only 25% of respondents mention reliability as important. This factor is included in the conceptual model since reliability has not been covered in a night train mode choice study.

3.2.8. Access and egress distance

In Zhen et al. (2019), Cascetta et al. (2011), Román et al. (2010) and Li et al. (2020) access and egress are included in analysis and highlighting its importance. Whereas in Cascetta et al. (2011), people are deterred away from using HSR services and opt instead for using the car, in Li et al. (2020) they opt instead for using HSR services instead of flying.

For night trains, access and egress times have not been studied scientifically, even though in grey literature like Lassner (2020) departing and arriving in the city centre are mentioned as factors that are advantageous for night trains. To test if access and egress are also relevant for night trains, they were included in the conceptual model. In this study, they were conceptualised through the access distance, as shown in chapter 4.

3.2.9. Transfers

Transfers play a role in determining mode choice on long distances. According to Ren et al. (2020), the odds of choosing a conventional train instead of HSR were found to be 20.7%−33.7% higher if passengers perceived that either HSR was not available at the destination or there was no direct HSR service for them to travel to their destination. For the same modes, this observation is confirmed by Ku et al. (2023). For night trains, Curtale et al. (2023) finds that passengers dislike connections with a transfer in the early morning. Van Goeverden (2009), however, concludes in his analysis that transfers are a non-significant factor for choosing modes. In grey literature, transfers are also assumed to be a relevant factor (Sonnenberg, 2023 and Walther et al., 2017). Due to its assumed significance, this factor was added to the conceptual model.

3.2.10. Frequency

Literature does not agree if frequency is a relevant factor in longer-distance mode choice. Ren et al. (2020) revealed in his research that the odds of choosing a conventional train were about 31.7% lower if the passengers felt that the frequency of conventional trains to the destination was reduced due to the operation of HSR. From the London-Paris passenger market, Avogadro and Redondi (2023) confirms the importance of frequencies. An increase in the daily frequency of Eurostar would stimulate demand for more than 94,500 passengers per year (2.3% of current ridership). Román et al. (2010), on the other hand, finds that frequencies are not significant, and Van Goeverden (2009) mentions that frequencies are less critical since the waiting time makes up a shorter part of the journey and people plan their travel. It was, therefore, decided not to include this factor in the conceptual model.

3.2.11. Safety, security and privacy

Thus, some studies including safety as a factor for long-distance like Petříček and Marada (2022) and Li et al. (2020), Burgdorf et al. (2018) and Yang et al. (2022) found safety to be not that relevant on long-distance transportation mode choice. Safety - conceptualised as the perceived probability of accidents - also seems irrelevant for night trains, contrasting sharply with security and privacy. Security denotes in this thesis the perceived danger from other passengers.

Heufke Kantelaar et al. (2022) and Moors (2023) both confirm comfort as the essential determinant of choosing night trains, especially the number of travellers in a compartment. This comfort requirement is deeply connected with privacy and security since passengers sleep during the train ride. In Lassner (2020), Plüss (2023), Garrod et al. (2021) and Cerny (2021), privacy is named as a deciding factor for choosing comfort categories in night trains. Buh and Peer (2022), Walther et al. (2017) and Probst and Kunze (2014) highlight, on the other hand, security as deciding factor (often called safety in these reports). Since privacy and security are strongly interwoven with the comfort levels offered in a transportation mode, it is waived to include this factor in a conceptual model.

3.2.12. Context

Besides the above-described operational factors, other factors play a role in describing mode choice on long distances. In this thesis, the traveller's decision context is separated into various parts, i.e., the trip purpose, the travel company, car ownership, the size of the origin and destination city, the country of residence and the weather.

Scenario In literature, the scenario has mixed effects on long-distance mode choice. In this thesis, the scenario is conceptualised to consist of three factors. Firstly, the trip purpose itself, thus if a passenger travels for business or leisure purposes. Secondly, if the passenger carries luggage with him and if he has to pay for the trip by himself.

The trip purpose has mixed effects in the literature. Whereas Bergantino and Madio (2020) and Cordera et al. (2023) discover a trip purpose to influence mode choice on long distances, Li et al. (2021) and Li et al. (2020) find no influence on the probability of using the mode train. For night trains, Moors (2023) uses a context comprising travel purpose and group size, finding slight impacts with business travellers less likely to use night trains. This is supported by Walther et al. (2017), which highlights the different preferences of these user groups.

Furthermore, luggage could play a role with significant amounts of luggage associated with a higher probability of using night trains. Walther et al. (2017). This factor is, therefore, also added to the conceptual model.

Lastly, financials are an essential factor in the scenario. With this, it refers to who is actually paying for the services and, secondly, to which costs are included in the comparison. Some grey literature sources state that night trains can save hotel costs since travel time is overnight (Buh and Peer, 2022).

Directorate General for Internal Policies et al. (2017) doubts this, stating that in many cases, these accommodation costs do not occur. Firstly, if assumed that the same mode travels both legs, accommodation costs occur just once, since for the second leg, people arrive home. Secondly, a rising share of leisure travellers is visiting friends and family, thus not paying accommodation costs. Lastly, for business trips, the employer pays the travel costs overall. Therefore, the traveller does not feel the financial repercussions. Cascetta et al. (2011) tries to include this in his analysis by introducing a dummy variable representing if the user is reimbursed travel costs. It was decided to add this factor to the conceptual model to increase the realism.

Travel group A few studies have included the travel group as a determining factor for mode choice. Cascetta et al. (2011) and Van Goeverden (2009) found that the travel group is the crucial variable for the likelihood of using the mode train for long-distance trips. If travelling in a group, the probability of choosing the mode railways was 60% lower Van Goeverden (2009). Shi et al. (2022) and Price and Matthews (2013) confirm this, stating that some travel groups are not significantly different.

Heufke Kantelaar et al. (2022) mentions that including the travel group as a context variable might increase the realism for modelling night train demand, which Moors (2023) does. However, the group size was relatively unimportant, unlike travelling with strangers in the compartment. In Curtale et al. (2023), the travel group is significant for using the mode night train in an ICLV model (family vs. solo); however, it is not substantial for couple vs. solo. Families are associated with a lower probability of choosing night trains, unlike stated in some grey literature (Walther et al., 2017 and Directorate General for Internal Policies et al., 2017). Because of this mixed picture regarding importance, it was decided to include the travel group in the conceptual model.

Country of residence As the origin and destination city, the country of residence influences mode choice preferences, confirmed through scientific literature in Van Goeverden (2009) and Ku et al. (2023) as well as in grey literature in Directorate General for Internal Policies et al. (2017). As the origin and destination city, the country of residence is fixed in this research and not included in the conceptual model.

Weather Even the attribute weather is said to have a minor influence on the mode prediction according to Li et al. (2021). Li et al. (2021) In his study, he argues that, among others, the inclusion of temperature, rainfall and wind significantly impact model predictions for the modes of aeroplane, high-speed rail, conventional train, and express bus. Since long-distance trips are usually planned and the weather is unknown, these results can be doubted, and this factor is not included in the conceptual model.

3.2.13. Travel experience

Travel experience has not been covered extensively in long-distance mode choice literature. Bergantino and Madio (2020) discovered no significant influence of travel frequency on mode choice. However, Cascetta et al. (2011) did for the mode HSR and Dällenbach (2020) as well as Ren et al. (2020) for trains in general. This seems to be true for night trains and Curtale et al. (2023) states. However, he refers to positive experience only. Buh and Peer (2022) generalises the impression to also negative experiences. Because of its unknown effect, travel experience was included in the conceptual model.

3.2.14. Psychological Variables

Various psychological variables might play a role in a preference for specific modes. A general preference for a particular mode can be covered through alternative specific constants Directorate General for Internal Policies et al. (2017). Another psychological influence might be the enjoyment of the scenery or romance associated with specific modes (Lassner, 2020). Since this factor is expected to influence the probability of choosing modes, it was added to the conceptual model.

For night trains in particular, two psychological variables are presumably the most important: the fear of flying and the intention to use environmentally friendly modes (Curtale et al., 2023). Therefore, it was decided to study the literature on these two factors in more detail.

Intention to use environmentally friendly modes In the general public, the motivation to reduce GHG emissions is one of the significant reasons respondents choose to use night trains as a means of transport (Sonnenberg, 2023, Hödl, 2006, Garrod et al., 2021, Directorate General for Internal Policies et al., 2017 and Buh and Peer, 2022). This is especially valid for younger travellers, according to the Dutch travel bureau Treinreiswinkel (Savelberg, 2019).

This factor has not drawn much attention from the scientific public, with only Curtale et al. (2023) covering this factor for night trains, revealing a significant influence on the probability of choosing this mode. Since effects are expected, this factor is used in the conceptual model according to the theory of planned behaviour, described in chapter 2.

Fear of Flying According to Curtale et al. (2023), the fear of flying is a relevant factor in choosing a night train. Like the environmental attitude, this factor significantly influences the probability of selecting a night train. It is, therefore, added to the conceptual model.

3.2.15. Socio-demographics

Age Age is included in a lot of long-distance mode choice models and found to be significant for various modes, under which are particularly HSR services and the night train (Cascetta et al., 2011, Ku et al., 2023, Bergantino and Madio, 2020, Price and Matthews, 2013 and Heufke Kantelaar et al., 2022). However, it is not completely clear since also some other studies suggest no influence on the probability of choosing modes, particularly the night train (Li et al., 2021, Curtale et al., 2023 and Moors, 2023). In this analysis, age is included in the conceptual model.

Gender Gender is also included in many studies concerning mode choice on long distances. The scientific community is divided regarding the question if gender is relevant for mode choices, whereas some like Ku et al. (2023), Li et al. (2021) and Ren et al. (2020) attribute high importance to gender, others like Curtale et al. (2023), Heufke Kantelaar et al. (2022), Shi et al. (2022) and Bergantino and Madio (2020) neglect this. The effect seems smaller, especially for the mode night train, compared to HSR services. Some grey literature sources attribute an influence of gender on the willingness to use night trains, however, with different conclusions (Höchsmann, n.d. and Buh and Peer, 2022). Due to its relevance in many studies, gender is also included in the conceptual model.

Employment status Except Román et al. (2010), employment status is generally assumed to influence mode choice in the long-distance transportation sector. Among others, Cascetta et al. (2011), Ku et al. (2023) and Van Goeverden (2009) confirm this. Heufke Kantelaar et al. (2022) and Moors (2023) emphasise education level and income more for night trains. In this study, employment status is expected to influence mode choice and is thus included in the conceptual model.

Education level Education level has turned out to be an influencing factor on mode choice in multiple studies like Wang et al. (2017), Heufke Kantelaar et al. (2022) and Bergantino and Madio (2020). In this line, Ren et al. (2020) finds out that lower income and education levels are associated with higher odds of choosing conventional trains over HSR. However, particularly for the mode night trains, the picture is slightly different with Curtale et al. (2023) and Moors (2023) concluding that education is insignificant on a 5% level. This factor is also included in the conceptual model.

Income Most scientific communities agree that income also influences transportation mode choice on longer distances. To name are here particularly Li et al. (2021), Ren et al. (2020), Van Goeverden (2009), Wang et al. (2017) and Heufke Kantelaar et al. (2022). This perception is also existent in the general public (Höchsmann, n.d.). However, some researchers doubt this by finding only a significant effect for certain modes only for HSR services and not for flights or Bergantino and Madio (2020) for HSR services only on particular distances. Regarding night trains, Curtale et al. (2023) is of an opposite opinion compared to Heufke Kantelaar et al. (2022), concluding that income has not a big impact on the willingness to use night trains. Due to the differences in assigned importance, it was decided to include this factor in the conceptual model.

Car ownership Car ownership is a determinant factor in short distances. However, on longer distances, it is less so. Still, Li et al. (2020) and Van Goeverden (2009) found this parameter significant. It was, therefore, added to the conceptual model.

Household composition Lastly, in some studies, household composition is also said to influence the probability of choosing particular modes. Moors (2023) includes this factor and concludes an impact on night train mode choice. However, this factor is not included in the conceptual model because very few studies include it, and it is assumed that the travel group rather than the household composition influences travel behaviour.

3.2.16. Other factors

Several other factors that have been found to have significant effects have been covered in previous analyses. However, in this thesis, they have not been considered relevant for the long-distance mode choice because they have only been covered in a single research and are deemed irrelevant. Regarding operational factors, De Graeff et al. (2020) mentions the travel information during a trip and Yang et al. (2022) the customer service. Probst and Kunze (2014) highlights the importance of cleanliness of night trains for their success while Gardner and Kries (2022) suggests that the scenery might be relevant. According to Van Goeverden (2009), borders and the number of destinations within a trip are relevant factors for long-distance international train travel. Buh and Peer (2022) explains the high share of well-educated train users through residential location choice. Lastly, Van Dalen (2022) adds to the literature by estimating the impact of a perceived COVID-19 risk. None of these factors has been included in the conceptual model.

3.3. Conceptual model

In Figure 3.1, the conceptual model for mode choice in the very long-distance transportation sector is drawn. This model consists of three sub-parts. The choice model is at the centre of the analysis, where it is assumed that decision-makers choose between alternatives and choose the alternative with the maximum utility. Attributes make up the utilities for each of the alternatives. This choice model is assumed to be class-specific, which means that different classes have various preferences regarding attributes. The booking convenience rating model assumes that context, travel experience and socio-demographics influence the importance of booking convenience factors. These factors are expected to impact the booking convenience in the mode choice model. The membership in latent classes is assumed to be determined by the context, psychological variables, socio-demographics and the travel experience. Together with the attributes of the alternatives, latent classes influence the utility of alternatives. Out of all variables, those in grey boxes were not used in the analysis to simplify the models.

Expectations for the Booking Convenience Rating Model Several expectations can be made for the booking convenience rating model. It is expected that having a search engine that compares train and flight connections has the most significant influence on the booking rating and has a positive sign. Furthermore, the single ticket is assumed to be the second most crucial factor. This is the case because the passenger rights state that the passenger is eligible for compensation for a missed transfer, and his further journey is ensured.

Out of the socio-demographics, gender is expected to have no significant difference. A more substantial effect is expected for age, with older people rating booking scenarios more complex than younger people. Similarly, respondents with pensions are expected to encounter more difficulties than working people and students. Regarding the experience with train travel, generally, a better rating of the booking experience is expected. Lastly, business travellers are expected to rank the booking convenience worse than leisure travellers due to lower time availability.

Expectations for the Mode Choice Model Also, for the mode choice experiment, several expectations can be stated. The night train and the plane alternative are expected to be more popular than the HS train alternative because of the high travel time of the HS alternative, which is spent awake. A relatively high joint preference/dislike for the two train modes is expected. This is due to the increasing

Figure 3.1: Conceptual model for mode choice in very long-distance transport

polarisation in society regarding environmental awareness. However, nests between all other combinations might also be existent. HS train and the plane might be in a nest because both harness a hotel to stay in, and the night train and the plane might be in a nest because of similar departure times.

Regarding the attributes, all parameters are expected to influence the attractiveness of modes. Higher total travel times, higher total travel costs, and higher access distances are expected to be disliked, whereas higher accommodation levels, higher booking convenience, and higher reliability are expected to increase the utility of the mode night train.

Expectations for the Class Membership Model Regarding personal variables, the scenario is expected to be relevant for separating into different classes. Whereas business travellers are expected to prefer the plane and dislike the train, leisure travellers are expected to behave opposite. Furthermore, business travellers are expected to prefer higher accommodation levels and are more price-insensitive. The experience with train travel is expected to influence class memberships as well. Train-affine respondents might dislike the plane option more than other groups. Furthermore, train-affine respondents are expected to value travel time less than other groups.

Also, the intention to use environmentally friendly modes is expected to affect the probability of belonging to specific classes. Expecting to have similar effects to experienced train travellers, respondents considering the environment important are expected to dislike the plane compared to other groups. Other expectations regarding attribute preferences, however, are not possible to state. Lastly, socio-demographics are expected to affect class memberships less (Moors, 2023).

4

Survey and model specification

Outgoing from the theoretical framework, the survey and model specification are presented in the following. Firstly, the content of the survey is presented in section 4.1. Then, it is explained how the survey was constructed and distributed in section 4.2. The retrieved data sample is provided in section 4.3 and lastly, the models used to analyse the data are specified in section 4.4.

4.1. Survey content

4.1.1. Alternatives

As stated in chapter 3, this thesis assumes three alternatives: a night train service, an HSR service and a flight. The reasoning is provided in chapter 3. The context specification shows that the case study is scoped on relations from Amsterdam to Barcelona. This implies that the service levels of the chosen alternatives are similar to currently operated services. For flights, this includes the airlines KLM, Transavia and Vueling. For the HS train, Eurostar and TGV services are assumed. For the night train, a hypothetical ÖBB service runs. The new NightJet rolling stock with a maximum speed of 230km/h is considered to be used. For modelling reasons, the HS train was chosen as the base alternative, where attribute levels remain unchanged.

4.1.2. Context

Context comprises various elements as shown in chapter 3. Included in this research are the scenario and the travel group. In total, two different contexts are applied in this stated preference survey.

Scenario Since night trains face profitability issues due to low usage during days Güntert (2021), this thesis focuses on longer distances from 1400km to 1600km. If night trains become popular on these long distances, the profitability of night trains could be improved significantly. A study from DB International GmbH (2013) confirms the potential of night trains on very long distances under reduced track access charges. The most popular flight destinations from Amsterdam were analysed to select a suitable origin-destination relation. Barcelona emerged as the second most popular destination with 1.6 million passengers annually (see CBS, 2021a), only topped by London. Since Barcelona is well within the previously defined distance (1554 km by car), it was chosen for a case study between these two cities. The night train and HS train are assumed to start in Amsterdam Centraal and run via Schiphol and Rotterdam Centraal to Barcelona Sants. For the flight, Amsterdam Schiphol was assumed. Travellers are expected to leave from their home address in the Netherlands and choose the closest railway station or Amsterdam Schiphol for a flight. Following Heufke Kantelaar et al. (2022), the run of a night train can be divided into three phases: a boarding phase, the main running phase and the alighting phase. To ensure high sleeping quality and to simplify the case study, only the stops mentioned above are assumed for the night train, whereas the HSR service calls more stops. These were, however, out of simplicity reasons not defined in the case study.

As Heufke Kantelaar et al. (2022) has shown, night trains are attractive for business and leisure travellers. This thesis focuses thus on both groups. Leisure travellers are considered to be vacation travellers and not those who are visiting friends and family. Depending on the trip's purpose, various travel days are chosen. Business travellers are expected to leave on a Tuesday, whereas leisure travellers are expected to go on a Friday. This assures that they can start their vacation on a Saturday. With a departure on a Friday, it is implied that respondents can still work remotely while taking the HSR service or the flight. For the night train, 19:00 was assumed to be the departure time; for the flight, 16:00; and for the HSR service, 8:00 to reach the destination in the distance of a day. In grey literature, many recommendations exist, especially regarding the optimal arrival times of night trains. Walther et al. (2017) suggests an arrival at around lunchtime for leisure travellers, whereas most other sources like Probst and Kunze (2014), Savelberg (2019) and Gardner and Kries (2022) suggest arrival times in the morning. According to them, the arrival time shall not be too early. In this thesis, the arrival times depend on the services' chosen departure and travel times, which will be presented later. A standard suitcase and a carry-on bag are assumed for leisure travellers, whereas business travellers are supposed to travel only with a carry-on bag.

It is expected that leisure passengers have to pay for the trip themselves, whereas the trip expenses are reimbursed for business travellers. Furthermore, passengers opting for the HSR service and the flight likely must stay in a hotel. It is expected that passengers consider these costs in their decision-making as Buh and Peer (2022) states. The assumed costs are presented later on. Respondents have been selected to be either business travellers or leisure travellers. Those currently working and have travelled internationally have been chosen as members of the business scenario. All other respondents have been selected to use the leisure scenario. Despite potentially underrepresenting people in the working population for the leisure scenario, this approach was chosen because of practicality.

Travel group Depending on the trip's purpose, various travel groups are assumed. Leisure travellers are expected to travel with their usual travel group; however, business travellers are expected to travel alone.

4.1.3. Total travel time

Night train In grey literature, assumptions on the optimal length of a night train ride differ significantly, from not less than 10 hours (Gardner and Kries, 2022) and 12 to 15 hours (Fahnenmüller, 2021) to the suggestion of longer travel times than 24 hours (Back on Track, 2021). A Google search was conducted to compute the realistic travel times of the modes. For current HSR services, travel times from 11:14 h till 12:21 h were derived, leading to the 12 h travel time assumption. For the night train, various attribute levels are assumed. In the slowest case, an average speed of a maximal 90 km/h is taken, leading to a travel time of 17:20 h. This will be rounded up to 18 h and is slightly faster than assumed by Heufke Kantelaar et al. (2022) due to an improved rolling stock and the typography on the line. The 18 h run time case assumes that the night train runs on conventional lines. Since the high speed of the new nightjet rolling stock is 230km/h, it might also be possible to use the high-speed lines. Additionally, assuming shorter stopping times in Paris overnight, running up to 12 hours between Amsterdam and Barcelona seems realistic. At this moment, it is believed that the infrastructure remains unchanged. Through different priority levels on the tracks, different maximum speeds and using the HS infrastructure just partly, running times of 14:00 and 16:00 are also possible.

Flight A total travel time of 5:00 from Amsterdam Schiphol is assumed for the flight. The travel time components are here: 2 hours for dropping off baggage, security and buffer on Schiphol, a six flight of 2 hours, and 1 hour egress time from the airport.

4.1.4. Total travel cost

As stated in the scenario, decision-makers are assumed to include the hotel costs for the flight and HS train alternative. A search on booking.com, the most popular booking site, was conducted for 3-star hotels with a booking horizon of 3 months for February. 80% of the offered hotels were in a price range between 50 EUR and 180 EUR, so 100 EUR were assumed to be a reasonable hotel price.

Night train Since there is currently no night train connection between Amsterdam and Barcelona, two destinations that could be reached by night train in the future have been selected: Budapest (1406 km) and Milan (1073 km). For both destinations, a night train is offered on the longest part of the leg. A hypothetical booking was conducted on the 15th of September with a booking horizon of one day, two months and six months. Since the night train offers different comfort categories, the maximum price was assumed to be the one for the highest comfort category with the shortest booking horizon. Conversely, the night train's lowest price was considered the lowest comfort category with the most extended booking horizon. The highest price derived was 209 EUR for the 16th of September between Amsterdam and Budapest in seating accommodation. Higher comfort categories were not available anymore. For a six-month horizon, tickets were not bookable. For the seating arrangement, prices were 92 EUR with a 2-month booking horizon between Amsterdam and Budapest. From my booking experience, prices have been as low as 40 EUR in seating accommodation between Freiburg and Amsterdam and, for the highest comfort category, up to 250 EUR. It was, therefore, decided to assume a price range between 50 and 290 EUR with intermediate attribute levels of 130 EUR and 210 EUR.

Flight Hypothetical flight bookings have occurred on the same day with the same booking horizons for Amsterdam - Barcelona. The prices ranged between 60 EUR with a 2-month booking horizon and 250 EUR with a booking the day before. Flight costs were therefore assumed to be 50 EUR, 150 EUR, and 250 EUR and added to the assumed hotel price of 100 EUR, which leads to the final attribute values of 150 EUR, 250 EUR, and 350 EUR.

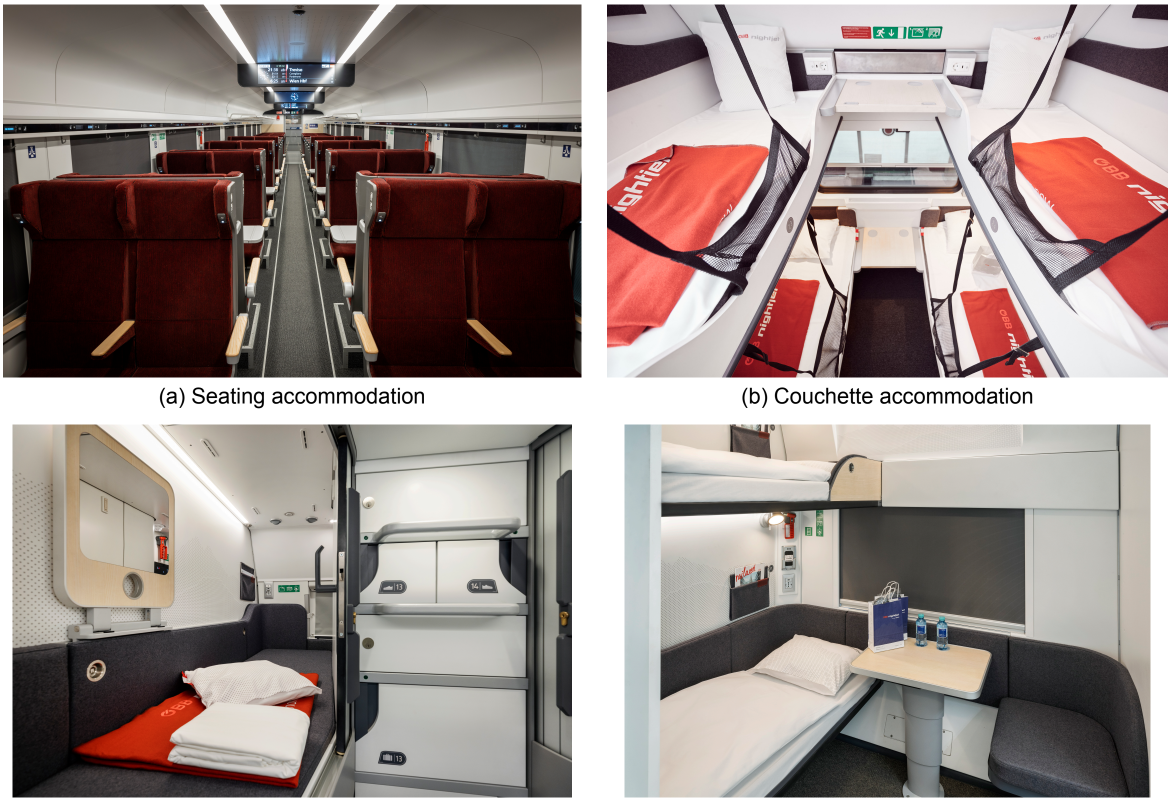
HSR service Lastly, a hypothetical booking of the HS train took place on the 15th of September with the same booking horizons and strategy to derive prices. Again, a booking was impossible six months in advance, and prices ranged between 154 EUR and 261 EUR. Since this alternative is the base alternative, one attribute value had to be chosen. It was decided to assume 150 EUR, as this value was the price with a booking horizon of 2 months, thus considered in the middle of the price range. With an additional 100 EUR costs for accommodation, the final attribute value is 250 EUR.

4.1.5. Accommodation

In the conceptual model, comfort was a decisive factor in the mode choice for night trains. According to Heufke Kantelaar et al. (2022) and Moors (2023), besides the accommodation type, the number of people in a compartment is an essential indicator of the comfort level. To simplify this complex variable, the focus was chosen on the comfort variable only on the accommodation type. The additional advantage is that accommodation types can be easily defined for the other alternatives.

Night train There is traditionally a seating carriage, a couchette, and a sleeper carriage in night trains. The seats are either in a six-seat compartment or an open carriage. Couchette accommodations commonly comprise six berths, which are narrower and more rigid than ordinary beds. Sometimes, couchette apartments also comprise four berths. Sleeper accommodation with two or three beds is frequently offered. Here, a bathroom is included in the carriage or the compartment in the more luxurious sort. This most luxurious manner of travelling on a night train can be compared to a single or double-bed hotel room. The Austrian Railways ÖBB run their fleet under the Nightjet brand and is a clear market leader in the European night train market, offering multiple connections from the Netherlands. From December 2023 to 2025, ÖBB will receive 33 new trains (Rieder, n.d.-b). Since this thesis will focus on this type of rolling stock, it will be quickly presented. The rolling stock of the nightjet can generally be considered a classical night train, offering various comfort categories. Besides providing a seating carriage, a couchette carriage has four berths. A new accommodation type from Japan, inspired by capsule accommodation or mini cabins, has been introduced, which offers more privacy for solo travellers.

The sleeping cabin or sleeper is the most luxurious way of travelling in the new Nightjet, offered in comfort and the comfort plus variant. The only difference is the more spacious compartment in the comfort plus variant (Rieder, n.d.-a). The stated preference survey assumes these four accommodation categories for the night train, and an overview of these categories is provided in Figure 4.1. For the seating arrangement, a maximum occupancy of 2/3 for the 60 people in a big carriage is considered, thus leading to 40 people in a carriage. For the shared couchette, it is believed that the compartment has to be shared with up to three strangers and that bedding and a pillow are provided. The mini cabin is supposed to have a similar comfort to the couchette but provides privacy through a lockable compartment. The private bedroom is considered to be identical to a hotel room, consisting of a comfortable bed that does not need to be shared with strangers. Included in the room are a toilet, a shower and two beds.



(a) Seating accommodation

(b) Couchette accommodation

(c) Mini Cabin accommodation

(d) Sleeper accommodation

Figure 4.1: Accommodation categories of the night train

Flight and HSR service For the flight alternative, it was decided not to vary comfort levels. Economy class is assumed since most people use this class. Similarly, people are considered to use second-class in the HSR service.

4.1.6. Access distance

The access distance towards the closest railway station or the airport was derived by asking people directly. The distance was defined as the distance by car to reach the transportation hub. For privacy reasons, it was impossible to derive the Postcodes of people responding for privacy reasons. By asking respondents directly, errors occur that are not possible to relieve. However, in some cases, respondents stated that Rotterdam was closer than Amsterdam but inserted higher distances for Rotterdam. In this case, the data set was modified, and the distance towards Amsterdam was assumed for Rotterdam.

4.1.7. Booking convenience

In this report, it was decided to conceptualise booking convenience twofold. Firstly, respondents were asked directly what they considered important while booking. This was done to understand the problems respondents currently face when booking international train connections. Since this procedure is prone to biases, the second step, booking scenarios, was constructed following the conceptual model. These booking scenarios then make up the booking convenience rating used in the mode choice experiment.

Booking experience experiment Firstly, respondents were filtered to derive answers for only those who have conducted an international train booking themselves in the last two years. Before evaluating different parts of the booking, respondents had to mention the booking site on which they booked their tickets. Furthermore, they had to say why they booked on this website. Because the population is assumed to be Dutch travellers, it was decided to use typical Dutch booking sites for international train connections. Several reasons for choosing a booking site are expected: The coverage of many train connections, the cheapest connection, habit, the availability in Dutch, payment options, user-friendliness, speed and reliability and the integration with other services such as hotels. All of these reasons were given to the respondent, with the option to name another reason. The possibilities were derived through online research. Furthermore, respondents were asked if booking took place only on this site. This revealed preference question makes determining whether people can book tickets on multiple sides possible. They requested an estimate to familiarise people with the booking time to search and book the trip. This furthermore enables us to validate this aspect used in the rating experiment.

Most importantly, people were asked to rate different steps of the booking process from 'very difficult' to 'very easy'. Here, a different perspective was chosen compared to the booking scenarios. Whereas in the scenarios, the point of view is current pain points in booking international train connections, the point of view of the revealed preference questions is the user journey of the client. This journey starts by finding the right website or app for booking and continues with checking the availability of tickets in the desired comfort category on the desired date. Then, people usually compare travel options and choose the most suitable one. In the last step, people are requested to rate the difficulty of entering their contact details, such as name, email address and phone number, paying the ticket, receiving a payment confirmation and receiving the ticket. Respondents were asked to rate the booking overall according to the difficulty of rounding the questionnaire off.

Rating experiment The five aspects used in the rating experiment, with their extensive description in the survey, will be explained in more detail below. All factors are binary.

A search engine comparing various train and flight connections by departure time, travel time, comfort, and price enables one to buy the cheapest ticket, similar to Skyscanner or Google Flights. The two offered attribute levels are whether the search engine exists or not.

The second variable describes if the entire trip can be booked as one ticket, which enables rebooking to be possible free of charge in case of a missed transfer.

Regarding the earliest possible booking date, two horizons were assumed. At the lower end, one month is considered the booking horizon for Polish intercity services. Furthermore, at the end of each year, the booking horizon shrinks to two months in multiple European countries because of timetable changes. At the higher end, a booking horizon of six months is assumed, which is when most Dutch people book their vacation and the current booking horizon of the German railways DB.

To derive attribute values for the time to search and book a connection, a study from Preslmayr et al. (2021) was consulted, where respondents were asked to book connections for various European destinations. Instead of providing average booking times, a distribution of booking intervals was provided. Taking the means of the intervals and averaging, an average booking time for flying of 8.59 minutes was derived, and for the train, 13.66 minutes was reported. Since in one-third of the cases, the booking time for the train was between 15 and 30 minutes, it was chosen to use the attribute levels 5 min and 20 min.

Lastly, the factor of a ticket provided digitally and on paper is included, with one attribute level being the ticket only available on paper and the other digitally and on paper. Meanwhile, all popular airlines offer smartphone apps to display flight tickets, which might be more cumbersome for railway companies. This is primarily the case for tickets within a country but not necessarily for international rail and night train connections. If a trip is booked on the website of Nightjet, the market leader of night trains in Europe, a ticket officially has to be printed out to be valid.

Choice experiment In the choice experiment, respondents will be presented with a booking scenario ranking in three attribute levels, ranging from "very difficult" to "very easy" via "not easy and not difficult".

4.1.8. Reliability

As seen in the theory part, reliability is differently conceptualised in literature. In this thesis, it will be defined as the 80% confidence interval, with 80% of arrivals being delayed by this threshold or less. This methodology has been applied before for shorter distances (Swierstra et al., 2017). Grey literature has been consulted to derive reasonable attribute levels. According to Eurocontrol (2023), 80% of flights were delayed by 30 minutes or less, whereas 80% of trains were on time. Thresholds for being on time vary between countries but are generally more restrictive than flights. However, night trains are assumed to be more prone to delays due to their long running distances. Therefore, the attribute levels of 15 min, 30 min, and 45 min were chosen to cover various delay scenarios.

4.1.9. Travel experience

Travel experience is added through three different variables. These are the usual travel frequencies by train, the last international train travel and the last international night train travel. Using these three indicators enables a nuanced description of the train travel experience, with people using trains just for their everyday lives expected to have less experience than those with international train or even night train experience.

The usual travel frequency by train was derived indirectly. As shown in chapter 2, the survey was distributed via the NS panel, where respondents had to fill in socio-demographic background data to sign up. One of these background data is the usual train frequency, which was harnessed.

Experience with international trains has been asked scenario-dependently to derive insights into differences in experiences between business and leisure travellers. Therefore, some people reported their last international train travel for business purposes and others in general.

Lastly, the last international night train travel was asked scenario-independently to simplify analysis.

4.1.10. Psychological Variables

Out of the two psychological variables added to the conceptual model - the fear of flying and the intention to use environmentally friendly modes - it was decided only to use the latter in the stated preference research. Whereas Curtale et al. (2023) mentions that both factors are relevant, the general public seems to focus more on environmental protection as a reason to choose night trains. Because of the general public's opinion and simplicity, it was only chosen to measure the intention to use environmentally friendly modes of transportation.

According to Ajzen (2012), an attitude, the subjective norm, and the perceived behavioural control lead to behaviour. These three elements will be measured through the three statements below. The first is how much respondents agree with the importance of using environmentally friendly modes such as cycling or public transport. The subjective norm is measured through essential people for the respondents (family and friends) motivating them. Lastly, the perceived behavioural control is measured by asking if respondents would be willing to use environmentally friendly modes of transportation, even if it might be inconvenient in some situations.

