Night train services

A stated choice experiment: exploring preferences for night trains

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Master thesis

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A stated choice experiment: exploring preferences for night trains

by

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Preface

Dear reader,

This thesis marks the final project for the master of Transport, Infrastructure and Logistics at Delft University of Technology. It is to be awarded with a Master of Science. This thesis is carried out in cooperation with the Belgian Railways (SNCB). The aim of this master thesis is to study the night train preferences of the Belgian population in order to gain more insight into the preferred service by potential travellers.

I would like to thank my graduation committee from the TU Delft and SNCB for all their help, feedback, guidance and patience. I had a long process finishing this project, but you kept supervising me with the same enthusiasm. Thank you Nathalie Van der Vurst and Goedele Van Goolen for their interest in this research and for giving me the opportunity to collect surveys on their trains. I would like to thank Bert van Wee for the guidance during the preparations for this research and for the useful enthusiastic and useful feedback during the official meetings. I would like to thank Rob van Nes for the guidance during the preparations for this research and for making time during setbacks to motivate me. I would like to thank Niels van Oort for taking over the guidance and always making time for me after Rob van Nes retired and for giving me the opportunity to do enjoyable extracurricular aspects of the thesis such as presenting my work and publishing an article in the mobility journey. I would also like to thank Eric Molin for making time for me any time of the day, even when you were not feeling well and for your very useful guidance and feedback in such a positive and patient way.

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Wouter Moors
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Summary

Since growing concerns about environmental issues and congested airports is the interest in international night trains growing. Many countries and operators are therefore investigating the possibility of reintroducing night train services. This is also the case in Belgium where the Belgian rail operator NMBS wants to gain more insights about the preferred service by potential travellers. In order to do so is more insight needed into the travel behaviour of potential travellers.
This problem statement has led to the main research question of this research:

”Which factors influence the preference and use of night train services among the Belgian population and what is the corresponding heterogeneity”

To answer this question, a stated choice experiment is conducted. Data is collected when respondents on Belgian IC train services were asked to fill in a survey which includes the choice experiment. The choiceset of this experiment consists of two night train options and a base alternative. The choiceset consists of 12 choices where the night train attributes ’comfort level’, ’cost’, ’arrival time’, ’night stop’, ’service carriage’, ’car carriage’ and ’facilities’ are varied. Included in the stated choice survey are socio-demographic factors and context variables as background variables.

An MNL model, MNL model with interaction effects and a Latent Class Choice model are estimated in order to gain more insight into the importance of attribute preferences that influences the choice of night train services. As well are these models used to find relating socio-demographic and journey context characteristics that attribute to the heterogeneity in preferences.

The inclusion of context variables regarding to trip purpose and travel companion could not influence the preference and use of the night train services. Besides this could the socio-demographic factors do influence the preference and use of the night train. ’Household with adults (studenthouse)’, ’age’, ’employed’, ’academic master’ and ’personal car’ influence the preferences and use of the night train services. The socio-demographic factors that influence the heterogeneity in preferences among the Belgian population are ’state’, ’age’, ’income’, ’academic master’, ’preferred mode car’ and ’preferred mode plane’. Five classes among the Belgian population could be found with different night train preferences. Class 1 (12.6%) who do not prefer the night train at all. Class 2 (15.6%) are French-speaking, high educated, young travellers, who do not prefer to take a car and have a low income. They prefer a capsule cabin (followed by a sleeper cabin) and are highly price sensitive. Class 3 (18.7%) prefer a sleeper cabin (followed by a capsule cabin) and are not price sensitive. They also prefer to have a service car, late arrival and private facilities. Class 4 (40%) prefer all comfort attributes similarly but capsule cabin the most. They prefer night stops and private facilities. French-speaking travellers with high education who prefer an aeroplane as mode have a high probability to belong in this class. Class 5 (13.1%) have the capsule cabin as the preferred comfort attribute followed by sleeper. They prefer private facilities and are the only ones who prefer to take a car on their journey. Those who prefer an aeroplane to travel with have a higher chance of belonging to this class. The highest ridership would be for the night train offering just capsule cabins at a price of €120. The lowest ridership would be for the night train offering low comfort at a low cost. 52.2% of the travellers would choose this option. The preferred mode seems to be a great influence on the ridership of the night train. When a car is preferred, this leads to low market shares. When an aeroplane is preferred, and still no train, a high market share results.

Contents

1
Introduction

Over the past decades, growing concerns relating to global warming began to rise globally. It led to many actions undertaken by climate participants. Recently, it led to global climate strikes carried out by school and university students in 2019 (The Guardian, 2019). Further, the Covid-19 pandemic did create an increase in environmental awareness since the local environment became an escape for many people (Severo et al., 2021).

World leaders acknowledge these climate concerns which resulted in an ambitious climate pact. The Paris Agreement shows the commitment of almost all countries around the world to limit global warming to less than two degrees Celsius (United Nations, 2021). To achieve this, European countries have combined forces in the European Green Deal. They want to become carbon neutral by 2050. A variety of actions resulted in the Green Deal and moving to cleaner and healthier transport modes is one of these (European Commission, 2020). Cars, aeroplanes and high-speed rail are commonly used as international travel modes when focusing on international travel within Europe. High-speed rail is the most ecological mode among these three. However, it is only served between several large cities within Europe. Although no high-speed rail is served in many European cities, conventional rail is widely spread within Europe and therefore are many cities served by conventional rail. Nonetheless, the average speed is relatively low for long-distance conventional trains. Therefore are cars and aeroplanes mostly the only attractive mode to travel within Europe (Bird et al., 2017). Therefore, many countries want to reintroduce night train services to offer an ecological mode. The intention to offer night trains is to create a modal shift towards rail which is stimulated by the Green Deal (Vanacker, 2020). This train can be defined as follows:

"A night train is a train which leaves in the evening and arrives in the morning while passengers can sleep during the ride."

An ideal night train operates between two stations which takes 8-10 hours, departs after 22:00 and arrives before 8:00 (Savelberg, 2019). It usually makes use of the conventional railway network since this network is widely expanded. Night trains can technically make use of high speed rail, but it is more expensive to operate on (Bird et al., 2017). Most common night trains offer seating carriage, couchettes and sleeper cabins. Sleeper cabins offer comfortable beds for two persons. For an additional fee can it also be used by one person. These cabins offer therefore an high level of privacy. Couchettes can be occupied by six people where seats can be converted into beds. These have a lower comfort (Bird et al., 2017). Night trains were an important mode for long distance travel for many decades. It started to compete with air and road transport after World War II and started to lose its share in the modal split. Air and road transport gained popularity which led that many night trains were withdrawn from service (Bird et al., 2017). Recently, many night train initiatives have been launched in Europe due to its ecological characteristic. Therefore do many countries support these initiatives since all countries need to reduce their greenhouse gas emissions. This is also the case in Belgium where they want Brussels to serve as a hub for night trains (Vanacker, 2020). Ongoing studies and research has shown that people are willing to use night trains in many EU-countries for long distance travel (Savelberg, 2019).

Despite the fact that recent and ongoing studies are dedicated to the willingness to use night trains, there is no insight on what peoples expect on night train services. Therefore is it crucial to carry out studies by gaining insight into people's preferences for night train services.

1.1. Research problem

For Belgian residents, car and airplane are the most popular modes for long distance travel within Europe. Car is the dominant mode to travel to neighbouring countries where an airplane is dominant mode once the distance increases or the geographical location is different to reach by car. However, cities like Paris, London and Lille have rail as an important or even as a dominant mode. This is due to the fact that rail is an attractive alternative mode for these cities which is served by direct high speed trains or direct intercity (IC) trains (FOD, 2021). Most other European cities don't have a good rail connection from Brussels. A night train can connect cities which are too far away to reach with IC trains or high speed trains. This train can serve as an attractive ecological alternative if people are willing to use a night train.

1.1.1. Willingness to use night train

A recent study by the Belgian government stated that 60% of the Belgians would consider to chose for a night train to travel within Europe (FOD, 2021). Also do other studies prove that people are willing to use a night train. A study carried out by Heufke Kantelaar (2019) estimates a mode choice model between a night train, evening plane (with overnight stay) and morning plane. These three options enables an early arrival at the destination. It has modelled a potential share of 60% for night trains (served as today) between these three alternatives. The study context focused on destinations of around 1200 km which would take around 12 -14 hours by night train. Destinations which are within the range of the night train seems therefore to have potential. KiM Netherlands Institute for Transport Policy Analysis also claims that destinations have potential to be served by night train under two conditions. The destinations must be within reach of 8 - 12 hours of travel and the city must be dense cities with high population (Savelberg, 2019).

The biggest and one of the few night train operators in Europe ÖBB also believes in the night trains potential. It has taken over the most lucrative night services from the German national railways in 2016. It has doubled its passengers numbers on Nightjet (their night train brand) ever since and claims that it transports more passengers than it expected. It is believed that the growing flight shame (flygskam) resulting from the growing climate awareness will only fuels the grow of ecological transport modes (Karasz, 2019).

1.1.2. Service attributes

The Belgian train operator, NMBS, wants to investigate the possibilities about offering night train services to connect Belgium with other European cities. When considering to offer services, it is essential to start to take customers' needs and expectations into account (Kuzmanović et al., 2011). However, it is not clear which services night train users expect. During the 1990s, transport researchers began to focus on service quality and user satisfaction. Awareness started to raise that travel behaviour relates to service quality. Service attributes have been proposed to define public transport service quality. It can can be categorised as physical attributes and perceived attributes. Physical attributes are measured without the involvement of users and assumptions on the impact on public transport users are made. Whereas perceived attributes refer to users' experiences. Basic requirements of public transport service quality are short travel time, no or few connections, reliability and frequency. Other important attributes are price and accessibility. Users also want mobility experience. Some people may find it important to have social interactions, while others may find the opportunity to work important. Perceived attributes cannot be generalised, but it is often related to functionality, information and comfort (Friman et al., 2020). An overview of these quality attributes are shown in table **??**.

Table 1.1: Quality attributes (Friman et al., 2020

Percieved attributes	**Physical attributes**
Comfort	Reliability
Safety	Frequency
Convenience	Speed
Aesthetics	Accessibility
	Price
	Information provision

Some attributes are more suitable to analyse service quality for specific services. Short travel times, which is a basic requirement for service quality is to a certain extent less relevant for night trains European Commission, 2020. It is more important that a sufficient time of sleep can be offered and that the travel time lies within a certain time range Bird et al., 2017. Therefore are departure and arrival time important attributes. These times must be suitable to the travellers daily routine Li et al., 2019). There is little knowledge on these times. However, a study from Japan shows that the ideal departure time is around 22:00 and the arrival time is around 7:00 Li et al., 2019. Another study carried out by the European Union came with similar findings. It states ideal departure and arrival time of respectively 22:00 and before 8:00 (Bird et al., 2017). On reliability, frequency and connections is no insight on night train travel. Perceived attributes like comfort and safety are important attributes since the night needs to be spend Li et al., 2019. Perceived comfort is influenced by many factors where some insight is known. It is influenced by the comfort level offered. It usually offers three accommodations which differ from comfort level. Seating carriages offer only seats during the night which has the lowest comfort level for sleeping. Couchettes has convertible seats which has a descent comfort level. Sleeper cabins has the highest comfort level which comes with comfortable beds. These comfort levels influences the perceived comfort of the user. As well is the perceived comfort of night trains heavily influenced by the number of people in shared accommodation as well (Heufke Kantelaar, 2019). Privacy is therefore an important variable. Sleeper cabin offer high privacy where up to two people can be occupied. Couchettes can be occupied by six people where privacy is therefore low. It can however be ideal for families or friends which also influences the perceived comfort. ÖBB has ordered new night trains carriages where couchettes has adapted to the growing expectation of privacy. These new couchettes offer more privacy for solo travellers by offering mini suites which can be closed separately (Nightjet, 2021). Comfort is an important attribute in mode choice when considering the night train instead of air travel (Heufke Kantelaar, 2019; Dupuis, 2021). Heufke Kantelaar (2019) shows that if night trains trade comfort for low fares like low cost airlines, it would lead to a significant drop in the market share.

Some studies revealed little insight on some specific attributes. Like stated earlier, there are many attributes that defines public transport quality. There is still little knowledge on the preferences relating to service attributes.

1.1.3. User groups

An earlier study from Heufke Kantelaar (2019) gain already much insight into the important night train attributes. As well is insight gained between the modal split of a night train, a morning flight and an evening flight which results in an extra hotel night. However, little insight is gained into user groups who have preferences for certain night train attributes. Some user groups might have different preferred attributes. A couchette can be ideal for users who travels in group, where a single user may want more privacy. Both user groups have therefore a different preferred service. A study carried out by Heufke Kantelaar (2019) has found that night trains are more attracted by leisure travellers than business travellers. This is also found at a case study carried out on the night train service Brussels-Vienna (Dupuis, 2021). Within the leisure travellers are likely to have different user groups who have similar preferences. Travelling with friends, family or alone also defines the mode choice and choice for certain night train attributes. These context variables are not yet investigated into detail and neither are their effect on the mode choice and night train preferences. Also is it not determined if heterogeneity exists within the smaller user group of business travellers. When these user groups are defined, train operators can adapt their services for each user group.

The little knowledge on the heterogeneity within the night train users and their preferences define the research gap that is addressed in this study.

1.2. Research objective

As mentioned in the introduction is the wish of the Belgian government to have in Brussels a international night train hub. The Belgian train operator NMBS wants to investigate the possibilities about offering night train services to connect Belgium with other European cities. Existing studies suggests that people are willing to use night trains but there is little insight on the travel preferences and travel behavior of night train users. This insight is crucial for a product design. A successful service can be achieved when user preferences are known instead of focusing on a successful formation of the service (Kuzmanović et al., 2011). When more insight is gained, train operator NMBS can start to investigate the possibilities for setting up night train services from Belgium which starts with designing their night train product focusing on the user groups and their preferences.

The goal of this research is to reveal the preferences of night train users and to identify user groups of these travellers. Besides filling the research gap, this research will also be relevant for train operator NMBS who has the interest in providing night train services from Belgium. Evidence will be provided on the preference of people based on perceived and physical attributes.

1.3. Research question

To gain more insight about night train travellers preferences and to reveal user groups within these night train travellers, the following research question will be answered:

”Which factors influence the preference and use of night train services among the Belgian population and what is the corresponding heterogeneity”

The following sub-questions will structure the research in order to answer the main research question:

- **Which night train service attributes are relevant for a night train?**
- **Which night train attributes are most important for the Belgian population, and to which extent?**
- **To which extent does heterogeneity in preferences exist among the Belgian population regarding the values of night train attributes, and to which socio-demographic characteristics can this heterogeneity be attributed?**
- **To what extent can night trains create a modal shift towards rail?**

1.4. Scoping

This research focuses on travellers who have used or who are willing to use night trains for long distance travel within Europe. Since having night train services from and to Brussels is the interest, the majority of users will be Belgian residents and residents of the served destination. Since the limited amount of time of this research, it will only be focused on the Belgian residents. Long distance travel within Europe will be defined as distances starting from 800 km. Up to this range, night trains travel times are too short to offer a good amount of sleep.

2 Methodology

2.1. Literature study

A literature review is conducted to gain more in-depth knowledge on the travel behaviour of long-distance travellers and their mode choice. This study is also used to identify the socio-demographic factors which influence the behaviour of these travellers and more specifically the choice of a night train. Moreover, this part is used to gain more insight into the existing night train services within Europe and their usage. These services are finally used to derive night train attributes.

Research engines like Google Scholar, Scopus and Science Direct are used to retrieve relevant studies. 'Long distance train travel', 'Modal split long distance travel', 'Travel behaviour long distance travel' and 'Night train services' are used as keywords. When searching through the results, the abstract and conclusion are first examined to decide about the relevancy. In addition is the snowball technique used to retrieve additional relevant studies.

The results of the literature study makes clear which socio-demographic factors influence the behaviour of long-distance travellers and their mode choice. These need to be included in the survey in order to make up the right conclusion. As well are the important night train attributes retrieved which are or are not fully researched yet. These are used to create the alternatives within the choice experiment.

2.2. Choice experiment

To gain insight into the travel behaviour of night train travellers is it necessary to capture their choice behaviour. In order to do so, the trade-offs of their choices need to be observed. Capturing people's trade-offs of their choices can be done with a revealed or stated choice experiment since trade-offs cannot be asked directly to people. A revealed choice experiment has observations in real life whereas a stated choice experiment is hypothetical (Molin, 2023b).

2.2.1. Revealed Preferences versus Stated preferences

Revealed preferences choice experiment generates choice data on what people actually did (real market alternatives). Therefore are the results of high validity. In addition is this experiment suitable for forecasting choices if the choice set does not change. Although, there are some shortcomings of this method. Since it only observes the choices that are made are the considered choices unknown. Therefore is the choice set incomplete and are assumptions necessary. It can only observe existing alternatives as well. Therefore can effects of the introduction of new alternatives not be examined. There is also an insufficient variation within the data between circumstances and many respondents are needed since only one choice is made per respondent. This makes this experiment very time-consuming and expensive (Molin, 2023b).

On the other hand, a stated preferences choice experiment has a pre-specified choice set (hypothetical alternatives). This overcomes some limitations of the revealed preferences choice experiment.

Because of the pre-specified choice set are all choices fully known. It also enables the inclusion of new alternatives which do not exist yet. As well can any variation be made for certain circumstances. Since respondents can make multiple choices, are fewer respondents needed to have reliable estimates which makes the experiment less time-consuming and less expensive (Molin, 2023b). Stated preferences do have some drawbacks where potential hypothetical bias is the main one. It is not certain that respondents really would make the choice in real life. This is due to the fact that (Molin, 2023b):

- the respondents have perfect information of all alternatives (not in real life)
- the consequences of choices are not felt
- new alternatives are not experienced

Because of the characteristics of the stated choice experiment is this method flexible in which trade-offs need to be captured. It also retrieves better significant effects of factors and therefore is this experiment widely used by researchers (Hensher, 2010). Besides these reasons is a never used attribute included in the experiment which makes the stated choice the only suitable experiment. The choice experiment includes two night train alternatives and a base alternative which includes other modes to undertake an international journey (aeroplane, car and bus). The design of this survey is discussed in chapter 4.

2.3. Discrete choice modeling

To analyse the data of the stated choice experiment is discrete choice modelling applied. Discrete choice models simplify the complexity of true choice behaviour to the form of a model. These models have been widely used in the past decades, especially for behavioural foundation in many decision-making problems (Hensher and Bradley, 1993). A variety of discrete choice models exist but the most popular model is the random utility model or also called 'Random Utility Maximisation (RUM) model'. It is based on the assumption that a decisionmaker chooses the alternative with the highest utility (Hensher and Bradley, 1993)(Chorus, 2023a). A utility is assigned to each alternative i of the choice set. The utility U_i has a deterministic component (V_i) and a random component (ε_i) which can be seen in equation 2.2. The deterministic component (V_i) is related to observed factors such as cost and comfort. The random component (ε_i) governs everything else of the individual's choice such as randomness in choices or heterogeneity in tastes Chorus, 2023a.
Respondent n chooses according to the RUM model for the highest utility U. Alternative i is chosen in equation 2.1.

$$U_{ni} > U_{nj} \qquad \forall j \neq i \tag{2.1}$$

$$U_{ni} = V_{ni} + \varepsilon_{ni} \tag{2.2}$$

Each alternative m within the choice set can be described as in equation 2.3 where taste parameters β for attribute m must be estimated. All variables X_m (attribute level of attribute m) are considered to be linear and must therefore be tested.

$$U_i = \sum \beta_m X_{im} + \varepsilon_i \tag{2.3}$$

The taste parameters (β_m) of the attributes must be estimated in order to predict the choices. These estimates provide insights into the relative importance of various factors and, as a result, impact choice behaviour. Different models can be used to estimate these taste parameters.

2.3.1. Multinomial Logit Model

In discrete choice modelling is the most widely used model the mulitnomial logit (MNL) model. It models the probability P that a decisionmaker n chooses alternative i where J is the choice set of j alternatives as seen in equation 2.4 (Chorus, 2023a) (So and Kuhfeld, 1995).

$$P(ni) = P(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}, \forall j \neq i) = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}} \tag{2.4}$$

The model is based on two property assumptions to reduce the complexity of the model. The first assumption holds that the error term of each alternative is identical and independently distributed (IID). It assumes therefore that all respondents have the same preferences. However, one of the goals of this study is to find a difference in choice behaviour among travellers who have different preferences. The second assumption is the independence from irrelevant alternatives (IIA). This means that each alternative is seen separately even though there may be similar attributes between alternatives (So and Kuhfeld, 1995)(Chorus, 2023a).

2.3.2. MNL model with interaction effects

To overcome the assumption that preferences are all the same within the population (IID assumption), the MNL model can be used with interaction effects. Using socio-demographic interaction combined with the model can capture variation between segments. Only will preferences still differ within the segments which are not captured with interaction effects (Chorus, 2023b).

2.3.3. Latent Class Choice Model

To capture heterogeneity in preferences within the population is one of the goals of this study which was neglected with the MNL model and partly with the MNL model with interaction effects. The latent class model is able to capture full heterogeneity in preferences. It, therefore, overcomes this limitation of the MNL model. Also, other limitations are overcome by this model such as capturing panel data (Molin and Maat, 2015). The latent class model separates the population into several classes based on homogeneous preferences (Kim et al., 2017). This gives the needed insight into the desired service for specific user groups. Per class are the parameters estimated by applying the latent class model. The number of classes is not known in advance. This number needs to be estimated by running multiple models with different amount of classes. Based on the model fit is the number of classes chosen which has the best fit (Molin and Maat, 2015).
The latent class model estimates the parameters per class together with a class membership model. It models the probability Π_{ns} of an individual n belonging to class s, which is seen in equation 2.6. It is based on the socio-demographic factors (included in the model as $g(\gamma_s, z_n)$) and other characteristics (included in the model as δ_s). The latent class model (seen in equation 2.5 uses as follows the class membership probabilities Π_{ns} as weights for modelling the probability $P_n(i \mid \beta)$ that individual n chooses alternative i, conditional on the model parameters β (van Cranenburgh, 2023).

$$P_n(i \mid \beta) = \sum_{s=1}^{S} \Pi_{ns} P_n(i \mid \beta_s) \quad (2.5)$$

$$\Pi_{ns} = \frac{e^{\delta_s + g(\gamma_s, z_n)}}{\sum_{l=1 \dots S} e^{\delta_l + g(\gamma_l, z_n)}} \quad (2.6)$$

where:

- Π_{ns} = class-membership of an individual n belonging to class s
- δ_s = class-specific constant
- $g(\gamma_s, z_n)$ = function with γ_s as class-estimate of variable (age, gender...) and variable value

3
Literature research

The focus of this research is to contribute additional knowledge about night train travel behaviour. Factors which explain the travellers' choice for the night train and which night train service attributes enlarge the share of night trains within the modal split. These factors are later used to optimally design the stated choice experiment to gain information from the experiment to the fullest extent. Firstly, literature research is carried out to provide insight into long-distance rail travel in general. In particular, it is focused on which factors influence long-distance travel and its mode. Furthermore, more information is gained specifically on night train service attributes. Important attributes that already exist today and new attributes that could contribute to the night train service choice are searched for. These factors are later used to design a stated choice experiment to retrieve extra knowledge about night train travel behaviour.