4.1.11. Socio-demographics

Age Age has been included as a socio-demographic potentially influencing long-distance mode choice for night trains. Respondents were not asked directly since this information is provided via the NS panel as described in chapter 2. However, for privacy reasons, it was impossible to derive exact values for the age of the respondents. Only age ranges with the size of 10 years were provided. Therefore, respondents were assumed to have the mean age of the range.

Gender Gender was also provided via the NS panel background data.

Education For privacy reasons, it was impossible to derive data on respondents' education. However, from earlier research about night trains using the NS panel Heufke Kantelaar et al. (2022), it was concluded that the data set is biased towards higher educated respondents.

Employment status Separating the respondents into business and leisure travellers made it possible to derive employment status data. The question was initially asked, with various categories to choose from. The categories are employee, employer, freelancer, without work, unable to work, in pension and pupil or student.

4.1.12. Overview over attribute levels

In the previous sub-sections, reasons were provided as to why specific attribute levels were chosen. In Table 4.1, an overview of the used attribute levels is provided.

Table 4.1: Overview over attribute levels

Overview attribute levels			
Mode choice experiment			
	night train	flight + hotel	HSR service + hotel
Total travel time	12, 14, 16, 18 h	5 h	12 h
Total travel cost	50, 130, 210, 290 EUR	150, 250, 350 EUR	250 EUR
Accommodation	seat, couchette, mini cabin, sleeper	Economy class	second class
Booking	very difficult, not difficult and not easy, very easy	very easy	very difficult
Delay	20% chance that delay is 15 min/ 30 min/45 min or longer	20% chance that delay is 30 min or longer	20% chance that delay is 30 min or longer
Booking rating experiment			
Search engine does/ does not compare various train and flight connections on departure time, travel time, comfort and price			
Booking on a website is/is not possible			
Earliest possible booking date is 1/6 months before the trip			
Average time needed to search and book a connection is 5/20 minutes			
Ticket is on paper/digital on your smartphone only			

4.2. Survey construction and distribution

4.2.1. Choice set generation

After defining the attributes and covariates with their attribute levels, choice sets were generated using the software tool ngene. The complete source code is provided in section B.2. Since including attributes like reliability has not been done before for night trains, determining priors might be tedious. Therefore, it was chosen for the more traditional orthogonal fractional factorial design for both experiments, the choice and rating experiments. The advantage of this approach is that all attribute values are included in the choice sets the same amount of times while not leading to too many choice sets like when a complete factorial design would have been used.

For the booking rating experiment, an unlabelled design is possible, leading to a sequential design (see ChoiceMetrics, 2018). Here, only one alternative had to be specified with attribute values. The second alternative was set to be the reference alternative. Ngene was able to find an orthogonal fractional factorial design with eight rows.

Three alternatives have been used in the mode choice experiment, of which the HSR service was the reference alternative. Because of having labelled alternatives, a simultaneous generation of the choice sets had to be applied. With the help of ngene, an orthogonal fractional factorial design was found for the mode choice experiment with 36 choice tasks. One interaction effect is assumed between the accommodation and the travel time, following previous research of Heufke Kantelaar et al. (2022). To limit the number of choice tasks each respondent faces, it was chosen to apply to block. With four blocks, the choice tasks were reduced to two for the booking convenience rating experiment and 9 for the mode choice experiment.

4.2.2. Necessary number of responses

It is more difficult to derive significant parameters without enough responses. To determine the survey construction and distribution, assuming a minimum number of responses is needed is helpful. Orme (2010) provides an indication with Equation 4.1.

$$\frac{n \cdot t \cdot a}{c} \geq 500 \tag{4.1}$$

In this formula, n denotes the minimum of needed responses, t the number of choice tasks and a the alternatives. c is the maximum number of attribute levels in any attribute (Heufke Kantelaar et al., 2022). The minimum number of needed responses for the booking rating experiment is provided in Equation 4.2 and for the mode choice experiment in Equation 4.3.

$$n \geq \frac{500 \cdot c}{t \cdot a} = \frac{500 \cdot 2}{2 \cdot 1} = 500 \tag{4.2}$$

Table 4.2: Response rate of invited respondents

First batch				Second batch			
Age group	Invited	Part.	Response rate	Age group	Invited	Part.	Response rate
18-24	977	107	10.95%	18-24	13	2	15.38%
25-34	1022	143	13.99%	25-34	109	20	18.35%
35-44	725	116	16.00%	35-44	45	17	37.78%
45-54	783	155	19.80%	45-54	82	25	30.49%
55-64	242	70	28.93%	55-64	157	63	40.13%
65-74	238	71	29.83%	65-74	62	28	45.16%
75+	956	216	22.59%	75+	16	8	50.00%

$$n \geq \frac{500 \cdot c}{t \cdot a} = \frac{500 \cdot 4}{9 \cdot 2} = 111 \tag{4.3}$$

4.2.3. Survey construction

To accurately represent the Dutch population aged 18 or higher, it was decided to use the NS panel as described in chapter 2. The survey was constructed in collaboration with the company MWM2, a subcontractor who manages the panel for NS. The author of this thesis designed all the questions. The questions were distributed in Dutch, for which a MWM2 employee provided some assistance regarding correct spelling and clearness.

27 fellow students tested the questionnaire. Suggestions for improvements were considered, especially regarding the layout of the mode choice scenarios and the number of available travel groups. Furthermore, the time to complete the survey was controlled for six of the fellow students to prevent the study from being too extensive.

An example of the booking convenience rating experiment questions and the mode choice questions is provided in Figure 4.2. The figure is, however, in Dutch. The complete survey, including the booking experience experiment, can be found in section B.2.

4.2.4. Survey distribution

The survey was initially distributed on the 19th of October when 4,945 respondents were invited. Based on a recommendation of an MWM2 employee, it was aimed to mimic the Dutch population as closely as possible. On the 24th of October, a reminder was sent. Since some additional respondents were aimed for, especially for business travellers, 516 respondents were asked on the 27th of October. Lastly, on the 31st of October, a second reminder mail was sent. The survey was finally closed on the 6th of November. Out of the total invited 5,461 respondents, 1,062 answered the survey, resulting in a response rate 19.5%, thus having significantly more responses as needed to derive significant parameters.

4.3. Data sample

4.3.1. Socio-demographic composition

The dataset comprises 1062 responses, as seen in Table 4.3. Due to a programming error, receiving mode choice data for 1031 responses was only possible. The socio-demographic statistic for this group is, however, still valid. The male population is slightly overrepresented, while the age distribution closely aligns with the Dutch population. Notably, there is an underrepresentation of respondents aged 55 to 74, with an overrepresentation observed from 75 onwards. The dataset predominantly includes individuals from the working population and retirees, followed by students. Regarding geographical distribution, respondents are scattered throughout the Netherlands, with over a quarter residing more than 100 km from Schiphol. In summary, from a socio-demographic standpoint, the data appears to mirror the Dutch population reasonably well. However, it is noteworthy that panel members who participated in similar

[1] compared to CBS, from 15 to 90 years old
[2] no meaningful comparison possible
[3] no meaningful comparison possible

En als u kijkt naar onderstaand boekingsscenario, hoe makkelijk of moeilijk zou u het boeken van uw treinreis beoordelen?

	Kenmerken
	Zoekmachine die diverse trein- en vluchtverbindingen op vertrektijd, reistijd, comfort en prijs vergelijkt
	Voor de gehele reis moet u **meerderde tickets** boeken, omboeken in het geval van een gemiste overstap is niét gratis
	Vroegst mogelijke boekingsdatum is **zes maanden voor de reis**
	Gemiddelde tijd nodig om een verbinding te zoeken en te boeken is **20 minuten**
	Het ticket is **alleen op papier**

- ◯ Zeer moeilijk
- ◯ Moeilijk
- ◯ Niet moeilijk, niet makkelijk
- ◯ Makkelijk
- ◯ Zeer makkelijk

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	**Nachttrein**	**Vliegtuig + Hotel**	**Dagtrein + Hotel**
	Vertrek- en aankomsttijd	19:00 – 11:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	16 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 210,-	€ 350,-	€ 250,-
	Accommodatie	Privé compartiment	Economy class	2e klas
	Uw verwachte boekingsgemak	Niet moeilijk, niet makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **45 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- ◯ De nachttrein
- ◯ Het vliegtuig
- ◯ De dagtrein

Figure 4.2: Booking convenience rating experiment and mode choice experiment

Table 4.3: Socio-demographic characteristics

Socio-demographic	**Category**	**Abs. Number**	**Percentage**	**Dutch Pop.** [1]
Gender	Male	554	52.2%	49.4%
	Female	487	45.9%	50.6%
	Other	16	1.5%	0.0%
	Rather not answer	5	0.5%	0.0%
	Total	1062	100%	
Age	18 - 24	119	11.2%	11.0%
	25 - 34	163	15.3%	16.0%
	35 - 44	133	12.5%	14.8%
	45 - 54	180	16.9%	16.6%
	55 - 64	133	12.5%	17.0%
	65 - 74	99	9.3%	13.7%
	75 +	224	21.1%	11.0%
	Unknown	11	1.0%	0.0%
	Total	1062	100%	
Profession [2]	Pupil or student	89	8.4%	
	Employee	543	51.1%	
	Employer with personnel	10	0.9%	
	Employer without personnel	59	5.6%	
	Unfit for work	20	1.9%	
	Unemployed/job seeking	19	1.8%	
	Retired	303	28.5%	
	Other	19	1.8%	
	Total	1062	100%	
Distance to Schiphol [3]	Less than 20 kilometres	90	8.5%	
	20-40 kilometers	179	16.9%	
	40-60 kilometers	242	22.8%	
	60-80 kilometers	89	8.4%	
	80-100 kilometers	133	12.5%	
	100-150 kilometers	182	17.1%	
	150-200 kilometers	104	9.8%	
	More than 200 kilometers	43	4.0%	
	Total	1062	100%	

studies Heufke Kantelaar et al. (2022) were found to be highly educated, with a significant percentage reporting meagre income, particularly students.

4.3.2. Train travel experience

In terms of representing the Dutch population's experience with national rail, international rail, and night train travel, a general overrepresentation of train travellers in the sample is persistent. This is mainly the case in international and night train travel. While the average Dutch population is reported to be in the train approximately 13 times per year (CBS, 2022), this sample reveals in Table C.1 in Appendix C that 23.8% to 47.7% of respondents are in the train 13 times or less per year, suggesting a potential bias towards more frequent train users.

Almost half of the 813 respondents with a leisure scenario (42%) and 45% of the 249 respondents with a business scenario have travelled internationally by train in the last 12 months. This high percentage of international travel, in combination with over 25% of the respondents having travelled by night train within the previous two years, suggests substantial train experiences. Furthermore, among the 551 respondents who have used night trains, the recency of their last night train experience varies significantly, ranging from within the previous year to over a fifth of respondents having travelled the last time by night train before the year 2000. This variability implies potential differences in the respondents' memory of comfort, reliability, and other factors related to night train travel.

4.3.3. Intention to use environmentally friendly modes

The representability of the sample regarding the willingness to use environmentally friendly modes is questionable. Firstly, 80% of respondents express a high level of importance in using environmentally friendly modes, which might supposedly be more than in the Dutch population (Table C.2 in Appendix C). On the contrary, family and friends only motivate respondents slightly more than on average to use environmentally friendly modes.

However, the most pivotal aspect emerges from the finding that two-thirds of all respondents agree or agree to opt for environmentally friendly modes, even if it entails discomfort or inconvenience. However, a survey from CBS (2021b) indicates that only 9% of all car travellers, constituting 37% of the population, actually reduce car usage due to climate impact. This stark contrast suggests that the dataset may overestimate the willingness to use environmentally friendly modes. These findings should be considered with a degree of caution, and potential biases should be accounted for.

4.3.4. Mode choice split

In Figure 4.3, the diversity of mode choices becomes apparent across different decision scenarios. On average, the HS train is selected in 23.2% of cases, while the night train is the most favoured option at 42.7%, and the plane follows closely at 34.1%. This distribution suggests that each mode represents a viable alternative. Examining the maximum and minimum shares for each mode, we observe that the HS train, night train, and plane reach peaks at 59.4%, 84.0%, and 59.8%, respectively, and lows at 6.4%, 7.6%, and 7.6%. This broad range of utility coverage in the experiment implies that each transportation mode appears attractive in specific scenarios and less so in others, reflecting a comprehensive exploration of preferences and choices.

4.4. Model specification

After designing the survey and conducting an initial analysis of the representability of the acquired data, further specification steps are needed to analyse the booking convenience experiment and the mode choice experiment. Firstly, the estimation strategy is provided, variables are coded, and expectations are set.

4.4.1. Booking convenience rating experiment

Coding In Table 4.4, all variables used to determine the booking convenience are presented. Note that for nominal variables, it was chosen to apply effects coding. Variables on a ratio scale have not been coded.

Some simplifications from the derived data had to be applied to receive a simpler model. Firstly, in the survey, respondents could provide various answers for their gender, including that they wish not to state their gender. To simplify, it was chosen to aggregate people with diverse genders, who would

Table 4.4: Variables and applied coding of variable levels for the booking rating experiment

Factor	Level	Variables and applied coding		
Main attributes				
Search engine		search_engine		
	Search engine comparing various train and flight connections by departure time, travel time, comfort and price	1		
	No search engine comparing various train and flight connections on departure time, travel time, comfort and price	-1		
Single ticket		one_ticket		
	You can book one ticket for the entire journey; rebooking in case of a missed transfer is free of charge	1		
	For the entire trip, you must book multiple tickets; rebooking in case of a missed transfer is not free of charge	-1		
Earliest booking date		earliest_booking		
	Earliest possible booking date is six months/one month before the trip	ratio scale		
Booking duration		time_booking		
	Average time needed to search and book a connection is 5/20 minutes	ratio scale		
Digital ticket		digital_ticket		
	It is possible to travel with a digital ticket (on your smartphone); a paper ticket is also possible	1		
	The ticket is on paper only	-1		
Socio-demographics				
Age		age		
	Mean of respondents age group	ratio scale		
Gender		gender		
	Female	1		
	Male and other	-1		
Workstatus		student	retired	working
	Student	1	0	0
	Retired	0	1	0
	Working	0	0	1
	Else	-1	-1	-1
Context				
Scenario		scenario		
	Business	1		
	Leisure	-1		
Travel group		alone	partner	
	alone	1	0	
	with partner	0	1	
	other	-1	-1	
Train experience				
Usual train frequency		usual_train		
	Once or multiple days a week	1		
	Else	-1		
International trains		intl_train		
	Travelled at least once in the last 2 years by train	1		
	Else	-1		
Night trains		night_train		
	Travelled at least once in the last 2 years by train	1		
	Else	-1		

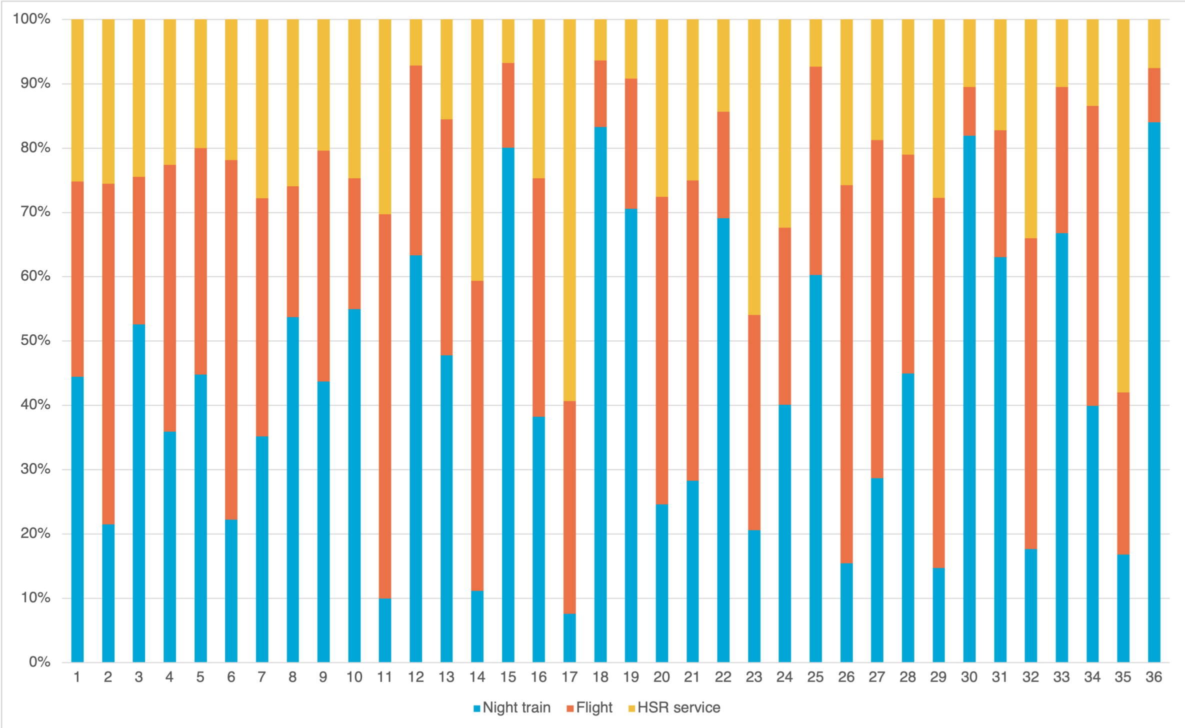


Figure 4.3: Modal split for various responses

instead not provide their gender and male into one group. Similarly, it was possible to offer various work statuses. Here, it was simplified to students, retired, working and others. Travel groups were simplified to alone, with partners and others. The train experience also had to be simplified, with the usual train frequency divided into travelling once or multiple days a week and regarding international and night train travel having had experience at least once in the last two years.

For access, it was necessary to modify the data due to irregularities. Some respondents mentioned in their survey that they live closer to Rotterdam Centraal than to Amsterdam Centraal despite providing a shorter distance from their home towards Amsterdam Centraal. This measurement error was corrected. Furthermore, for the given interval, the mean value was assumed.

The choice variable is the booking convenience rating on an interval scale, where 5 denotes a very comfortable booking, and 1 denotes a highly complex booking scenario.

Model selection for booking convenience As stated in the methodology, linear regression has been used to determine the importance of factors comprising booking convenience. After estimating the basic model with only attributes, covariates were step-wise in groups added. Firstly, socio-demographics were added, then the context and the train experience. Each group was tested via an F-test to determine if this group significantly reduces the unexplained variance of the model. Since literature regarding booking convenience interactions is rare, no interactions are assumed. For the implementation, the statsmodels package and the programming language python have been used (see Seabold and Perktold, 2010). The code is provided in section D.1.

4.4.2. Mode choice experiment

Coding In Table 4.5, the coding for all variables is presented, used in the code provided in Appendix D. Note that most variables are on an interval or ratio scale and do not have to be explicitly coded. However, some scaling was conducted to improve parameter estimation. Other nominal coded variables like accommodation, work status, travel group, gender, the scenario and train experience variables are effects coded.

Table 4.5: Variables and applied coding for the mode choice experiment

Factor	Level	Variables and applied coding		
Main attributes				
Total travel time night train		tt_ntrain		
	12, 14, 16 and 18 hours	ratio scale: 1.2, 1.4, 1.6, 1.8		
Travel cost night train		tc_ntrain		
	50, 130, 210, 290 EUR	ratio scale: 0.50, 1.30, 2.10, 2.90		
Accomodation for the night train		sleeper	minicabin	couchette
	Private sleeper	1	0	0
	Private mini cabin	0	1	0
	Shared couchette	0	0	1
	Seat	-1	-1	-1
Booking convenience		book		
	Very easy	5		
	Not difficult, not easy	3		
	Very difficult	1		
Access distance train		distance_station		
	distance of the respondent towards the station	ratio scale, divided by 100		
Delay		delay		
	20% chance of a delay of more than 15 min, 30 min and 45 min	ratio scale, converted into hours: 0.25, 0.5, 0.75		
Total travel cost plane		tc_plane		
	150, 250, 350 EUR	ratio scale: 1.50, 2.50, 3.50		
Access distance flight		distance_plane		
	distance of the respondent towards the airport	ratio scale, divided by 100		
Socio-demographics				
Age		age		
	Mean of the respondents age group	ratio scale		
Gender		gender		
	Female	1		
	Male and other	-1		
Workstatus		student	retired	working
	Student	1	0	0
	Retired	0	1	0
	Working	0	0	1
	Else	-1	-1	-1
Context				
Scenario		scenario		
	Business	1		
	Leisure	-1		
Travel group		alone	partner	
	Alone	1	0	
	With partner	0	1	
	Other	-1	-1	
Train experience				
Usual train frequency		usual_train		
	Once or multiple days a week	1		
	Else	-1		
International trains		intl_train		
	Travelled at least once in the last two years by train	1		
	Else	-1		
Night trains		night_train		
	Travelled at least once in the last two years by train	1		
	Else	-1		
Intention to use environmentally friendly modes				
Importance to use environmentally friendly modes		importance_env		
	5 levels of agreement from completely agree to completely disagree	Interval scale from 5 (comp. agree) to 1 (completely disagree)		
Social pressure to use env. friendly modes		pressure_env		
	5 levels of agreement from completely agree to completely disagree	Interval scale from 5 (comp. agree) to 1 (completely disagree)		
Usage of env. friendly modes under inconvenient circumstances		inconvenience_env		
	5 levels of agreement from completely agree to completely disagree	Interval scale from 5 (comp. agree) to 1 (completely disagree)		

Model selection for MNL and Panel ML model To determine factors influencing the probability of choosing the mode night train on average, it was decided to use the MNL model and the Panel ML model. It was assumed that preferences for attributes among respondents are homogeneous for both models. However, preferences for modes are expected to be heterogeneous in the ML model, significantly leading to a higher model fit and more reliable results. The MNL was also estimated due to its simplicity, widespread usage and fast computation times.

Firstly, the MNL model is estimated only with attributes, thus only with total travel time, total travel cost, accommodation, access distance, booking convenience and reliability. Then, non-linearity was assumed for the booking convenience and the travel time. A Likelihood Ratio Test test determines whether the model, including non-linearity, fits the model better than the one without. Due to an LRS statistic of 15.15, more significant than the threshold value of 5.99, it can be concluded that the MNL model, including non-linearity, fits the data better than the model without. The coding of the test, including log likelihood (LL) values of the models, is provided in Appendix E.

After defining the optimal model specification through the MNL model, this specification was used to estimate the Panel ML model. Two decisions have been made for the Panel ML model: The number of Halton draws and the nesting structure. Three different nesting structures were tested simultaneously with the smallest number of Halton draws, defined as 50. It was assumed that the joint preferences of respondents could emerge between all binary combinations of the three alternatives. A nest between the two train options is the most logical due to customers' similar comfort expectations. But also other joint preferences might exist. For example, respondents might consider the flight and the HSR service identical due to both options offering a hotel stay. Lastly, the night train and the flight might also be considered identical due to the similar comfort levels provided. All mutual mode preferences (nesting effects) have been estimated jointly.

After estimating the ML model with 50 Halton draws, it was chosen to double the number of draws to 100. As seen in Table E.1 in Appendix E, the estimated parameters have converged, indicating that 100 Halton draws are sufficient to derive reliable parameters.

Lastly, the Ben-Akiva & Swait test has been used to compare the MNL model with the Panel ML model. In Equation 4.4, it is confirmed that the Panel ML model is with a probability of almost 100% superior to the MNL model. Therefore, the Panel ML model with 100 Halton draws will be used for further analyses. In Table E.2 in Appendix E, the LL values of the models are presented along with their ρ^2 values.

$$p = NormSDist(-\sqrt{2 \cdot 9588 \cdot ln(3) \cdot \frac{-8801.41 + 6290.41}{-10,194.02}}) = NormSDist(-72.04) < 0.001 \quad (4.4)$$

Model selection for the Panel LCCM Panel LCCM enable the division of the population into latent classes, which have preferences regarding the importance of attributes. When estimating a MNL or Panel ML model, the LL function is globally concave, meaning that the optimisation algorithm automatically finds the global maximum. LCCM, on the other hand, are not globally concave, meaning that the optimisation algorithm can get stuck in local maxima or even saddle points (see Hernandez, n.d.). Therefore, selecting starting values is crucial in determining the model's outcome. In this thesis, it was chosen to apply the 'searchStart' function of the software package apollo (see Hess and Palma, 2023). This function explores 100 potential starting value candidates and selects, after iterating five times, the candidate with the highest LL value. After applying this function, the actual optimisation uses the starting values.

Secondly, the number of classes has to be determined by the researcher. Here, usually, discrete mixture models with various numbers of classes are estimated. These are models without a class-membership function. In this thesis, it was decided to estimate Panel LCCM from 2 to 5 classes. Five classes were not exceeded due to the facilitation of simple explanations. For each model, it was decided to search first for optimal staring values before estimating the model. The estimation results with LL values, Bayesian information criterion (BIC) values and the number of parameters are provided in Table E.3 in Appendix E. Despite the model with five classes performing superior, even corrected for additional parameters, it was chosen for four classes. The main reason for this is that in the model with four classes, 59 parameters are already estimated. Interpreting 74 parameters like in the Panel

LCCM model with five classes is challenging. Furthermore, an analytic estimation of the model with five classes was not possible, which could indicate overfitting.

Lastly, the Panel LCCM and the Panel ML model were compared regarding model fit, despite both models having different goals and answering other questions. Whereas the former highlights heterogeneity regarding attribute and mode preferences, the latter showcases average effects while accounting for joint preferences for modes. Through a Ben-Akiva and Swait test in Equation 4.5, it could be determined with almost 100% certainty that the Panel LCCM fits the data better than the Panel ML model.

$$p = NormSDist(-\sqrt{2 \cdot 9588 \cdot ln(3) \cdot \frac{-6,290.41 + 5940.19}{-10,194.02}}) = NormSDist(-26.90) < 0.001 \quad (4.5)$$

The Python programming code for the regression model, the MNL model, Panel ML model and Panel LCCM is provided in Appendix D.

5 Results

This chapter on results aims to answer sub-questions 1 to 4 by analysing the data retrieved from the survey. To achieve this, in section 5.1, an overview of the current booking behaviour of Dutch citizens is provided, and factors are derived that comprise a convenient booking situation. In section 5.2, the second part of sub-questions 1 and 2 is answered, providing insights into the importance of operational factors in the decision-making process. Then, section 5.3 provides insights into heterogeneity, revealing four latent classes and answering sub-question 4. Lastly, section 5.4 answers sub-question four by exploring possible market shares for night train services, flights and HSR services under various scenarios.

5.1. Booking experience and components of a convenient booking

5.1.1. Booking experience of Dutch citizens

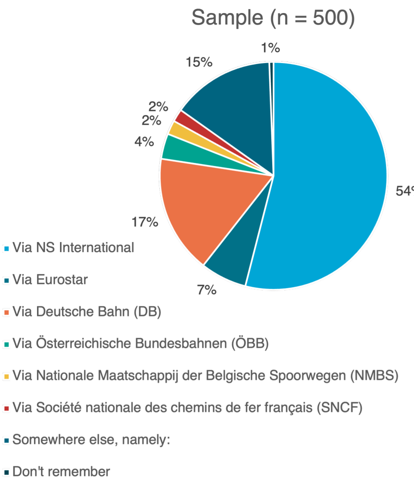
Most Dutch respondents choose to book their international train travel on NS International (see Figure 5.1a). After the German National Railways Deutsche Bahn being the second most popular booking site, Eurostar emerged as the third most popular.

The booking site appears to be the only one where people have booked, as seen in Figure 5.1b. This indicates that people will not travel at all with international rail services if booking them on one website is impossible. They are not willing to take the risk of missing connections without travelling rights.

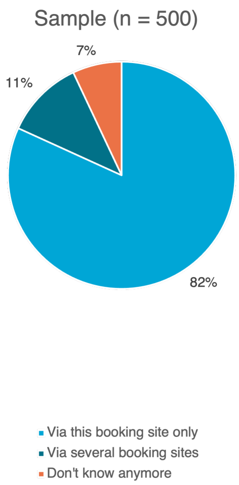
For Dutch citizens, the most popular reason to choose booking sites is out of habit, as visualised in Figure 5.1c. This implies a great reluctance to switch to other booking sites. Furthermore, user-friendliness, speed and reliability are factors. Generally, respondents named a lot of factors to be similarly significant. For example, the speed and reliability, the coverage of many train connections and the offer of the cheapest train connection are equally important. The differences between leisure and business travellers are not as stark as expected, with business travellers emphasising habit and user-friendliness slightly more than leisure travellers.

In Figure 5.1d, the booking difficulty is drawn for several stages of the booking process. Overall, respondents seem to be content with their overall booking experience. In particular, entering the contact details, paying, and receiving the payment confirmation works well. However, more difficulties emerge in the first three stages of the booking process. Comparing travel options for international train connections is the biggest problem when booking. Over a third of the respondents mention that comparing train travel options is complex or challenging. Furthermore, 20% of the respondents mention that finding available tickets is complex or challenging. Finding a fitting website is for over 15% of the respondents problematic. Train operators should, therefore, focus on increasing the availability of transportation options and improving the comparability of train options.

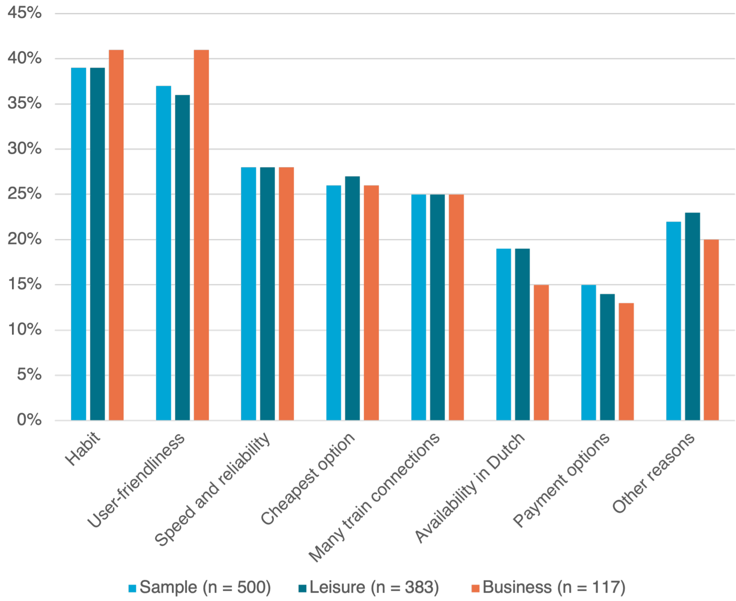
In Figure 5.1, the minutes people estimate to need for the booking process are shown. This is the search and choice for the best connection after knowing the departure and arrival location. In the histogram, it was chosen for steps of 10 min. Whereas most people estimate the booking process to be shorter than 20 minutes, many respondents estimate it to be busy for more than one hour. This could imply that the respondents did not entirely understand the factor, that people have a lot of difficulties



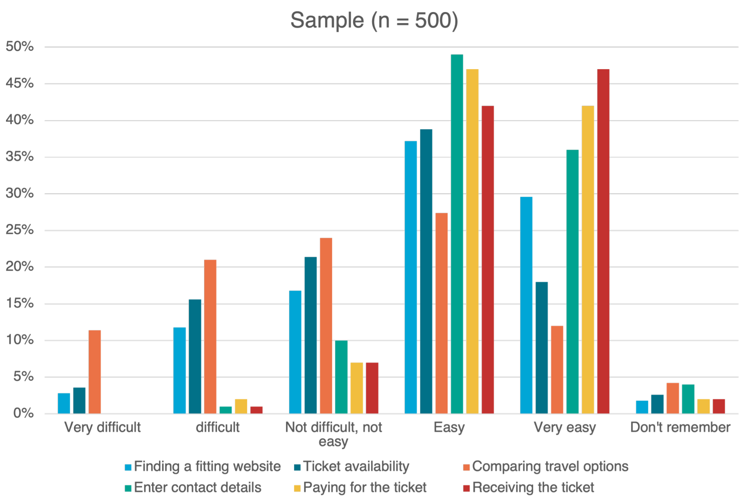
(a) Booking sites of Dutch travellers



(b) Inclination to use multiple booking sites



(c) Reasons for choosing booking sites



(d) Difficulties in the booking process

Figure 5.1: Booking experience of Dutch travellers

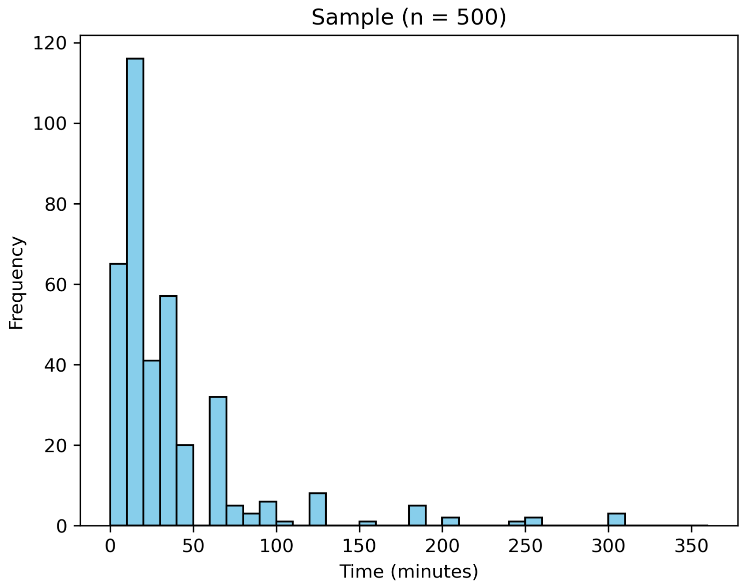


Figure 5.2: Estimated booking duration

Table 5.1: Linear regression results for booking convenience

Model	Base Model			Final Model		
Parameter	Value	t	Sig	Value	t	Sig
constant	**2.652**	51.455	<0.001	**2.622**	50.457	<0.001
Search engine	**0.216**	10.073	<0.001	**0.216**	10.122	<0.001
Single ticket	**0.433**	20.193	<0.001	**0.433**	20.292	<0.001
Earliest booking date	**0.044**	5.119	<0.001	**0.044**	5.145	<0.001
Digital ticket	**0.123**	5.756	<0.001	**0.123**	5.785	<0.001
Booking duration	-0.002	-0.553	0.581	-0.002	-0.716	0.474
Usual train frequency				-0.029	-1.281	0.200
International trains				**0.106**	4.679	<0.001
Night trains				**-0.056**	-2.275	0.023
R-squared	0.214			0.223		

estimating the duration of the process or that people's booking skills vary a lot. Most of all, it shows that the booking time estimation is widely distributed, which could infer that the chosen attribute values are considered not to be very relevant.

5.1.2. Factors determining booking convenience

In Table 5.1, the estimation results are drawn for the booking convenience rating experiment. Due to the model including train experience, which turned out to have a slightly better model fit with 23.4% explained variance, it was chosen to use this model. The results for the main attributes are intuitive, with all variables being significant.

Having a search engine available, booking the trip in one ticket, a high early booking time, and the availability of a digital ticket all increase booking convenience. Furthermore, short booking times increase the booking convenience as well. On the other hand, the booking duration was insignificant. The booking time is not essential when choosing rating booking scenarios. A possible explanation is that the overall decision process takes significantly longer than the booking itself, making the booking duration less critical. However, as Figure 5.2 showed, people varied in estimating the duration of booking situations, with some estimating significantly longer booking times than the provided attribute values.

The expectations raised in section 2.1 were largely unconfirmed. Firstly, context variables were insignificant and could not improve the model fit. This means that business travellers do not rate

Table 5.2: Utility contribution of booking convenience factors

	Estimate	Min utility contribution	Max Utility contribution	Difference
Search engine	**0.216**	**-0.2158**	**0.216**	**0.432**
Single ticket	**0.433**	**-0.4326**	**0.433**	**0.865**
Earliest booking date	**0.044**	**0.044**	**0.263**	**0.220**
Digital ticket	**0.123**	**-0.1233**	**0.123**	**0.247**
Booking duration	-0.002	-0.01	-0.040	-0.030
Usual train frequency	-0.029	0.0286	-0.029	-0.057
International trains	**0.106**	**-0.1064**	**0.106**	**0.213**
Night trains	**-0.056**	**0.0556**	**-0.056**	**-0.111**

booking situations worse or better than leisure travellers, nor does the travel group have an influence. Whereas it was expected that older adults and pensioners rate booking situations as more complex, this observation could not be confirmed. Socio-demographics, thus gender, age and work status, all do not influence the perception of a convenient booking situation. The only expectation that could be confirmed was that respondents who have travelled in the last two years but have international train connections would rate booking situations better than those who have not travelled internationally.

On the other hand side, experienced night train travellers rate booking scenarios worse than their counterparts. Usual and national train travel seems unrelated to booking international train connections. One possible explanation might be that due to a card system like the OV-Card, most people do not have to book train connections within the Netherlands but can tap in and out.

After exploring the direction and existence of effects, the magnitude of the impact will now be elaborated on. In Table 5.2, the minimum utility contribution, the maximum utility contribution and the difference are displayed. The maximal utility difference serves here as an indicator of importance. Initially, the search engine was expected to have the most considerable effect on a convenient booking situation. However, it turned out that booking one ticket for the whole journey is twice as crucial as having a search engine available (max. utility contribution of 0.865 vs. 0.432). Booking one ticket is almost as important as all other booking convenience factors (max. utility contribution 0.865 vs. 0.926). Confirming the observation in Figure 5.1, respondents are reluctant to choose train connections when multiple tickets are necessary.

The availability of a search engine comparing various train and flight connections is the second most important determinant of a convenient booking scenario, with a utility contribution of 0.432. It is almost as important as the possibility of a digital ticket on a smartphone and the booking horizon with a combined contribution of 0.496. Both factors are similarly crucial whereas the effect of the booking time is neglectable. To achieve high booking convenience values, have one ticket for the connection and have a search engine available. Lastly, international train experience is equally important, like a digital ticket or the earliest possible booking time, underscoring the effect of experience.

Regarding rating booking convenience levels, some heterogeneity emerges between people with various train experiences. Respondents with no train experience at all rate booking situations on average 0.022 utils lower, equivalent to 15 days shorter booking horizon. Very experienced train users who use the train once or multiple times a week and have travelled internationally by train and night train over the last two years rate booking situations 0.022 utils higher compared to someone without known experience. However, this is the same effect as non-experienced train travellers in the other direction. Both effects are, however, only minor, especially in comparison with being able to book one ticket, which is valued over 40 times more important. The highest impact on the booking convenience rating is to have only international train experience, with respondents rating booking situations 0.191 utils higher compared to someone with unknown expertise. This value is similar to five months of booking horizon and ten times more potent than people with whole or none train experience.

Lastly, in Table 5.3, examples are provided for various booking convenience levels. Train experience was assumed to be unknown for respondents. The results show that people have ranked booking convenience levels only from 1.9 to 3.6, thus not considering significant parts of the scale. The levels could change slightly by adding the previously mentioned utils for heterogeneity regarding train experience. In Table 5.3, it can be seen that a booking experience level of three relates to not having a search engine available but being able to book the connection with one ticket. Furthermore, the earliest booking is possible six months in advance; there is, however, no app integration for the ticket, and the

Table 5.3: Examples of respective scenarios for booking convenience levels

	Search engine	Single ticket	Earliest booking date	Digital ticket	Booking duration	Level
Minimum	-1	-1	1	-1	20	1,9
2	-1	-1	6	-1	20	2,1
3	-1	1	6	-1	5	3,0
Maximum	1	1	6	1	5	3,6

Table 5.4: Parameter estimation result

	MNL Final			ML Final 100 draws		
Parameter	Value	t	Sig	Value	t	Sig
ASC night train	**0.020**	0.011	0.991	-2.940	-0.929	0.353
ASC plane	**1.889**	21.863	<0.001	**3.403**	9.659	<0.001
STD night train HSR				**3.006**	19.015	<0.001
STD night train plane				**-2.847**	-23.094	<0.001
STD plane HSR				**-0.785**	-9.786	<0.001
travel time night train	2.611	1.040	0.298	**9.008**	2.074	0.038
sq. travel time night train	**-1.211**	-1.446	0.148	**-3.496**	-2.420	0.016
cost night train	**-0.757**	-24.290	<0.001	**-1.040**	-19.589	<0.001
couchette	**-0.363**	-8.518	<0.001	**-0.583**	-7.945	<0.001
mini cabin	**0.684**	12.662	<0.001	**0.920**	10.152	<0.001
sleeper	**0.785**	19.729	<0.001	**1.085**	16.541	<0.001
booking convenience	**0.382**	5.006	<0.001	**0.474**	6.575	<0.001
sq. booking convenience	**-0.044**	-3.535	<0.001	**-0.052**	-4.560	<0.001
delay	0.031	0.268	0.788	0.085	0.819	0.413
access distance train	0.041	0.866	0.386	0.065	0.421	0.674
cost plane	**-0.559**	-18.956	<0.001	**-1.287**	-22.816	<0.001
access distance plane	**-0.157**	-3.259	0.001	-0.074	-0.216	0.829
LL	-8,801			-6,290		

booking time is five minutes. Various other combinations are also possible, especially when accounting heterogeneity regarding train experience.

5.2. Average factor importance

5.2.1. Parameter estimation results

In Table 5.4, the various model results are shown. For the analysis, it was chosen to use the Panel ML model with 100 Halton draws due to its significantly higher LL value and the results of the Ben-Akiva and Swait test as shown in chapter 4. Many expectations made in chapter 4 could be confirmed regarding the operational factors. Firstly, the alternative specific constant for the mode plane is positive and significant, with a value of 3.403. If all attribute values were zero, people would choose the plane option. Furthermore, all nesting parameters are significant, indicating that between all alternatives, there are factors that could not have been covered in this analysis. As expected, both total time parameters - linear and quadratic - have turned out significant. Also, travel costs have become highly significant for both the night train option and the aeroplane. People also consider the accommodation when choosing for the night train. All offered accommodation categories are significantly different from each other. Lastly, the linear and the quadratic booking convenience terms were highly significant.

However, some variables were surprisingly not significant. First, the night train alternative specific constant is insignificant, making it uncertain if the night train is perceived differently from a HSR service. Additionally, reliability turned out insignificant, meaning people do not mind delays exceeding 15, 30, or 45 minutes in 20% of the cases. Lastly, the access distances for the night train and the aeroplane were insignificant. This means the choice of transportation modes and the distance to reach them are independent. They do not prefer either mode for short or long access distances.

Table 5.5: Average factor importance of operational factors

	Estimates	**min ut. contribution**	**max ut. contribution**	**Utility diff.**
Attributes for the alternative night train				
travel time night train	**9.008**	4.88736	5.77536	**0.8880**
cost night train	**-1.040**	-3.016	-0.52	**2.4960**
accommodation	**-0.583**	-1.422	1.085	**2.5070**
booking	**0.474**	0.422	1.07	**0.6480**
delay	0.085	0.02125	0.06375	0.0425
access distance train	0.065	0.0065	0.14625	0.1398
Attributes for the alternative plane				
cost plane	**-1.287**	-4.5045	-1.9305	**2.5740**
access distance plane	-0.074	-0.0074	-0.1665	-0.1591

5.2.2. Similarity of alternatives

Of the three significant nesting parameters, joint preferences for both train options are the strongest, with a standard deviation of 3.006. Converted to willingness to pay (WTP) values, this implies that two-thirds of the respondents differ in their WTP for the HSR and night train service by less than 289 EUR. In other words, one-third of the respondents are willing to pay up to 145 extra not to use the plane option, and one-third are willing to pay 145 EUR or less extra to use the plane. Note that a normal distribution was assumed with the mean value of 0; thus, most people are willing to pay less. The second nesting effect, the one between a night train and a flight, is almost as strong as the train nesting effect, with a standard deviation of 2.847 utils or 274 EUR. This means that half of the respondents are more willing to pay for the mode HSR train, with a third willing to pay up to 137 EUR extra. Conversely, a third of respondents will pay up to 137 EUR to avoid using a HSR service. Lastly, there are also joint preferences for flying and using HSR services, however, to a lesser extent. Here, the standard deviation is only 0.785 or 75 EUR. This means that a third of the population will spend only 38 EUR not using night trains.

These results indicate that heterogeneity among the population is splendid. The polarisation of the population is exceptionally high for the mode aeroplane on the one hand and train options on the other hand. However, people spend almost the same amount of money to avoid HSR services as flights. However, people will pay only a fourth of these sums to avoid night train services. This implies firstly that there are no particular groups in the population that favour night trains but neither a group that tries to avoid night trains at all costs. Furthermore, nesting effects of night trains are almost equally strong with flights and HSR services, meaning that night trains are nearly as different from an HSR service than from a flight. People, however, consider the other two options, HSR services and flights significantly more different.

5.2.3. Average importance of operational factors

As for the booking convenience rating experiment, the absolute importance of attributes in a mode choice experiment can be described through the maximum utility difference of its attribute levels. Considering this metric, three attributes have almost the same average importance for increasing the probability of using night trains.

The most crucial operational factor for opting for the night train is the cost of the night train competitor, the aeroplane, with a utility difference of 2.57. Having previously detected strong nesting effects with this mode, a high competition between the two modes is assumed. The second most crucial operational factor is the accommodation, with a utility contribution of 2.51, followed by the costs of the night train, with a contribution of 2.50. These values are almost identical, indicating that people consider these three operational factors equally important. The fourth most important factor is travel time, with a utility contribution of only 0.89. Thus, the other factors are almost three times more important for decision-making. Booking convenience is the least essential significant factor in night train mode choice, with a maximum utility contribution of 0.65. However, booking situations have been ranked only between the levels of 1.9 and 3.6, leading to a further decrease of this factor to a maximum utility contribution of only 0.32. This value is roughly a fifth of the most critical factors. Note that travel time and booking convenience are nonlinear factors, so it was decided to highlight the different importance depending

Table 5.6: WTP for upgrading attribute levels of operational factors

Attribute	Increasing attribute levels	Ut. Difference	WTP
Total travel time night train	12 - 14h	-0.016	-1.57
	14 - 16h	-0.296	-28.46
	16 - 18h	-0.576	-55.35
Accommodation	Seat - Couchett	0.839	80.67
	Couchette - Mini cabin	1.503	144.52
	Mini cabin - Sleeper	0.165	15.87
booking convenience	1 to 2	0.318	30.58
	2 to 3	0.214	20.58
	3 to 4	0.110	10.58
	4 to 5	0.006	0.58

on their attribute level by WTP values.

5.2.4. Average WTP for operational factors

Booking convenience influences the willingness to use night train services of all the significant effects the least. However, the effect is still persistent. Considering the booking convenience rating experiment, all booking situations were ranked between a convenience level of 1.9 and 3.6, leading to a maximum WTP of around 31 EUR. In Table 5.6, WTP values are calculated for various booking convenience values. Being able to book one ticket and a reduction of the booking time to 5 minutes is worth 21 EUR per booking if no search engine is available. The earliest possible booking time is six months ahead; no digital ticket is available. A further increase in booking convenience up to the maximum is worth less than 11 EUR. Therefore, it can be concluded that the gain of a very high booking convenience is low, which means that booking convenience is a factor that satisfies people instead of delighting them.

As mentioned in the previous section, the travel time of the night train is the second least crucial operational factor for night train mode choice. However, this variable is highly nonlinear, with respondents willing to spend over 55 EUR to reduce the travel time from 18 hours to 16 hours but only 2 EUR to reduce the travel time from 14 to 12 hours. The optimal time for night train travellers is around 13 hours (12.9 hours exactly).

Besides costs with almost the same importance, accommodation is the most critical operational factor that night train operators can influence to increase night train demand. Here, the highest WTP emerges for an upgrade from a couchette to a mini cabin, with a WTP of 145 EUR. An upgrade from a seat to a couchette is valued at 81 EUR. Increasing from a mini cabin to a sleeper appears not worth the additional space needed, with respondents only willing to pay 16 EUR additionally. Generally, these values are extraordinarily high and greatly exceed previous research. However, several factors that increase the likelihood of such high values must be considered. Firstly, the data collection of the night train studies of Heufke Kantelaar et al., 2022 and Curtale et al., 2023 dates some years ago and in recent times, inflation has been remarkably consistent. However, this cannot explain the difference entirely. The alternatives have assumed that the hotel price is included, leading to higher attribute values. Lastly, the Panel is known to be skewed toward high-earning individuals with higher WTP. Since unreliability and the access distance were not statistically significant, it is impossible to compute reliable WTP values.

Compared with varying WTP for avoiding or using particular modes, the WTP values for operational factors are relatively small. This indicates that high heterogeneity exists among respondents. In the following, a Panel LCCM will highlight this heterogeneity for mode preferences and different tastes. Personal factors will be used to highlight the composition of the classes.

5.3. Four segments of night train demand

After having elaborated on the average effects, a LCCM was estimated to determine how the importance of operational factors depends on population segments. An overview of all classes, including their population share, is presented in Figure 5.3. Night train travellers can generally be divided into four classes: The smallest are comfort lovers, making up 13% of the population. The second smallest

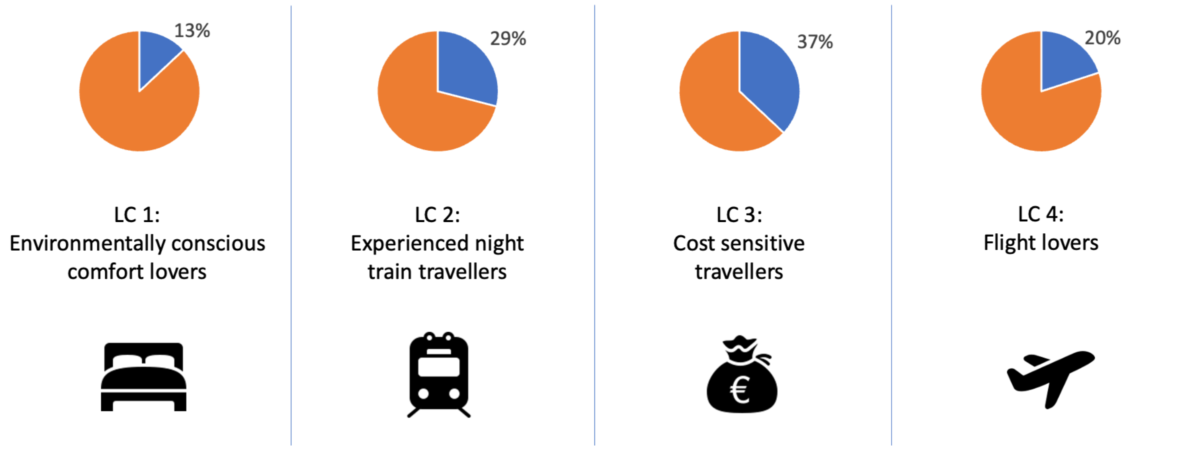


Figure 5.3: Latent classes with share

group is flight lovers, with 20%, which contradicts experienced night train travellers, which amounts to 29%. The largest demand segment is cost-sensitive travellers, which comprise more than a third of the population, thus 37%. Some personal and operational factors have turned out irrelevant for all classes.

Firstly, no class has a significant initial preference for night trains. This confirms the results from the Panel ML model, where heterogeneity for the nest plane and HSR was more minor. Furthermore, contradicting the results from the Panel ML model, travel time does not significantly influence the likelihood of choosing modes, neither in a linear way nor in a quadratic way. This implies that people do not consider travel times worse across all classes. However, negative signs indicate that a dislike for high travel times might be present. Using even longer night train travel times might deter people from using this mode. The second operational variable that turned out irrelevant is unreliability. This means people do not mind the insecurity regarding delays, at least in the chosen attribute range. Lastly, the distance towards the airport is irrelevant when choosing an alternative aeroplane.

When looking at Table 5.7, it can be generally concluded that many class membership parameters turned out insignificant and are thus not statistically relevant for determining any classes. Firstly, the context in which people travel was expected to influence the probability of choosing transportation modes, consisting of the scenario and the travel group. Thus, for people travelling for business or leisure purposes, the scenario does not influence mode choice. This variable includes the luggage and whether the travel has to be paid for by the traveller or if the employer reimburses travel costs. This result is surprising and highlights that the night train can attract both leisure and business travellers at the same time. The travel group partially influences mode choice, with people travelling with their partner travelling distinctively from other groups. Solo travellers, on the other hand side, do not determine membership to classes. Regarding train experience, the usual train experience and international train experience are not decisive either, with only night train experience being a significant factor for some classes. However, the intention to use environmentally friendly modes turned out to be a more decisive factor, with none of the estimated three parameters, only the pressure from essential people like friends and family being insignificant. Socio-demographics, again, do have almost no impact on the probability of belonging to classes, with work status and gender being insignificant. In the following, the four segments that could be derived are presented. Focus is laid on their preferences on the one hand and their composition on the other hand side.

5.3.1. Class 1: Environmentally conscious comfort lovers

13% of the population can be considered environmentally conscious comfort lovers. They choose between modes while considering only three attributes: the accommodation, the booking convenience and the distance towards railway stations as highlighted in Table 5.7. The three previously noted parameters are marked boldly, indicating significance at the 5% level. Therefore, only these values are considered in the analysis. Aligning with the findings of the Panel ML model, people prefer the sleeper over the mini cabin, the couchette and the seat. Furthermore, higher booking convenience levels lead to a higher utility. This effect can be described by a negative quadratic function, which indicates that in the beginning, high levels of utility increase and lower utility increases for higher levels of booking con-

Table 5.7: Parameters of the LCCM

	Class 1		Class 2		Class 3		Class 4	
Parameter	Estimate	Sig	Estimate	Sig	Estimate	Sig	Estimate	Sig
Alternative Specific constants								
ASC night train	-3.739	0.436	-2.461	0.358	5.941	0.307	-16.691	0.192
ASC plane	-1.980	0.141	1.371	0.075	**4.925**	<0.001	**5.278**	0.001
Attributes for the alternative night train								
Travel time night train	5.738	0.431	7.520	0.215	-2.725	0.433	28.875	0.117
Sq. travel time night train	-3.044	0.396	-2.872	0.185	0.374	0.472	-10.721	0.083
cost night train	-0.671	0.092	**-1.013**	<0.001	**-1.477**	<0.001	**-0.785**	0.004
couchette	**-1.835**	0.045	**-0.563**	0.003	**-0.705**	<0.001	-0.830	0.231
mini cabin	**1.931**	0.002	**0.989**	<0.001	**1.369**	<0.001	0.906	0.092
sleeper	**2.632**	<0.001	**1.095**	<0.001	**1.136**	<0.001	**1.508**	<0.001
booking convenience	**0.801**	0.007	**0.689**	<0.001	0.238	0.055	0.583	0.093
sq. booking convenience	**-0.122**	0.002	**-0.083**	<0.001	-0.005	0.415	-0.078	0.100
delay	-0.243	0.282	0.074	0.366	0.699	0.111	-0.537	0.127
access distance train	**-1.769**	0.023	-0.074	0.374	0.004	0.492	0.848	0.213
Attributes for the alternative plane								
cost plane	-1.403	0.051	**-1.462**	0.001	**-1.463**	<0.001	**-0.584**	0.008
access distance plane	0.833	0.102	-0.446	0.168	-0.056	0.421	1.010	0.299
Class membership parameters								
delta	0.000	N.A.	1.545	0.116	**7.467**	<0.001	**8.232**	<0.001
scenario	0.000	N.A.	-0.139	0.248	-0.103	0.308	0.370	0.180
alone	0.000	N.A.	-0.174	0.198	-0.307	0.083	-0.442	0.071
partner	0.000	N.A.	**0.431**	0.008	0.365	0.027	**0.544**	0.012
usual train frequency	0.000	N.A.	0.210	0.076	0.207	0.080	0.142	0.218
intl. train experience	0.000	N.A.	0.039	0.380	-0.200	0.071	-0.131	0.302
night train experience	0.000	N.A.	**0.408**	0.001	-0.012	0.475	-0.079	0.421
importance env. modes	0.000	N.A.	-0.123	0.290	**-0.337**	0.049	**-0.517**	0.010
pressure env. modes	0.000	N.A.	-0.024	0.449	-0.054	0.379	-0.165	0.206
inconvenience env. modes	0.000	N.A.	0.265	0.113	**-0.756**	<0.001	**-1.124**	<0.001
age	0.000	N.A.	-0.181	0.082	**-0.359**	0.004	**-0.243**	0.035
gender	0.000	N.A.	0.074	0.272	0.122	0.165	-0.008	0.483
student	0.000	N.A.	0.355	0.340	0.991	0.088	-0.065	0.480
retired	0.000	N.A.	-0.211	0.327	-0.593	0.116	-0.090	0.461
working	0.000	N.A.	-0.075	0.426	0.265	0.265	0.701	0.055

venience. The distance towards the closest train station hurts the probability of using a night train, with respondents living in the Randstad, thus having a high likelihood of being in this class if they choose the night train. All other attributes are insignificant. Neither the total travel time, travel costs, nor the delay of services are relevant for this group. Furthermore, no preferences for modes exist. This is a remarkable result, considering that travel times and costs are usually the most decisive factors in choosing transportation modes. Diving deeper into the importance of the relevant factors, Table 5.8 reveals the utility range of each parameter. Again, bold-marked parameters are significant. This table shows that accommodation is the most crucial attribute for choosing night trains with a utility contribution of 5.360. The distance is also enormously influential, contradicting previous findings from the Panel ML model. With a utility range of 3.803, this variable is 50% less critical. Lastly, booking convenience has only an impact of 0.276 utils, which makes this variable 20 times less important than comfort. Considering that in the rating experiment, people ranked booking scenarios only between the booking convenience level of 1.9 in the worst and 3.6 in the best case, the importance of booking convenience diminishes. WTP have been computed for upgrading attribute levels of two significant operational factors, the accommodation and the booking convenience. However, because the cost parameter is not substantial, the preciseness of the variables is highly doubtful, and a meaningful analysis is not possible. This can be confirmed by extremely high WTP values; for example, environmentally conscious comfort lovers are willing to spend 561 EUR to upgrade from a couchette accommodation to a mini cabin. However, these values still indicate that these 13% of the population have a very high WTP for night train services with high comfort.

Determining the characteristics of members of this class is less straightforward since this class served as a reference class. However, by analysing the values of the other courses, it is possible to infer the directions of potential class members. It will be focused only on class membership parameters that have turned out significant in other classes.

Environmentally conscious comfort lovers are more likely to use environmentally friendly modes of transportation, even under inconvenient circumstances. Furthermore, they find it essential to use environmentally friendly modes. This can be concluded from classes 3 and 4, which are less likely to agree with this statement. Furthermore, members of class 1 are more likely to be older and travel less with the night train and not with a partner. However, all these interpretations must be taken cautiously since they are not directly observed.

5.3.2. Class 2: Experienced night train travellers

29% of the population can be considered as experienced night train travellers. This demand segment is the only one where people who have travelled at least once by night train in the last two years are overrepresented. The second distinguishing factor of this class is that couples are more likely to be in this demand segment than other travel groups like families with children or friend groups. These findings indicate that people using the night train usually travel in smaller groups.

The most crucial factor for experienced night train travellers in choosing the night train is, surprisingly, the cost of the flight alternative. One possible explanation is that the price sensitivity for flights is 50% higher than for night trains, meaning that high prices for flights are considered worse than for night trains. This finding leads to the assumption that experienced night train travellers prefer the night train as a transportation mode. However, this also cannot be confirmed. Experienced night train travellers neither prefer the mode plane nor the night train over HSR services. Regarding the operational factors of night trains, the accommodation level is the most crucial variable for this group, with a maximal utility contribution range of 2.6, thus slightly more critical than night train costs, with a contribution range of 2.4. However, the booking convenience level also turns out to be a relevant factor in the decision-making process of this group, with a contribution range of 0.8. Booking convenience is essential in the decision-making process for experienced night train travellers. Thus, a third of costs, making this demand segment value booking convenience the most. It is the only segment with significant WTP values, with respondents willing to pay up to 35 EUR to improve booking convenience levels from the minimum level of 1.9 to the maximum level of 3.6. Possible improvements include, as earlier in the report described, being able to compare various train and plane connections via a search engine, being able to book one ticket, an increase in the earliest possible booking time from one month to six months and being able to display the ticket digitally via an application. Furthermore, this group also has a significant WTP to increase their accommodation. As seen in Table 5.8, members of this group are willing to spend 95 EUR on upgrading a seat to a couchette, 153 EUR to further upgrade to a mini

Table 5.8: Maximal utility range and WTP values of factors for demand segments

Class	Class 1	Class 2	Class 3	Class 4
Share	13%	29%	37%	20%
		Max. ut. range		
ASC night train	3.739	2.461	5.941	16.691
ASC plane	1.980	1.371	**4.925**	**5.278**
travel time night train	2.036	0.658	0.962	1.973
cost night train	1.610	**2.431**	**3.545**	**1.884**
accommodation	**5.360**	**2.616**	**2.936**	**3.092**
Booking	**0.276**	**0.764**	0.832	0.560
delay	0.122	0.037	0.350	0.269
access distance train	**3.803**	0.159	0.009	1.823
cost plane	2.806	**2.924**	**2.926**	**1.168**
access distance plane	1.791	0.959	0.120	2.172
	Class Membership parameters			
delta		1.545	**7.467**	**8.232**
scenario		0.278	0.206	0.740
Travel group		**0.688**	0.672	**0.986**
usual train frequency		0.420	0.414	0.284
intl. train experience		0.078	0.400	0.262
night train experience		**0.816**	0.024	0.158
importance env. modes		0.492	**1.348**	**2.068**
pressure env. modes		0.096	0.216	0.660
inconvenience env. modes		1.060	**3.024**	**4.496**
age		0.109	**0.215**	**0.146**
gender		0.148	0.244	0.016
work status		0.566	1.654	1.247
	Accommodation: WTP for increase in Accommodation level			
		WTP		
Seat - Couchette	133.08 EUR	**94.57** EUR	**74.14** EUR	**96.05** EUR
Couchette - Mini Cabin	561.25 EUR	**153.21** EUR	**140.42** EUR	**221.15** EUR
Mini Cabin - Sleeper	104.47 EUR	**10.46** EUR	**-15.78** EUR	**76.69** EUR
	Booking: WTP for increase in booking convenience levels			
1 to 2	64.83 EUR	**43.44** EUR	15.10 EUR	-6.24 EUR
2 to 3	28.46 EUR	**27.05** EUR	14.42 EUR	27.13 EUR
3 to 4	-7.90 EUR	**10.66** EUR	13.74 EUR	25.86 EUR
4 to 5	-44.26 EUR	**-5.73** EUR	13.07 EUR	24.59 EUR

cabin and lastly, 10 EUR to upgrade from a mini cabin to a sleeper. This confirms the results of the Panel ML model, where a low WTP for an upgrade from a mini cabin to a sleeper could be observed, underscoring the attractiveness of a mini cabin.

5.3.3. Class 3: Cost-sensitive travellers

Having the highest price sensitivity for both the mode night train and flights, cost-sensitive travellers amount to 37% of the population. Remarkably, cost-sensitive travellers are 50% more price-sensitive regarding night train travel costs than experienced night train travellers; however, for flight travel costs, both groups have the same preference. Cost-sensitive travellers do not consider prices only when choosing between modes; also, the night train accommodation plays a role. With a maximum utility range of 2.9 compared to 3.5 for costs, the accommodation is roughly 20% less critical for this group. These results indicate the importance of the night train accommodation: Even for the most price-sensitive group, accommodation is only 20% less critical. Also, for this group, WTP values for accommodation upgrades could be derived, where people are willing to spend 74 EUR more to sleep in a couchette and 140 EUR more to upgrade from a couchette to a mini cabin. Remarkably, people will pay 16 EUR less for a sleeper than a mini cabin. This outcome is odd since, generally, the sleeper offers more space and the same privacy. A potential explanation could be that this group avoids a sleeper because of fears regarding higher hidden costs or reactions of social peers regarding their luxurious way of travel and their wanting to be seen as modest. Lastly, when ignoring all features of alternatives, this group initially prefers the plane, which is almost as strong as flight lovers.

Cost-sensitive travellers are more likely to be less environmentally concerned and younger. The leading indicator denoting the likelihood of being a member of this demand segment is if travellers are unwilling to use environmentally friendly modes of transportation under inconvenient circumstances. Furthermore, suppose people do not consider it essential to use environmentally friendly modes of transportation to reduce GHG gases. In that case, they are less likely to be members of this latent class. However, this effect is only half as significant as the first one. Lastly, age turned significant, with younger respondents more likely to belong to this group, while this effect was almost negligible. Ignoring all other covariates, people are initially more likely to belong to this group, raising the share.

5.3.4. Class 4: Flight lovers

The last class to have been discovered are flight lovers. A distinctive feature of this class is the highest initial preference for the mode aeroplane among all classes, slightly higher than the cost-sensitive travellers. Again, the most critical operational factor is accommodation, like for the environmentally conscious comfort lovers in class 1. However, for flight lovers, comfort is less important compared to environmentally conscious comfort lovers, which can be seen by lower WTP values of 96 EUR for an upgrade from a seat to a couchette, 221 EUR from a couchette to a mini cabin and 77 EUR from mini cabin to a sleeper. Note that environmentally conscious comfort lovers statistically do not consider price in their decision process, which makes it impossible to compute statistically significant WTP values. The willingness to pay for comfort upgrades of night trains is significantly higher compared to the other latent classes, two and three, indicating that a focus on this group might be able to boost revenues. Flight lovers do not consider booking convenience in their decision process, just as price-sensitive travellers. A possible explanation might be that booking tickets is generally not considered a significant issue in the aviation industry, which is why this group might not be aware of the caveats of international booking processes for railway connections.

Not considering any covariates, people are most likely to be flight lovers, indicated by a high delta value in Table 5.8. Similarly, like cost-sensitive travellers, flight lovers find it unnecessary to use environmentally friendly modes and are unwilling to use them under inconvenient circumstances. These effects are even more potent for flight lovers than for cost-sensitive travellers. Results suggest that people are aware of the adverse environmental impact of using aeroplanes as a transportation mode but still opt to fly.

Furthermore, passengers are more likely to be members of this class if they travel with their partner. In this regard, they resemble experienced night train travellers; however, the effect is relatively lower for flight lovers. This is because the previously mentioned (missing) intention to use environmentally friendly modes is more prominent for flight lovers. Lastly, like for cost-sensitive travellers, flight lovers are likelier to be younger. However, this effect is also almost negligible in magnitude.

5.4. Exploring night train market shares

After presenting various classes that segment the population, these classes will be used to predict class-dependent market shares for the night train under multiple scenarios. Note that these market shares have to be seen under the context of this study and are hypothetical. The market has been defined as the current flight market between the two cities since neither direct HSR connections are available nor night train connections. According to CBS, this market covers roughly 1.6 million passengers (see CBS, 2021a). Note that these values also include transfer passengers that are strictly not market members. However, it was waived to apply a correction factor due to its high complexity. Firstly, the scenarios will be presented, and secondly, it will elaborate on night train demand.

5.4.1. Scenario description

From the analysis of the segments, the accommodation level and prices for flights and night trains emerged as the most determining mode choice on distances from 1400 to 1600km. Only flight prices can be observed on the current route between Amsterdam and Barcelona, which vary considerably. They are primarily dependent on the season, holidays and the booking horizon. Three different price environments were assumed to cover an extensive range of possible choice situations for constructing scenarios. In a low-cost scenario, low ticket costs for flights were taken, often achieved through booking outside of the season. The middle-priced scenario serves as a base scenario, where people book less in advance and where it can be assumed that travel takes place within a season with higher demand. Lastly, a high-price scenario is considered, where people are expected to book only a short time before the trip, and the journey takes place during the season. For all scenarios, adequate accommodation categories were chosen. Besides night train operators, policymakers can also alter night train demand. On the one hand, an increase in GHG taxation is conceivable, which comprises scenario 4. On the other hand side, night train subsidies are possible, as elaborated on in scenario 5.

1. **Base case scenario** In this scenario, it is assumed that passengers book their vacation or business trip well in advance and flight and hotel prices are expected to be 150 EUR. Regarding the night train attributes, a strategy comprising a medium level of comfort is assumed, thus a mini cabin. It is assumed that the travel time amounts to 16 hours through partly using the high-speed tracks. The background for just partly using high-speed tracks is that often, high-speed tracks are maintained during the night. For travel costs, 210 EUR are assumed, which is a realistic price considering the high track access charges for a long trip and the high operational costs for staff. The current booking convenience level of NS International is assumed. This is defined as having currently no search engine available, being able to book one ticket since connections are offered in the whole Netherlands, being able to book at a maximum of 4 months in advance, needing 20 minutes for the completion of the booking process and having a digital ticket available. This leads to a booking convenience level of 3.1. For the insignificant delay, it was assumed that trains are in 80% of the cases delayed by 30 minutes or less.

2. **Low-cost scenario** In this scenario, it is assumed that the travel takes place during the off-season, which results in relatively low flight prices of 150 EUR. Furthermore, the night train operator is expected to follow a low-cost strategy, thus refurbishing old seats or buying old couchette cars. Since the old rolling stock is not allowed to be operated on high-speed tracks, travel times of 18 hours must be considered. Furthermore, the travel costs of the night train are expected to be 130 EUR. Due to high fixed costs and high track access charges, tickets cannot be offered at lower prices. The train is again expected to be delayed by more than 30 min in 20% of the cases. Due to the insignificance of this attribute level, it is held constant across all scenarios. Booking comfort is, however, expected to be the bare minimum. Booking a ticket from any station in the Netherlands towards Barcelona is impossible due to missing cooperation with NS, which causes the need for two tickets. Furthermore, no integration into a search engine takes place, and booking is expected to be possible only one month in advance. Likewise, 20 minutes are needed for the booking process, and programming an application is too expensive; thus, there is no digital ticket on the smartphone. This leads to a booking comfort level of 1.9, the worst possible to observe.

3. **Luxury scenario** In this scenario, a high season with a short booking horizon is expected. Therefore, flight prices (including hotel costs) are expected to be 350 EUR. The assumed night train

operator offers sleeper accommodations by executing a luxury strategy. Due to the high spacial requirements of the sleeper accommodation, these cannot be provided at less than 290 EUR. This night train is conceptualised as a premium product, thus using the high speed (HS) line over the whole stretch, leading to a travel time of only 12 hours. Regarding booking convenience, an airline standard is assumed, where the night train operator manages to collaborate with various agencies to make the ticket available on multiple search engines, enables a booking horizon of 6 months, manages a user-friendly interface leading to booking times of 5 minutes, providing one ticket and programming an app. This leads to a booking rating of 3.6, the maximum observed in the rating experiment.