3.1. Long-distance travel

The focus of the long-distance travel review is to delve into the factors influencing modal choices, preferences of rail users and the trip purpose of these travellers. The definition of long-distance journeys varies between studies. Many studies focus on travellers' behaviour on national problems. It results in different ranges of long-distance journeys which makes it difficult to be consistent with conclusions. However, it gives a good indication of which factors influence the behaviour of these long-distance travellers.

3.1.1. Modal split

Several modes can be used in order to execute a long-distance trip within Europe. Plane, bus, car and train are therefore the most common modes. Generally, air travel has the biggest share followed by car, which can be seen in table 3.1. Some OD-pairs within Europe have a contrary modal split where rail travel has the biggest share which includes high-speed and conventional rail. The introduction of high-speed rail service has created a significant decrease in air travel in favour of rail which is the case for example for the corridor between the Netherlands and Paris (van Goeverden, 2009).
Zumkeller et al. (2005) reported very significant variables influencing the modal split. Travel cost and the number of interchanges are found to be important variables. The higher the cost and number of interchanges, the lower the share of train service within the modal split. Consistent with expectations, the travel cost is reported in many studies to have a great influence on the modal split (van Goeverden, 2009)(Mandel et al., 1997)(Bird et al., 2017).
Mandel et al. (1997) and van Goeverden (2009) reported a large significance of travel time where an increase in travel time has a negative effect on the use of train services. Travel time is found to be less sensitive for night train service compared to other day modes (Heufke Kantelaar(2019). One minute of travel time on a night train is valued less than one minute on an aeroplane. Trip purpose has been found to be an important variable influencing the mode choice. Business travellers have a higher probability of selecting evening flights and opting for hotel accommodations, rather than choosing for night train transportation. (Heufke Kantelaar, 2019). Other important factors are the number of interchanges, seat

reservation, comfort and destination. It is more likely to take a train to a more dense urban area of the destinations. It arrives in the middle of a city which makes egress trips much shorter compared to other modes (Ding et al., 2017). Other minor factors are the number of destinations in a journey, luggage volume, distance and frequency (van Goeverden, 2009). Travellers tend to plan their long-distance journeys ahead whereby other factors are more important than frequency (Wardman, 2004).

Table 3.1: Modal split for European long-distance travel (>100 km) (van Goeverden, 2009)

	Modal share (%) in 2001
Car	32,8%
Bus, coach	4,0%
Train	7,7%
Aeroplane	53,7%
Other	1,7%

3.1.2. Rail users

The travel behaviour of train travellers is important to gain more insight into their motives whether to choose or not for rail services. Travellers can be in favour or disfavour for rail services. Their motives are important to take into account for the stated choice experiment.

Favour for rail services

Travellers who make use of long-distance rail services are mostly travellers who have made at least one long-distance journey a year by train (Department of Transport, 2019). This suggests that it is likely that regular train travellers use rail services for long-distance journeys as well. The European Parlement also concludes that regular train travellers are the majority who use rail services for long-distance journeys, including night train services (Bird et al., 2017). This user group is therefore ideal as respondents for the stated choice experiment. To gain insight into the travel behaviour of night train travellers, it is essential to target these travellers. Using regular train users as the respondent group has a higher probability of targeting these travellers.
That common rail users prefer rail services were also found in a case study in Sweden. A night train service was removed between Norrland and Narvik and the biggest share of the travellers would still continue by train. It would either be on another night train or a day train. Only if no train option would have been available, the majority of the rail users would switch to air services, followed by car and bus. A very small portion would have chosen not to travel at all (Bird et al., 2017).

A study from Great Britain (Department of Transport, 2019) shows that travellers prefer to take the train because it was easier than any other mode and/or it was quicker. This was the case for respectively 41% and 47%. Rail users tend to use trains for its **convenience** which is one of the main factors unless the travel time and cost are reasonable. van Goeverden(2009) found a significant effect between convenience and train demand, particularly in the number of interchanges. The train demand decreases by 30 - 60% by an increase of 1 interchange. It is found to be one of the most important factors that influence train demand on conventional long-distance travel. The impact of convenience on train demand is therefore big. An example of this impact can be found during the summer of 2022 in Europe. Train travel has become much more convenient compared to air travel. It was due to staff shortages at airports that resulted in long waiting times and high crowd levels. Therefore chose many travellers to take the train instead (Kompeer, 2022).
Other motives were because travellers did not want or were not able to drive. It enables the traveller to do other things while travelling and trains are more comfortable. Around 15% was this the case. Only 10% of the travellers used the train for long-distance travel because it was cheaper (Department of Transport, 2019).

Disfavour for rail services

Besides the fact that users are in favour of travelling with rail services are there also long-distance travellers who are in disfavour. The same study of Department of Transport (2019) found evidence of why they are in disfavour of these services. The main reason was mostly because it was easier by car

or plane (36%). Convenience is therefore the main reason to choose or not to choose rail services. The second common reason was that train fares were too high (19%) (Department of Transport, 2019). To encourage more infrequent users to use rail services, infrequent users suggested that lowering the fares would result in using rail more often. This would be the case for 66% of the infrequent users. More frequent trains and/or more routes would also be an improvement which was indicated by these users for respectively 18% and 17% (Department of Transport, 2019). Travel cost, travel time and service frequency are therefore found as the major factors to explain the mode choice which was also found by a study from the European Parliament. Trip generation is influenced by these factors as well (Bird et al., 2017).
van Goeverden has quantified the importance of cost and the consequence to rail demand compared to the car. When the ratio between train and car increases by 10% will the train demand decreases by 10 - 40%.

3.1.3. Trip purpose

Long-distance rail journeys are most commonly used for **visiting friends and relatives**. A study from Great Britain (Department of Transport, 2019) showed that more than 50% of the journeys are used for this reason. As well are day-out journeys a popular reason which is the second most used reason for more than 30%. About 25% of the reason is used for **holidays** or **business** journeys. Other leisure journeys make up for 20% of long-distance rail use. This suggests that leisure journeys are more common than business journeys. Some studies were carried out specifically for night trains on long-distance journeys. These found that the majority are leisure travellers and that a smaller portion are business travellers (Heufke Kantelaar, 2019)(Dupuis, 2021). Although the European Parliament (2017) comes with the same conclusion based on several studies, it also claims that a night train operator from Great Britain suggests that 50% were business travellers. A study from the same country suggested that it only was 21%. These different shares in trip purpose are most likely dependent on the trip destination (Bird et al., 2017).

3.2. User groups

Travellers form diverse user groups influenced by various background variables with different motives and preferences. These variables are crucial to understand the travel behaviour of the travellers. The composition of the travel parties is found to play an important role in decision-making as well.

3.2.1. Background variables

The background variables of the user groups influence the choice that is considered for undertaking long-distance travel and between modal alternatives (Ding et al., 2017). Many studies have researched factors that play a role in engaging in long-distance trips and in the decision for rail travel. The main background factors found in the literature are the following:

- Gender: Long-distance trips are more frequently taken by men (Dargay and Clark, 2012). Ding et al.(2017) found that this is due to twice as many business trips being made by men and they tend to take more trips for outdoor recreation.

- Age: Middle-aged people have a higher probability of undertaking longer long-distance journeys (Dargay and Clark, 2012)

- Household size: It has a clear impact on the frequency of long-distance trips. Compared to households with two persons, one-person households travel more whereas three or four-person households travel less. Additionally, it impacts car travel as well. Households with a higher number of individuals have a higher car usage which presumably reflects the shared costs (Dargay and Clark, 2012).

- Car ownership: The possession of a car has a positive association with the number of long-distance trips (Ding et al., 2017) (Dargay and Clark, 2012). Car ownership has a positive impact on car use and therefore a negative impact on rail usage (Ding et al., 2017)(Zumkeller et al., 2005).

- Education level: High-educated travellers have a positive association with the frequency of taking long-distance journeys (Ding et al., 2017).
- Employment: Full-employed travellers tend to engage in long-distance travel more often and longer journeys (Ding et al., 2017).
- Income: Travellers with a higher income have a higher probability of making long-distance journeys and longer journeys as well (Ding et al., 2017). Travellers who have a lower income tend to have more journeys for visiting friends and relatives whilst higher incomes undertake most business and leisure journeys. Car use was found to be more dominant for lower-income travellers (Dargay and Clark, 2012).
- Occupation level: Travellers who have a higher level occupation are more likely to have long-distance journeys (Ding et al., 2017).
- Group size: Having travel parties influence the mode choice in favour of car travel since the cost can be shared among the travel party (Koppelman and Sethi, 2005). This is the reason why household size had the same effect on car use. The household is the travel party in many cases (Dargay and Clark, 2012).

3.2.2. Travel parties

Household size and group size influence the mode choice as stated earlier. Car usage emerges as the prevailing mode of transportation among a higher number of individuals in households and travel groups. (Koppelman and Sethi, 2005)(Dargay and Clark, 2012). It is assumed that the travel party not only influence the mode choice but influences the importance of mode attributes as well. A travel party can consist of the following composition:

- alone
- with partner
- with partner and kids
- with friends/colleagues

For example, a 6-person couchette cabin can be considered attractive for travel parties of friends. However, it can not be considered attractive to solo travellers since it needs to be shared with other unknown travellers (Heufke Kantelaar, 2019). No evidence is found in the literature that night train attributes are valued differently depending on the travel party. This study is interested as well in the influence of travel parties and night train attributes in particular.

3.3. Night train services attributes

As stated in the introduction, there are some insights on the preferred service attributes. Nordenholz et al.(2017) suggest that 96% of travel time can be used efficiently by train passengers. Having on-board services such as providing entertainment, wireless internet or catering improves the on-board comfort. It is suggested that this is a powerful measure to increase train usage (Nordenholz et al., 2017).
Providing better service can have a significant effect on the ridership of train services which is proved by the Swedish Railways (SJ). It offers domestic night train services and had declining ridership prior to 2015. The retimed departure time was found as one the main reasons. It has been changed from 21:30 to 23:15. Passengers have the ability to stay onboard until 7:00 at their destination station. First-class passengers would have access to the SJ lounge for breakfast or at a nearby hotel if there is no SJ lounge. All these measures resulted in an increase in ridership (Railjournal, 2015).

Popular ways of passing time while travelling long distance journeys on rail services are reading (57%), looking at the view (56%), applying emails and making calls (51%), using a device for movies, music, games or the internet (51%) and eating or drinking (44%) (Department of Transport, 2019).
A recent study carried out by Heufke Kantelaar(2019) showed that the perceived comfort of travellers is heavily influenced by the number of people in the cabin. Their perceived comfort is scored higher for a basic night train with just a 2-person cabin compared to a 6-person cabin with all luxury facilities such

as lockable compartments, showers, restaurant car etc. The market share for night train services is most sensitive to the comfort level of the train which is most influenced by the amount of people in the cabin. As stated in the introduction 1, OBB has introduced a new comfort attribute in their new night trains that accounts for the higher expectation of the travellers in terms of privacy. The new comfort attribute (capsule) is a little cabin with a solo bunk and therefore not shared with any other passengers (Nightjet, 2021). This is therefore very interesting to take into account for the stated choice experiment.