4. **High GHG tax scenario** The last scenario refers to the base scenario. Instead of operators altering their market strategies, policymakers are assumed to influence the market environment. Various policies are possible; in this scenario, it is believed that the current GHG taxation policy is enforced, with all attributes of the night train being the same as in the base scenario but with higher flight costs. A 200 EUR increase in flight costs is assumed, a solid increase and a rather extreme policy measure.

5. **NT subsidy scenario** Instead of increasing GHG taxation, night trains are subsidised in scenario 5. Here, an 80 EUR subsidy is assumed, which leads to a price of 130 EUR for a mini cabin. Additionally, infrastructure managers are influenced to let night trains have priority access to HS tracks, leading to a total travel time of 14 hours. Furthermore, an increase in flight tickets of 100 EUR is assumed. This is a more balanced approach with almost equally sharing subsidies for NT services and higher GHG emission taxes.

5.4.2. Demand response for various scenarios

Potential market shares in the annually 1.6 million passengers strong flight market between Amsterdam and Barcelona (see CBS, 2021a) are displayed in Table 5.9. It is assumed that flights comprise almost 100% of the market. The night train and the direct HSR service are hypothetical alternatives that currently do not exist.

Base case scenario In the base case, the night train can capture 40% of the transportation market. At the same time, the flight alternative sinks to 45% market share. Remarkable is the heterogeneity among the population. Whereas within class 4, the flight lovers, 92% of the respondents choose to fly, in class 1, the environmentally conscious comfort lovers, only 3% do so. Whereas members of class 1 prefer the HSR service over the night train, members of the experienced night train travellers choose predominantly the night train with 89%. These results indicate that among the population, there are strong ties to the favourite modes of the respective classes. The only class with a more widespread market share are cost-sensitive travellers, with two-thirds opting for the aeroplane and almost a third (29%) for the night train.

Low-cost scenario In the low-cost scenario 2, night train market shares plummet to 20%, confirming the findings of Heufke Kantelaar et al. (2022). This indicates that a low-cost strategy with expected comfort levels in the previous century does not align with current passenger preferences. In this scenario, customers would primarily consist of experienced night train travellers. For all other classes, very low market shares can be observed. The environmentally conscious comfort lovers are interesting: These primarily urban class values overwhelmingly travel by HSR services with a market share of 96%, underscoring the competition from long-distance, direct HSR services. Opposite to class 1 are the flight lovers, who only choose the flight (99%). Also, cost-sensitives opt primarily for the flight with a market share of 87%.

Luxury scenario If a night train operator focuses on the luxury sector, where the booking takes place only a couple of days before the departure and, therefore, flight prices are high, the night train can capture significant market shares when a high comfort level is assumed. 61% would opt for a night train, with the other market shares evenly divided for choosing a flight and the HSR service. Also, for this scenario, significant heterogeneity emerges with classes 1 and 2 not opting for the aeroplane, whereas class 4 chooses to fly in 70% of the cases. Overall, the market share for the night train is the highest in this scenario, which the severely changed price environment might cause. Especially class 3 switches to night train services if the comfort and price of a night train service are attractive.

High GHG tax scenario Similar market shares (NT: 62%) compared to the luxury scenario are derived if off-season is assumed and flight prices are raised to 350 EUR. By raising GHG emission taxes, policymakers can alter market shares significantly and shape the market. Remarkably, only class 4, the flight lovers, refuse to switch to environmentally friendly modes with a flight market share of 78%. These 20% of the population are not possible to reach via high pricing. On the other hand, the price-sensitive part of the population now switches predominantly to night trains, with a market share of 78% for this class. Also insightful is the attractiveness of HSR services, which make up 18% of the whole market, almost as vital as flights.

NT subsidy scenario Subsidising night trains and raising the prices of flights expectably boosts the night train market share the strongest. With 72% opting for the night train, this mode dominates the market. Comparing this policy with the previous one, almost the same number of people choose to fly (17% vs. 19%), only the attractiveness of the HSR connection differs. In the NT subsidy scenario, only 11% choose to travel by HSR service. This implies that when considering subsidies, competing modes also have to be taken into consideration. Heterogeneity also persists in this scenario, with members of class 1 predominantly opting for the HSR service, members of class 2 predominantly choosing the night train, and flight lovers still choosing to fly.

Whereas the market shares vary significantly, the behaviour of the various classes persists. Class 1, the environmentally conscious comfort lovers, always choose predominantly for the HSR connection. Class 2, on the other hand, chooses primarily the night train in all scenarios, and the flight lovers in class 4 choose primarily for flying. Only class 3, the price-sensitive, choose transportation modes depending on the offered price and comfort level.

Passenger numbers for base case It is assumed that annually, 800,000 passengers depart from Amsterdam Schiphol to Barcelona El Prat Airport (see CBS, 2021a) and that the night train can compete with planes that depart in the afternoon. Roughly four aeroplanes leave each evening from Amsterdam, leading to a demand of 600 travellers daily. By multiplying the night train market shares derived from Table 5.9 with the daily demand for the base case, it can be concluded that 240 passengers would be willing to travel by night train daily. Considering a standard night train capacity of 254 passengers (see Maier, 2023), a night train could be filled with passengers. Out of these 240 passengers, only 12 would be environmentally conscious comfort lovers, 154 would be experienced night train travellers, 64 would be cost-sensitive travellers, and 10 would be flight lovers. The willingness to pay for upgrades regarding the accommodation can be found in Table 5.8.

Table 5.9: Market shares for various scenarios

S1-base: 16 hours, mini cabin, 210 EUR NT, 3.1 booking level, 150 EUR flight + hotel					
	Average	Class 1	Class 2	Class 3	Class 4
Night train	40%	16%	89%	29%	8%
Flight	45%	3%	3%	67%	92%
HSR service	15%	80%	8%	5%	1%
S2-low cost: 18 hours, couchette, 150 EUR NT, 1.9 booking level, 150 EUR flight + hotel					
Night train	20%	0%	60%	7%	0%
Flight	56%	4%	9%	87%	99%
HSR service	24%	96%	30%	6%	1%
S3-luxury: 12 hours, sleeper, 290 EUR NT, 3.6 booking level, 350 EUR flight + hotel					
Night train	61%	39%	88%	65%	29%
Flight	20%	0%	0%	15%	70%
HSR service	19%	61%	12%	20%	1%
S4-high GHG tax: 16 hours, mini cabin, 210 EUR NT, 3.1 booking level, 350 EUR flight + hotel					
Night train	62%	17%	92%	78%	20%
Flight	19%	0%	0%	10%	78%
HSR service	18%	83%	8%	12%	2%
S5-NT subsidies: 14 hours, mini cabin, 130 EUR NT, 3.1 booking level, 250 EUR flight + hotel					
Night train	72%	37%	97%	87%	34%
Flight	17%	1%	0%	10%	65%
HSR service	11%	62%	3%	3%	1%

6

Discussion and Conclusion

This chapter rounds this study off. Firstly, the findings from chapter 5 are compared with previous research in section 6.1. Then, some limitations are mentioned in section 6.2. It is elaborated on if the findings of this study can be generalised in section 6.3. This thesis ends with a conclusion in section 6.4 and recommendations for research and practice in section 6.5.

6.1. Discussion

Discussion of sub-question 1: What comprises a convenient booking, and to what extent does it influence night train demand on average? In this thesis, Dutch citizens' international train booking behaviour was examined, revealing that Dutch citizens book their international rail tickets mainly on NS International. Predominantly, train tickets for one trip are booked on one site, while booking sites are chosen based on habit and user-friendliness. These results are slightly surprising since many booking sites in the aviation industry compare ticket prices to reveal the cheapest prices. Many advertisements are issued, claiming to be the most affordable flight booking site. Booking international train tickets is significantly different from booking flights. Unsurprisingly, comparing travel options is the biggest issue in booking international rail tickets. Currently, booking international train tickets is only possible on cooperating railway operators. Further problems mentioned are the availability of a ticket and finding a fitting website, which is also intuitive results. Often, it happens that a lot of comfort categories are booked out in night train services. In the past, this was mainly due to fixed booking systems. Therefore, the market leader ÖBB introduced a new flexible ticket system, leading to higher customer prices (see treinreiziger.nl, 2023). People mentioning finding a fitting website is a problem might be due to passengers not having a clear overview of active night train operators and collaborations. Whereas airlines are known to the general public, night trains are still a niche mode; thus, their operators are unknown.

This study revealed that a convenient booking situation mainly involves booking one ticket for the whole journey and easily comparing various train and flight connections through a search engine. This could be confirmed by the experience questions previously stated, where comparing connections was one of the most prominent problems mentioned and where over 80% of the respondents mentioned booking their train ticket on one website. In the choice experiments, respondents were willing to spend up to 31 EUR for improved booking convenience for their trip. This confirms the work of Li et al. (2020) and Yang et al. (2022), which both found booking relevant. Also, Preslmayr et al. (2021) and Curtale et al. (2023) mentioned the importance of booking convenience while applying different methodologies. Preslmayr et al. (2021) let people book their train and plane connections directly, whereas Curtale et al. (2023) asked people directly for the importance of the factor. In this study, the importance of booking was compared in a stated preference study with other factors like ticket prices and accommodation, which turned out to be four times as important. Still, considering the prices of low-cost airlines, the WTP of 31 is a lot and might not be realistic. Another interpretation of booking convenience might be better: People consider train options only in their choice set if booking convenience is high. Curtale et al. (2023) thinks this way by stating that an easy booking scenario means that people can choose between transportation options as quickly as they have indicated in the stated preference survey.

Discussion of sub-question 2: How do other operational factors influence average travellers' night train preferences? Contradicting the findings of Curtale et al. (2023), this thesis found flight prices more critical than night train prices for determining night train market shares. The accommodation was as crucial as night train travel costs, confirming the findings of Heufke Kantelaar et al. (2022). However, this study mainly disagrees with Heufke Kantelaar et al., 2022 regarding the importance of travel time. Whereas he found travel time to be as important as comfort, this study reveals a significantly less important. The optimal length of a night train service seems to be around 13 hours, despite longer travel times not reducing market shares significantly. The findings of Heufke Kantelaar et al., 2022, where people do value travel times less critical for night trains compared to flights, can therefore be confirmed by this study. However, the difference is more tremendous in this study. Various WTP values were found for upgrades in accommodation levels. In total, it was found in this study that people are willing to spend 242 EUR on upgrading from a seat to a sleeper. Heufke Kantelaar et al. (2022) has found a similar value, 241 EUR for business and 162 EUR for leisure travellers. In light of this study having been conducted four years later and with significant inflation rates, these values seem to coincide. Still, the values found in this study are at the upper limit of previous findings, which might have been caused by including hotel costs in the analysis, which significantly raises the general price level of the study. The slight difference between the perceived attractiveness of a mini cabin and a sleeper is remarkable, which confirms the thesis's thesis of Moors, 2023. New in this study was the inclusion of nesting effects between all possible competitors. Not surprisingly, the night train is perceived as similar to a HSR service with a hotel stay. However, night trains are perceived almost as identical to aeroplanes, which is surprising, given the differences in the travel experience and the impacts of a trip.

The population is highly willing to pay for accommodation upgrades; for example, people are willing to spend 144 EUR on average to upgrade from a traditional couchette to a mini cabin. This shows the high attractiveness of the new accommodation category. The total travel time for a night train does play a less critical role in choosing this mode of transportation. Around 13 hours is the optimal time for people on a night train. However, longer travel times are not considered a knock-out factor. Almost as crucial as travel time is booking convenience. Delay and the access distance do not affect the decision process. This indicates that the night train can capture demand from large areas around departure stations and that no buffers are needed in the timetable. People's joint preferences vary significantly, with some disliking and others liking travelling by plane. Similar effects emerge for HSR services. However, preference heterogeneity for night trains is present to a lesser extent. This high observed heterogeneity among respondents indicates that when modelling preferences for night trains, it is insufficient to rely only on average effects.

Discussion of sub-question 3: Which night train demand segments can be identified, how do personal factors influence them, and what are their preferences regarding operational factors? To highlight heterogeneity, in this study, it was assumed that personal variables (or covariates) influence class membership, thus influencing tastes of attributes and initial preferences for modes. At the same time, Moors (2023) used a LCCM as well with other covariates and attributes, Heufke Kantelaar et al. (2022) highlighted heterogeneity through latent class cluster analysis and by incorporating covariates and interactions into a Panel ML model. He assumed that preferences regarding morning planes are distributed generally among the population. Adding the group of covariates' intention to use environmentally friendly modes' revealed stark differences regarding the influence of covariates compared to previous studies. For highlighting heterogeneity, this study showed that regarding the context, only travelling by partner compared to a group is a decisive factor for being in a particular class. Whereas Curtale et al. (2023) found differences between families and solo travellers instead, Moors (2023) found this factor not decisive altogether. For the travel group, it can thus be concluded that the studies do not agree; however, they hint at being a factor that is not very relevant. Similarly, Heufke Kantelaar et al. (2022) found differences in preferences among business and leisure travellers, whereas Moors (2023) did not, which is supported by this study. The results of Curtale et al. (2023) could mainly be confirmed by highlighting the importance of the intention to use environmental modes and night train experience. This study found regarding socio-demographics only age significant, which aligns with Heufke Kantelaar et al. (2022) and Moors (2023) but not with Curtale et al. (2023). Also, the insignificance of gender aligns with previous studies. Work status, however, was found to be relevant in Moors (2023) and Heufke Kantelaar et al. (2022) but not in this study. Generally, it can be concluded that heterogeneity among the population in this study is mainly expressed if people intend to use environmentally friendly modes of transportation. This factor potentially explains many previously used factors to highlight heterogeneity. This thesis aligns with the findings of Curtale et al. (2023), despite not including this many psychological variables.

Demand has been split up in this study into four latent classes, each with their preferences. 13% of the respondents were classified as environmentally conscious comfort lovers, 29% as experienced night train travellers, 37% as cost-sensitive travellers and 20% as flight lovers. Besides the cost-sensitive travellers, all groups strongly favour one of the modes, with class 1 favouring the HSR service, class 2 night trains and class 4 flights. Whereas Curtale et al. (2023) did not separate the population into latent classes, Moors (2023) applied a LCCM with five classes and Heufke Kantelaar et al. (2022) used latent class clustering to reveal seven classes. Out of computational reasons and to simplify, it was chosen for four courses in this study. Generally, the classification of night train demand in this study aligns more with the results of Moors (2023), with him finding patterns like non-night train users (in this study flight lovers), young price-sensitive night train lovers (experienced night train travellers), price-insensitive users with extra services (environmentally conscious comfort lovers) and newborn night train lovers (cost-sensitive travellers). Only the fifth class, the autotrain users, seems to stand out. The shares roughly align with the ones found in this study. The most significant difference is experienced night train travellers, double as prominent in this study (29% vs. 15% in Moors (2023)). This discrepancy might be due to the usage of the NS Panel in this study, which consists of many train-affine members. This can be confirmed by the findings of Heufke Kantelaar et al. (2022), who also used the NS panel, which states that 29% are night train lovers. This is the same share as found in this study. Regarding other classes, results differ significantly, with Heufke Kantelaar et al. (2022) not detecting cost-sensitive travellers and estimating a share of 32% of comfort-minded people (13% in this study). Due to differences regarding the significance of personal factors, the class membership functions vary significantly from Moors (2023). To summarise, whereas the influence of individual factors resembles the results of Curtale et al. (2023), the found latent classes resemble Moors (2023) to a certain extent. This leads to the conclusion that the approach chosen in this study might be suitable to adequately represent heterogeneity among the population. Lastly, it will evaluate how estimated market shares behave compared to other research.

Discussion of sub-question 4: What are the predicted market shares of night train services for various demand segments in different scenarios? In this study, market shares have been estimated for various scenarios. Whereas in the base case scenario, 40% of respondents are willing to use the night train, 72% use it in the maximum scenario with night train subsidies and only 20% if lower comfort levels are offered. Moors (2023) and Heufke Kantelaar et al. (2022) estimated night train market shares for closer distances, significantly higher than found in this study. Moors (2023) found the market share to be 65% in the base case scenario, 52% in the lowest and 70% in the highest scenario. Heufke Kantelaar et al. (2022) agrees with finding market shares from 60% in the base case to 68% in the most optimal scenario. However, both studies considered smaller distances. Curtale et al. (2023) on the other hand, estimated market shares from Sweden towards central and southern Europe by dividing into medium (under 1000km) and long-distance (above 1000km). He generally found significantly lower market shares, ranging from 20% to 30% in the medium distance and from 6% to 10% in the long distance. However, this study predicts market shares to lie between those studies closer to those conducted in the Netherlands and Belgium. Taking train-affine respondents in the NS Panel into account, the estimated 40% might be the upper end of market share, and slightly lower market shares might be more realistic. In the following, this study's various shortcomings will be elaborated on more extensively.

6.2. Limitations

This thesis contains several limitations, especially those related to constructing a conceptual model, constructing the survey, acquiring the data via the NS panel and analysing it via discrete choice models.

Constructing the conceptual model, especially regarding booking convenience, has turned out to be challenging. Little data was available on the internet to detect current issues of international (rail) travellers. More qualitative research methods might have significantly helped discover and categorise current problems of the booking process.

As several sources from the literature pointed out, transfers play a significant role in the decision to use particular transportation modes. In this thesis, it was assumed that there are direct trains for both the night and HS trains. For the HSR service, it seems likely that people will still have to transfer, potentially reducing the market share even further. Additionally, the variable of fear of flying has not been used in the survey, which plays a potential role in people not choosing the aeroplane. Including this variable might have increased the model's performance. In the scope, it has been assumed that people compare night trains with flight and HS train connections, including hotel stays. For the hotel, prices of 100 EUR were assumed. However, as indicated in the theoretical framework chapter, this assumption is highly questionable. Some might consider couch surfing or hostels where significantly lower prices emerge. Furthermore, hotel costs are often shared with travel companions, for example, by booking a double room. It was not considered that hotel prices vary significantly depending on the time of the year and that hotel costs are also considerably higher in peak season when flight prices are higher. Lastly, people might consider travel and accommodation costs separated, not considering any saving possibilities. Furthermore, this thesis only predicts market shares on the outgoing vacation leg. The incoming vacation leg, where people sleep at home, is not part of this study, potentially further decreasing the modal share of the night train.

The NS Panel has been used to acquire data. Panel members voluntarily participate in surveys like this, which might alter conclusions. Through an increased share of train enthusiasts, market shares for night trains might be overestimated. On the other hand side, people might be opposed to trains, liking other modes of transportation and showing NS what is going wrong with railways. Furthermore, researchers might be more aware of the value of surveys and, therefore, more likely to be panel members. Lastly, pensioners might have more time and be more willing to spend it by answering surveys. All these factors contribute to a known skewness of the panel. Members are known to be frequent train users with high education and income and are over-proportionally pensioners. Because of NS 's privacy requirements, it was impossible to test the extent of the overrepresentation. As the study has shown, experienced night train travellers are likelier to choose this transportation option. Also, 29% of experienced night train travellers do not represent the whole population. However, the magnitude of train bias was impossible to determine and could not be corrected.

Furthermore, if all questions have been understood correctly and the respondents' estimations represent reality, the question remains. In the results section, for example, it is shown that people could not estimate the booking time of their last train trip. This variable is understandably challenging to conceptualise. Many respondents mention that after deciding to travel on a specific day to a particular location, the booking process took several hours, from comparing travel options to receiving the ticket. In the rating experiment, however, attribute levels 5 and 20 minutes have been used for the average booking times. Therefore, it is logical that the variable turned insignificant, and the indicator fails to describe the convenience of the booking site. To assess the importance of access, people were asked directly how far they lived away from the stations because of privacy requirements. These estimations are often complex for humans to process and suffer from high errors.

In the estimation process, adding piecewise groups of factors was decided. If different model estimation methods had been used, other variables that are now insignificant might have been significant. Furthermore, to describe heterogeneity among the population, the Panel ML model is suitable by modelling attributes normally distributed and not only nesting parameters. When applying this model, results might have been different and thus also the conclusions.

Lastly, estimating market shares with stated preference surveys is difficult. Firstly, market shares are heavily influenced by the assumptions regarding departure times, travel costs, alternatives, etc. For example, a booking horizon of only one month lets the night train fall out of the choice set if respondents book six months ahead. Also, if people do not find night train booking sites, this mode again is not included in the choice set. Furthermore, a gap exists between stated preference and actual behaviour (see Chorus, 2022). The generation effect of new night train services has been neglected while computing demand for the night train, potentially altering the values. Lastly, the market was assumed to be uniform the whole year, which also does not represent reality, potentially underestimating night train demand in peak season and potentially overestimating demand for the off-season.

6.3. Generalisibility

Despite all the limitations of this study, the Discussion showed that the results might be a realistic representation of the long-distance passenger market between Amsterdam and Barcelona. However, the results of this study also apply to other relations within Europe. Multiple relations with a distance of 1500 km (distance by car) are, in theory, suitable for night train connections. In Western European countries like France, Spain, and Italy are vast parts of the railway networks HSR lines. This implies that only there, HSR services are a serious competitor to night trains and flights. Therefore, it is argued that the scope where mode share predictions are valid refers to these countries, including Belgium, the Netherlands and southern England. In the Dach region, HSR lines are not coherent, which might lead to higher market shares due to HSR services not being competitive. In Northern Europe, the predicted market share might be lower as Curtale et al. (2023) has found in a study. However, the results of these studies might not be transferable to Eastern Europe since. Generally, WTP values are lower, and the price structure is different. Furthermore, it might not be easy to generalise the results to other continents due to different cultures, economic conditions and geography. In China, for example, high-speed night trains are standard due to the country's vast size. Lastly, the results of this study might only be valid for a maximum horizon of 10 years since the price environment and social norms change. Technological innovations might alter the market environment further.

6.4. Conclusion

In recent years, night trains have enjoyed a comeback and rising popularity, mainly driven by the general public's higher importance on the environment (Danson, 2023). Further societal benefits of night trains include increased land use efficiency and accessibility improvements. To harness environmental benefits through an increased usage of night trains, insights are needed.

Firstly, insights are provided into the Dutch traveller's habits and preferences regarding booking international rail connections. In the second step, the importance of booking is compared with other operational factors. Then, insights into population heterogeneity are provided and market shares are predicted under various scenarios.

Sub-question 1: What comprises a convenient booking, and to what extent does it influence night train demand on average? Dutch citizens book their international rail tickets mainly on NS International. Predominantly, train tickets for one trip are booked on one site, while booking sites are chosen based on habit and user-friendliness. The most significant issues in booking international rail tickets are comparing travel options, ticket availability, and finding a fitting website. A convenient booking situation mainly involves booking one ticket for the whole journey and easily comparing various train and flight connections through a search engine. Respondents are willing to spend up to 31 EUR to improve their booking experience. However, while people consider booking convenience a factor for long-distance mode choice, the effect is relatively small. Accommodation, for example, is four times more important in decision-making.

Sub-question 2: How do other operational factors influence travellers' night train preferences on average? Flight prices emerged as the most crucial determinant for choosing night trains. Total travel costs of the night train and accommodation are equally important. The population is highly willing to pay for accommodation upgrades; for example, people are willing to spend 144 EUR on average to upgrade from a traditional couchette to a mini cabin. This shows the high attractiveness of the new accommodation category. The total travel time for a night train does play a less critical role in choosing this mode of transportation. Around 13 hours is the optimal time for people on a night train. However, longer travel times are not considered a knock-out factor. Almost as crucial as travel time is booking convenience. Delay and the access distance do not affect the decision process. This indicates that the night train can capture demand from large areas around departure stations and that no buffers are needed in the timetable. People's joint preferences vary significantly, with some disliking and others liking travelling by plane. Similar effects emerge for HSR services. However, preference heterogeneity for night trains is present to a lesser extent. This high observed heterogeneity among respondents indicates that when modelling preferences for night trains, it is insufficient to rely only on average effects.

Sub-question 3: Which night train demand segments can be identified, how do personal factors influence them, and what are their preferences regarding operational factors? This study revealed four demand segments with various preferences. 13% of respondents can be considered environmentally conscious comfort lovers, who think when choosing for modes only the accommodation, booking convenience and the distance towards railway stations. Whereas booking convenience only influences decisions to a limited extent, accommodation has the most considerable influence. Members of this class find it essential to use environmentally friendly modes of transportation and also use them under inconvenient circumstances. They tend to be older and are less likely to travel with their partner.

The second revealed class are experienced night train travellers, who make up 29% of the population. The most crucial variable for their decision to choose the night train is flight costs. Furthermore, the accommodation and the costs of the night train are relevant decision variables. Lastly, booking convenience plays a role for this group, however, to a lesser extent. Most likely in this class are people who have travelled by night train in the last two years and travellers with their partners.

The most significant demand segment is cost-sensitive travellers, who make up 37% of the population. For them, ticket prices are the most critical determinant of mode choice, and accommodation is 20% less important. Most likely to be in this group are respondents who are less environmentally concerned and younger people.

The last observed group are flight lovers, who make up 20% of the population. They have a high initial preference for the mode aeroplane, and their most crucial operational factor to decide on is the accommodation level. The most determining personal variable is the intention to use environmental modes. Members of this class are least likely to use environmentally friendly modes under inconvenient circumstances and do not find it essential to use them.

None of the groups considers travel times or delays of night trains to be decisive variables in their choice of transportation modes. A lot of personal variables turned out not to influence class membership. Firstly, leisure and business travellers are likely to be members of each latent class, highlighting that the scenario does not influence preferences regarding night trains. Further variables that do not affect class membership are usual train frequency and experience with international train travel. Lastly, also socio-demographics vastly do not alter preferences regarding transportation modes. Gender, as well as work status, do not play a role, whereas age does.

Sub-question 4: What are the predicted market shares of night train services for various demand segments in different scenarios? In the base case scenario, where a mini cabin as an accommodation category is offered for 210 EUR, 40% of the respondents would choose the night train. Remarkable is the heterogeneity: Whereas 92% of flight lovers decide to fly and 80% of the environmentally-conscious comfort lovers choose the HSR, experienced night train travellers choose the night train (89%) predominantly. In the low-cost scenario, where the night train offers a couchette accommodation for 130 EUR, only a market share of 20% can be reached. In each class, the night train loses market share, with the most potent effect on experienced night train travellers, where only 60% still opt for the night train. For a luxury scenario, however, where a sleeper for 290 EUR is assumed, the night train can reach a market share of 61%. Heterogeneity among the population persists, whereas classes 1 and 2 do not fly at all; 70% of class 4 members choose to fly. The night train can capture slightly less market share if a high GHG tax is introduced compared to when night trains are subsidised (61% vs. 71%). However, this results at the expense of HSR services. Applying the base case scenario on the stretch Amsterdam - Barcelona, 240 passengers would choose to use night train services daily, with customers being predominantly experienced night train travellers (154 passengers) and 64 cost-sensitive travellers. Having answered all previous sub-questions, it is possible to answer the following main research question:

Main research question: How do operational and personal factors influence Dutch travellers' preferences for night train services headed to European very-long-distance destinations?

Total travel costs and accommodation are the most critical operational factors for choosing night train services on European long-distance destinations. Booking convenience and access distance are only relevant for particular parts of the population, and their importance is significantly lower. High heterogeneity is present among the population and must be considered when describing night train demand. Demand patterns vary mainly depending on peoples' intention to use environmentally friendly modes. Other factors that separate travellers are the travel group and age, however, to a lesser extent.

Travel times and unreliability do not influence travel demand when opting for night trains on very long European distances. This study revealed that most customers of a hypothetical night train service are experienced night train travellers and cost-sensitive travellers.

6.5. Recommendations for research and practice

6.5.1. Recommendations for research

Several suggestions can be made for further research. Firstly, it might be interesting to investigate other more qualitative methods to determine essential booking factors in the model conception phase. Especially factors that can capture the visual attractiveness and simplicity of booking sites. Furthermore, it might be interesting to study the incorporation of pictures of the booking system in choice models. On the one hand, people would be more familiar with the booking systems they are rating. On the other hand, it would be possible for researchers to detect areas or situations where booking convenience could be improved. Using AI methods, it is possible to include visuals in choice models, which would be another option to enhance the design of booking sites more directly.

Secondly, hindrances to the widespread introduction of night train services are track capacity issues and the scarcity of rolling stock. It would be interesting to study the effect of these factors on choice models. Suppose, for example, it is only possible to run a one-night train per night from Amsterdam to Barcelona. In that case, it might make more sense to focus on high-paying customers to maximise revenue instead of focusing on the middle segment, which cannot be served entirely anyway.

Thirdly, in recent years, many night train connections have been established. Still, the scientific community lacks studies that have rated the results of the stated preference surveys with revealed preference data. It might be that, primarily by selecting the NS Panel as a data source, night train market shares are overestimated.

Fourthly, all-night train studies focus on the introduction of services in Europe. The potential of the mode night train might be different in other continents like America, Africa or Asia, where night trains have been operating for many years. Studying people's preferences in these continents might be insightful to highlight similarities and differences worldwide.

Fifthly, other attributes and attribute values could be used to expand the understanding of night train demand further. For example, this study has not included transfers due to overparametrisation. If on the route Amsterdam Barcelona, the currently necessary two transfers in Paris would have been considered for the HSR alternative; this alternative probably would have been rated worse. In addition, this study covered travel times up to 18 hours, where travel time was insignificant for the LCCM. It might be insightful to study even longer night train travel times to determine the maximal running time, optimising revenues for these systems.

Lastly, psychological variables have been treated in this study as standard attributes. It might be interesting to treat the train experience and intention to use environmentally friendly modes as psychological variables in the hybrid choice model to mimic the decision process of individuals even more realistically, especially after finding the high importance of these variables.

6.5.2. Recommendations for practice

Besides research and practice, several recommendations can be stated. Firstly, travel costs and accommodation have become the most decisive variables for choosing night trains. For night train operators, trade-offs must be made between offering as much comfort as possible for low prices. Due to the additional required space for sleeper accommodation, it might be most economical for night train operators to focus on offering as many mini cabins as possible on a night train. Couchette accommodations, which take up as much space as a mini cabin, seem not worth offering.

Flight costs are equally relevant for influencing night train market shares. Therefore, night train operators should establish new connections on routes where few low-cost airlines are active.

The total travel time is insignificant at a 5% level. Valid for attribute values from 12 to 18 hours, people do not consider travel times to a great extent when choosing night trains. A bed conversion to a seat could further increase comfort during the day and enable even longer travel times. Furthermore, the results of this study indicate that it is not necessary to construct HS night trains that can operate up to 300km/h to reach travel times of 12 hours. However, this kind of rolling stock might be used if it is desired to connect cities of an even longer distance.

Delays are not crucial for the choice of night trains, given the context of this study. This implies that not too extensive buffer times are needed in the timetable for night train operators.

Furthermore, access does not seem to influence the attractiveness of night trains to a great extent. This means that people are willing to choose the night train even though they might travel a significant distance (up to 200km) to board it. The catchment area of night trains - at least on the access side - is thus extensive. Amsterdam and Rotterdam might be enough stations to cover demand from the whole Netherlands.

Despite previous studies indicating that a third of international train bookings fail (see Preslmayr et al., 2021), this study recommends that night train operators spend not too many resources on the booking system. With all respondents rating various booking scenarios between levels 1.9 and 3.6, the difference between these booking levels causes only a marginal difference in mode share.

However, Suppose night train operators decide to improve their booking systems to harness the increased willingness to pay up to 31 EUR. In that case, they should try collaborating with other train operators - primarily national railways of the respective countries - to integrate tickets for access and egress. This makes booking a night train ticket from various stations in the Netherlands to smaller towns in the European Union possible. Booking one ticket and being therefore eligible for remunerations in case of delays is the most critical factor for the booking convenience. Collaborating with other railway companies enables us to offer tickets to smaller towns in foreign countries. The second most important factor to improve booking convenience is integrating into search engines like Google Flights, Skyscanner, Omio and more. Listing the night train connection in one of these search engines can significantly improve booking convenience. The impact of integrating these surveys might be vastly more extensive than stated in this survey. Many travellers might not consider currently night trains to travel, but listing night train services in search engines might enable night trains to appear in real-world choice sets. Being more straightforward to implement and potentially significantly improving booking convenience is increasing the booking horizon.

The easiest and the most common way for policymakers to stir demand is via pricing, for example, through subsidies and taxation. This study suggests that subsidies for night trains are more effective in boosting market shares for night trains. 80 EUR invested in subsidising night train travel and 100 EUR in additional flight taxation can boost night train market share by 32%. On the other hand, a flight tax of 200 EUR can only boost night train market shares by 22%. However, this is at the expense of HSR services operated during the day; the market share for flights remains constant. Therefore, raising taxation for flights through increased airport charges or introducing fuel taxes on international relations might be reasonable to teach if it is desired to reduce GHG emissions. If it is decided to highly tax GHG emissions, mainly flight lovers and cost-sensitive travellers are affected to a lesser extent.

If it is decided to subsidise night train services, the beneficiaries are primarily experienced night train travellers and, to a lesser extent, cost-sensitive travellers. Environmentally conscious comfort lovers and flight lovers do not profit from night train subsidies and are not affected by a higher GHG taxation.

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A

Scientific Paper

Unravelling night train travel behaviour: A stated preference survey into the influence of operational and personal factors

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***Abstract*—Night trains benefit society in multiple ways. They are environmentally friendly, improve the accessibility of regions and are space-effective. Understanding travellers preferences enables night train operators to improve night train services and leads to harness the societal benefits better. This study conducted a stated preference survey with 1031 respondents from the Netherlands to dive deeper into the importance of operational factors like booking convenience, travel costs, long travel times up to 18 hours and accommodations. Additionally, factors were revealed that make up a convenient booking scenario. Lastly, a latent class choice model (LCCM) was applied to derive insights into heterogeneity and to determine to which extend personal factors influence class membership. Results reveal that for a convenient booking scenario, being able to book one ticket and comparing travel options are most important. However, booking convenience does only play a minor role in determining night train mode choice, travel costs and accommodation are significantly more important. Several classes have been revealed: Environmentally conscious comfort lovers make up 13% of the respondents, experienced night train travellers 29%, cost sensitive travellers 37% and flight lovers 20%. Applying a scenario analysis, night train market shares vary from 20% to 71% with significant heterogeneity among the population. For practitioners, this implies to focus mainly on prices and accommodation, while taking the significantly different preferences of the population into consideration.**

***Index Terms*—night trains, stated preference survey, panel latent class choice model, panel mixed logit model, booking convenience**

I. Introduction

In recent years, night trains have enjoyed a comeback and rising popularity, mainly driven by the higher perceived importance of the environment [39]. They become a viable option for many environmentally minded people by emitting significantly less GHG emissions than flying [38]. Besides this, night trains benefit society in multiple other ways. For users, night trains are pleasant and, for some, even adventurous. The main advantage from a user's perspective is that the travel time can be used for sleeping. The lower value of time lets passengers accept higher travel times for reaching their destination, which increases the catchment area of night trains and, thus, the accessibility of regions. For society, benefits emerge mainly through improved land use efficiency. In general, new night train connections do not rely on constructing dedicated new tracks, which destroys natural habitats and human settlements [39]. Furthermore, the accessibility of regions can be improved through additional travel options.

By incorporating the preferences of night train users, the societal benefits associated with this mode can be harnessed to a greater extent. Therefore, this paper will focus on deciphering people's preferences regarding night trains destined for an improved policy- and operational design of night trains.

Few previous studies have elaborated on uncovering people's preferences regarding night trains. Heufke Kantelaar et al. [35] pioneered by estimating the replacement potential of night trains towards aeroplanes, concluding that comfort among price is the most significant variable in determining night train mode choice. Curtale, Larsson, and Nässén [38] followed suit by including psychological variables like environmental attitude and fear of flying into their analysis. Lastly, Moors [45] conducted a stated choice experiment of Belgian customers, revealing various classes with different preferences regarding night train interior design.

First and foremost, booking convenience has not been included in previous analyses. For 43.2% of the respondents, booking convenience was important for long-distance mode choice in a study conducted by Curtale, Larsson, and Nässén [38]. Currently, booking international trains is tedious in Europe [14] [30]. Preslmayr et al. [32] showed that a third of all international train bookings failed, compared with only 3% of flight bookings.

Similarly, night trains in Europe are unreliable [40], which is a decisive factor for over a quarter of customers [38]. The influence of experience on mode choice for night trains was not studied before. Also, it might be attractive to research night train demand for different attribute levels. Longer running times of night trains towards more remote destinations would utilise the rolling stock more efficiently and increase the catchment area. A study from DB International GmbH [12] confirms the potential of night trains on very long distances under reduced track access charges.

Besides operational factors, personal factors are responsible for heterogeneity within the population. Insights into joint preferences for modes and deeper insights into latent classes are especially missing. Insights are needed into which type of passengers are more likely to use night trains instead of other modes and how the preferences for operational factors vary among respondents. To group the multiple factors, this paper decided to separate factors into personal and operational ones. Whereas night train operators and policymakers can influence operational factors, personal factors depend solely on the passenger. The primary research and sub-research questions are presented in Table I and aim to fill the research gaps.

This paper provides insights for night train operators, policymakers, and Royal HaskoningDHV (RHDHV), identifying factors like booking convenience and travel preferences that can improve night train services and market positioning. It recommends to policymakers and night train operators measures to promote night train travel. Additionally, it contributes to research by integrating booking convenience into transportation mode choice models. The findings aim to boost the societal benefits derived from night trains.

This paper is organised like the following. Firstly, in section II, the used methods are explained for this paper. In section III, through a literature review, a conceptual model was derived. This states which attributes, background variables and contexts might influence business and leisure travellers' night train use. In section IV, the specification of the used variables is highlighted. Furthermore, the questionnaire, the model specification and the scenario design are shown. Various models will be estimated and compared in section V. The best-fitting model will be presented extensively, and the importance of various operational factors will be highlighted, thus answering all sub-research questions besides the last. A particular focus is laid on latent classes, enabling the splitting of the population into various parts. These demand segments are used to predict market shares for night trains. In section VI, the study's findings are compared with previous research, limitations are provided, and the generalisation of the results is elaborated on. Lastly, it is concluded, and recommendations for research and practice are provided.

II. Methodology

The following methodology chapter outlines the methods used for this paper. The steps to derive a conceptual model are presented as a basis for further analyses. The survey section highlights the scope of the research, the experiments, the survey method and the survey construction and distribution procedure. Some parts of the data were analysed by descriptive analysis and regression, whereas most were analysed using discrete choice modelling. In particular, the discrete choice models multinomial logit, panel mixed logit and latent class choice are used.

A. Literature Review

The literature review aims to determine relevant alternatives, attributes, background variables and specific contexts that might influence travel demand for night trains. It was focused on only mode choice. Other choices, like the destination choice and time of day choice, are out of the scope of this literature review. The literature review was conducted through Scopus in a three-step procedure. Firstly, it focuses on the long-distance passenger market to derive general variables before focusing specifically on the mode of night trains.

Similar to the scientific literature review, a grey literature review was conducted. Here, the search engine "Google" was used. Two different search terms have been used. Since most night trains in Europe are operated by the Austrian railways ÖBB and night trains are very popular in German-speaking countries, it was decided to search the same terms in German as well.

B. Behavioural modelling paradigms

Travel behaviour in this paper is assumed to follow various behavioural modelling paradigms. The primary focus is on the econometric modelling paradigm, which assumes that travellers choose the option offering maximum utility. This approach helps assess factors influencing night train demand and forecast their impact. Additionally, the study incorporates the mobility styles paradigm, identifying latent classes with distinct experiences and needs, thus aiding in adjusting services to people's preferences (see Kroesen [41].

C. Survey

After defining a conceptual model, a survey was used to acquire data. Firstly, the scope of the study is presented, then the experiments which have been used are highlighted, and lastly, the survey methods used in the experiments are shown.

Europe was chosen as scope because of its ambitious climate policy and vast railway network. It was decided to specifically look at the substitution effect of night train demand. Possible generation effects of new night train services are neglected to simplify the used model. Furthermore, it is assumed that people behave according to the classical four-step transportation planning model [11]. This paper focuses only on mode choice and assumes no capacity constraints for rolling stock and infrastructure. Therefore, a theoretical demand potential is calculated.

Night trains in Europe are categorised into standard day trains, classic night, tourist journey trains, and seasonal charter night trains [12]. The research primarily focuses on classical night trains that operate for a single night. The population for the study is Dutch citizens aged 18 and older, divided into business and leisure travellers.

The study involves three experiments: a booking experience experiment, a booking convenience experiment, and a mode choice experiment. The first two experiments describe experiences of Dutch travellers and factors comprising booking convenience. The last experiment, on the other hand, explores the importance of various factors regarding mode choice. A questionnaire was used to gather data for the first experiment, whereas a stated preference survey was used for the last two experiments. stated preference (SP) surveys provide several advantages compared to RP data, for example being able to include hypothetical alternatives, to observe choices for rare situations and to retrieve multiple choices per respondent, causing reliable estimates Molin [44].

TABLE I: Research sub-questions and applied methods

How do operational and personal factors influence Dutch travellers' preferences for night train services headed to European very-long-distance destinations?

Sub-question	**Method**
What comprises a convenient booking, and to what extent does it influence night train demand on average?	Descriptive analysis, Regression, mixed logit (ML)
How do other operational factors influence travellers' night train preferences on average?	ML
Which night train demand segments can be identified, how do personal factors influence them, and what are their preferences regarding operational factors?	LCCM
What are the predicted market shares of night train services for various demand segments in different scenarios?	LCCM, Scenario analysis

The booking convenience experiment is a sub-experiment of the mode choice experiment, using the Hierarchical Information Integration (HII) approach [2]. According to Johnson and Orme [4], people can only consider seven factors in their decision process simultaneously, which is why it was chosen to separate both experiments. The booking convenience experiment detects factors that comprise a convenient booking situation. This booking convenience was then a factor in the mode choice experiment.

The survey was constructed using the ngene tool and distributed via the NS panel, which consists of potential respondents interested in railway-related issues. This enables us to get sufficient responses in various age groups, resembling the Dutch population as closely as possible. However, using the panel implies also accepting a skewness of the respondents towards older members and railway-favouring opinions.

D. Analysis

For the analysis of the data, various methods have been used. The questions regarding booking experience were chosen for a descriptive study. The booking convenience was analysed through linear regression due to the rating questions.

Numerous discrete choice models can analyse stated preference surveys. Most of them assume that decision-makers adhere to random utility maximisation. This utility of one alternative is comprised of weighing several attributes that make up this alternative.

The first model used is the multinomial logit model from McFadden [1]. The probability of choosing the alternative i depends on the choice set C and can be calculated in a closed form. Here, it is assumed that error terms are independent and identical Gumbel distributed (i.i.d) [5] and that the probability of one alternative is independent of irrelevant alternatives. Furthermore, the importance of attributes b_k is homogeneous among individuals, and decisions are independent of each other if one respondent has collected multiple observations.

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

Since most assumptions do not hold if some alternatives are more similar, respondents answer multiple times and differ in their preferences; the mixed logit model has been developed. By incorporating variables for heterogeneous tastes and preferences, it is possible to acquire higher model fits [34]. In Equation 2, v_n denotes the variance of a taste parameter β_n.

$$P(n,i) = \int_{v_n,\beta_n} (\prod_{t=1}^{T} (P_{ni}^t | v_n, \beta_n) \cdot f(v_n, \beta_n)) dv_n d\beta_n \quad (2)$$

One drawback of the Panel ML logit model is that respondents' preferences are assumed to follow specific distributions. Latent class choice models, however, think that the population has various latent classes with different tastes. In a class-membership function, the probability of one individual belonging to one latent class is determined. This probability is determined by a traditional multinomial logit model, where γ_{sq} and δ_S denote the class membership parameters and z_n the covariates that determine the class. In Equation 3, the class membership model is presented.

$$\pi_{ns} = \frac{e^{\delta_S + g(\gamma_{sq}, z_n}}{\sum_{l=1...S} e^{\delta_l + g(\gamma_{lq}, z_n}} \quad (3)$$

This approach has the advantage that it is a mixture between the mobility styles modelling paradigm and the econometric modelling paradigm. The latent class model is provided in Equation 4, where S denotes the classes and π_{ns} the class membership function [6]

$$P(n,i) = \sum_{s=1}^{S} \pi_{ns} (\prod_{t=1}^{T} P_n(i_t|\beta_s)) \quad (4)$$

Various metrics have been used to compare the model performance. This thesis uses the ρ^2 value, the likelihood ratio test, the Ben-Akiva and Swait test, and the Bayesian information criterion (BIC).

To get an initial indication of the model performance, the ρ^2 value is used. It is a statistical measure representing the proportion of the initial uncertainty the model explains and usually ranges from 0 to 1. However, it is impossible to determine if a model is statistically superior only by the ρ^2 value [34].

To compare models statistically, a likelihood ratio test is more suited. It also compares the goodness of fit of two competing statistical models using the likelihood. The null hypothesis of the likelihood ratio test is that a more restrictive model represents the data adequately. The test statistic can be computed by subtracting the log-likelihood values of the models: $\lambda = -2 \cdot LL_0 - LL_1$, where LL_0 denotes the Log-likelihood value of the more restrictive model, thus comprising fewer parameters.

However, the likelihood ratio test demands that the same decision rules have been used. For comparing different models like the Panel ML model with the MNL model, the Ben-Akiva & Swait test [3] is used. It provides a conservative estimate for the probability that although model B fits the data better than A, A is the better model in the population 5. N denotes the number of observations, and j is the number of alternatives in the choice set.

$$p = NormSDist(-\sqrt{2 \cdot N \cdot ln(j) \cdot \frac{LL(B) - LL(A)}{LL(0)}}) \quad (5)$$

As it is good practice in estimating Latent class choice models to determine the number of optimal classes, the Bayesian Information Criterion (BIC) has been used. It is defined through Equation 6, where k denotes the number of alternatives, and N is the number of observations.

$$BIC = -2 \cdot LL + k \cdot ln(N) \quad (6)$$

III. Theoretical Framework

The conceptual model, derived mainly through literature research, can be found in Figure 1. Factors highlighted as grey are part of the conceptual model but not included in the study, primarily to reduce the complexity of the model. In the following, the components of the conceptual model are highlighted piecewise.

Relevant modes on long distances over 500 km have turned out to be the car, flying by aeroplane, riding the train and lastly, using the bus [20] [14]. Night trains as a mode are only covered very seldom in analyses. This study will focus only on high speed rail (HSR) trains, night trains, and flights. Cars are conceptually different through the ownership structure and the vehicle's private mode. For simplicity reasons, it was decided to waive the mode of long-distance buses.

Various factors play a role when choosing modes on long and very long distances. Included in almost all analyses, travel time plays a significant role in the decision of respondents [10] [42]. However, since travellers on night trains usually sleep for the longest part of the leg, the effect on night trains might be less. Furthermore, travel time might be perceived differently depending on departure and arrival times [35]. In other studies - mainly in China - travel time was conceptualised as the total travel distance [27].

Besides travel times, travel costs are essential in long-distance mode choice [36] [37]. Further factors included in this analysis are the perceived comfort, which is considered crucial across different modes of transport. Several studies support this [10] [9] [28] [16] [18]. For night trains, perceived comfort is more important, as highlighted by Heufke Kantelaar et al. [35].

Furthermore, booking convenience is also relevant in long-distance travel mode choice, a factor often overlooked. However, according to Li et al. [27] and Yang, Chen, and Yang [36], this factor is crucial. A study by Curtale, Larsson, and Nässén [38] found that easy booking was a key factor for 43.2% of respondents for choosing the night train, ranking fourth in importance. However, booking trains in Europe is complex [14], and this complexity discourages customers from using night trains [30]. A study by Preslmayr et al. [32] demonstrated the difficulty of booking international train connections compared to flights.

To investigate the booking process, a grey literature review identified ten factors contributing to the perception of a problematic booking process. These factors include the lack of a comprehensive search engine for comparing international train and flight connections [39], the possibility to book one ticket for the whole journey [46], and the earliest possible booking date [19]. Furthermore, a modern website with easy-to-follow steps [29] and the time needed to book after having chosen a connection were found. Additional points are seat selection, booking completion time, comfort level consistency, and the possibility to re-book [13] [43] [35].

A survey with the personal network revealed that five factors emerged as the most critical factors comprising booking convenience. The first is a search engine, where various train and plane connections can be compared. Furthermore, being able to book one ticket is relevant. Through this, passengers are eligible for passenger rights according to EU legislation. The earliest possible booking date and the time to complete the booking are further factors. Lastly, a digital ticket describes if a ticket can be conveniently shown on a mobile application on a smartphone.

Another factor influencing long-distance mode choice is reliability, as highlighted in various studies including Román, Espino, and Martín [9], Cascetta et al. [10], Mándoki and Lakatos [16], and Burgdorf, Eisenkopf, and Knorr [21]. Specifically for night trains, punctuality is essential to 75% of respondents, as indicated by Hödl [7]. Contrarily, in a study by Curtale, Larsson, and Nässén [38], only 25% of respondents considered reliability crucial.

Transfers significantly influence mode choice for long-distance travel. Ren et al. [28] and Ku et al. [42] found that the likelihood of choosing conventional trains over high-speed rail increases when direct high-speed services are unavailable. Van Goeverden [8] argues that transfers are not a significant factor in mode selection, though grey literature sources like Sonnenberg [46] and Walther et al. [17] suggest otherwise. As a result, the impact of transfers has been incorporated into the conceptual model.

Furthermore, context is also expected to influence long-distance mode choice. In particular, factors like trip purpose, travel group, luggage, financials and access are considered. Studies reveal mixed results on the influence of trip purpose and travel group on mode choice. The travel group has been included in demand analysis for night trains, with Curtale, Larsson, and Nässén [38] concluding this factor as relevant, whereas Moors [45] discovers otherwise. Luggage size has been linked to a higher likelihood of using night trains [17], and financial aspects, such as who bears travel costs and potential savings on accommodation, are also included in the analysis [33] [15] [10]. Access and egress times are crucial in choosing transportation modes, as indicated in studies by Zhen, Cao, and Tang [23], Cascetta et al. [10], Román, Espino, and Martín [9], and Li et al. [27]. Despite the lack of scientific studies on night trains, grey literature indicates that short access and egress times are beneficial for using night trains [26].

The impact of travel experience on long-distance mode choice is varied: while Bergantino and Madio [24] sees no effect, Cascetta et al. [10], Dällenbach [25], and Ren et al. [28] observe an influence, especially for high-speed rail and general train travel. This factor, including both positive and negative experiences Curtale, Larsson, and Nässén [38] Buh and Peer [33], is added to the conceptual model to explore further its significance on the probability of choosing night trains.

Psychological factors, such as a general preference for specific modes and the enjoyment of scenic or romantic aspects [15], [26], play a role in transportation mode choice. Relevant for night trains are the fear of flying and the intention to use environmentally friendly modes. The latter is present among younger travellers and has been shown to impact the choice of night trains significantly [46] [7] [30] [15] [33] [22] [38]. These factors have been integrated into the conceptual model to explore their effects on mode choice further.

Lastly, socio-demographic factors like age, gender, employment status, education level, income, and car ownership significantly influence long-distance mode choice. Studies reveal age and gender's varying impacts on choices for high-speed rail [10] [42] [24] [31]. Employment status, education, and income are factors as well, with differing views on their effects on night train usage [35] [45] [38]). Car ownership, while less relevant for longer distances, is also considered significant [27] [8].

In the conceptual model in Figure 1, various groups of covariates are expected to influence the attributes of the alternatives. In grey highlighted attributes and covariates are not included in the case study in order to simplify the model. All covariates are expected to influence the class membership, which influences the utility of the attributes of the alternatives. Only socio-demographics, travel experience and the context are expected to influence the booking convenience.

IV. Specification

a) Survey Design: For the experiments, one scenario with specific sub-scenarios has been used. Distances of 1400 to 1600 km are assumed, and it was decided for an outbound trip to Barcelona departing from the Netherlands. The flight is scheduled to depart from Schiphol, and the night train and the HS train are expected to stop in Amsterdam Centraal, Schiphol and Rotterdam Centraal. Furthermore, people are expected to consider the price of an additional hotel night when choosing the plane and the HS train option.

Two scenarios have been chosen. For business trips, respondents were considered to be working and to travel occasionally to international destinations. They are expected to leave on a Tuesday, and the employer paid for the trip. Furthermore, only hand luggage is assumed. Other respondents were assigned to leisure purposes. They are expected to depart on a Friday for holidays. Furthermore, they are expected to travel in their usual group.

The total travel time for the night train varies from 12 to 18 hours. The plane is expected to fly 5 hours and the HS train is expected to take 12 hours. The HS train option was defined as a reference alternative. The attribute values are thus not changing for the HS train. Travel costs are expected to vary significantly for both the night train and the plane option. For the night train, costs from 50 EUR to 290 EUR are expected, whereas the flight expenses are 150, 250 and 350 EUR. In each attribute level, a hotel stay with a price of 100 EUR is assumed to be considered. For the night train, the new rolling stock is assumed, with comfort classes thus being seating arrangement, a couchette, a mini-cabin and a sleeper. A couchette provides a berth, but strangers must share the compartment. Recently introduced by the market leader of night trains in Europe, ÖBB, is the mini-cabin. It is similar to a couchette, with the difference that passengers sleep more separated in a Japanese-style capsule accommodation. This provides more private sphere but the sleeping comfort is the same. Lastly, a sleeper accommodation is available, which can be compared to a hotel room. Economy class is assumed for the flight, and second class for the HS train. Access distance was defined as the distance of respondents towards the closest boarding station, both for the plane and train alternative.

Several questions were posed to reveal the booking experience of Dutch travellers. They referred to the usual booking sites, pain points in booking international rail connections in Europe and whether they booked multiple tickets to reach their destination. The factors mentioned in the conceptual model have been used for the booking convenience scenarios. For realistic booking horizons, one month and six months have been assumed. Regarding the average booking time, a study from [32] was taken as input, delivering 5 and 20 minutes attribute values. In the mode choice experiment, it was chosen to use the reliability attribute levels 15, 30 and 45 minutes. Train travel experience was measured through three indicator variables: The usual train travel, experience with international train travel and experience with night train travel.

The intention to use environmentally friendly modes is determined by three factors. The first indicator is finding it essential to use environmentally friendly modes, the second to be influenced by people important to the respondents, and the third to use environmentally friendly modes even under inconvenient circumstances.

Fig. 1: Conceptual framework of long-distance transport

b) Survey construction and distribution: After having defined the survey, choice sets were determined by ngene. It was chosen for an orthogonal fractional factorial design, where 111 responses are necessary, considering each respondent answering nine choice situations.

c) Data sample: Out of the invited 5,461, 1,062 respondents answered the survey, resulting in a response rate of 19.5%. One 1,031 answers have been used for the analysis due to a programming error. Regarding age, the survey respondents closely align with the Dutch population. However, there are slightly more males in the data set, and according to [35], the panel is prone to be skewed to higher educated respondents with higher salaries. This could not be validated in this survey due to privacy restrictions from NS. On average, the HS train is selected in 23.2% of cases, while the night train is the most favoured option at 42.7%, and the plane follows at 34.1%. This suggests that each mode represents a viable alternative.

d) Model specification: In the following steps, the estimation strategy will be highlighted both for the booking convenience experiment and the mode choice experiment.

Furthermore, it is emphasised on the coding of variables.

For the booking convenience rating model, a model including only attributes was first added, and then covariates were added in groups. Firstly, socio-demographics, then context, and travel experience variables were included. Every time, it was tested if the whole group improved the model through an F-test.

Nominal variables were effects coded in this paper. Additionally, several variables were simplified compared to the questionnaire. Gender was reduced into two categories: female on the one hand and male and others on the other hand. Work statuses were reduced to basic types, and travel groups were aggregated into groups. Train experience was categorised based on frequency for the usual train travel and recency for international train travel and night train travel. Incorrect access distances were corrected, and the choice variable was defined as a booking convenience rating on a scale of 1 to 5.

Coding for the variables in the mode choice experiment is similar to the coding used for the booking convenience experiment, with nominal variables being effects coded. A multinomial logit (MNL) model and a ML model were used to reveal the average influence of operational factors. Two attributes were assumed to be non-linear: travel time and booking convenience. In the ML model, joint preferences for all binary combinations of modes were assumed. The optimal number of Halton draws was determined through starting at 50 draws, doubling the draws and evaluating if the parameters have converged. Via a Ben-Akiva and Swait test, it was determined that the Panel ML model is statistically superior compared to the MNL model.

To derive a LCCM with the optimal number of classes, BIC values of discrete mixture models were compared. Further categories were the explainability of parameters and if the derived estimation results are robust. Discrete mixture models do not comprise any variables in class membership functions but only variables consisting of the utility of alternatives. The operational factors, thus travel time, costs, accommodation, booking convenience, reliability and access distance, are expected to influence the alternatives' utility directly. Due to interpretability and computational reasons, it was chosen for four latent classes. Class-membership functions were added after finding the model with the optimal number of classes. These consist of personal factors, thus socio-demographics, context, train experience and the intention to use environmentally friendly modes. Despite having different goals, the LCCM and the Panel ML model were compared via a Ben-Akiva and Swait test regarding their predictive power, revealing that the LCCM is statistically superior.

V. Results

A. Booking experience and components of a convenient booking

a) Booking experience of Dutch citizens: Most Dutch citizens book their international train travel on NS International, which is unsurprising given that NS is the incumbent in the Netherlands. For people in Figure 2c, the most popular reason to choose booking sites is out of habit. Furthermore, user-friendliness, speed and reliability are factors. The differences between leisure and business travellers are not as stark as expected, with business travellers emphasising habit and user-friendliness slightly more than leisure travellers. Most people appear to book only on one booking site, indicating they will not travel with international rail services if booking them on one website is impossible. Furthermore, they vary a lot in their estimation time of an average booking situation but seem overall content in their booking experience. In particular, entering the payment details and paying and receiving the payment confirmation works well. Comparing travel options for international train connections is the biggest problem when booking. Over a third of the respondents mention that comparing train travel options is complex or challenging.

TABLE II: Linear regression results for booking convenience

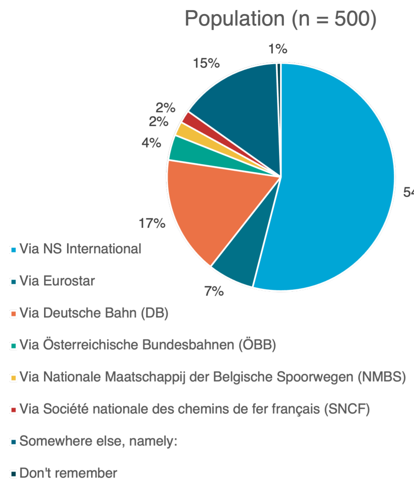
Model	Base Model			Final Model		
Parameter	Value	t	Sig	Value	t	Sig
constant	**2.652**	51.455	<0.001	**2.622**	50.457	<0.001
Search engine	**0.216**	10.073	<0.001	**0.216**	10.122	<0.001
Single ticket	**0.433**	20.193	<0.001	**0.433**	20.292	<0.001
Earliest booking date	**0.044**	5.119	<0.001	**0.044**	5.145	<0.001
Digital ticket	**0.123**	5.756	<0.001	**0.123**	5.785	<0.001
Booking duration	-0.002	-0.553	0.581	-0.002	-0.716	0.474
Usual train frequency				-0.029	-1.281	0.200
International trains				**0.106**	4.679	<0.001
Night trains				**-0.056**	-2.275	0.023
R-squared	0.214			0.223		

b) Factors determining booking convenience: In Table II, the booking convenience rating experiment results are presented. The model incorporating train experience, which demonstrated a slightly improved fit with 23.4% explained variance, was selected. Almost all main attributes were significant and contributed to booking convenience. Contrarily, the duration of booking did not significantly impact booking convenience. This suggests that the time to book is not that extensive compared to the whole process.

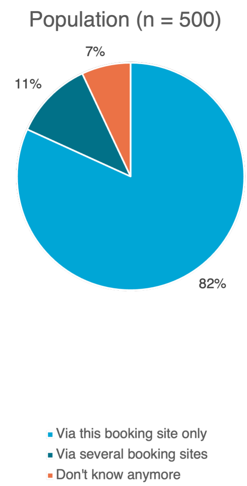
Expectations were largely not met. Many covariates did not influence booking convenience. Travel purpose, the size of the travel group, and socio-demographic characteristics did not influence booking convenience. Only respondents with international train travel experience within the past two years rated booking situations better. In contrast, experienced night train travellers rated booking scenarios less favourably.

Contrary to initial expectations, the ability to book the entire journey with a single ticket emerged as the most critical factor, with a maximal utility contribution of 0.865, significantly outweighing the utility of having a search engine (0.432). This finding, supported by the reluctance towards multi-ticket bookings observed in Figure 2, underscores the importance of single tickets over other convenience factors.

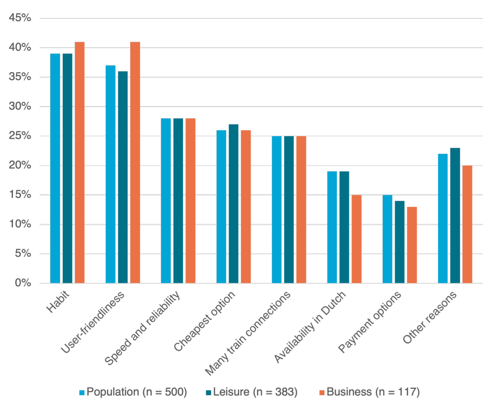
The utility contributions reveal a hierarchy of importance among factors influencing booking convenience. The availability of a search engine is second most important factor and the combined value of digital ticket availability and early booking horizon (0.496) follow suit. Interestingly, the contribution of booking time was revealed to be negligible,



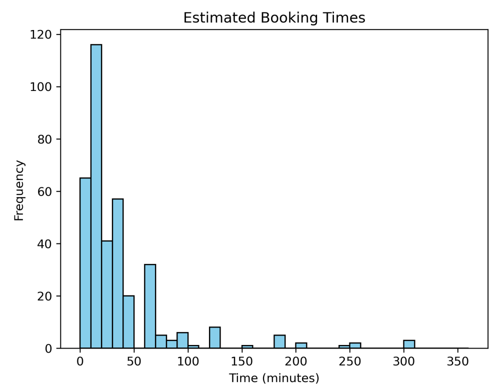
(a) Booking sites of Dutch travellers



(b) Inclination to use multiple booking sites



(c) Reasons for choosing booking sites



(d) Estimated booking duration

Fig. 2: Booking behaviour of the Dutch population

whereas international train experience is as important as digital ticketing and early booking, highlighting the significant role of user experience.

Diverse responses were noted in booking convenience ratings among individuals with varying levels of train experience. Those with no train experience rated booking scenarios slightly lower, equivalent to a 15-day shorter booking horizon. In contrast, highly experienced train users exhibited marginally higher utility values, illustrating minor yet observable differences. Remarkably, the utility of booking with a single ticket far surpasses these variations, underscoring its overwhelming importance in booking convenience.

However, people rated booking convenience only on a scale between 1.9 and 3.6. For instance, a booking convenience level of three corresponds to scenarios lacking a search engine but offering a one-ticket booking option, with the earliest possible booking six months in advance without app integration for the ticket and a booking duration of five minutes. This suggests that the booking experience is perceived not very differently among respondents.

B. Average factor importance

a) Parameter estimation results: The analysis in Table III utilised the Panel ML model, selected for its superior LL value and the Ben-Akiva and Swait test, as detailed in section IV. Several expectations could be met:

- The alternative specific constant for flights was positive and significant (3.403), indicating an initial preference for air travel.
- Significant nesting parameters suggest the presence of unaccounted heterogeneity.
- Both linear and quadratic terms for total travel time, alongside travel costs for night train and aeroplane options, were significant, indicating these aspects are critical in transportation mode selection.
- Accommodation options for the night train were significant as well, like the booking convenience parameters.

Contrary to expectations, some variables were not significant:

- The night train's alternative specific constant was not significant, night trains are thus not perceived differently

TABLE III: Parameter estimation result for the MNL and ML model

	MNL Final			ML Final 100 draws		
Parameter	Value	t	Sig	Value	t	Sig
ASC night train	**0.020**	0.011	0.991	-2.940	-0.929	0.353
ASC plane	**1.889**	21.863	<0.001	**3.403**	9.659	<0.001
STD night train HSR				**3.006**	19.015	<0.001
STD night train plane				**-2.847**	-23.094	<0.001
STD plane HSR				**-0.785**	-9.786	<0.001
travel time night train	2.611	1.040	0.298	**9.008**	2.074	0.038
sq. travel time night train	**-1.211**	-1.446	0.148	**-3.496**	-2.420	0.016
cost night train	**-0.757**	-24.290	<0.001	**-1.040**	-19.589	<0.001
couchette	**-0.363**	-8.518	<0.001	**-0.583**	-7.945	<0.001
mini cabin	**0.684**	12.662	<0.001	**0.920**	10.152	<0.001
sleeper	**0.785**	19.729	<0.001	**1.085**	16.541	<0.001
booking convenience	**0.382**	5.006	<0.001	**0.474**	6.575	<0.001
sq. booking convenience	**-0.044**	-3.535	<0.001	**-0.052**	-4.560	<0.001
delay	0.031	0.268	0.788	0.085	0.819	0.413
access distance train	0.041	0.866	0.386	0.065	0.421	0.674
cost plane	**-0.559**	-18.956	<0.001	**-1.287**	-22.816	<0.001
access distance plane	**-0.157**	-3.259	0.001	-0.074	-0.216	0.829
LL	-8,801			-6,290		

compared to HSR services.

- The insignificance of reliability suggests that potential delays (exceeding 15, 30, or 45 minutes in 20% of cases) do not deter travellers.
- Access distances for both night train and aeroplane were irrelevant in mode choice, indicating that the distance to access transportation does not swing preference towards either mode.

b) Similarity of alternatives: People have strong and varied preferences when choosing how to travel, especially between HSR and night trains. A key finding is that a third of the respondents are willing to pay more, with a maximum of 145 EUR, to avoid flying. Joint preferences for night trains and flights are quite similar. On the other hand, fewer people are willing to pay extra to avoid night trains. This reveals that opinions on travel modes are diverse, especially between air travel and trains. Despite this, night trains don't stand out as strongly preferred or disliked, making them a middle-ground option between HSR and flights. Essentially, while people see HSR and flights as very different from each other, night trains are viewed more neutrally.

c) Average importance of operational factors: The cost of air travel, accommodation quality, and the cost of night train tickets emerged as nearly equally important, each playing an important role in the decision to opt for night trains. The utility ranges for these attributes were closely aligned, with airfare cost leading at 2.57, followed closely by accommodation at 2.51, and night train cost at 2.50, indicating a balanced consideration among these factors. Travel time and booking convenience were identified as less critical, with utility contributions of 0.89 and 0.65, respectively. Booking convenience's importance is further diminishing to 0.32 when considering the limited range of rated booking scenarios.

d) Average willingness to pay (WTP) for operational factors: Booking convenience slightly impacts the decision to use night train services, being the least important factor that turned out significant. A maximum willingness to pay (WTP) of around 31 EUR for improved booking convenience can be observed. Specifically, being able to book a single ticket and reducing booking time to five minutes was valued at 21 EUR. It is assumed that no search engine is available, the earliest booking time is six months, and neither is a digital ticket available. A further increase in booking convenience was valued at less than 11 EUR, indicating that increasing booking convenience to a very high level might not be economically valid.

Travel time is another crucial factor, with its value decreasing nonlinearly. Improving the travel time from 18 to 16 hours is valued much higher than 14 to 12 hours. An optimal travel duration of approximately 13 hours can be observed. Accommodation is vital, with substantial WTP for upgrades, indicating that comfort significantly influences night train demand. The full WTP values can be found in Table IV. These findings, however, might be influenced by factors such as inflation, the inclusion of hotel prices in alternatives, and a panel skewed towards higher-income individuals, which may increase WTP values. The forthcoming analysis with a Panel LCCM aims to dive deeper into heterogeneity further.