3.3.1. Existing services

Additional to the insights retrieved from studies on the night train service attributes are current night train services reviewed to see if other attributes can be taken into account for the stated choice experiment. Today, several night train services are running throughout Europe to connect main cities. An overview of the main services gives additional knowledge on which service attributes are offered.

- OBB Nightjet is an Austrian railway company which connects several European countries to Austria with night train connections. Its destinations are served on a regular base or on a seasonal base. It offers seating, couchette and sleeping accommodations. Meals and snacks can be ordered to your compartment but no dining car is available. Starting prices range from 30 - 140 euros dependent on the comfort category and are demand dependent. The Nightjet also offers the possibility of taking the travellers' car to the destination on a car carriages. This has an additional cost ranging from 100 - 200 euros depending on the destination and car type.
- Caledonian Sleeper is a Scottish railway company which has night train services between Scotland and London. It runs on a regular base and offers besides seating also comfortable sleeping accommodation. This accommodation is offered in two comfort levels where the highest level is with a twin bed and the lower level has a single bed. Besides the given room service does this night train also have a restaurant carriage. This night train service is one of the highest class where no couchette compartment is available. This results in higher prices. Starting prices range from 84 euros to 282 euros dependent on the comfort category. The twin bed cabin starts at a price of 414 euros.
- The Swedish Railways (SJ) offer a domestic night train service on a regular basis. This offers regular seating, couchette and sleeping accommodations. This train also includes a restaurant carriage. Starting prices are not identified on their website.
- The SNCF started recently with domestic night train services after several years of absence. It offers just the regular seating and couchette accommodations. This couchette has the possibility to book compartments just for women who travel alone. It is also possible to book a private compartment for an additional fee starting from 45 euro. This train does not include a dining carriage but snacks and meals can be served to your seat. Starting prices start from 19 euro for seating and 29 euro for the couchette compartment. This price is demand and season dependent.

3.4. Summary and framework

The main modes used for long-distance travel are aeroplanes, buses, cars and trains. The train can either be high-speed rail, conventional day or night train.
Travellers who are regular train travellers have a higher probability of using rail services for long-distance journeys. This user group is therefore ideal as respondents for the stated choice experiment.
Travellers use rail services for their convenience which is impacted the most by the number of interchanges.
The convenience of other modes is found to be the most important factor for not choosing rail services followed by the travel cost.
Trip purpose is an important factor for the mode choice since business travellers have a higher probability of choosing an aeroplane. The most common trip purpose can be visiting friends and relatives (VFR), business or holiday.
Important background variables influencing long-distance travel behaviour are gender, age, household size, car ownership, education level, employment, income, occupation level and group size.
Most common night train comfort attributes on existing night trains are seating, couchette and sleeper cabins. Some trains offer dining possibilities on their restaurant carriage and the ability to take the

travellers' car to the destination on a car carriage.
Comfort is found to be the most influencing factor for the market share of night trains. A new comfort level (capsule) is introduced by OBB to account for the higher expectation in terms of privacy.

All the retrieved information from the literature review is included in the theoretical framework. It is used to set up the Discrete Choice Experiment. The important socio-demographic factors, context variables and night train attributes are included in the framework. A visualisation of the framework can be seen in figure 3.1.

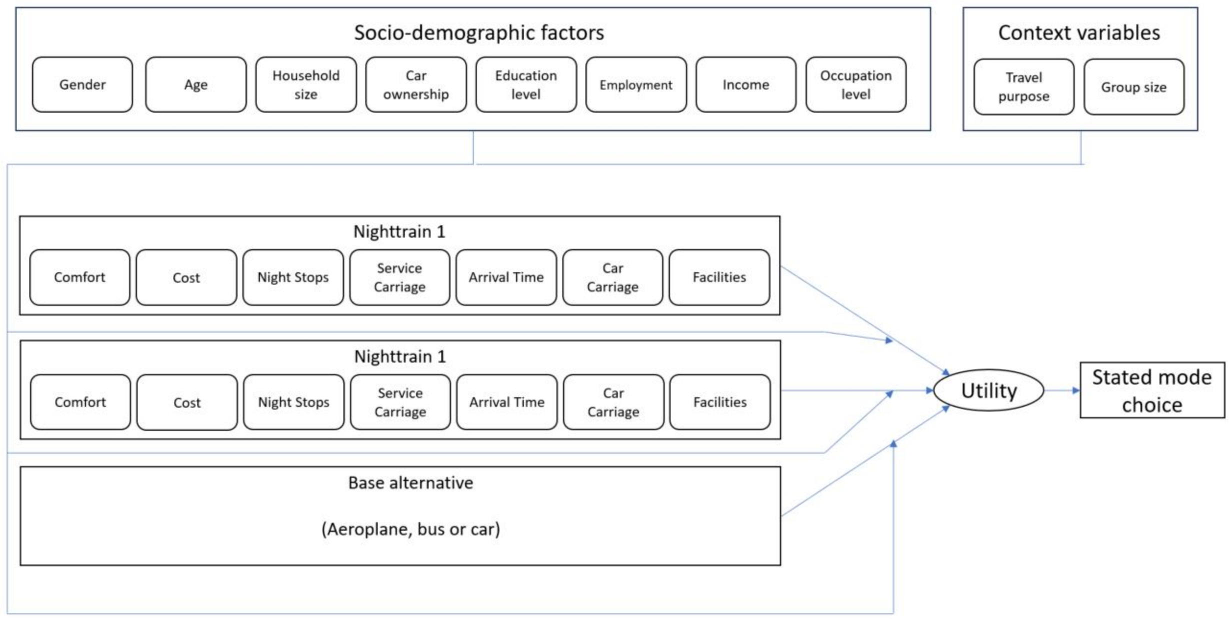


Figure 3.1: Theoretical framework for the choice experiment

4

Survey Design

To collect data is the stated choice experiment used in the form of a survey. In the course of this experiment, participants are presented with diverse scenarios and are tasked with making decisions concerning whether to opt for a night train or another mode of transportation. The experiment exists of a choice set with three alternatives. Two alternatives are different night train options, and the third alternative is a base alternative. Each alternative has several attributes that define the alternative. Two night train options have the same attributes. Each attribute has several attribute levels, and it is therefore possible to create variations in night train options within the choice set. An overview of these terms of the choice experiment can be seen in figure 4.1

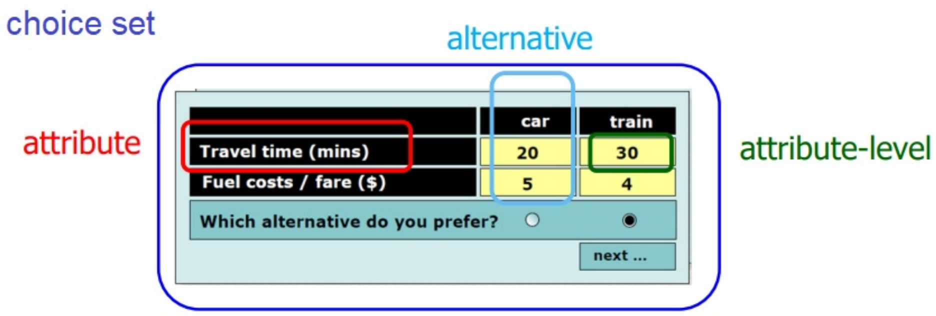


Figure 4.1: Stated choice experiment terms (Molin, 2023b)

4.1. Survey construction

As stated in the literature review 3.1.1 are buses, aeroplanes and cars the most used modes next to the train. Therefore refers the base alternative to the modes of bus, aeroplane and car.

In order to have a successful stated choice experiment, the choice tasks must be comprehensive and realistic to enable the respondents to make appropriate trade-offs. This is achievable with a limited amount of attributes so respondents understand the experiment immediately (Molin, 2023a).

As stated in the literature 3.1.1, trip purpose and group size influence the mode choice behaviour. It is expected that it influences the choice between different night train services as well (subsection: 3.2.2). For example, a couchette cabin can be found attractive to travel with friends but can not be attractive for solo travellers due to limited privacy. To find evidence of whether the trip purpose and group size influence the choice of night train services, context variables are taken into account. These variables create a trip context per respondent in terms of trip purpose and group size. These variables are asked prior to the night train choice experiment. Respondents are asked to recall a long-distance trip within Europe and asked what their trip purpose and group size were. This information creates the context for each respondent to continue to the choice experiment.

With the context in mind given by the respondents, they are asked to choose between two night train alternatives followed by the question if the respondent would choose the chosen night train or an alternative mode. This enables capturing the peoples' trade-offs between the two night train options and capturing information about the modal split.

4.2. Survey context

Respondents make additional assumptions about missing information. It results in less accurate data. A complete and clear context of the survey prevents respondents from making these assumptions. The following extra information is presented in the survey.

Since the interest of this research is focused on long-distance travel, it is important that respondents are familiar with the destinations that can be served by a night train. As stated in the introduction, night trains can reach destinations within 800-1200 km which takes between 8 to 12 hours. To illustrate this range, example destinations are given. Milan, Geneva, Munich and Copenhagen are used as examples. These are chosen because these are the most popular destinations from Brussels Airport in 2018 (Brussels Airport, 2018) and are within the range of 800-1200 km from Brussels.

From the literature 3.3 is concluded that arrival time has an influence on the trade-offs between night trains or between modes (Li et al., 2019). It is chosen that the travel time of the night train takes 12 hours since it is found to be the ideal travel time during the night (Bird et al., 2017). Arriving later in the morning, therefore, results in a later departure. It is chosen to only include the early and late arrival times (8:00 and 10:00) in the survey to keep the survey as simple as possible together with the travel time of 12 hours. If the night train arrives at 8 AM or 10 AM, will the train depart respectively at 8 PM or 10 PM.

The access and egress trips are excluded from the survey context since the focus of this research lies on the long-distance part of the journey which is the night train.

The presented night trains are assumed to have basic services on board such as free WiFi connection and a power socket per traveller.

4.3. Context variation

Varying the context can either be stated or revealed. It is chosen to vary the context variables revealed. This has the advantage that the respondents are familiar with the context. A stated context can include a given context which is not familiar to the respondent. He/she makes in this case their own assumptions which result in less accurate data. On the other hand, changes that all varied context variables are statistically significant can be at risk.

The varied context attributes are *trip purpose* and *group size*.

Trip purpose has the following attribute levels:

- Business
- Vacation
- Visiting friends or family

Group size has to following attribute levels:

- Alone
- With kids

- With partner
- With partner and kids
- With friend(s)/colleague(s)

From the literature is seen that leisure trips have a bigger share as a trip purpose than business trips. Therefore, the risk is high for not having a statistically significant context variable for business trips. This is solved by first asking if the respondent had travelled for business before. If so, he/she is asked to fill in the following night train choice sets as it is for a business trip. The possibility to choose between vacation and visiting friends or family is therefore not given. If the respondent did not travel for business before, he/she can subsequently choose between vacation or visiting friends or family.