C. Four segments of night train demand

The analysis using a Latent Class Choice Model (LCCM) segmented night train travellers into four classes: comfort lovers (13%), flight lovers (20%), experienced night train travellers (29%), and cost-sensitive travellers (37%). This indicates diverse preferences within the population. Across segments classes do not prefer the night train inherently, aligning with earlier Panel ML model results. Travel time and unreliability were found irrelevant across all classes, suggesting a general tolerance for longer travel times and delays but with a potential aversion to very long journeys. Surprisingly, factors like travel context (scenario and travel group) and demographics (work status, gender) showed little to no significance in influencing mode choice. This highlights the night train's appeal to a broad audience. The only significant factors affecting class membership were travelling with a partner, the night train

TABLE IV: WTP for upgrading attribute levels of operational factors

Attribute	Increasing attribute levels	Ut. Difference	WTP
Total travel time night train	12 - 14h	-0.016	-1.57
	14 - 16h	-0.296	-28.46
	16 - 18h	-0.576	-55.35
Accommodation	Seat - Couchett	0.839	80.67
	Couchette - Mini cabin	1.503	144.52
	Mini cabin - Sleeper	0.165	15.87
booking convenience	1 to 2	0.318	30.58
	2 to 3	0.214	20.58
	3 to 4	0.110	10.58
	4 to 5	0.006	0.58

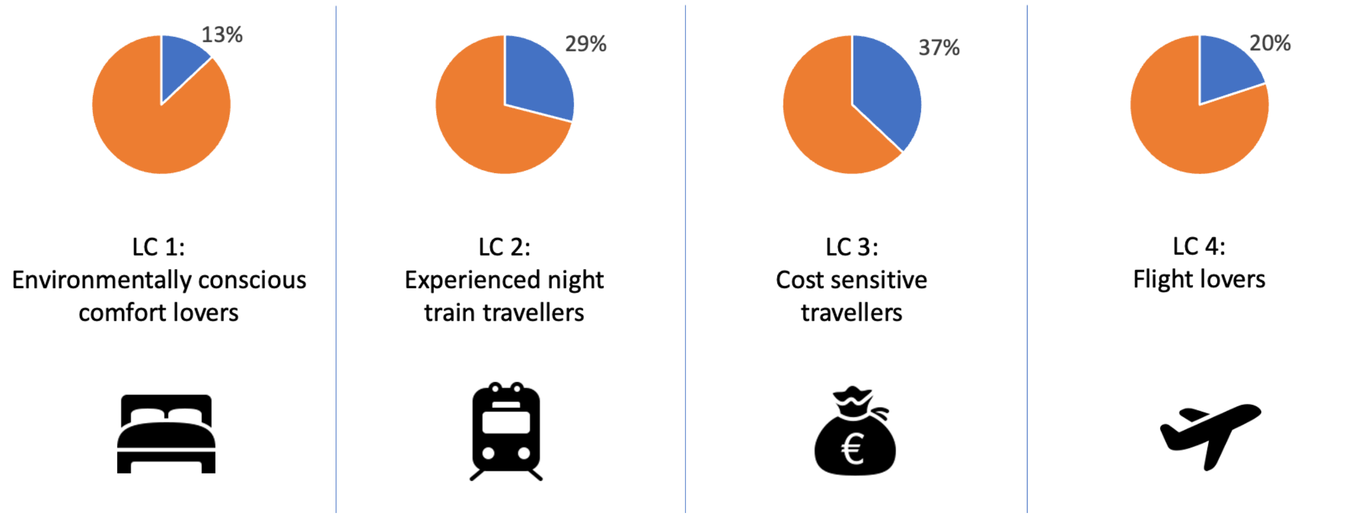


Fig. 3: Latent classes with share

experience and the intention to use environmentally friendly modes. Except for the perceived pressure from close contacts, the importance to use environmentally friendly modes and to do so under inconvenient circumstances are highly relevant.

a) Class 1: Environmentally conscious comfort lovers: Among the population, 13% are identified as environmentally conscious comfort lovers. They prioritise accommodation, booking convenience, and proximity to railway stations when choosing transportation modes. Surprisingly, the distance to the nearest train station significantly influences their choice, being more important than the typically decisive factors of travel time and cost, which are irrelevant for this group. Comfort lovers are more likely to emphasise environmental considerations. Furthermore, they will likely be older individuals who travel less frequently by night train and often alone.

b) Class 2: Experienced night train travellers: Experienced night train travellers make up 29% of the population. Predominantly, they comprise individuals who have used night trains at least once in the past two years. Furthermore, they are more likely to travel as couples. Surprisingly, when choosing transportation modes, their primary consideration is the cost of flight alternatives, indicating a higher price sensitivity towards flights. The accommodation level is the second most crucial factor for this segment, slightly outweighing the importance of night train costs. Lastly, booking convenience plays a minor role. They show the highest willingness to pay (WTP) for booking convenience improvements, valuing it at up to 35 EUR. Additionally, they are willing to spend significantly on accommodation upgrades.

c) Class 3: Cost-sensitive travellers: Cost-sensitive travellers, comprising 37% of the population, exhibit the highest price sensitivity for both night train and flight costs. For example, they have a 50% higher sensitivity to night train costs compared to experienced night train travellers. Despite their price sensitivity, accommodation on night trains is also a significant factor for them, only 20% less critical than cost. Initially, this group showed a strong preference for aeroplanes over other modes. Demographically, they are younger and less inclined to prioritise environmental considerations in their travel choices.

d) Class 4: Flight lovers: Flight lovers, the final identified class, shows the strongest initial preference for aeroplanes. Accommodation is a significant factor for them: 96 EUR for a seat to couchette upgrade, 221 EUR for couchette to mini cabin, and 77 EUR for mini cabin to sleeper. Unlike the first two classes, booking convenience is not a significant factor in their decision-making. Flight lovers share a disinterest in environmental considerations, more so than cost-sensitive travellers, highlighting a recognition and acceptance of the environmental impacts of flying. They also tend to travel with partners, similar to experienced night train travellers and are typically younger, similar to cost sensitive travellers. However,

TABLE V: Parameters of the LCCM

	Class 1		Class 2		Class 3		Class 4	
Parameter	Estimate	Sig	Estimate	Sig	Estimate	Sig	Estimate	Sig
Alternative Specific constants								
ASC night train	-3.739	0.436	-2.461	0.358	5.941	0.307	-16.691	0.192
ASC plane	-1.980	0.141	1.371	0.075	**4.925**	<0.001	**5.278**	0.001
Attributes for the alternative night train								
Travel time night train	5.738	0.431	7.520	0.215	-2.725	0.433	28.875	0.117
Sq. travel time night train	-3.044	0.396	-2.872	0.185	0.374	0.472	-10.721	0.083
cost night train	-0.671	0.092	**-1.013**	<0.001	**-1.477**	<0.001	**-0.785**	0.004
couchette	**-1.835**	0.045	**-0.563**	0.003	**-0.705**	<0.001	-0.830	0.231
mini cabin	**1.931**	0.002	**0.989**	<0.001	**1.369**	<0.001	0.906	0.092
sleeper	**2.632**	<0.001	**1.095**	<0.001	**1.136**	<0.001	**1.508**	<0.001
booking convenience	**0.801**	0.007	**0.689**	<0.001	0.238	0.055	0.583	0.093
sq. booking convenience	**-0.122**	0.002	**-0.083**	<0.001	-0.005	0.415	-0.078	0.100
delay	-0.243	0.282	0.074	0.366	0.699	0.111	-0.537	0.127
access distance train	**-1.769**	0.023	-0.074	0.374	0.004	0.492	0.848	0.213
Attributes for the alternative plane								
cost plane	-1.403	0.051	**-1.462**	0.001	**-1.463**	<0.001	**-0.584**	0.008
access distance plane	0.833	0.102	-0.446	0.168	-0.056	0.421	1.010	0.299
Class membership parameters								
delta	0.000	N.A.	1.545	0.116	**7.467**	<0.001	**8.232**	<0.001
scenario	0.000	N.A.	-0.139	0.248	-0.103	0.308	0.370	0.180
alone	0.000	N.A.	-0.174	0.198	-0.307	0.083	-0.442	0.071
partner	0.000	N.A.	**0.431**	0.008	0.365	0.027	**0.544**	0.012
usual train frequency	0.000	N.A.	0.210	0.076	0.207	0.080	0.142	0.218
intl. train experience	0.000	N.A.	0.039	0.380	-0.200	0.071	-0.131	0.302
night train experience	0.000	N.A.	**0.408**	0.001	-0.012	0.475	-0.079	0.421
importance env. modes	0.000	N.A.	-0.123	0.290	**-0.337**	0.049	**-0.517**	0.010
pressure env. modes	0.000	N.A.	-0.024	0.449	-0.054	0.379	-0.165	0.206
inconvenience env. modes	0.000	N.A.	0.265	0.113	**-0.756**	<0.001	**-1.124**	<0.001
age	0.000	N.A.	-0.181	0.082	**-0.359**	0.004	**-0.243**	0.035
gender	0.000	N.A.	0.074	0.272	0.122	0.165	-0.008	0.483
student	0.000	N.A.	0.355	0.340	0.991	0.088	-0.065	0.480
retired	0.000	N.A.	-0.211	0.327	-0.593	0.116	-0.090	0.461
working	0.000	N.A.	-0.075	0.426	0.265	0.265	0.701	0.055

TABLE VI: Maximal utility range and WTP values of factors for demand segments

Class	Class 1	Class 2	Class 3	Class 4
Share	13%	29%	37%	20%
		Max. ut. range		
ASC night train	3.739	2.461	5.941	16.691
ASC plane	1.980	1.371	**4.925**	**5.278**
travel time night train	2.036	0.658	0.962	1.973
cost night train	1.610	**2.431**	**3.545**	**1.884**
accommodation	**5.360**	**2.616**	**2.936**	**3.092**
Booking	**0.276**	**0.764**	0.832	0.560
delay	0.122	0.037	0.350	0.269
access distance train	**3.803**	0.159	0.009	1.823
cost plane	2.806	**2.924**	**2.926**	**1.168**
access distance plane	1.791	0.959	0.120	2.172
		Class Membership parameters		
delta		1.545	**7.467**	**8.232**
scenario		0.278	0.206	0.740
Travel group		**0.688**	0.672	**0.986**
usual train frequency		0.420	0.414	0.284
intl. train experience		0.078	0.400	0.262
night train experience		**0.816**	0.024	0.158
importance env. modes		0.492	**1.348**	**2.068**
pressure env. modes		0.096	0.216	0.660
inconvenience env. modes		1.060	**3.024**	**4.496**
age		0.109	**0.215**	**0.146**
gender		0.148	0.244	0.016
work status		0.566	1.654	1.247
	Accommodation: WTP for increase in Accommodation level			
		WTP		
Seat - Couchette	133.08 EUR	**94.57** EUR	**74.14** EUR	**96.05** EUR
Couchette - Mini Cabin	561.25 EUR	**153.21** EUR	**140.42** EUR	**221.15** EUR
Mini Cabin - Sleeper	104.47 EUR	**10.46** EUR	**-15.78** EUR	**76.69** EUR
	Booking: WTP for increase in booking convenience levels			
1 to 2	64.83 EUR	**43.44** EUR	15.10 EUR	-6.24 EUR
2 to 3	28.46 EUR	**27.05** EUR	14.42 EUR	27.13 EUR
3 to 4	-7.90 EUR	**10.66** EUR	13.74 EUR	25.86 EUR
4 to 5	-44.26 EUR	**-5.73** EUR	13.07 EUR	24.59 EUR

this demographic factor is almost negligible in influencing class membership. An overview over the various WTP values, including the importance measured in the absolute utility difference, is provided in Table VI

D. Exploring night train market shares

a) Scenario description: After having discovered various classes that make up demand for night trains, this study delves into possible market shares. Five scenarios explore various pricing and accommodation levels for night trains between Amsterdam and Barcelona. An overview over all scenarios including estimated market shares is provided in Table VII. In the base case scenario, a mini cabin, a 16-hour journey partly on high-speed tracks, and costs of 210 EUR are assumed. The low-cost scenario assumes the usage of old couchette wagons which lead to travel times of 18 hours, flight costs at 150 EUR, and a minimal booking convenience level of 1.9. Conversely, the luxury scenario postulates high-season travel with a sleeper accommodation, a travel time of 12 hours and booking convenience the level 3.6. Policy scenarios both assume the base case scenario and change only the pricing environment. In the high green house gases (GHG) tax scenario, a 200 EUR increase in flight costs is imposed. In the night train subsidy scenario on the other hand, night train prices are reduced by 80 EUR while slightly increasing flight costs by 100 EUR.

TABLE VII: Market shares for various scenarios

	Average	Class 1	Class 2	Class 3	Class 4
S1-base: 16 hours, mini cabin, 210 EUR NT, 3.1 booking level, 150 EUR flight + hotel					
Night train	40%	16%	89%	29%	8%
Flight	45%	3%	3%	67%	92%
HSR service	15%	80%	8%	5%	1%
S2-low cost: 18 hours, couchette, 150 EUR NT, 1.9 booking level, 150 EUR flight + hotel					
Night train	20%	0%	60%	7%	0%
Flight	56%	4%	9%	87%	99%
HSR service	24%	96%	30%	6%	1%
S3-luxury: 12 hours, sleeper, 290 EUR NT, 3.6 booking level, 350 EUR flight + hotel					
Night train	61%	39%	88%	65%	29%
Flight	20%	0%	0%	15%	70%
HSR service	19%	61%	12%	20%	1%
S4-high GHG tax: 16 hours, mini cabin, 210 EUR NT, 3.1 booking level, 350 EUR flight + hotel					
Night train	62%	17%	92%	78%	20%
Flight	19%	0%	0%	10%	78%
HSR service	18%	83%	8%	12%	2%
S5-NT subsidies: 14 hours, mini cabin, 130 EUR NT, 3.1 booking level, 250 EUR flight + hotel					
Night train	72%	37%	97%	87%	34%
Flight	17%	1%	0%	10%	65%
HSR service	11%	62%	3%	3%	1%

b) Demand response for various scenarios: The analysis reveals in Table VII varying potential market shares for night train services in the 1.6 million annual passenger market between Amsterdam and Barcelona. In the base scenario, night trains could attract 40% of the market. The low-cost scenario drops to 20% for night trains. Conversely, a luxury focus or high GHG tax policy could significantly boost night train shares to 61% and 62%, respectively, by attracting environmentally conscious comfort lovers. Subsidies for night trains push their market share to 72%, however, to the extent of HSR services. Across scenarios, environmentally conscious comfort lovers choose primarily HSR services, experienced night train travellers choose night trains, and flight lovers remain loyal to air travel. Only price-sensitive travellers switch based on cost and comfort levels. Daily, 240 passengers might opt for the night train in the base case, demonstrating the service's capacity to compete effectively with afternoon flights.

VI. Discussion and Conclusion

A. Discussion

This paper investigated booking convenience on the one hand side and mode choice for night trains on the other hand side. Dutch travellers mainly choose to book international rail connections via NS International and opt for this side mainly due to user-friendliness and habit. This contrasts with price comparing sites for booking flights. Booking convenience, mainly if a single ticket can be booked and if connections can easily be compared, significantly influences night train demand, with respondents willing to pay up to 31 EUR. Confirming the results of [45], the mini-cabin was revealed as the most popular accommodation category. Four latent classes have been determined: environmentally conscious comfort lovers, experienced night train travellers, cost-sensitive travellers, and flight lovers, each with unique preferences. These are different than found by Heufke Kantelaar et al. [35]. Market share predictions vary across scenarios, from 40% in the base case to 72% with night train subsidies. Here, the results seem to be in the middle regarding other studies, however, Curtale, Larsson, and Nässén [38] found lower market shares.

B. Limitations

This paper contains several limitations, notably in conceptual model construction, survey design, data acquisition via the Nederlandse Spoorwegen (NS) panel, and analysis through discrete choice models. Challenges included the scarcity of data on international (rail) travellers' preferences regarding booking convenience. A lot of assumptions have been made that influence the model results, like omitting transfers and the fear of flying. Furthermore, Assumptions around hotel costs and the exclusion of the incoming vacation leg might have skewed the night train modal share predictions. The use of the NS Panel, with its many train enthusiasts, might have influenced the findings. Additionally, the study's assumptions regarding booking times and the limitations of stated preference surveys in accurately predicting market shares hinder reliable results.

C. Generalisibility

Despite its limitations, this study potentially offers a realistic view of the long-distance passenger market, particularly between Amsterdam and Barcelona, and may extend to similar European routes of around 1500 km. In Western European countries with extensive HSR networks, like France, Spain, and Italy, HSR services might be potential competitors. Conversely, in the Dach region's less cohesive HSR network, night trains could gain higher market shares, while in Northern Europe, market shares might align with lower estimates similar to those found by Curtale, Larsson, and Nässén [38]. In Eastern Europe, a lower WTP might alter the results. Generalising these findings to other continents, such as Asia where high-speed night trains are common due to vast distances, might be challenging. Moreover, the study is likely relevant for only up to 10 years. Prices, social norms and technology might change over time.

D. Conclusion

This study offers insights into booking convenience as well as mode choice for night trains at very long distances. Dutch travellers' booking habits for international rail connections were analysed, finding that people choose primarily booking sites because of habit and convenience. Being able to book one ticket and to compare various train and flight connections cause a convenient booking scenario. However, when comparing modes, booking convenience does only play a minor role. Main factors to decide for the night train on very long distances are the travel costs of the night train, costs of flights and the accommodation. Night trains are perceived as similar to HSR services as flights. Demand is very heterogeneous:

Four distinct traveller segments have been determined: environmentally conscious comfort lovers, experienced night train travellers, cost-sensitive travellers, and flight lovers, each with unique preferences. Market share predictions across various scenarios vary: in the base case, 40% prefer the night train, which can rise to 61% or even 71% with subsidies. On the other hand side, if using couchette accommodation, market shares are at around 20%.

E. Recommendations for research and practice

For future research, exploring qualitative methods for identifying key booking convenience factors could deliver interesting results. Via incorporating AI, visual appearances of booking sites could be integrated. Additionally, researching night train potential outside Europe, where conditions vary significantly could deepen the understanding of night train demand. Lastly, including other attribute level ranges could be insightful, especially for travel times.

Night train operators should balance offering comfort at competitive prices, focusing on mini cabins over sleepers and couchettes due to space efficiency. Routes should be established where competition from low-cost airlines is not that strong. Furthermore, high-speed night trains seem not to be necessary. Regarding booking systems, collaboration with other railway operators is suggested to be able to compare offers and to offer coherent travels. Lastly, policy makers are able to effectively shift market shares through pricing methods, however, the question remains if the benefits of the measures outweigh the costs.

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B

Survey construction and distribution

This appendix highlights some necessary steps to take to hand out the survey. Firstly, the ngene coding for the booking convenience rating experiment and the mode choice experiment is provided to derive the choice sets. The complete survey is provided below. Note that due to the survey being distributed via the NS panel, the language used was Dutch.

B.1. Choice set generation

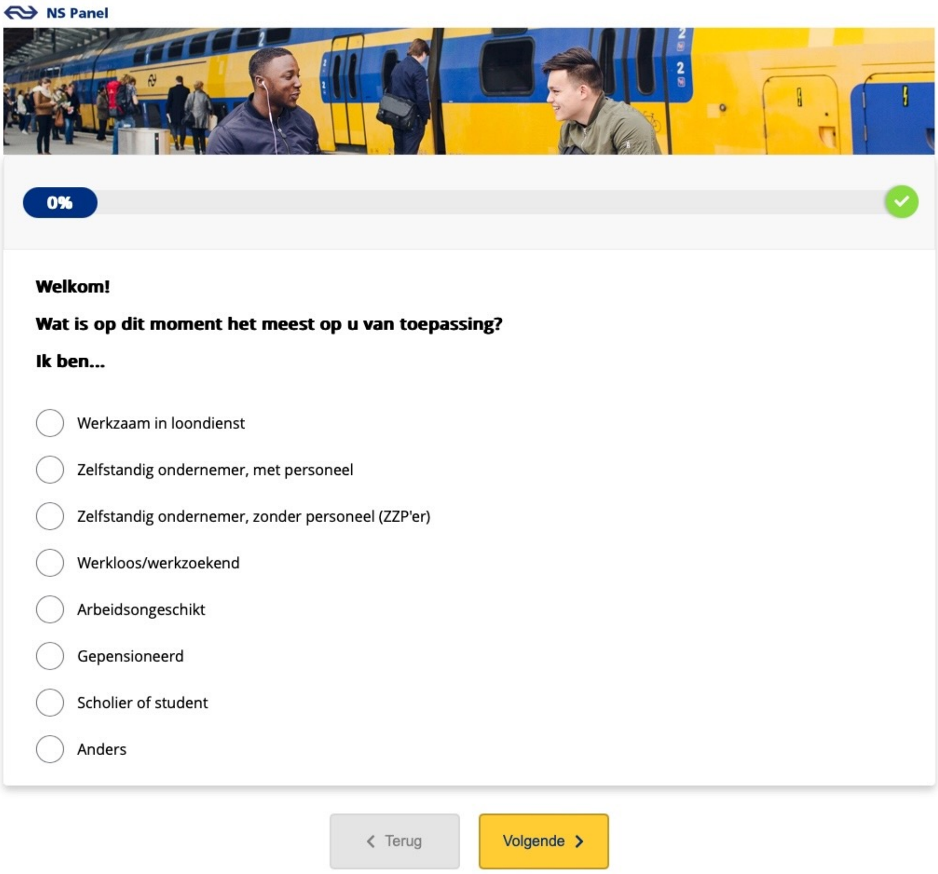
B.1.1. Booking convenience rating experiment

```
? Design for booking convenience
    design
    ;alts = alt1,alt2
    ;rows = 8
    ;block = 4
    ;orth = seq
    ; model :
    U(alt1) =
    Bsearch * Search[0,1]
    + Bticket * Ticket [0,1]
    + BbookingDate * BookingDate[1,6]
    + Btime * Time [5,20]
    + Bdigital * Digital[0 ,1] $
```

B.1.2. Mode choice experiment

```
? Design for mode choice experiment
    design
    ;alts = ntrain, plane, dtrainref
    ;rows = 36
    ;block = 4
    ;orth = sim
    ; model:
    U( ntrain ) = ASC_ntrain
    + Btt_ntrain * TT_ntrain [12,14,16,18]
    + Btc_ntrain * TC_ntrain [50,130,210,290]
    + Bacc * Acc[0,1,2,3]
    + Batt * TT_ntrain * Acc
    + BBooking * Booking [0,1,2]
    + BBuffer * Buffer [15,30,45] /
    U ( plane ) = ASC_plane
    +Btc_plane * TC_plane [150,250,350] $
```

B.2. Survey construction


NS Panel

0%

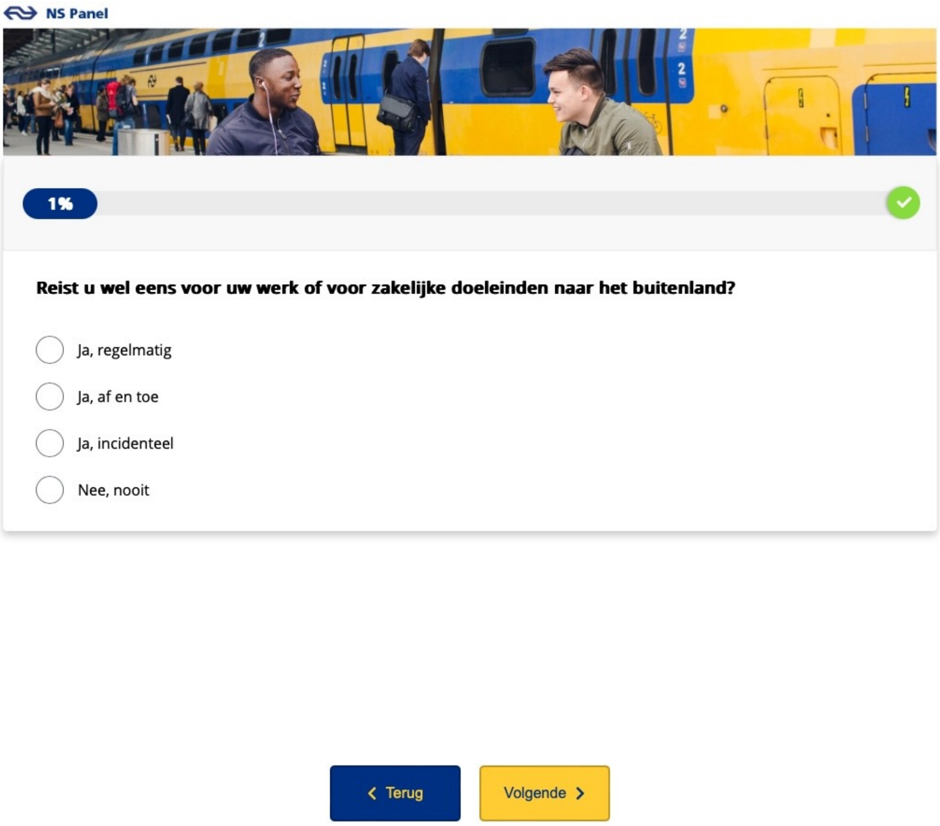
Welkom!

Wat is op dit moment het meest op u van toepassing?

Ik ben...

- Werkzaam in loondienst
- Zelfstandig ondernemer, met personeel
- Zelfstandig ondernemer, zonder personeel (ZZP'er)
- Werkloos/werkzoekend
- Arbeidsongeschikt
- Gepensioneerd
- Scholier of student
- Anders

< Terug | Volgende >


NS Panel

1%

Reist u wel eens voor uw werk of voor zakelijke doeleinden naar het buitenland?

- Ja, regelmatig
- Ja, af en toe
- Ja, incidenteel
- Nee, nooit

< Terug | Volgende >

NS Panel

3%

Deze vragenlijst gaat over internationale reizen voor werk of zakelijke doeleinden.

Wanneer heeft u voor het laatst een internationale treinreis gemaakt (vanuit Nederland naar een Europese bestemming), voor uw werk of voor zakelijke doeleinden?

- In de afgelopen 12 maanden
- 1-2 jaar geleden
- 3-4 jaar geleden
- Langer dan 5 jaar geleden
- Nog nooit

Terug | Volgende

NS Panel

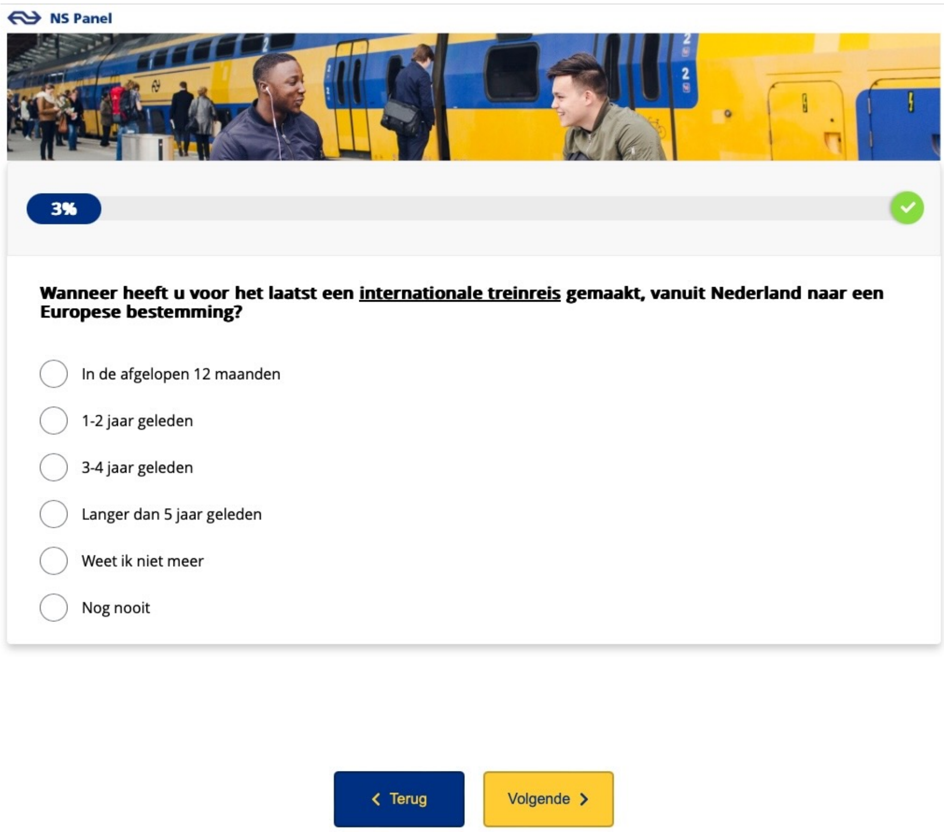
2%

Deze vragenlijst gaat over internationale reizen.

Als u een reis naar het buitenland maakt binnen Europa (met de trein of een ander vervoermiddel), met wie reist u dan normaal gesproken?

- Alleen
- Met partner
- Met kinderen
- Met partner en kinderen
- Met andere famlieleden
- Met vrienden
- Ander reisgezelschap

Terug | Volgende



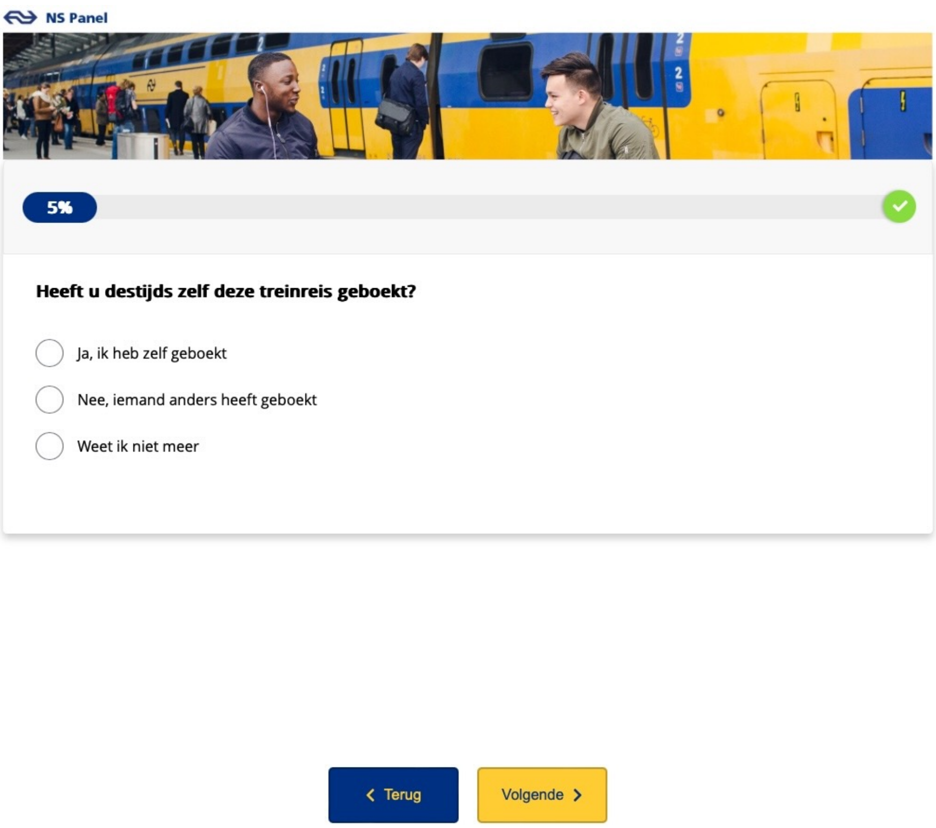
NS Panel

3%

Wanneer heeft u voor het laatst een internationale treinreis gemaakt, vanuit Nederland naar een Europese bestemming?

- In de afgelopen 12 maanden
- 1-2 jaar geleden
- 3-4 jaar geleden
- Langer dan 5 jaar geleden
- Weet ik niet meer
- Nog nooit

Terug | Volgende



NS Panel

5%

Heeft u destijds zelf deze treinreis geboekt?

- Ja, ik heb zelf geboekt
- Nee, iemand anders heeft geboekt
- Weet ik niet meer

Terug | Volgende

NS Panel

6%

Waar heeft u toen uw ticket geboekt?

Indien u meerdere tickets moest boeken voor uw reis, kies dan de partij waar u het ticket voor het langste deel van de reis heeft geboekt.

- ○ Via NS International
- ○ Via Eurostar
- ○ Via Deutsche Bahn (DB)
- ○ Via Österreichische Bundesbahnen (ÖBB)
- ○ Via Nationale Maatschappij der Belgische Spoorwegen (NMBS)
- ○ Via Société nationale des chemins de fer français (SNCF)
- ○ Ergens anders, namelijk:
- ○ Weet ik niet meer

‹ Terug | Volgende ›

NS Panel

10%

Verliep de boeking alleen via deze boekingswebsite of via meerdere boekingswebsites?

- ○ Alleen via deze boekingssite
- ○ Via meerdere boekingssites
- ○ Weet ik niet meer

‹ Terug | Volgende ›

NS Panel

11%

Hoelang duurde het proces om uw reis te zoeken en te boeken? Geef een zo goed mogelijke schatting, in aantal minuten.

Aantal minuten:

☐ Weet ik echt niet meer

Terug | Volgende

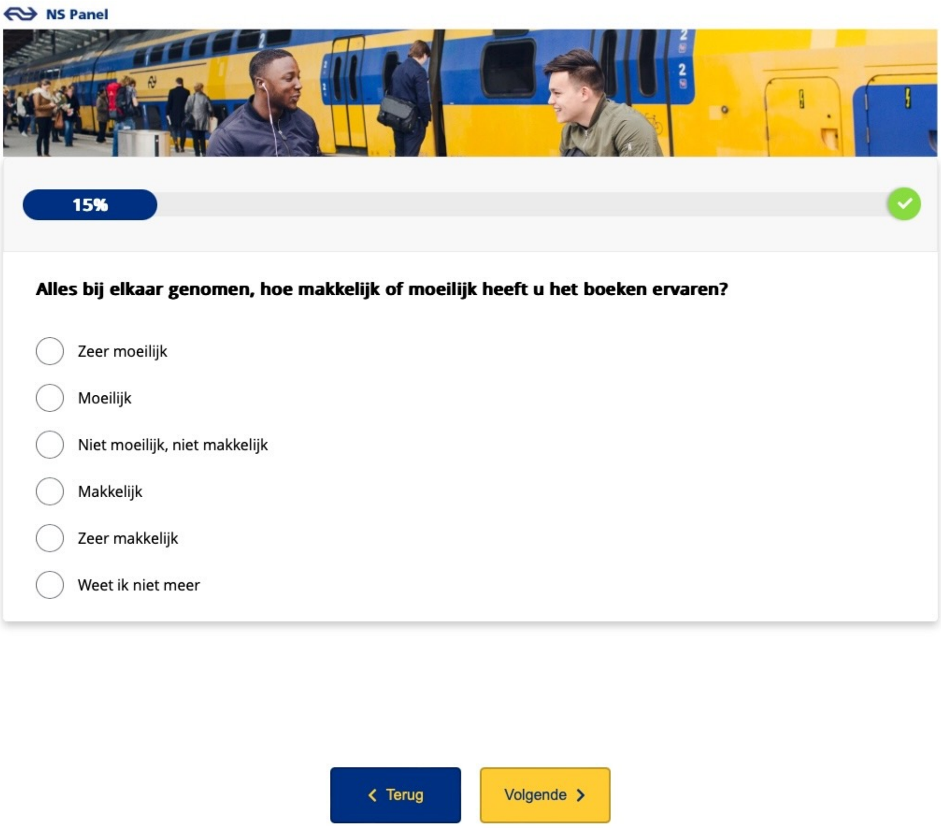
NS Panel

13%

Hoe beoordeelt u elk van de volgende stappen bij de boeking van uw laatste internationale treinreis?

	Zeer moeilijk	Moeilijk	Niet moeilijk, niet makkelijk	Makkelijk	Zeer makkelijk	Weet ik niet meer
Het vinden van de juiste website of app om te boeken	○	○	○	○	○	○
De beschikbaarheid van tickets in de gewenste comfortcategorie op de gewenste datum	○	○	○	○	○	○
Het kunnen vergelijken van reisopties en de meest geschikte kiezen	○	○	○	○	○	○
Contactgegevens invoeren, zoals naam, e-mailadres en telefoonnummer	○	○	○	○	○	○
Het betalen van het ticket	○	○	○	○	○	○
Het ontvangen van een betalingsbevestiging	○	○	○	○	○	○
Het ontvangen van het ticket	○	○	○	○	○	○

Terug | Volgende



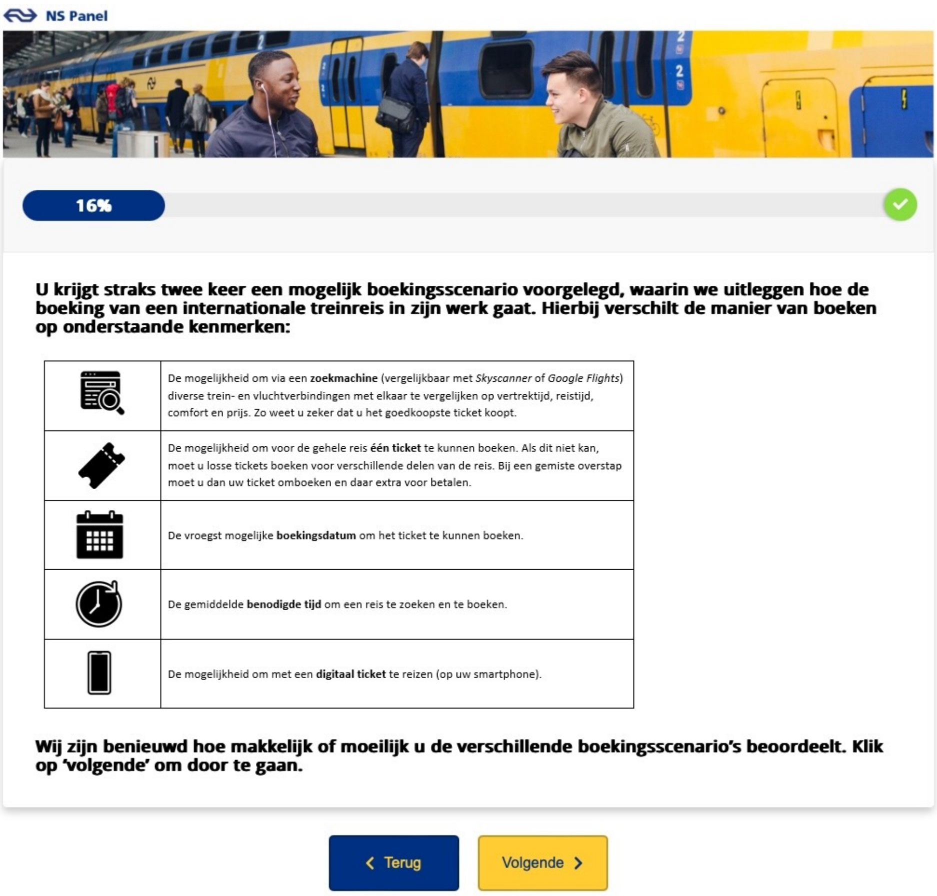
NS Panel

15%

Alles bij elkaar genomen, hoe makkelijk of moeilijk heeft u het boeken ervaren?

- Zeer moeilijk
- Moeilijk
- Niet moeilijk, niet makkelijk
- Makkelijk
- Zeer makkelijk
- Weet ik niet meer

Terug Volgende



NS Panel

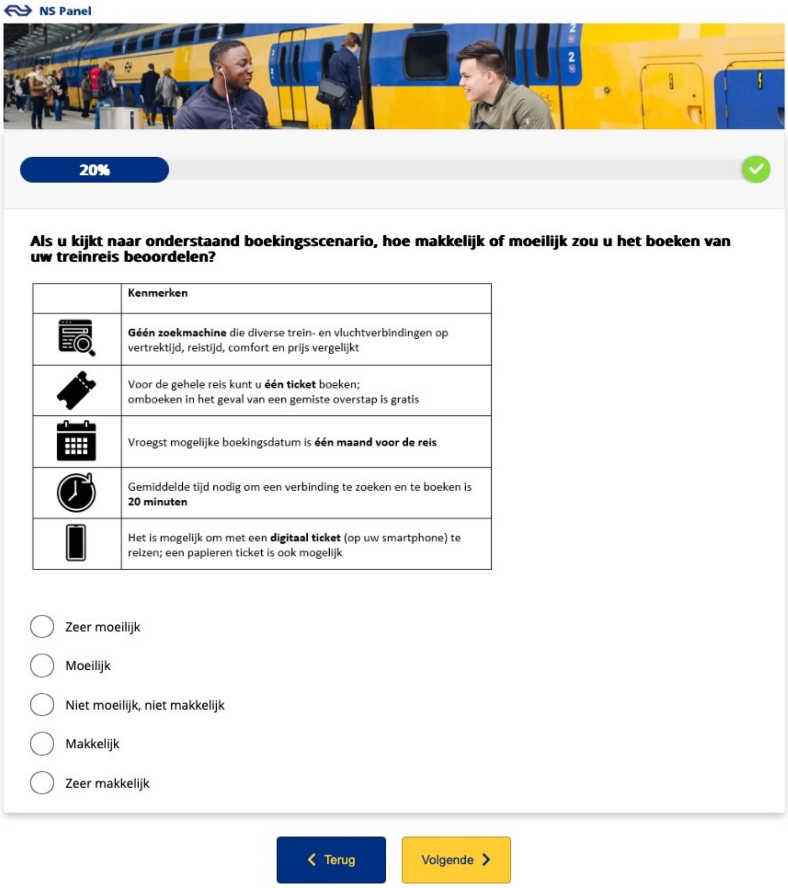
16%

U krijgt straks twee keer een mogelijk boekingsscenario voorgelegd, waarin we uitleggen hoe de boeking van een internationale treinreis in zijn werk gaat. Hierbij verschilt de manier van boeken op onderstaande kenmerken:

	De mogelijkheid om via een **zoekmachine** (vergelijkbaar met *Skyscanner* of *Google Flights*) diverse trein- en vluchtverbindingen met elkaar te vergelijken op vertrektijd, reistijd, comfort en prijs. Zo weet u zeker dat u het goedkoopste ticket koopt.
	De mogelijkheid om voor de gehele reis **één ticket** te kunnen boeken. Als dit niet kan, moet u losse tickets boeken voor verschillende delen van de reis. Bij een gemiste overstap moet u dan uw ticket omboeken en daar extra voor betalen.
	De vroegst mogelijke **boekingsdatum** om het ticket te kunnen boeken.
	De gemiddelde **benodigde tijd** om een reis te zoeken en te boeken.
	De mogelijkheid om met een **digitaal ticket** te reizen (op uw smartphone).

Wij zijn benieuwd hoe makkelijk of moeilijk u de verschillende boekingsscenario's beoordeelt. Klik op 'volgende' om door te gaan.

Terug Volgende



NS Panel

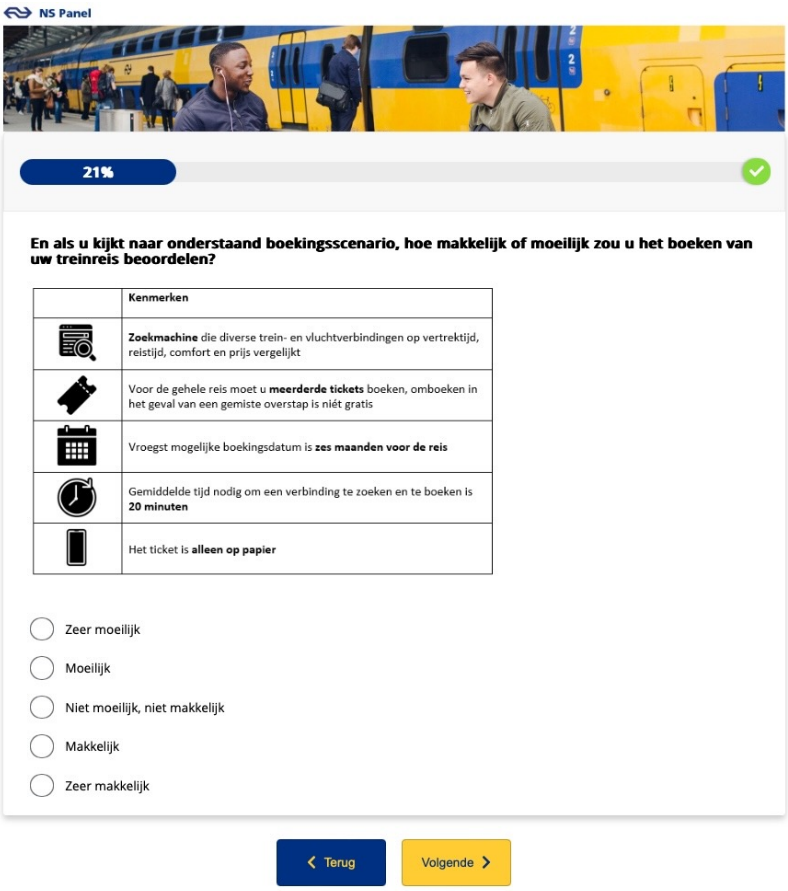
20%

Als u kijkt naar onderstaand boekingsscenario, hoe makkelijk of moeilijk zou u het boeken van uw treinreis beoordelen?

	Kenmerken
	Géén zoekmachine die diverse trein- en vluchtverbindingen op vertrektijd, reistijd, comfort en prijs vergelijkt
	Voor de gehele reis kunt u **één ticket** boeken; omboeken in het geval van een gemiste overstap is gratis
	Vroegst mogelijke boekingsdatum is **één maand voor de reis**
	Gemiddelde tijd nodig om een verbinding te zoeken en te boeken is **20 minuten**
	Het is mogelijk om met een **digitaal ticket** (op uw smartphone) te reizen; een papieren ticket is ook mogelijk

- Zeer moeilijk
- Moeilijk
- Niet moeilijk, niet makkelijk
- Makkelijk
- Zeer makkelijk

Terug Volgende



NS Panel

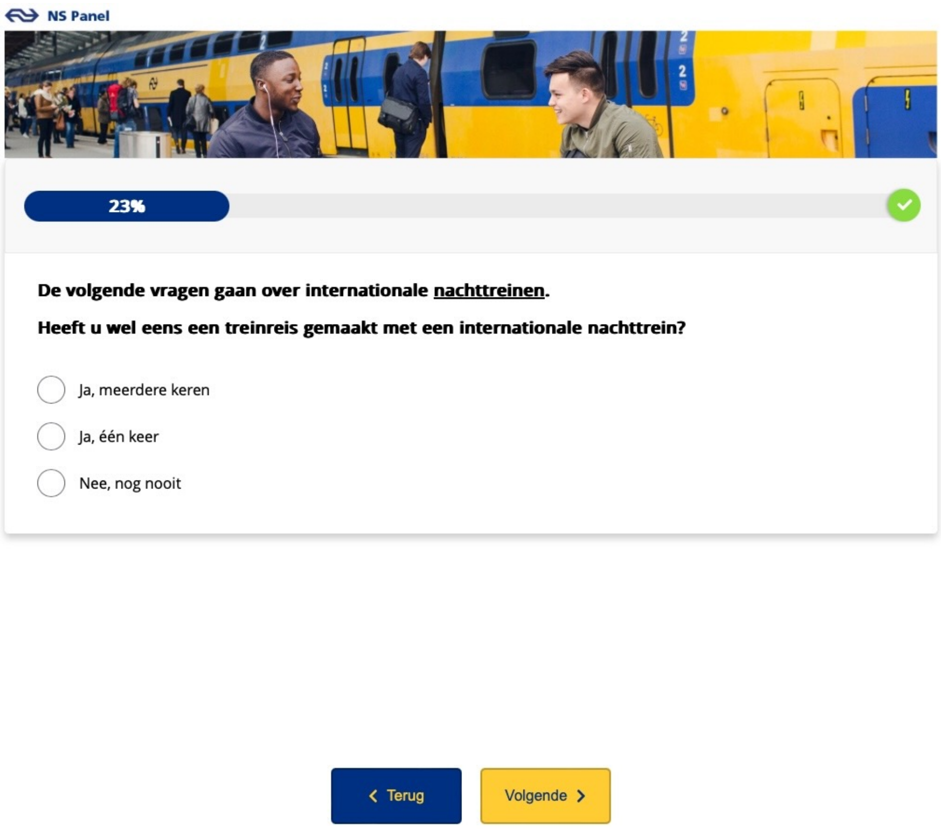
21%

En als u kijkt naar onderstaand boekingsscenario, hoe makkelijk of moeilijk zou u het boeken van uw treinreis beoordelen?

	Kenmerken
	Zoekmachine die diverse trein- en vluchtverbindingen op vertrektijd, reistijd, comfort en prijs vergelijkt
	Voor de gehele reis moet u **meerderde tickets** boeken, omboeken in het geval van een gemiste overstap is niét gratis
	Vroegst mogelijke boekingsdatum is **zes maanden voor de reis**
	Gemiddelde tijd nodig om een verbinding te zoeken en te boeken is **20 minuten**
	Het ticket is **alleen op papier**

- Zeer moeilijk
- Moeilijk
- Niet moeilijk, niet makkelijk
- Makkelijk
- Zeer makkelijk

Terug Volgende


NS Panel

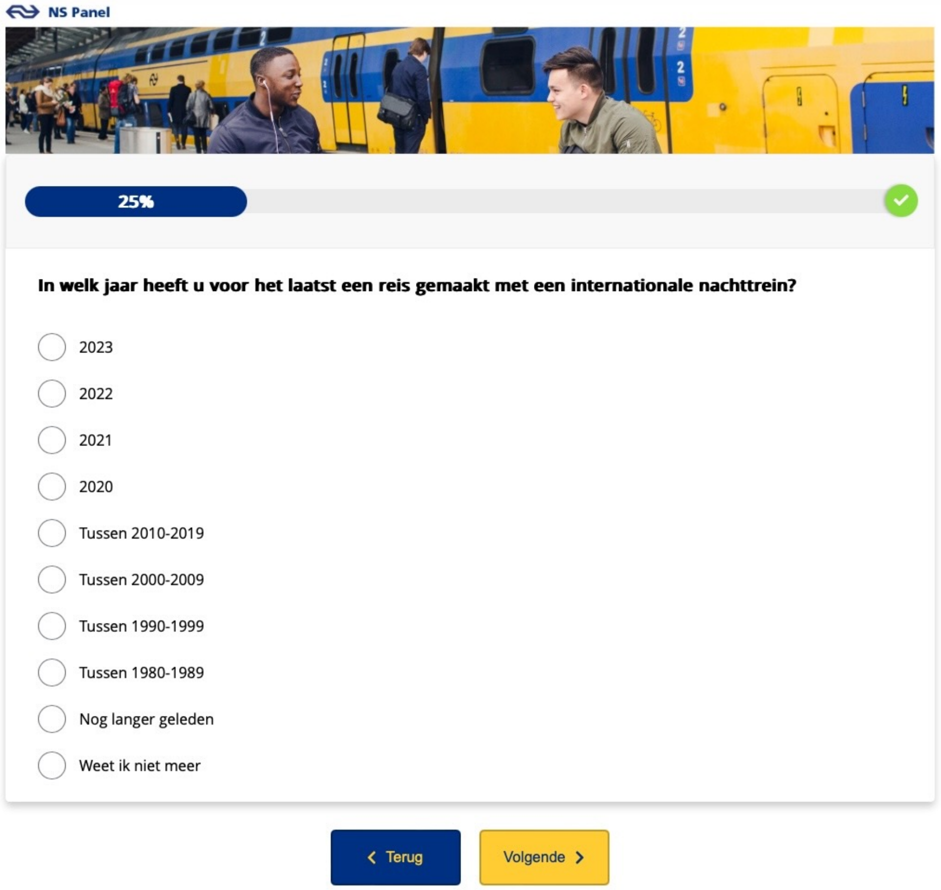
23%

De volgende vragen gaan over internationale nachttreinen.

Heeft u wel eens een treinreis gemaakt met een internationale nachttrein?

- Ja, meerdere keren
- Ja, één keer
- Nee, nog nooit

Terug | Volgende


NS Panel

25%

In welk jaar heeft u voor het laatst een reis gemaakt met een internationale nachttrein?

- 2023
- 2022
- 2021
- 2020
- Tussen 2010-2019
- Tussen 2000-2009
- Tussen 1990-1999
- Tussen 1980-1989
- Nog langer geleden
- Weet ik niet meer

Terug | Volgende

NS Panel

27%

De volgende vragen gaan over het maken van een internationale reis binnen Europa, naar een bestemming die ongeveer 1500 kilometer ver is. Als voorbeeld nemen we Barcelona.

Wij zijn benieuwd welk vervoermiddel u in verschillende situaties zou kiezen. U kunt daarbij telkens kiezen tussen de nachttrein, het vliegtuig en de dagtrein.

We leggen u in totaal 9 keer een keuze voor, waarbij de kenmerken per vervoermiddel telkens verschillen. Deze verschillen telkens op de volgende onderdelen:

	Vertrektijd en aankomsttijd *Ga er hierbij vanuit dat het vliegtuig vertrekt vanaf Amsterdam Schiphol en de trein vertrekt vanaf Amsterdam Centraal, Amsterdam Schiphol of Rotterdam Centraal (wat voor u het makkelijkst is).*
	Totale reistijd *De totale benodigde reistijd vanaf Amsterdam Centraal, Amsterdam Schiphol of Rotterdam Centraal tot uw eindbestemming (het centrum van Barcelona). Eventuele wachttijd en/of overstaptijd is inbegrepen.*
	Prijs *De prijs per persoon. Voor de dagtrein en het vliegtuig betreft dit de prijs inclusief een hotelovernachting, omdat u een dag eerder arriveert.*
	Accommodatie *De nachttrein heeft verschillende accommodatie opties:* Zitplaats Een gewone treinstoel in een rijtuig met maximaal 40 andere passagiers.  Gedeelde ligplaats Een compartiment dat gedeeld wordt met maximaal drie andere passagiers. U slaapt op een ligplaats, die smaller en harder is dan een bed. U krijgt beddengoed en een kussen.  Privé compartiment Een slaapplaats met hetzelfde comfort als in de gedeelde ligplaats, maar in een afsluitbare privé-capsule. Dus de capsule wordt niet gedeeld met andere passagiers. U krijgt beddengoed en een kussen.  Privé slaapkamer Vergelijkbaar met een hotelkamer, bestaat uit een comfortabel bed en wordt niet gedeeld met vreemden. In de kamer is er een WC en een douche. Er kunnen maximaal twee personen verblijven. 
	Boekingsgemak *Het gemak waarmee u de reis kunt boeken, uitgedrukt in een score.*
	Mogelijke vertraging *Het risico op een mogelijke vertraging in de reistijd.*

Wij zijn benieuwd welk vervoermiddel u kiest in verschillende scenario. Klik op 'volgende' om door te gaan.

Stel u gaat op vakantie naar Barcelona. U vertrekt op een vrijdag. U vertrekt vanaf uw huis en reist naar het centrum van Barcelona. U neemt handbagage en een standaard koffer mee. U reist met uw gebruikelijke reisgezelschap.

Houd rekening met de tijd die u nodig hebt om Schiphol, Amsterdam Centraal of Rotterdam Centraal te bereiken en ga ervan uit dat het bereiken van deze stations geen probleem vormt.

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	**Nachttrein**	**Vliegtuig + Hotel**	**Dagtrein + Hotel**
	Vertrek- en aankomsttijd	19:00 – 11:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	16 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 210,-	€ 250,-	€ 250,-
	Accommodatie	Privé compartiment	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel moeilijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- ○ De nachttrein
- ○ Het vliegtuig
- ○ De dagtrein

Stel u gaat voor een zakelijke reis naar Barcelona. U vertrekt op een dinsdag. U vertrekt vanaf uw huis en reist naar het centrum van Barcelona. U neemt handbagage mee en u reist alleen. Ga ervan uit dat de werkgever de kosten voor uw reis betaalt.

Houd rekening met de tijd die u nodig hebt om Schiphol, Amsterdam Centraal of Rotterdam Centraal te bereiken en ga ervan uit dat het bereiken van deze stations geen probleem vormt.

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	**Nachttrein**	**Vliegtuig + Hotel**	**Dagtrein + Hotel**
	Vertrek- en aankomsttijd	19:00 – 11:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	16 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 130,-	€ 250,-	€ 250,-
	Accommodatie	Privé slaapkamer	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **45 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- ○ De nachttrein
- ○ Het vliegtuig
- ○ De dagtrein

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 09:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	14 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 290,-	€ 150,-	€ 250,-
	Accommodatie	Gedeelde ligplaats	Economy class	2e klas
	Uw verwachte boekingsgemak	Niet moeilijk, niet makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **15 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 09:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	14 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 50,-	€ 350,-	€ 250,-
	Accommodatie	Privé compartiment	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **15 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

U krijgt in totaal 9 keer een keuze voorgelegd. Nog 6 te gaan!

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
Vertrek- en aankomsttijd	19:00 – 11:00	16:00 – 21:00	08:00 – 20:00
Totale reistijd vanaf station/luchthaven	16 uur	5 uur	12 uur
Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 210,-	€ 350,-	€ 250,-
Accommodatie	Privé compartiment	Economy class	2e klas
Uw verwachte boekingsgemak	Niet moeilijk, niet makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **45 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
Vertrek- en aankomsttijd	19:00 – 09:00	16:00 – 21:00	08:00 – 20:00
Totale reistijd vanaf station/luchthaven	14 uur	5 uur	12 uur
Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 290,-	€ 250,-	€ 250,-
Accommodatie	Gedeelde ligplaats	Economy class	2e klas
Uw verwachte boekingsgemak	Heel makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 09:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	14 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 50,-	€ 150,-	€ 250,-
	Accommodatie	Privé compartiment	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel moeilijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

Nog 3 te gaan!

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 11:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	16 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 210,-	€ 150,-	€ 250,-
	Accommodatie	Privé compartiment	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **15 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 13:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	18 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 130,-	€ 150,-	€ 250,-
	Accommodatie	Zitplaats	Economy class	2e klas
	Uw verwachte boekingsgemak	Niet moeilijk, niet makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

En de laatste:

Als u kijkt naar onderstaande reismogelijkheden voor uw reis naar Barcelona, welke zou u kiezen?

	Kenmerken	Nachttrein	Vliegtuig + Hotel	Dagtrein + Hotel
	Vertrek- en aankomsttijd	19:00 – 07:00	16:00 – 21:00	08:00 – 20:00
	Totale reistijd vanaf station/luchthaven	12 uur	5 uur	12 uur
	Totale kosten *Per persoon, voor vliegtuig en dagtrein incl. hotel*	€ 210,-	€ 150,-	€ 250,-
	Accommodatie	Gedeelde ligplaats	Economy class	2e klas
	Uw verwachte boekingsgemak	Heel makkelijk	Heel makkelijk	Niet moeilijk, niet makkelijk
	Mogelijke vertragingstijd	20% kans op een **vertraging** van meer dan **15 minuten**	20% kans op een **vertraging** van meer dan **30 minuten**	20% kans op een **vertraging** van meer dan **45 minuten**

- De nachttrein
- Het vliegtuig
- De dagtrein

Terug Volgende

NS Panel

86%

De volgende vraag gaat over duurzaamheid.

In hoeverre bent u het eens met de volgende stellingen?

	Helemaal niet mee eens	Niet mee eens	Neutraal	Mee eens	Helemaal mee eens
Ik vind het belangrijk om milieuvriendelijke vervoermiddelen te gebruiken, zoals de fiets of het openbaar vervoer	○	○	○	○	○
Mensen die belangrijk voor me zijn (bijv. familie, vrienden) motiveren mij om milieuvriendelijke vervoermiddelen te gebruiken	○	○	○	○	○
Ik maak gebruik van milieuvriendelijke vervoermiddelen, ook al kan dat in sommige situaties ongemakkelijk of lastig zijn	○	○	○	○	○

< Terug Volgende >

NS Panel

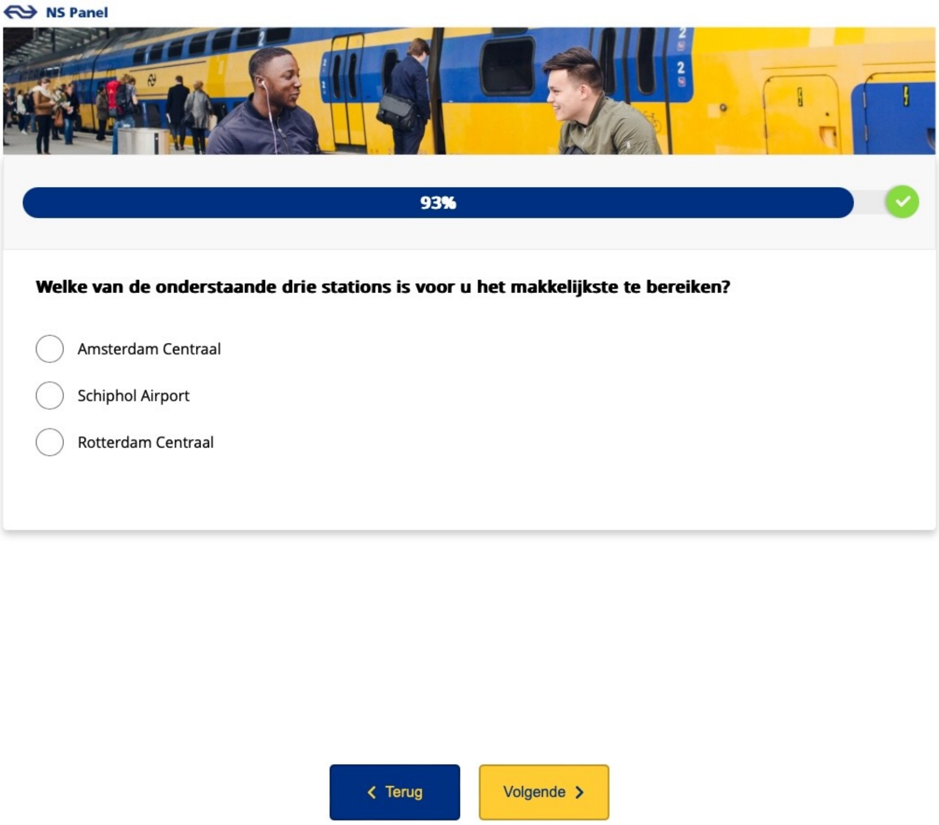
90%

Als laatste nog enkele achtergrondvragen.

Hoe ver woont u van Schiphol af? Ga uit van de snelste route met de auto. Als u het niet zeker weet, geef dan een schatting.

- ○ Minder dan 20 kilometer
- ○ 20-40 kilometer
- ○ 40-60 kilometer
- ○ 60-80 kilometer
- ○ 80-100 kilometer
- ○ 100-150 kilometer
- ○ 150-200 kilometer
- ○ Meer dan 200 kilometer

< Terug Volgende >



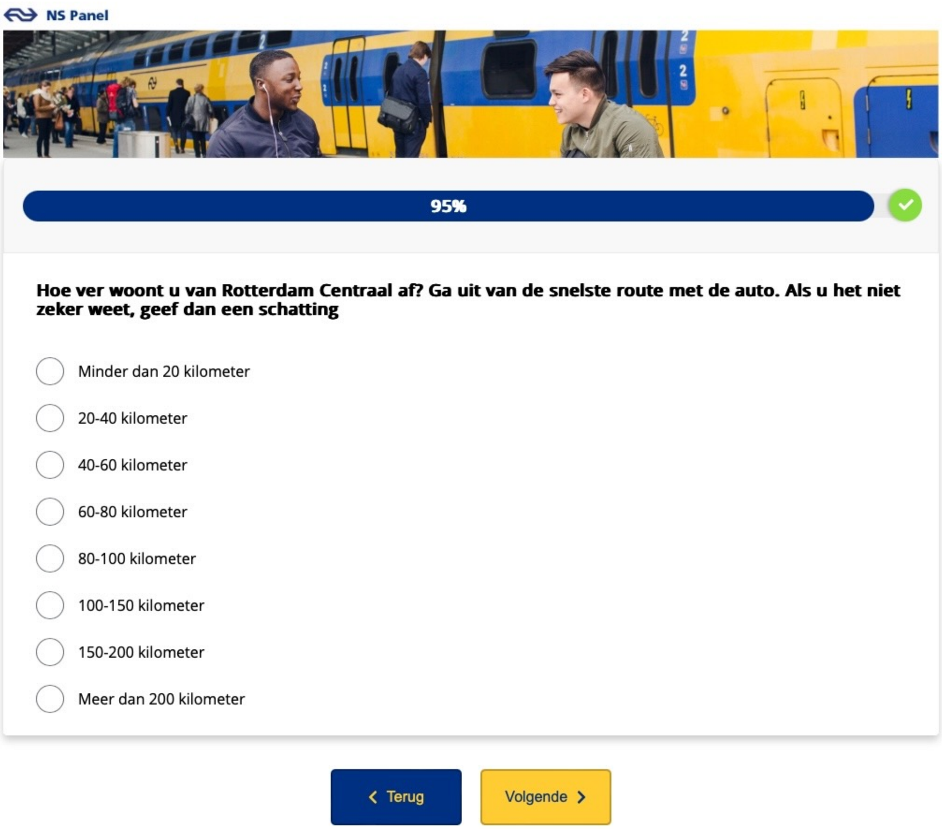
NS Panel

93%

Welke van de onderstaande drie stations is voor u het makkelijkste te bereiken?

- ◯ Amsterdam Centraal
- ◯ Schiphol Airport
- ◯ Rotterdam Centraal

< Terug | Volgende >



NS Panel

95%

Hoe ver woont u van Rotterdam Centraal af? Ga uit van de snelste route met de auto. Als u het niet zeker weet, geef dan een schatting

- ◯ Minder dan 20 kilometer
- ◯ 20-40 kilometer
- ◯ 40-60 kilometer
- ◯ 60-80 kilometer
- ◯ 80-100 kilometer
- ◯ 100-150 kilometer
- ◯ 150-200 kilometer
- ◯ Meer dan 200 kilometer

< Terug | Volgende >

C
Data sample

In this appendix, two tables are provided. In Table C.1, a detailed overview of the train experience of the respondents is provided. Furthermore, in Table C.2, the answers to environmental questions are provided. Through this, it is possible to determine the degree of importance of the environment for the respondents.

Table C.1: Train travel experience

Variable	Category	Abs. number	Percentage
National train travel	1 or 2 days in the past 12 months	32	3.0%
	3-5 days in the past 12 months	56	5.3%
	6-11 days in the past 12 months	165	15.5%
	1-3 days per month	254	23.9%
	1-3 days per week	325	30.6%
	4 days per week or more	204	19.2%
	Not travelled within the last 12 months	16	1.5%
	No answer	10	0.9%
	Total	1062	100%
Last intl. train travel for leisure travel	In the past 12 months	342	42.1%
	1-2 years ago	103	12.7%
	3-4 years ago	84	10.3%
	More than 5 years ago	174	21.4%
	Never	87	10.7%
	Don't remember	23	2.8%
	Total	813	100%
Last intl. train travel for business travel	In the past 12 months	114	45.8%
	1-2 years ago	36	14.5%
	3-4 years ago	33	13.3%
	More than 5 years ago	29	11.6%
	Never	37	14.9%
	Total	249	100.0%
Last nighttrain	2023	83	15.1%
	2022	56	10.2%
	2021	21	3.8%
	2020	14	2.5%
	Between 2010-2019	121	22.0%
	Between 2000-2009	72	13.1%
	Between 1990-1999	81	14.7%
	Between 1980-1989	44	8.0%
	Even longer ago	42	7.6%
	Do not remember	17	3.1%
	Total	551	100%

Table C.2: Intention to use environmentally friendly modes

I think it is important to use environmentally friendly means of transport, such as cycling or public transport		
Agreement	**Abs. number**	**Percentage**
Completely agree	441	41.5%
Agree	418	39.4%
Neutral	147	13.8%
Disagree	25	2.4%
Completely disagree	31	2.9%
People who are important to me (e.g. family. friends) motivate me to use environmentally friendly means of transport		
Completely agree	73	6.9%
Agree	273	25.7%
Neutral	431	40.6%
Disagree	187	17.6%
Completely disagree	98	9.2%
I use environmentally friendly means of transport, even if it can be uncomfortable or inconvenient in some situations		
Completely agree	216	20.3%
Agree	410	38.6%
Neutral	265	25.0%
Disagree	128	12.1%
Completely disagree	43	4.0%

D
Model Codes

After distributing and analysing the booking experience experiment, further analysis was conducted for the booking convenience rating experiment and the mode choice experiment. The source code for both experiments is provided below. Firstly, the python regression code is provided. Then, the codes for the MNL model, the Panel ML model, the discrete mixture model and the Panel LCCM are provided.