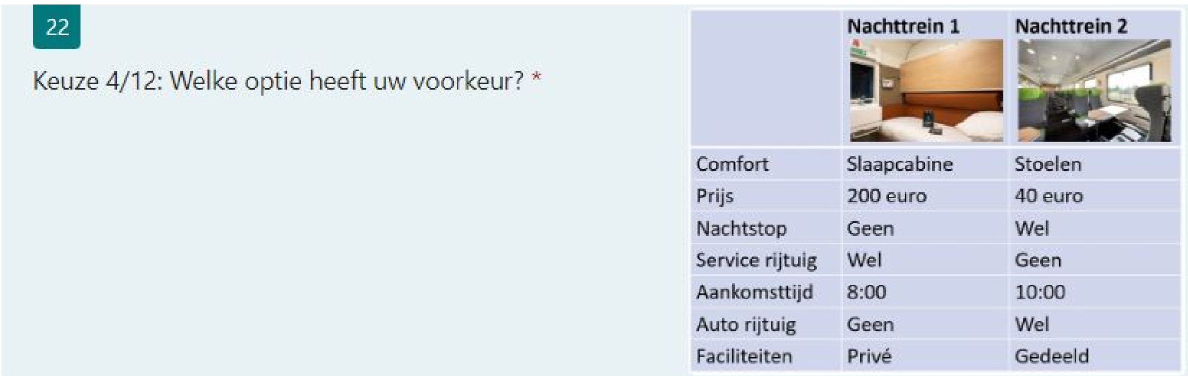
From the literature is not found that any level within the group size has a dominant share. It is assumed that all levels appear equally since the respondent group has a high probability of having a wide variety between the household size which affects the travel group size.

4.4. Specification of the choice experiments

Subsequently the context experiment, respondents are told to keep the purpose trip and group size in mind to fill in the following choice sets. It is mentioned after the context experiment and before the start of the choice experiment. This highlands the importance of taking the context into account.

4.4.1. Unlabeled alternatives

The choice experiments consists of two unlabeled alternatives which is night train 1 and night train 2. All alternative attributes are varied between 12 choice sets. An example of 1 choice set is seen in figure 4.2. A base alternative is foreseen after the choice between the unlabeled alternatives as an additional choice between the chosen night train or an base alternative. This has the advantage to capture the trade-offs between both night trains in the case the respondent chooses the opt-out alternative. An example of 1 choice set between the night train and the base alternative is seen in figure 4.3.


22

Keuze 4/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1	Nachttrein 2
Comfort	Slaapcabine	Stoelen
Prijs	200 euro	40 euro
Nachtstop	Geen	Wel
Service rijtuig	Wel	Geen
Aankomsttijd	8:00	10:00
Auto rijtuig	Geen	Wel
Faciliteiten	Privé	Gedeeld

Figure 4.2: Night train choice within survey

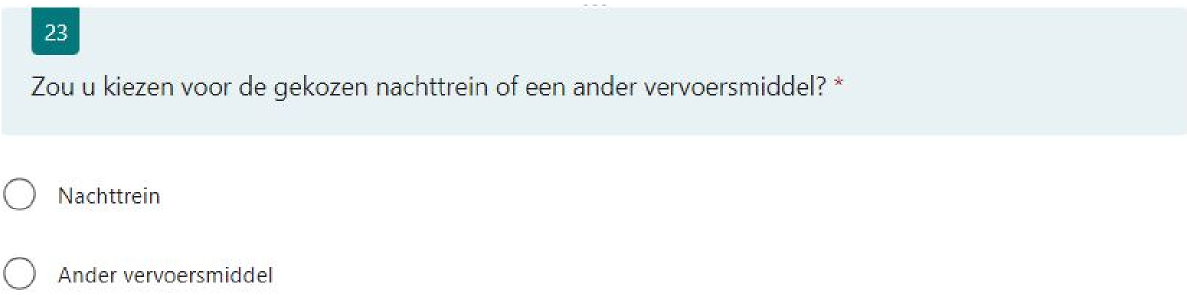


Figure 4.3: Mode choice within survey

4.4.2. Attributes

The attributes comfort, price, night stop, service carriage, arrival time, car carriage and facilities were defined as the attributes for the choice experiment. These attributes are mostly found today in existing night train services around the world.

- **Comfort**, the night train has 4 different accommodation categories which differ in comfort level.
- **Price**, the price of the journey which includes all given attributes.
- **Night stop**, the night train does or does not stop 6 times between midnight and 6 AM.
- **Service carriage**, the night train does or does not include a carriage where it is possible to relax, have a meal or have a drink.
- **Arrival time**, the time of arrival at the destination.
- **Car carriage**, the night train does or does not have the possibility to transport the traveller's personal car.
- **Facilities**, includes a sink, toilet and shower which can be shared or private.

4.4.3. Attribute levels

All attributes have two to four levels. Comfort has four levels which are the possible accommodation types of a night train. Price has three levels starting from 40 to 360 euros. The minimum and maximum price is based on the average Nightjet price of the journey Brussels - Vienna. This train service is chosen since it is the only current night train service that serves Brussels. It also has a similar trip context as stated in the survey in terms of comfort, distance and time. The maximum price includes the additional price of transporting your own car. This is not possible in the night train service Brussels - Vienna. This price is based on other services where this possibility exists within the Nightjet-network.

An overview of all used attribute levels can be found in table 4.1.

Table 4.1: Attribute levels used in the choice experiment

Attribute	**Attribute Levels**			
Comfort	*Seats*	*Couchette*	*Capsule*	*Sleeper*
Price [min]	*40*	*200*	*360*	
Night stops [#]	*Yes*	*No*		
Service carriage	*Yes*	*No*		
Arrival time	*8 AM*	*10 AM*		
Car carriage	*Yes*	*No*		
Facilities	*Shared*	*Private*		

4.5. Generation of choice sets

In order to capture possible trade-offs between attributes and attribute levels, a choice set needs to be generated which is capable of doing so. A fully factorial design needs a high amount of choice sets in order to reveal all the information about the trade-offs between the attributes. Therefore was this design eliminated because of the high amount of choice sets it would generate. Other options to have fewer choice sets in the survey are fractorial factorial designs which are orthogonal or efficient designs.

Orthogonal designs is on the principle of orthogonality. This is where attribute level balance occurs and therefore all attribute levels are observed an equal number of times. From an earlier night train study was found that price is a dominant factor for choosing the night train. As well was found that the amount of people within the cabin had a dominant effect on the percieved comfort. Since there are dominant attributes, it will lead to dominant alternatives within the choice set. This results in no information about trade-offs, since orthogonal design observe all attributes an equal number of times. If dominant attributes are present within the choice set, it cannot reveal any information about the trade-offs.
Efficient designs aims to balance the utilities between alternatives. It therefore aims to avoid dominant alternatives. Information about trade-offs is maximised and makes therefore an efficient use of of the number of respondents. Prior estimates are necessary in achieving this. In addition does it lead to a minimization of the standard errors of parameters. Compared to orthogonal designs does efficient result in smaller standard errors compared to orthogonal designs with the same number of respondents.

Because of the presence of dominant attributes, an efficient design is used to aim to maximise the information about trade-offs. AS well to make efficient use of the collected data since it is not certain how many respondents are going to participate and to achieve a as low as possible standard error of the parameters as well.

4.5.1. Model specification

Efficient design requires prior estimates in order to create an efficient design. These were found in earlier research for most attributes from an earlier study (Heufke Kantelaar, 2019).These prior estimates are not found for the comfort level 'capsule', a carcarriage and a service carriage. These were estimated based on the other estimates.
Based on the alternatives, attributes and attributes levels can the model be specified. These are found in the utility function in equation 4.1.

$$V_i = \beta_{COMcou} \cdot COMcou_i + \beta_{COMcap} \cdot COMcap_i + \beta_{COMsle} \cdot COMsle_i + \beta_{Cost} \cdot Cost_i + \beta_{Nstop} \cdot Nstop_i + \beta_{ServCar} \cdot ServCar_i + \beta_{ArrTime} \cdot ArrTime_i + \beta_{CarCarr} \cdot CarCarr_i + \beta_{Fac} \cdot Fac_i \tag{4.1}$$

Together with the prior estimates can the choice set be generated. This is done by the software Ngene. It makes use of the efficient design which is chosen earlier to use. It creates the choiceset in order to capture at an efficient way the trade-offs between the night train alternatives. This is therefore a choice between two night train alternatives which is seen in figure 4.2. To capture the modal split is an additional question be asked in the survey whether the respondent would travel with the chosen night train or another mode which is seen in figure 4.3

4.6. Collecting data

Data is collected on 6 main IC connection services within Belgium. These services are:

- IC service Eupen - Oostende
- IC service Essen - Charleroi
- IC service Tongeren - Gent
- IC service Brussel - Luxemburg

- IC service Antwerpen - Poperinge
- IC service Luik - Bergen

These services are chosen in order to cover all regions equally. It is aimed that all cardinal points are covered with these IC trains as seen in figure 4.4.

Data is retrieved based on an online survey which is asked on the travellers to fill in. By scanning a QR-code, respondents open the online survey on their smartphone. Respondents who do not want to fill it in during the train ride or did not have a smartphone are offered an URL-link that direct them to the online survey as well.

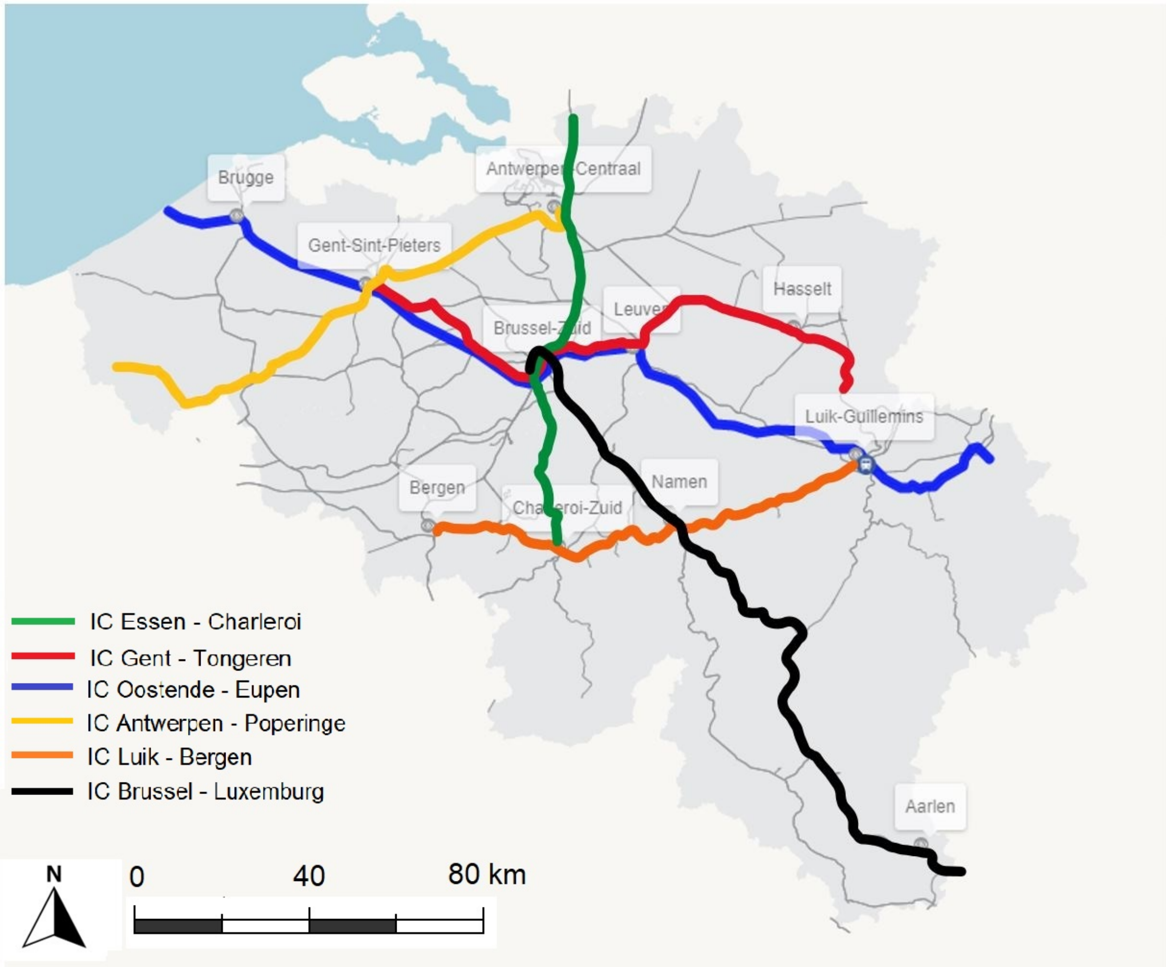


Figure 4.4: Collecting data on 6 IC-trains

5 Results

5.1. Data description

The target of the survey was 600 respondents. 610 respondents filled in the survey on the last day of taking the survey. Since the survey took place on trains in Flanders and Wallonia, it was aimed to reach 60% of the data within Flanders and the other 40% in Wallonia. This is the division of the Belgian population between the two regions. Although the Flemish part produced the most data, it had a share of 53% of the respondents contrary to the aimed 60%. The Walloon part had a share of 47%. The collected data was monitored while taking the surveys. It was noticed that the share of the younger population (18-29 years old) was prominent compared to the older population (40+ years old). The last 100 remaining answers of the survey was actively searched by the older population which resulted in higher shares within the higher age categories. When all 610 respondents were collected, the first analyses were carried out. Respondents who were younger than 18 years were excluded as well as responses with inconsistent answers. It resulted in 594 useful answers.

From table 5.1 is seen that the final data sample still has a high share of young respondents. They were more willing to fill in the survey because they were familiar with it from their study. The elderly were mostly working in the train which made it more difficult to let them fill in the survey. The share of the final data sample per age category can be found in table 5.1 compared to the Belgian population. The age category (18-29) has the highest offset compared to the population which is more than 3,5 times higher. The highest age category (70-79) is 9 times lower than the population. Other age categories are relatively similar. The youngest population is therefore overrepresented and the older population is underrepresented.

Table 5.1: Share per age category: respondents versus Belgian population (Statbel, 2021)

Age category	Share data [%]	Share Belgian population [%]
18-29	54	14
30-39	18	13
40-49	12	13
50-59	9	14
60-69	5	12
70-79	1	9

The respondents were also asked which mode they prefer to travel within Europe. As seen in figure 5.1, 19% of the respondents chose the car as their preferred mode where 38% chose an aeroplane and 43% chose the train. No comparing data was found about the Belgian population.
In order to include context variables in the choice models, enough respondents had to choose for each trip purpose option and travel company options. This was only not the case for the travel frequency of 0 times per year. Therefore is chosen to merge the data of ’0 times per year’ together with the data of ’1-3 times’.

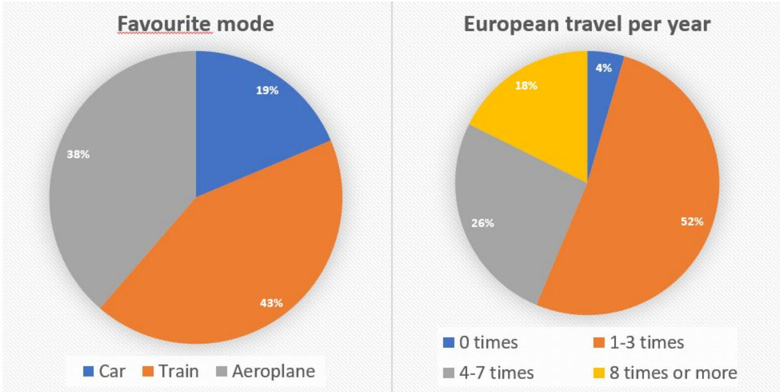


Figure 5.1: Respondent's favourite mode and current travel frequency

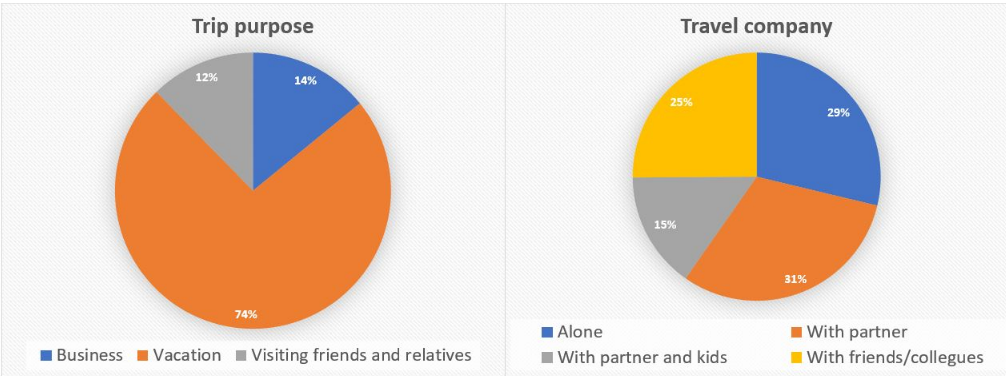


Figure 5.2: Respondent's chosen context variables

As stated in 4.6 is data collected on the main IC trains which run to all cardinal directions. It was aimed to have the best possible representation of the population within the states. In table 5.2 are the shares of the final data shown per state together with the share of the Belgian population per state retrieved from Statbel (2021). The data is similarly distributed geographically over the states than the population. Only the states Luxemburg and Namen are shares twice as high which are low-density states. Luxemburg has a share of the population of 3% where the data has a share of 7% and Namen has a population share of 4% where the data share is 8%. Overall can be concluded that the share of the respondents is similarly distributed to the one of the population.

An overview of the remaining sociodemographic factors is seen of the data compared to the Belgian population in table 5.3. The data and the population has the greatest share of woman but the share of the data is 3% higher than the population. Men have the lowest share where the data is 5% lower than the population. As seen in table 5.1 was already stated that the younger respondents are overrepresented. The mean of the variable **age** is therefore 8 years lower than the population. The data division of the **household situation** is relatively similar to the population although the people who live alone and households with parents and children were respectively 7% and 8% higher. The division between 'with parents and siblings' and 'with partner and kids' were made to investigate the difference in travel behaviour between the young adult and the parent. Because of the higher share of young adults is the percentage of the **drivers-license** lower than the population. This is also the case for **car-ownership**. 48% of the respondents own a car compared to 64% of the Belgians. Although the majority of the respondents were young, the average **income** is quite high. The mean income of the respondents is €34 100 whereas the mean of the population is €19 671. Also are the respondents highly **educated**. The share of academic study is almost 3 times higher whereas the share of secondary school is half as the population. Respondents who finished a professional bachelor are roughly representative. About the **travel frequency in the EU** is it more difficult to compare. Data on the population has different variable levels unless who never travels or who travels very frequently. The share of the respondents who never travels is representative of the population and the share who travels more than 10 times is

Table 5.2: Share per state: respondents versus population (Statbel, 2021)

State/region	Share of respondents [%]	Share of population [%]	absolute difference [%]
West-Vlaanderen	10	10	0
Oost-Vlaanderen	13	13	0
Brussel	12	11	1
Waals-Brabant	3	4	1
Vlaams-Brabant	9	10	1
Antwerpen	14	16	2
Limburg	6	8	2
Luik	7	10	3
Henegouwen	9	12	3
Namen	8	4	4
Luxemburg	7	3	4

slightly higher. The majority of the respondents travel 1-3 times a year which is also the case for the population where the attribute level has a slightly higher range (1-4 times a year).

Table 5.3: Sociodemographic factors: data versus Belgian population (Statbel, 2021)(Brussels Airport, 2018)

<table>
<tr><th>Variable</th><th>Level</th><th>Data</th><th>Belgian population</th></tr>
<tr><td>Gender</td><td>Man</td><td>44 %</td><td>49 %</td></tr>
<tr><td></td><td>Woman</td><td>54%</td><td>51%</td></tr>
<tr><td></td><td>Other</td><td>2%</td><td>-</td></tr>
<tr><td>Age</td><td>Mean</td><td>33 year</td><td>41 year</td></tr>
<tr><td>Household situation</td><td>Alone</td><td>21%</td><td>15%</td></tr>
<tr><td></td><td>with parents and siblings</td><td>31%</td><td rowspan="2">48%</td></tr>
<tr><td></td><td>with partner and kids</td><td>24%</td></tr>
<tr><td></td><td>with partner</td><td>21%</td><td>22%</td></tr>
<tr><td></td><td>co-housing</td><td>6%</td><td>3%</td></tr>
<tr><td>Drivers-license</td><td></td><td>69%</td><td>77,5%</td></tr>
<tr><td>Car-ownership</td><td>Per person</td><td>48%</td><td>64%</td></tr>
<tr><td>Yearly netto income</td><td>Mean</td><td>€34.100</td><td>€19.671</td></tr>
<tr><td>Study</td><td>Secondary school</td><td>25%</td><td>53%</td></tr>
<tr><td></td><td>Professional bachelor</td><td>16%</td><td>19%</td></tr>
<tr><td></td><td>Academic bachelor/master</td><td>55%</td><td>18%</td></tr>
<tr><td></td><td>Other</td><td>4%</td><td>10%</td></tr>
<tr><td>Travel frequency in EU</td><td>0 times a year</td><td>5%</td><td>4%</td></tr>
<tr><td></td><td>1-3 times a year</td><td>52%</td><td>74% (1-4 times a year)</td></tr>
<tr><td></td><td>4-7 times a year</td><td>26%</td><td rowspan="2">13% (5-10 times a year)</td></tr>
<tr><td></td><td>8-10 times a year</td><td>4%</td></tr>
<tr><td></td><td>>10 times a year</td><td>13%</td><td>9%</td></tr>
</table>

5.2. Data preparation

All data which comes from the survey needs to be re-coded for model estimation. Dummy coding is used for categorical night train attributes. In table 5.4 is seen that the comfort attributes ’seat’, ’couchette’, ’capsule’ and ’sleeper’ are dummy coded. As well, the early and late arrival time, and shared or private facilities are dummy coded. Attributes ’cost’, ’service carriage’ and ’car carriage’ are not dummy coded. The inclusion of all socio-demographic factors and context variables needed to be dummy coded. An overview of these factors and variables is seen in table 5.5.