D.1. Booking convenience rating experiment

```
# importing all standard packages
    import numpy as np
    import pandas as pd
    import datetime
    import time
    import os
    import openpyxl
    import statsmodels.api as sm

    df = pd.read_excel('booking_data.xlsx')

    data = df[['CHOICE', 'search_engine', 'one_ticket', 'earliest_booking', 'time_booking',
          'digital_ticket', 'age', 'gender', 'student', 'retired', 'working', 'scenario',
          'alone', 'partner', 'usual_train', 'intl_train', 'night_train']]

    # Variables
    X = data[['search_engine', 'one_ticket', 'earliest_booking', 'time_booking', 'digital_ticket']]
    y = data[['CHOICE']]

    # Add a constant term for the intercept
    X_with_intercept = sm.add_constant(X)

    # Create and fit the model with statsmodels
    model_basic = sm.OLS(y, X_with_intercept).fit()

    # Print summary including t-values and p-values
    print(model_basic.summary())

    # Adding socio-demographics
    model_socio.compare_f_test(model_basic)
    Out: (1.752031649696727, 0.11953680328155143, 5.0)

    # Adding context
```

```
model_context.compare_f_test(model_basic)
Out: (2.283864948486201, 0.07710328296253921, 3.0)

# Adding train experience

# Dependent variables
X = data[['search_engine', 'one_ticket', 'earliest_booking', 'digital_ticket',
    'time_booking', 'usual_train', 'intl_train', 'night_train']]

y = data[['CHOICE']]

# Add a constant term for the intercept
X_with_intercept = sm.add_constant(X)

# Create and fit the model with statsmodels
model_experience = sm.OLS(y, X_with_intercept).fit()

# Print summary including t-values and p-values
print(model_experience.summary())

# Compare Model fit
model_experience.compare_f_test(model_basic)
Out: (7.978094712283961, 2.7427987436359218e-05, 3.0)
```

D.2. Mode choice experiment

D.2.1. Multinomial Logit model

```
# Biogeme
import biogeme.logging as blog
import biogeme.database as db
import biogeme.biogeme as bio
import os
from biogeme import models
from biogeme.expressions import Beta, Variable, bioDraws, log, MonteCarlo, exp, bioMultSum,
    PanelLikelihoodTrajectory

# General packages
from pathlib import Path
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pathlib import Path
import toml
import time
from scipy.stats import norm, lognorm

# 1. Load the data set
data = pd.read_excel('choice_data.xlsx')
data[['availability1', 'availability2', 'availability3']] =1
data['CHOICE'] = data['CHOICE'] + 1
data['tt_ntrain'] = data['tt_ntrain']/10
data['tc_ntrain'] = data['tc_ntrain']/100
data['tc_plane'] = data['tc_plane']/100
data['distance_airport'] = data['distance_airport']/100
data['distance_station'] = data['distance_station']/100

Mydatabase = db.Database('modechoice', data)
```

```
# defining variables
globals().update(Mydatabase.variables)

# Defining betas
Beta_tt_ntrain = Beta('Beta_tt_ntrain', 0, None, None, 0)
Beta_tc_ntrain = Beta('Beta_tc_ntrain', 0, None, None, 0)
Beta_tc_plane = Beta('Beta_tc_plane', 0, None, None, 0)
Beta_sleeper = Beta('Beta_sleeper', 0, None, None, 0)
Beta_minicabin = Beta('Beta_minicabin', 0, None, None, 0)
Beta_couchette = Beta('Beta_couchette', 0, None, None, 0)
Beta_book = Beta('Beta_book', 0, None, None, 0)
Beta_del = Beta('Beta_del', 0, None, None, 0)
Beta_distance_airport = Beta('Beta_distance_airport', 0, None, None, 0)
Beta_distance_station = Beta('Beta_distance_station', 0, None, None, 0)
asc_plane = Beta('asc_plane', 0, None, None, 0)
asc_HSR = Beta('asc_HSR', 0, None, None, 1)
asc_ntrain = Beta('asc_ntrain', 0, None, None, 0)

# Non-Linearity
Beta_book_2 = Beta('Beta_book_2', 0, None, None, 0)
Beta_tt_ntrain_2 = Beta('Beta_tt_ntrain_2', 0, None, None, 0)

# defining utility functions
# Order: nighttrain, airplane, HSR

V1 = asc_ntrain +
        Beta_tt_ntrain * tt_ntrain +
        Beta_tt_ntrain_2 * tt_ntrain * tt_ntrain +
        Beta_tc_ntrain * tc_ntrain +
        Beta_book * book_ntrain +
        Beta_book_2 * book_ntrain * book_ntrain +
        Beta_del * del_ntrain +
        Beta_sleeper * sleeper +
        Beta_minicabin * minicabin +
        Beta_distance_station * distance_station +
        Beta_couchette * couchette

V2 = asc_plane +
        Beta_tc_plane * tc_plane +
        Beta_distance_airport * distance_airport +

V3 = asc_HSR

# Give the model a name
model_name = 'MNL Final'

# Associate utility functions with alternatives
V = 1: V1, 2: V2, 3: V3

# Associate the availability conditions with the alternatives
av = 1: availability1, 2: availability2, 3: availability3

# Compute logarithmic probability of the chosen alternative
logprob = models.loglogit(V, av, CHOICE)

# Create the Biogeme estimation object containing the data and the model
biogeme = bio.BIOGEME(Mydatabase, logprob)
```

```
biogeme.modelName = model_name

# Set reporting levels
biogeme.generate_pickle = True
biogeme.generate_html = True
biogeme.saveIterations = True

# Compute the null loglikelihood for reporting
biogeme.calculateNullLoglikelihood(av)

# Estimate the model and print the results
results = biogeme.estimate()
print(results.short_summary())

# Get the results in a pandas table
beta_hat = results.getEstimatedParameters()
print(beta_hat)
```

D.2.2. Panel Mixed Logit model

```
# Biogeme
import biogeme.logging as blog
import biogeme.database as db
import biogeme.biogeme as bio
import os
from biogeme import models
from biogeme.expressions import Beta, Variable, bioDraws, log, MonteCarlo, exp, bioMultSum,
PanelLikelihoodTrajectory
import biogeme.tools as tools

# General packages
from pathlib import Path
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pathlib import Path
import toml
import time
from scipy.stats import norm, lognorm

# Change the number of draws in the .toml file with open('biogeme.toml', 'r') as file:
tomldata = toml.load(file)

# Modify the number of draws
tomldata['MonteCarlo']['number_of_draws'] = 100

# Write the modified data back to the .toml file
with open('biogeme.toml', 'w') as file:
        toml.dump(tomldata, file)

# Create a logger to monitor the estimation progress
# if logger does not exist create it, else use it
try:
    logger
except NameError:
    logger = blog.get_screen_logger(level=blog.INFO)

# 1. Load the data set
```

```
data = pd.read_excel('choice_data.xlsx')
data['tt_ntrain'] = data['tt_ntrain']/10
data['tc_ntrain'] = data['tc_ntrain']/100
data['tc_plane'] = data['tc_plane']/100
data['distance_airport'] = data['distance_airport']/100
data['distance_station'] = data['distance_station']/100
Mydatabase = db.Database('modechoice', data)

# defining variables
globals().update(Mydatabase.variables)

# Defining betas
Beta_tt_ntrain = Beta('Beta_tt_ntrain', 0, None, None, 0)
Beta_tc_ntrain = Beta('Beta_tc_ntrain', 0, None, None, 0)
Beta_tc_plane = Beta('Beta_tc_plane', 0, None, None, 0)
Beta_sleeper = Beta('Beta_sleeper', 0, None, None, 0)
Beta_minicabin = Beta('Beta_minicabin', 0, None, None, 0)
Beta_couchette = Beta('Beta_couchette', 0, None, None, 0)
Beta_book = Beta('Beta_book', 0, None, None, 0)
Beta_del = Beta('Beta_del', 0, None, None, 0)
Beta_distance_airport = Beta('Beta_distance_airport', 0, None, None, 0)
Beta_distance_station = Beta('Beta_distance_station', 0, None, None, 0)
asc_plane = Beta('asc_plane', 0, None, None, 0)
asc_HSR = Beta('asc_HSR', 0, None, None, 1)
asc_ntrain = Beta('asc_ntrain', 0, None, None, 0)

# Non-Linearity
Beta_book_2 = Beta('Beta_book_2', 0, None, None, 0)
Beta_tt_ntrain_2 = Beta('Beta_tt_ntrain_2', 0, None, None, 0)

#Random parameter to model the nest
NtrainPlane_mean = Beta('NtrainPlane_mean',0,None,None,1)
NtrainPlane_std = Beta('NtrainPlane_std',0,None,None,0)
NtrainHSR_mean = Beta('NtrainHSR_mean',0,None,None,1)
NtrainHSR_std = Beta('NtrainHSR_std',0,None,None,0)
PlaneHSR_mean = Beta('PlaneHSR_mean',0,None,None,1)
PlaneHSR_std = Beta('PlaneHSR_std',0,None,None,0)

# Define a random parameter, normally distributed, designed to be used
# for Monte−Carlo simulation
Sig_NtrainPlane = NtrainPlane_mean + NtrainPlane_std
    * bioDraws('Sig_NtrainPlane','NORMAL_HALTON2')
Sig_NtrainHSR = NtrainHSR_mean + NtrainHSR_std
    * bioDraws('Sig_NtrainHSR','NORMAL_HALTON2')
Sig_PlaneHSR = PlaneHSR_mean + PlaneHSR_std
    * bioDraws('Sig_PlaneHSR','NORMAL_HALTON2')

# defining utility functions
# Order: nighttrain, airplane, HSR

V1 = asc_ntrain +
        Beta_tt_ntrain * tt_ntrain +
        Beta_tt_ntrain_2 * tt_ntrain * tt_ntrain +
        Beta_tc_ntrain * tc_ntrain +
        Beta_book * book_ntrain +
        Beta_book_2 * book_ntrain * book_ntrain +
```

```
            Beta_del * del_ntrain +
            Beta_sleeper * sleeper +
            Beta_minicabin * minicabin +
            Beta_distance_station * distance_station +
            Beta_couchette * couchette +
            Sig_NtrainPlane +
            Sig_NtrainHSR

V2 = asc_plane +
            Beta_tc_plane * tc_plane +
            Beta_distance_airport * distance_airport +
            Sig_NtrainPlane +
            Sig_PlaneHSR

V3 = asc_HSR +
            Sig_NtrainHSR +
            Sig_PlaneHSR

# Give the model a name
model_name = 'Panel ML Final'

# Associate utility functions with alternatives
V = 1: V1, 2: V2, 3: V3

# Associate the availability conditions with the alternatives
av = 1: availability1, 2: availability2, 3: availability3

# Compute probability of the chosen alternative
obsprob = models.logit(V,av,CHOICE)
condprobIndiv = MonteCarlo(PanelLikelihoodTrajectory(obsprob))
logprob = log(condprobIndiv)

# Create the Biogeme estimation object containing the data and the model
biogeme = bio.BIOGEME(Mydatabase, logprob)
biogeme.modelName = model_name

# Set reporting levels
biogeme.generate_pickle = True
biogeme.generate_html = True
biogeme.saveIterations = True

# Compute the null loglikelihood for reporting
biogeme.calculateNullLoglikelihood(av)

# Estimate the model and print the results
results = biogeme.estimate()
print(results.short_summary())

# Get the results in a pandas table
beta_hat = results.getEstimatedParameters()
print(beta_hat)
```

D.2.3. Discrete Mixture model

```
# Discrete mixture model with 4 classes
    # Step 1: Load modules and data

    # Clear memory
    rm(list = ls())

    # Load Apollo library
    library(apollo)

    # Initialise code
    apollo_initialise()

    # Set core controls
    apollo_control = list(
        modelName = "DM4",
        modelDescr = "Discrete Mixture model to determine the optimal number of classes",
        indivID = "ID",
        outputDirectory = "output",
        nCores = 8,
        panelData = TRUE )

    # Load data
    database = read.csv('choice_data.csv',sep = ';',header = TRUE)

    # Sort ID column
    database = database[order(database[,'ID']),]
    database <- na.omit(database)
    database$tt_ntrain = database$tt_ntrain/10
    database$tc_ntrain = database$tc_ntrain/100
    database$tc_plane = database$tc_plane/100
    database$distance_airport = database$distance_airport/100
    database$distance_station = database$distance_station/100
    database$age = database$age/10

    # Step 2: Define parameters

    # Define parameters
    apollo_beta = c(
        Beta_tt_ntrain_1 = 0,
        Beta_tt_ntrain_2 = 0,
        Beta_tt_ntrain_3 = 0,
        Beta_tt_ntrain_4 = 0,
        Beta_tt_ntrain_sq_1 = 0,
        Beta_tt_ntrain_sq_2 = 0,
        Beta_tt_ntrain_sq_3 = 0,
        Beta_tt_ntrain_sq_4 = 0,
        Beta_tc_ntrain_1 = 0,
        Beta_tc_ntrain_2 = 0,
        Beta_tc_ntrain_3 = 0,
        Beta_tc_ntrain_4 = 0,
        Beta_book_1 = 0,
        Beta_book_2 = 0,
        Beta_book_3 = 0,
        Beta_book_4 = 0,
        Beta_book_sq_1 = 0,
```

```
    Beta_book_sq_2 = 0,
    Beta_book_sq_3 = 0,
    Beta_book_sq_4 = 0,
    Beta_del_1 = 0,
    Beta_del_2 = 0,
    Beta_del_3 = 0,
    Beta_del_4 = 0,
    Beta_sleeper_1 = 0,
    Beta_sleeper_2 = 0,
    Beta_sleeper_3 = 0,
    Beta_sleeper_4 = 0,
    Beta_minicabin_1 = 0,
    Beta_minicabin_2 = 0,
    Beta_minicabin_3 =0,
    Beta_minicabin_4 = 0,
    Beta_couchette_1 = 0,
    Beta_couchette_2 = 0,
    Beta_couchette_3 = 0,
    Beta_couchette_4 = 0,
    Beta_distance_station_1 = 0,
    Beta_distance_station_2 = 0,
    Beta_distance_station_3 = 0,
    Beta_distance_station_4 = 0,
    Beta_tc_plane_1 = 0,
    Beta_tc_plane_2 = 0,
    Beta_tc_plane_3 = 0,
    Beta_tc_plane_4 = 0,
    Beta_distance_airport_1 = 0,
    Beta_distance_airport_2 = 0,
    Beta_distance_airport_3 = 0,
    Beta_distance_airport_4 = 0,
    delta_1 = 0,
    delta_2 = 0,
    delta_3 = 0,
    delta_4 = 0,
    asc_ntrain_1 = 0,
    asc_ntrain_2 = 0,
    asc_ntrain_3 = 0,
    asc_ntrain_4 = 0,
    asc_plane_1 = 0,
    asc_plane_2 = 0,
    asc_plane_3 = 0,
    asc_plane_4 = 0,
    asc_HSR = 0)

# Set fixed parameters
apollo_fixed = c('delta_1', 'asc_HSR')

# Define class membership functions

apollo_lcPars=function(apollo_beta, apollo_inputs)
    lcpars = list()
    lcpars[["Beta_tt_ntrain"]] = list(Beta_tt_ntrain_1, Beta_tt_ntrain_2, Beta_tt_ntrain_3,
        Beta_tt_ntrain_4, Beta_tt_ntrain_5)
    lcpars[["Beta_tt_ntrain_sq"]] = list(Beta_tt_ntrain_sq_1, Beta_tt_ntrain_sq_2, Beta_tt_ntrain_sq_3,
        Beta_tt_ntrain_sq_4, Beta_tt_ntrain_sq_5)
```

```
    lcpars[["Beta_tc_ntrain"]] = list(Beta_tc_ntrain_1, Beta_tc_ntrain_2, Beta_tc_ntrain_3,
        Beta_tc_ntrain_4, Beta_tc_ntrain_5)
    lcpars[["Beta_book"]] = list(Beta_book_1, Beta_book_2, Beta_book_3,
        Beta_book_4, Beta_book_5)
    lcpars[["Beta_book_sq"]] = list(Beta_book_sq_1, Beta_book_sq_2, Beta_book_sq_3,
        Beta_book_sq_4, Beta_book_sq_5)
    lcpars[["Beta_del"]] = list(Beta_del_1, Beta_del_2, Beta_del_3, Beta_del_4, Beta_del_5)
    lcpars[["Beta_sleeper"]] = list(Beta_sleeper_1, Beta_sleeper_2, Beta_sleeper_3,
        Beta_sleeper_4, Beta_sleeper_5)
    lcpars[["Beta_minicabin"]] = list(Beta_minicabin_1, Beta_minicabin_2,
        Beta_minicabin_3, Beta_minicabin_4, Beta_minicabin_5)
    lcpars[["Beta_couchette"]] = list(Beta_couchette_1, Beta_couchette_2, Beta_couchette_3,
        Beta_couchette_4, Beta_couchette_5)
    lcpars[["Beta_distance_station"]] = list(Beta_distance_station_1, Beta_distance_station_2,
        Beta_distance_station_3, Beta_distance_station_4, Beta_distance_station_5)
    lcpars[["Beta_tc_plane"]] = list(Beta_tc_plane_1, Beta_tc_plane_2, Beta_tc_plane_3,
        Beta_tc_plane_4, Beta_tc_plane_5)
    lcpars[["Beta_distance_airport"]] = list(Beta_distance_airport_1, Beta_distance_airport_2,
        Beta_distance_airport_3, Beta_distance_airport_4, Beta_distance_airport_5)
    lcpars[["asc_ntrain"]] = list(asc_ntrain_1, asc_ntrain_2, asc_ntrain_3, asc_ntrain_4)
    lcpars[["asc_plane"]] = list(asc_plane_1, asc_plane_2, asc_plane_3, asc_plane_4)

    V=list()
    V[["class_1"]] = delta_1
    V[["class_2"]] = delta_2
    V[["class_3"]] = delta_3
    V[["class_4"]] = delta_4

    classAlloc_settings = list(
        classes = c(class_1=1, class_2=2, class_3=3, class_4=4),
        utilities = V)
    lcpars[["pi_values"]] = apollo_classAlloc(classAlloc_settings)
    return(lcpars)

# Validate inputs
apollo_inputs = apollo_validateInputs()

# Step 3: Define choice probs

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate")

    # Attach inputs and detach after function exit
    apollo_attach(apollo_beta, apollo_inputs)
    on.exit(apollo_detach(apollo_beta, apollo_inputs))

    # Create list of probabilities P
    P = list()
    # Define settings for MNL model component that are generic across classes
    mnl_settings = list(
        alternatives = c(Nighttrain=0, Plane=1, HSR=2),
        avail = list(Nighttrain=1, Plane=1, HSR=1),
        choiceVar = CHOICE)

    # Loop over classes
    for(s in 1:4)
      # Compute class-specific utilities
```

```
        V=list()
        V[["Nighttrain"]] = asc_ntrain[[s]] + Beta_tt_ntrain[[s]] * tt_ntrain +
          Beta_tt_ntrain_sq[[s]] * tt_ntrain * tt_ntrain + Beta_tc_ntrain[[s]] * tc_ntrain +
          Beta_del[[s]] * del_ntrain + Beta_book[[s]] * book_ntrain +
          Beta_book_sq[[s]] * book_ntrain * book_ntrain + Beta_sleeper[[s]] * sleeper +
          Beta_minicabin[[s]] * minicabin + Beta_couchette[[s]] * couchette +
          Beta_distance_station[[s]] * distance_station

        V[["Plane"]] = asc_plane[[s]] + Beta_tc_plane[[s]] * tc_plane +
          Beta_distance_airport[[s]] * distance_airport

        V[["HSR"]] = asc_HSR

        mnl_settings$utilities = V
        mnl_settings$componentName = paste0("Class_",s)

        # Compute within-class choice probabilities using MNL model
        P[[paste0("Class_",s)]] = apollo_mnl(mnl_settings, functionality)

        # Take product across observation for same individual
        P[[paste0("Class_",s)]] =
          apollo_panelProd(P[[paste0("Class_",s)]], apollo_inputs ,functionality)

      # Compute latent class model probabilities
      lc_settings = list(inClassProb = P, classProb=pi_values)
      P[["model"]] = apollo_lc(lc_settings, apollo_inputs, functionality)

      # Prepare and return outputs of function
      P = apollo_prepareProb(P, apollo_inputs, functionality)
      return(P)

  # Step 4: Estimate and print output

  # starting values search
  apollo_beta=apollo_searchStart(apollo_beta, apollo_fixed,apollo_probabilities, apollo_inputs)

  # Estimate
  model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)

  # Print output
  apollo_modelOutput(model)

  # Save output
  apollo_saveOutput(model)
```

D.2.4. Panel Latent Class choice model

```
# Latent class choice model with 4 classes

  # Step 1: Load modules and data

  # Clear memory
  rm(list = ls())

  # Load Apollo library
  library(apollo)

  # Initialise code
```

```
apollo_initialise()

# Set core controls
apollo_control = list(
    modelName = "LC4",
    modelDescr = "LC choice model for choosing the night train",
    indivID = "ID",
    outputDirectory = "output",
    nCores = 8,
    panelData = TRUE )

# Load data
database = read.csv('choice_data.csv',sep = ';',header = TRUE)

# Sort ID column
database = database[order(database[,'ID']),]
database <- na.omit(database)
database$tt_ntrain = database$tt_ntrain/10
database$tc_ntrain = database$tc_ntrain/100
database$tc_plane = database$tc_plane/100
database$distance_airport = database$distance_airport/100
database$distance_station = database$distance_station/100
database$age = database$age/10

# Step 2: Define parameters

# Define parameters
# use parameters of the start search of the discrete mixture model
apollo_beta = c(
    Beta_tt_ntrain_1 = 0.0321,
    Beta_tt_ntrain_2 = 1.4335,
    Beta_tt_ntrain_3 = 1.4875,
    Beta_tt_ntrain_4 = 1.8324,
    Beta_tt_ntrain_sq_1 = -1.0503,
    Beta_tt_ntrain_sq_2 = -0.8854,
    Beta_tt_ntrain_sq_3 = -1.0462,
    Beta_tt_ntrain_sq_4 = -1.5480,
    Beta_tc_ntrain_1 = -0.6337,
    Beta_tc_ntrain_2 = -0.9498,
    Beta_tc_ntrain_3 = -1.5211,
    Beta_tc_ntrain_4 = -0.7194,
    Beta_book_1 = 0.7970,
    Beta_book_2 = 0.6890,
    Beta_book_3 = 0.3116,
    Beta_book_4 = 0.4734,
    Beta_book_sq_1 = -0.1210,
    Beta_book_sq_2 = -0.0847,
    Beta_book_sq_3 = -0.0165,
    Beta_book_sq_4 = -0.0616,
    Beta_del_1 = -0.3260,
    Beta_del_2 = 0.0943,
    Beta_del_3 = 0.6594,
    Beta_del_4 = -0.6245,
    Beta_sleeper_1 = 2.6198,
    Beta_sleeper_2 = 1.0906,
    Beta_sleeper_3 = 1.1490,
```

```
Beta_sleeper_4 = 1.4821,
Beta_minicabin_1 = 2.0277,
Beta_minicabin_2 = 1.0249,
Beta_minicabin_3 = 1.3048,
Beta_minicabin_4 = 1.3618,
Beta_couchette_1 = -1.8920,
Beta_couchette_2 = -0.6350,
Beta_couchette_3 = -0.6750,
Beta_couchette_4 = -0.9452,
Beta_distance_station_1 = -1.9241,
Beta_distance_station_2 = -0.1212,
Beta_distance_station_3 = 0.0184,
Beta_distance_station_4 = 0.6813,
Beta_tc_plane_1 = -1.4388,
Beta_tc_plane_2 = -1.9242,
Beta_tc_plane_3 = -1.4123,
Beta_tc_plane_4 = -0.6520,
Beta_distance_airport_1 = 0.7442,
Beta_distance_airport_2 = -0.3233,
Beta_distance_airport_3 = 0.0228,
Beta_distance_airport_4 = 0.9713,
delta_1 = 0.0000,
delta_2 = 0.7660,
delta_3 = 1.0442,
delta_4 = 0.3771,
asc_ntrain_1 = 0.3245,
asc_ntrain_2 = 2.0219,
asc_ntrain_3 = 2.9292,
asc_ntrain_4 = 2.7757,
asc_plane_1 = -1.8003,
asc_plane_2 = 1.9923,
asc_plane_3 = 4.7658,
asc_plane_4 = 5.4297,
gamma_night_train_1 = 0,
gamma_night_train_2 = 0,
gamma_night_train_3 = 0,
gamma_night_train_4 = 0,
gamma_imp_env_1 = 0,
gamma_imp_env_2 = 0,
gamma_imp_env_3 = 0,
gamma_imp_env_4 = 0,
gamma_pres_env_1 = 0,
gamma_pres_env_2 = 0,
gamma_pres_env_3 = 0,
gamma_pres_env_4 = 0,
gamma_usual_train_1 = 0,
gamma_usual_train_2 = 0,
gamma_usual_train_3 = 0,
gamma_usual_train_4 = 0,
gamma_intl_train_1 = 0,
gamma_intl_train_2 = 0,
gamma_intl_train_3 = 0,
gamma_intl_train_4 = 0,
gamma_incon_env_1 = 0,
gamma_incon_env_2 = 0,
gamma_incon_env_3 = 0,
```

```
        gamma_incon_env_4 = 0,
        gamma_age_1 = 0,
        gamma_age_2 = 0,
        gamma_age_3 = 0,
        gamma_age_4 = 0,
        gamma_gender_1 = 0,
        gamma_gender_2 = 0,
        gamma_gender_3 = 0,
        gamma_gender_4 = 0,
        gamma_student_1 = 0,
        gamma_student_2 = 0,
        gamma_student_3 = 0,
        gamma_student_4 = 0,
        gamma_retired_1 = 0,
        gamma_retired_2 = 0,
        gamma_retired_3 = 0,
        gamma_retired_4 = 0,
        gamma_working_1 = 0,
        gamma_working_2 = 0,
        gamma_working_3 = 0,
        gamma_working_4 = 0,
        gamma_scenario_1 = 0,
        gamma_scenario_2 = 0,
        gamma_scenario_3 = 0,
        gamma_scenario_4 = 0,
        gamma_alone_1 = 0,
        gamma_alone_2 = 0,
        gamma_alone_3 = 0,
        gamma_alone_4 = 0,
        gamma_partner_1 = 0,
        gamma_partner_2 = 0,
        gamma_partner_3 = 0,
        gamma_partner_4 = 0,
        asc_HSR = 0)

# Set fixed parameters
apollo_fixed = c('delta_1', 'gamma_usual_train_1', 'gamma_intl_train_1',
    'gamma_night_train_1', 'gamma_imp_env_1', 'gamma_pres_env_1', 'gamma_incon_env_1',
    'gamma_age_1', 'gamma_gender_1', 'gamma_student_1', 'gamma_retired_1',
    'gamma_working_1', 'gamma_scenario_1', 'gamma_alone_1', 'gamma_partner_1',
    'asc_HSR')

# Define class membership functions

apollo_lcPars=function(apollo_beta, apollo_inputs)
    lcpars = list()
    lcpars[["Beta_tt_ntrain"]] = list(Beta_tt_ntrain_1, Beta_tt_ntrain_2, Beta_tt_ntrain_3,
        Beta_tt_ntrain_4, Beta_tt_ntrain_5)
    lcpars[["Beta_tt_ntrain_sq"]] = list(Beta_tt_ntrain_sq_1, Beta_tt_ntrain_sq_2,
        Beta_tt_ntrain_sq_3, Beta_tt_ntrain_sq_4, Beta_tt_ntrain_sq_5)
    lcpars[["Beta_tc_ntrain"]] = list(Beta_tc_ntrain_1, Beta_tc_ntrain_2, Beta_tc_ntrain_3,
        Beta_tc_ntrain_4, Beta_tc_ntrain_5)
    lcpars[["Beta_book"]] = list(Beta_book_1, Beta_book_2, Beta_book_3,
        Beta_book_4, Beta_book_5)
    lcpars[["Beta_book_sq"]] = list(Beta_book_sq_1, Beta_book_sq_2, Beta_book_sq_3,
        Beta_book_sq_4, Beta_book_sq_5)
```

```
    lcpars[["Beta_del"]] = list(Beta_del_1, Beta_del_2, Beta_del_3, Beta_del_4, Beta_del_5)
    lcpars[["Beta_sleeper"]] = list(Beta_sleeper_1, Beta_sleeper_2, Beta_sleeper_3,
        Beta_sleeper_4, Beta_sleeper_5)
    lcpars[["Beta_minicabin"]] = list(Beta_minicabin_1, Beta_minicabin_2,
        Beta_minicabin_3, Beta_minicabin_4, Beta_minicabin_5)
    lcpars[["Beta_couchette"]] = list(Beta_couchette_1, Beta_couchette_2, Beta_couchette_3,
        Beta_couchette_4, Beta_couchette_5)
    lcpars[["Beta_distance_station"]] = list(Beta_distance_station_1, Beta_distance_station_2,
        Beta_distance_station_3, Beta_distance_station_4, Beta_distance_station_5)
    lcpars[["Beta_tc_plane"]] = list(Beta_tc_plane_1, Beta_tc_plane_2, Beta_tc_plane_3,
        Beta_tc_plane_4, Beta_tc_plane_5)
    lcpars[["Beta_distance_airport"]] = list(Beta_distance_airport_1, Beta_distance_airport_2,
        Beta_distance_airport_3, Beta_distance_airport_4, Beta_distance_airport_5)
    lcpars[["asc_ntrain"]] = list(asc_ntrain_1, asc_ntrain_2, asc_ntrain_3, asc_ntrain_4)
    lcpars[["asc_plane"]] = list(asc_plane_1, asc_plane_2, asc_plane_3, asc_plane_4)

    V=list()
    V[["class_1"]] = delta_1 + gamma_usual_train_1 * usual_train + gamma_intl_train_1 * intl_train
        + gamma_night_train_1 * night_train + gamma_imp_env_1 * importance_env
        + gamma_pres_env_1 * pressure_env + gamma_incon_env_1 * inconvenience_env
        + gamma_age_1 * age + gamma_gender_1 * gender + gamma_student_1 * student
        + gamma_retired_1 * retired + gamma_working_1 * working
        + gamma_scenario_1 * scenario + gamma_alone_1 * alone + gamma_partner_1 * partner

    V[["class_2"]] = delta_2 + gamma_usual_train_2 * usual_train + gamma_intl_train_2 * intl_train
        + gamma_night_train_2 * night_train + gamma_imp_env_2 * importance_env
        + gamma_pres_env_2 * pressure_env + gamma_incon_env_2 * inconvenience_env
        + gamma_age_2 * age + gamma_gender_2 * gender + gamma_student_2 * student
        + gamma_retired_2 * retired + gamma_working_2 * working
        + gamma_scenario_2 * scenario + gamma_alone_2 * alone + gamma_partner_2 * partner

    V[["class_3"]] = delta_3 + gamma_usual_train_3 * usual_train + gamma_intl_train_3 * intl_train
        + gamma_night_train_3 * night_train + gamma_imp_env_3 * importance_env
        + gamma_pres_env_3 * pressure_env + gamma_incon_env_3 * inconvenience_env
        + gamma_age_3 * age + gamma_gender_3 * gender + gamma_student_3 * student
        + gamma_retired_3 * retired + gamma_working_3 * working
        + gamma_scenario_3 * scenario + gamma_alone_3 * alone + gamma_partner_3 * partner

    V[["class_4"]] = delta_4 + gamma_usual_train_4 * usual_train + gamma_intl_train_4 * intl_train
        + gamma_night_train_4 * night_train + gamma_imp_env_4 * importance_env
        + gamma_pres_env_4 * pressure_env + gamma_incon_env_4 * inconvenience_env
        + gamma_age_4 * age + gamma_gender_4 * gender + gamma_student_4 * student
        + gamma_retired_4 * retired + gamma_working_4 * working
        + gamma_scenario_4 * scenario + gamma_alone_4 * alone + gamma_partner_4 * partner

    classAlloc_settings = list(
        classes = c(class_1=1, class_2=2, class_3=3, class_4=4),
        utilities = V)
    lcpars[["pi_values"]] = apollo_classAlloc(classAlloc_settings)
    return(lcpars)

# Validate inputs
apollo_inputs = apollo_validateInputs()

# Step 3: Define choice probs

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate")
```

```
    # Attach inputs and detach after function exit
    apollo_attach(apollo_beta, apollo_inputs)
    on.exit(apollo_detach(apollo_beta, apollo_inputs))

    # Create list of probabilities P
    P = list()
    # Define settings for MNL model component that are generic across classes
    mnl_settings = list(
        alternatives = c(Nighttrain=0, Plane=1, HSR=2),
        avail = list(Nighttrain=1, Plane=1, HSR=1),
        choiceVar = CHOICE)

    # Loop over classes
    for(s in 1:4)
      # Compute class-specific utilities
      V=list()
      V[["Nighttrain"]] = asc_ntrain[[s]] + Beta_tt_ntrain[[s]] * tt_ntrain +
        Beta_tt_ntrain_sq[[s]] * tt_ntrain * tt_ntrain + Beta_tc_ntrain[[s]] * tc_ntrain +
        Beta_del[[s]] * del_ntrain + Beta_book[[s]] * book_ntrain +
        Beta_book_sq[[s]] * book_ntrain * book_ntrain + Beta_sleeper[[s]] * sleeper +
        Beta_minicabin[[s]] * minicabin + Beta_couchette[[s]] * couchette +
        Beta_distance_station[[s]] * distance_station

      V[["Plane"]] = asc_plane[[s]] + Beta_tc_plane[[s]] * tc_plane +
        Beta_distance_airport[[s]] * distance_airport

      V[["HSR"]] = asc_HSR

      mnl_settings$utilities = V
      mnl_settings$componentName = paste0("Class_",s)

      # Compute within-class choice probabilities using MNL model
      P[[paste0("Class_",s)]] = apollo_mnl(mnl_settings, functionality)

      # Take product across observation for same individual
      P[[paste0("Class_",s)]] =
        apollo_panelProd(P[[paste0("Class_",s)]], apollo_inputs ,functionality)
    # Compute latent class model probabilities
    lc_settings = list(inClassProb = P, classProb=pi_values)
    P[["model"]] = apollo_lc(lc_settings, apollo_inputs, functionality)
    # Prepare and return outputs of function
    P = apollo_prepareProb(P, apollo_inputs, functionality)
    return(P)

# Step 4: Estimate and print output

# Estimate
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)

# Print output
apollo_modelOutput(model)

# Save output
apollo_saveOutput(model)

# Step 5: Simulation
```

```
# Load previous model
model = apollo_loadModel('output/LC4')

# Define simulation values

database$tt_ntrain = 1.8 # Attribute values: 1.2 - 1.8
database$tc_ntrain = 0.50 # Attribute values: 0.50 - 0.29
database$book_ntrain = 3.4 # Attribute values: 1 - 5
database$del_ntrain = 0.5 # Attribute values: 0.25 - 0.75
database$sleeper = -1 # Attribute values: -1, 0, 1
database$minicabin = -1 # Attribute values: -1, 0, 1
database$couchette = -1 # Attribute values: -1, 0, 1
database$tc_plane = 1.50 # Attribute values: 150, 250, 350

apollo_inputs = apollo_validateInputs()

# Predict probabilities for each of the classes
forecast = apollo_prediction(model, apollo_probabilities, apollo_inputs)
```

E

Model selection

This appendix further emphasises the model selection for the mode choice model. Firstly, the model selection procedure of the MNL and Panel ML model is presented and secondly, the procedure for the Panel LCCM.

E.1. Model selection for the MNL and Panel ML model

E.1.1. Model selection for the MNL model

Firstly, for the MNL model, it was determined if adding non-linearity effects increases the model fit. For this, a likelihood ratio test has been conducted. As can be seen in the source code below, adding non-linear effects increases the model fit.

 # Base MNL model LL results:
LL: -8808.987, Parameters: 12

 # Including Non-linearity:
LL: -8801.412, Parameters: 14

tools.likelihood_ratio_test((-8808.987, 12), (-8801.412, 14)) Out: LRTuple(message='H0 can be rejected at level 5.0%', statistic=15.149999999997817, threshold=5.991464547107979)

E.1.2. Model selection for the Panel ML model

A Panel ML model was estimated with several numbers of Halton draws. In Table E.1, estimation results are shown for both the Panel ML with 50 and 100 draws. The last column denotes the difference between the estimated parameter values, divided by twice the standard error of the Panel ML model with 50 draws. Values over 1 indicate that the model has not converged. As the table shows, all parameters have converged in the model with 100 draws. It was, therefore, decided to choose the Panel ML model with 100 draws. This model is then compared with the extensive MNL model and the base MNL model. In Table E.2, it can be seen that the Panel ML model with 100 draws fits the data significantly better than the other options. It was, therefore, chosen to use the Panel ML model with 100 draws as a final model.

E.1.3. Model comparison of the MNL and the Panel ML model

They were compared regarding model fit after determining the final MNL and Panel ML model. The results are presented in Table E.2.

E.1.4. Model selection for the Panel Latent Class Choice Model

Various discrete mixture models have been estimated to determine the appropriate class for the LCCM. The estimation results are presented in Table E.3.

Table E.1: Parameter estimations for Panel ML model with 50 and 100 draws

	Value 50	Rob. std. err. 50	Value 100	Rob. std. err. 100	Converged if <1
Alternative specific constants					
ASC night train	-2.856	3.148	-2.940	3.163	0.0
ASC plane	3.354	0.336	3.403	0.352	-0.1
STD night train HSR	3.034	0.163	3.006	0.158	0.1
STD night train plane	-2.887	0.126	-2.847	0.123	-0.2
STD plane HSR	-0.772	0.083	-0.785	0.080	0.1
Attributes for the alternative night train					
travel time night train	8.847	4.324	9.008	4.343	0.0
sq. travel time night train	-3.440	1.438	-3.496	1.445	0.0
cost night train	-1.034	0.053	-1.040	0.053	0.1
couchette	-0.581	0.073	-0.583	0.073	0.0
mini cabin	0.912	0.090	0.920	0.091	0.0
sleeper	1.085	0.065	1.085	0.066	0.0
booking	0.474	0.072	0.474	0.072	0.0
sq. booking	-0.052	0.011	-0.052	0.011	0.0
delay	0.082	0.104	0.085	0.104	0.0
access distance train	0.068	0.151	0.065	0.154	0.0
Attributes for the alternative plane					
cost plane	-1.285	0.056	-1.287	0.056	0.0
access distance plane	-0.076	0.334	-0.074	0.342	0.0

Table E.2: Model comparison

Model	# Parameters	Rho square	Initial LL	Final LL
MNL Base	12	0.136	-10,194.02	-8,808.99
MNL Final	14	0.137	-10,194.02	-8,801.41
Panel ML Final 100 draws	17	0.383	-10,194.02	-6,290.41

Table E.3: Model fit of Latent Class Models

Classes of Discrete Mixture Model	2	3	4	5
LL	-7,288.39	-6,547.46	-6,183.02	-6,000.13
BIC	14,842.58	13,498.19	12,906.78	12,678.47
Parameters	29	44	59	74