Table 5.4: Dummy coding of night train attributes for model estimation

Comfort	**COMcou**	**COMcap**	**COMsle**
Seat	0	0	0
Couchette	1	0	0
Capsule	0	1	0
Sleper	0	0	1
Arrivaltime		**Arrtime**	
Early arrival (8:00)		0	
Late arrival (10:00)		1	
Facilties		**Fac**	
Shared facilities		0	
Private facilities		1	

Table 5.5: Dummy coding of socio-demographic factors for model estimation

Gender	GENDER
Male	1
Female	0

State	STATE
Flanders	1
Walloon	0

Household	household_part	household_partkid	household_fam	household_stuhouse
Household alone	0	0	0	0
Household with partner	1	0	0	0
Household with partner and kids	0	1	0	0
Household with parents (and siblings)	0	0	1	0
Household with adults (studenthouse, co-housing)	0	0	0	1

Carownership	PersonalCar	BusinessCar
No car	0	0
Personal car	1	0
Business car	0	1

Status	Stat_stud	Stat_empl	Stat_entr	Stat_unempl	Stat_hous	Stat_retir	Stat_incap
High school student	0	0	0	0	0	0	0
Student	1	0	0	0	0	0	0
Employed	0	1	0	0	0	0	0
Entrepreneur	0	0	1	0	0	0	0
Unemployed	0	0	0	1	0	0	0
Houseman/housewife	0	0	0	0	1	0	0
Retired	0	0	0	0	0	1	0
Incapacitated	0	0	0	0	0	0	1

Education	Aca_profbach	Aca_acabach	Aca_acamas
Secondairy school	0	0	0
Profesional bachelor	1	0	0
Academisc bachelor	0	1	0
Academic master	0	0	1

Context travel group	Con_part	Con_partkid	Con_friends
Alone	0	0	0
With partner	1	0	0
With partner and kids	0	1	0
With friends/collegues	0	0	1

5.3. MNL model estimation

The first estimation is the base MNL model. This model only estimates the choice experiment which includes the night train attributes. The socio-demographic factors are not included yet. It estimates the night train preferences compared to the base alternative (bus, aeroplane or car).

5.3.1. Base: MNL model

The base estimation for the night train within the modal split estimates the trade-offs between two night train options and the base alternative (bus, aeroplane or car). The choice experiment consists therefore of three utility functions. V1 (equation 5.1) and V2 (equation 5.2) are the two night train alternatives where V3 (equation 5.3) is the base alternative. The base alternative V3 was chosen during the choice experiment when the respondent preferred another possible mode to undertake the journey instead of the proposed night train services. It is chosen to set V3 as a reference (set to 0) and add a constant to V1 and V2 which is called 'Alternative Specific Constant (ASC)'. The interpretation of this constant is explained later in this section.

$$V_1 = ASC + \beta_{COMcou} \cdot COMcou1 + \beta_{COMcap} \cdot COMcap1 + \beta_{COMsle} \cdot COMsle1 + \beta_{Cost} \cdot Cost1 + \beta_{Nstop} \cdot Nstop1 + \beta_{ServCar} \cdot ServCar1 + \beta_{ArrTime} \cdot ArrTime1 + \beta_{CarCarr} \cdot CarCarr1 + \beta_{Fac} \cdot Fac1 \tag{5.1}$$

$$V_2 = ASC + \beta_{COMcou} \cdot COMcou2 + \beta_{COMcap} \cdot COMcap2 + \beta_{COMsle} \cdot COMsle2 + \beta_{Cost} \cdot Cost2 + \beta_{Nstop} \cdot Nstop2 + \beta_{ServCar} \cdot ServCar2 + \beta_{ArrTime} \cdot ArrTime2 + \beta_{CarCarr} \cdot CarCarr2 + \beta_{Fac} \cdot Fac2 \tag{5.2}$$

$$V_3 = 0 \tag{5.3}$$

Where:
V_1 = utility of alternative 1
V_2 = utility of alternative 2
V_3 = utility of alternative 3
β_{COMcou} = generic parameter for the attribute comfort, level couchette
β_{COMcap} = generic parameter for the attribute comfort, level capsule
β_{COMsle} = generic parameter for the attribute comfort, level sleeper
β_{Cost} = generic parameter for the attribute cost
β_{Nstop} = generic parameter for the attribute night-stop
$\beta_{Servcar}$ = generic parameter for the attribute service-car
$\beta_{ArrTime}$ = generic parameter for the attribute arrival-time
$\beta_{CarCarr}$ = generic parameter for the attribute car-carriage
β_{Fac} = generic parameter for the attribute facilities
ASC = Alternative Specific Constant

ASC: explaining the interpretation of the alternative specific constant
The alternative specific constant interpretation is a little complicated. The constant ASC is the utility of the alternatives when all attributes would be zero, including cost. Since the base alternative (other modes) is zero, it results in a systematic utility difference between the night train alternatives and the base alternative. Although, this does not result in 'real' travel options. ASC can only be interpreted when all attribute levels of the night train are zero (zero-alternatives) and then it can be compared to the base alternative. This result in a systematic utility difference between the night train alternatives and the base alternative (other modes). Therefore is the interpretation of ASC described as the systematic utility difference in the following chapters.

Estimation
The Apollo syntax of the MNL model is included in appendix C. The model has a **final log-likelihood of -6243.35** and an adjusted **rho-squared of 0.2014**. The estimates of this base model are presented in table 5.6. All parameters are significant except for ASC. Since it represents a systematic utility difference between the night train alternatives and the base alternative, it is a part of explaining the mode choice (night train compared to other modes). As stated in the literature review 3.2.1 are the background variables important factors for explaining the mode choice. It is therefore expected that ASC becomes significant when the background variables are taken into account which is not the case yet in the base model.
All parameters have the expected sign except for 'Night Stop'. A negative estimate was expected since having night stops would result in a less attractive night train option compared to having no night stops. Having night stops interrupt the passengers' sleep. A reason for this positive sign might be that it was interpreted as additional flexibility for embarking and disembarking along the route. The comfort attributes estimates β_{COMcou}, β_{COMcap}, β_{COMsle} were expected to be positive because these comfort levels offer a higher comfort compared to the base comfort level 'seat'. A sleeper cabin offers more comfort compared to a seat than a couchette. This can be concluded from the estimates where β_{COMsle} is higher than β_{COMcou}, A sleeper cabin contributes therefore to a higher utility compared to a couchette. Since the capsule cabin has not been offered yet in practice, it is unknown how potential travellers will value this comfort level. The offered comfort level is described as a bunk (like a couchette cabin) but with the privacy of a sleeper cabin (Nightjet, 2021). For this reason, it is coherent that β_{COMcap} is estimated between β_{COMcou} and β_{COMsle}.
β_{Cost} has a negative sign. 'Cost' has a negative contribution to the night train utility. Higher prices result in higher disutility which means that higher prices are less attractive than lower prices. The inclusion of a service carriage, a car carriage or private facilities results in a more attractive service. From the results, this can be concluded as well since $\beta_{CarCarr}$, $\beta_{ServCar}$ and β_{Fac} are estimated positive.
From the literature review is stated that the ideal arrival time is 8 o'clock in the morning (Bird et al., 2017). A negative sign for $\beta_{ArrTime}$ is therefore expected since 10 o'clock would be less attractive. However,

a positive sign is estimated which suggests that 10 o'clock is found more attractive compared to 8 o'clock. Another study showed that early arrival is just attractive to business travellers (Heufke Kantelaar, 2019). As seen earlier in section 5.1, the majority of the respondents chose as context to travel for leisure (vacation or visiting friends and family). This might suggest that leisure travellers do not want to arrive early in the morning. This will be further investigated in section 5.4.
The constant 'ASC' has a negative value which means that there is a systematic negative utility difference for the night train alternatives compared to the base alternative. The parameter is not statistically significant on a 95% confidence interval. Although, it suggests the direction of its influence on the utility.

Table 5.6: BASE: MNL model estimates

Parameter name	Parameter	Estimate	Rob. s.e.	Rob. t.ratio
Comfort seat (reference)				
Comfort couchette	β_{COMcou}	0.92	0.09	10.63
Comfort capsule	β_{COMcap}	1.44	0.09	15.60
Comfort sleeper	β_{COMsle}	1.49	0.08	18.43
Cost	β_{Cost}	-0.72	0.03	-23.36
Night Stop	β_{Nstop}	0.10	0.035	2.91
Service Carriage	$\beta_{ServCar}$	0.08	0.03	2.46
Arrival Time	$\beta_{ArrTime}$	0.15	0.03	5.65
Car Carriage	$\beta_{CarCarr}$	0.14	0.04	3.86
Facilities	β_{Fac}	0.24	0.04	5.78
Alternative Specific Constant	ASC	-0.11	0.11	-0.96

Relevance of the night train attributes
In order to compare all attributes to each other in terms of importance, the relative importance is calculated where the utility range is taken into account. The relative importance is achieved by multiplying the attribute estimate with its attribute range and taking the difference between the maximum and minimum values. The ranking of the relative importance is shown in table 5.7.
The largest contributor to disutility is the attribute 'Cost' whereas comfort ('Sleeper', 'Capsule' and 'Couchette') is the largest positive contributor to the utility since the comfort level 'sleeper' has the highest relative importance. This was found as well in the literature review where 'Cost' is found to be the largest contributor to the disutility function and 'Comfort' positively to the utility (Heufke Kantelaar, 2019). Having private facilities follows comfort levels in the ranking of relative importance followed by 'Arrival Time', 'Car-carriage', 'Night Stop' and 'Service-car'. Their relative importance is similar where 'Service-car' is the lowest. Another study dedicated to night trains found that having a service car did not contribute much to the utility as well (Heufke Kantelaar, 2019).

Table 5.7: Relative importance of night train attributes

	Relative importance of attributes					
Parameter	Estimate	Attribute range		Utility range		Relative importance
β_{Cost}	-0.72	0.4	3.6	-0.29	-2.60	-2.31
β_{COMsle}	1.49	0	1	0	1.49	1.49
β_{COMcap}	1.44	0	1	0	1.44	1.44
β_{COMcou}	0.92	0	1	0	0.92	0.92
β_{Fac}	0.24	0	1	0	0.24	0.24
$\beta_{ArrTime}$	0.15	0	1	0	0.15	0.15
$\beta_{CarCarr}$	0.14	0	1	0	0.14	0.14
β_{Nstop}	0.10	0	1	0	0.10	0.10
$\beta_{ServCar}$	0.08	0	1	0	0.08	0.08

Willingness to Pay within the modal split
The relative importance gives good insight into the contribution of the night train utility. However, for train operators (like NMBS) who are interested in setting up night train services, it is more relevant to

put the attributes' importance into monetary value. To do so, the willingness to pay (WTP) is calculated for each attribute. This is done by dividing the attribute estimate by the estimate of cost followed by multiplying by 100. This equation is seen in equation 5.4. The results of the WTP are shown in table 5.8.

$$WTP_k = \frac{\beta_k}{\beta_{tc}} \cdot 100 \tag{5.4}$$

Based on the prices that were found on existing night train services are the estimated WTP-values of the comfort levels relatively high. The WTP for the comfort levels is based on the reference of the comfort level which are seats. The WTP for couchette, capsule and sleeper is therefore the surplus on the price of seats. For all WTP values for the comfort levels must be noted that a certain surplus must be added. As seen in the literature review 3.3, OBB for example offers couchette cabins starting from €59 and sleeper cabins from €140. Compared to €127 (plus surplus) for a couchette cabin and €206 (plus surplus) for a sleeper cabin, these values are higher. It must be noted that starting prices are rarely paid and can therefore be higher than given on the website of night train operators. An earlier study calculated the WTP for a night train with the highest offered service and was estimated to be €240 (Heufke Kantelaar, 2019). This night train does not include a car-carriage. For comparison, if the price of the highest offered service from this study is calculated (car-carriage not included), the cost of the night train service is €285. This is found by adding the comfort level 'sleeper' with all other WTP of the attributes except for 'car-carriage'. €285 is still higher but it has the same order of magnitude.

The WTP for a capsule is relatively similar valued to a sleeper which is the highest comfort level offered. This suggests a high preference for this comfort level. Having night stops during the night and the availability of a service-car is valued the lowest at respectively €14 and €10. Having a late arrival time are travellers willing to pay €21 and for having private facilities €34. The possibility of taking a car to your destination is valued at €20. This is much lower than the prices that are asked in practice. As seen in the literature review 3.3, OBB asks €100-200 depending on the car which is from another order of magnitude.

Table 5.8: WTP of night train attributes

WTP: night train preferences		
Parameter	**Estimate**	**WTP [€]**
β_{COMcou}	0.92	127
β_{COMcap}	1.44	200
β_{COMsle}	1.49	206
β_{Nstop}	0.10	14
$\beta_{ServCar}$	0.08	10
$\beta_{ArrTime}$	0.15	21
$\beta_{CarCarr}$	0.14	20
β_{Fac}	0.24	34

5.4. MNL model with interaction effects

One of the shortcomings of the MNL model is that it is based on the assumption that respondents have the same preferences. Different attributes of an alternative can be preferred by individuals. This heterogeneity is taken into account by including background variables of the respondents as interaction effects in the MNL model. These variables are obtained in the survey as the socio-demographic and context variables. The night train attributes with their interaction effects give insights into certain attributes that are preferred to certain travellers (socio-demographic) and/or a certain trip context.
The literature review 3.2.1 found that socio-demographic variables, trip purpose and travel parties influenced travel behaviour. The most common background variables were taken into account and asked in the survey. These variables are dummy coded which is found in section 5.2 and table 5.5. The dummy coded variable which is coded as '0' is the base. Any estimates are therefore in reference to the base which was the case earlier about the comfort attribute where the level 'seat' was coded as base. The Apollo syntax of the MNL model with interaction effects can be found in the appendix D.

Since the most common variables were taken into account, the background variables and the context variables were all estimated as an interaction effect for each night train attribute. Not all interaction effects were found significant on a 95% confidence interval. For the attributes 'Sleeper', 'Night stop', 'Arrivaltime' and 'Facilities' were no interaction effects found. Therefore are the preferences for these attributes not described by socio-demographic variables or journey context variables.
An overview of the results of the MNL model with interaction effects can be found in table 5.9.

Table 5.9: Estimates MNL model with interaction effects

>->—— Parameter	Estimates and (Rob.t.rat.) (MNL with interaction)	Age (numeral)	Household with adults	Employed (status)	Academic Master (education)	Personal car
β_{COMcou}	1.03 (10.96)		0.94 (3.76)			
β_{COMcap}	1.49 (17.02)		1.07 (4.0)			
β_{COMsle}	1.56 (18.59)					
β_{COST}	-1.14 (-15.5)	0.01 (6.7)				
β_{NSTOP}	0.33 (2.96)					
$\beta_{ServCar}$	-0.02 (-0.48)			0.18 (2.9)		
$\beta_{ArrTime}$	0.17 (6.11)					
$\beta_{CarCarr}$	0.04 (0.64)				0.30 (4.01)	
β_{Fac}	0.23 (5.43)					
ASC	-0.01 (-4.95)					-50.36 (-3.72)

As seen in table 5.9 are the following interaction effects found:

- **Couchette & Household with adults (student-house)**: From the data is seen that household with adults is primarily chosen by students. It refers therefore to students who live in a student house. This group of travellers prefer a couchette. This is likely due to the fact that students undertake more journeys in group such as student holidays. The utility for choosing a couchette is described as (1.03 + 0.94*househ_with_adults)*COMcou. Not living in a household with adults (student house) results in a utility function of 1.03*COMcou compared to travellers who live in a household with adults results in 1.97*COMcou.

- **Capsule & Household with adults (student-house)**: From the data is seen that household with adults is primarily chosen by students. It refers therefore to students who live in a student house. This group of travellers prefer a capsule. This is likely due to the fact that students undertake more solo journeys. The utility for choosing a capsule is described as (1.49 + 1.07*househ_with_adults)*COMcap. Not living in a household with adults (student house) results in a utility function of 1.49*COMcap compared to travellers who live in a household with adults results in 2.56*COMcou.

- **Cost & Age**: The older the travellers are, the less sensitive they are to price (positive interaction estimate). This is most likely that the older the people are, the higher their financial recourses are. The utility of cost is described as (-1.14 + 0.01*age)*COST. A person of 20 years old has a cost-utility function of -0.94*COST compared to a person of 50 years old who has a cost-utility function of -0.64*COST.

- **Service car & Employed**: The importance of a service car is only valid when travellers are employed. This is because only the interaction estimate is found statistically significant. The utility function for a service-car carriage is 0.18*employed*ServCar. For employed travellers, this results in 0.18*ServCar whereas for unemployed travellers, it is 0. Unemployed travellers (like students) do not find this option important whether or not to be available on the night train for choice making.

- **Car carriage & Academic Master**: Travellers who are higher educated are willing to take a car on their journey and are the only group of travellers who find this option interesting. For other travellers, it does not influence their choice-making since only the interaction effect is found statistically significant. The utility function for a car-carriage is 0.3*AcademicMaster*CarCarr. For travellers who have a master's degree result the utility function of 0.3*CarCarr whereas for those who have no master's degree 0.

- **ASC & Personal Car**: The utility function of ASC strongly depends on car ownership. Only travellers who own a personal car result in a higher systematic disutility difference for the night train. The utility of ASC is described as -0.01-50.36*PersonalCar. Having no personal car results in a systematic disutility of -0.01 compared to -50.37 for those who do not own a car. This is a significant difference.

5.4.1. Insignificant interaction effects

Besides the found insignificant effects of the socio-demographic factors were also the context variables included as interaction effects. These variables denote the trip purpose and travel companion. However, none of these variables was found significant and does not describe the heterogeneity of the preferences.

5.5. Latent class model choice model

Taking heterogeneity into account can be done with a latent class model as well with consideration of panel data. It is therefore an improvement compared to the MNL model (with interaction effects). The model searches for latent classes containing travellers with homogeneous preferences. It can predict which travellers belong to each class based on the observed socio-demographic variables. It can therefore result in insights into the desired service for specific user groups of the night train.
The latent class model is used for the night train preferences within the modal split. The same utility function is therefore used as the base MNL model from section 5.3.1. As stated in section 2.3.3 needs the number of classes firstly to be determined.

5.5.1. Number of classes

Different models are estimated to determine the amount of classes. These models do not include any socio-demographic variables yet but only the class-specific constant. The model (with a certain number of classes) that fits the data the best is chosen. The corresponding LL (Log-likelihood), BIC (Bayesian Information Criterion), and R^2 (Rho-squared) are compared and can be found in table 5.10. A comparison is made between the models. Adding an extra class to the model results in more parameters describing the data. Therefore will the modal fit increase resulting in improved values for the LL and R^2. Adding parameters may lead to overfitting. In order to find the best modal fit without overfitting the data, the Bayesian Information Criterion (BIC) is used. It makes use of a penalty term for the number of parameters that are used in the model. This solves the problem of overfitting (Molin and Maat, 2015). The lower the value of BIC, the better the model fits the data. The estimation results shown in table 5.10 show that 5 classes fit the data the best. This is because it has the lowest BIC value.

Table 5.10: Class estimation: results model fit per class

Classes	LL	BIC	R^2
Base RUM model	-6243.35	12575.48	0.20
2	-5138.23	10462.88	0.34
3	-4641.09	9566.25	0.40
4	-4438.36	9258.41	0.43
5	-4214.04	8907.43	0.45
6	-4211.19	8999.38	0.45

5.5.2. Class membership

Some attribute estimates are not significant in all segments. It indicates that these attributes do not influence the class' choices. The attribute 'service carriage' in class 3 is a little lower than the significance level. Since it is very close of becoming significant, is it chosen to include this attribute estimate in the results. It reveals therefore more insight on class 3 than not including it. This is done in earlier studies as well (Amrhein et al., 2019). The Apollo syntax of the Latent Class Choice model with interaction effects can be found in the appendix E.

The delta of the class membership function is not statistically significant for classes 3 and 5. This denotes that classes 3 and 5 are not significantly larger than class 1 (reference). An overview of all the estimated parameters can be found in table 5.11.

Table 5.11: Estimated parameters in the five classes

	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Attributes					
ASC	-4.50	2.25	-0.70	2.14	1.60
β_{COMcou}	-	-	-	2.52	-
β_{COMcap}		2.37	0.78	2.65	1.44
β_{COMsle}	-	2.18	1.38	2.36	1.36
β_{COST}	-1.17	-3.89	-0.58	-1.25	-
β_{NSTOP}	-	-	-	0.41	-
$\beta_{ServCar}$	-	-	0.16	-	-
$\beta_{ArrTime}$	-	-	0.15	-	-
$\beta_{CarCarr}$	-	-	-	-	0.25
β_{Fac}	-	-	0.37	0.37	0.67
Class membership					
Delta (δ_s)	0 (fixed)	2.42	-	1.13	-
State	0 (fixed)	-0.74	-	-0.82	-
Age	0 (fixed)	-0.052	-	-	-
Income	0 (fixed)	-0.11	-	-	-
Academic Master	0 (fixed)	1.42	-	0.91	-
Preferred mode Car	0 (fixed)	-1.23	-	-	-
Preferred mode Plane	0 (fixed)	-	-	2.36	1.91
Class probability	12,6%	15,6%	18,7%	40%	13,1%

- **Class 1: 'Non night train users'**: This is the smallest class among the long-distance travellers. 12,6% of the travellers belong to this class. An ASC constant of -4,5, which is a relatively high systematic disutility for the night train. Only the attribute 'cost' is found statistically significant and contributes to its disutility as well. No attributes that are found statistically significant have a positive contribution to the utility. This makes it clear that these travellers are in great disfavour of the night train. This means that no attributes affect the choice of the night train for these travellers. This suggests that even a night train with the best service attributes does not influence their choice. For these travellers is therefore the night train not an option to use on a long-distance journey.

- **Class 2: 'Young price sensitive night train lovers'**: To this class belongs 15,6% of the travellers. They have a great favour for night trains but are highly sensitive to high prices. With a parameter estimate of cost of -3,98, it is the highest of all classes and more than 3,5 times higher than the second highest. These travellers have the highest preference for capsules. The sleeper cabin is just a little lower valued. A couchette cabin is not found statistically significant and does therefore not influence their choice. Travellers who have a higher probability of belonging to this class are French-speaking travellers (negative 'State' constant) who are younger (negative 'Age' constant) and have a lower income (negative 'Income' constant). That these travellers belong to the price-sensitive segment is not a surprise. Younger travellers who have a lower income were found to be price sensitive as well in section 5.4. Also, higher educated travellers have a higher probability of belonging to this class (positive ’Academic Master’ constant). ASC has a relatively high positive value which results in a relatively high positive systematic utility difference. Travellers who have a car as their preferred mode have a low probability of belonging to this class (negative ’Prefered mode Car’ constant).

- **Class 3: ’Price insensitive users with extra services’**: 18,7% of the travellers belong to this class. They have a low sensitivity for the price since β_{COST} is relatively low. As well do they have a slight disfavour for the night train. Although it can be compensated with additional service attributes. The comfort attributes are lowered valued compared to other classes. The comfort level for a sleeper cabin has the highest value and is twice as high as the capsule comfort level. Therefore do these travellers rather travel in a sleeper cabin. As stated earlier in this section, $\beta_{ServCar}$ has nearly reached the significance level. Therefore is chosen to include this estimate. This is the only class which prefers to have a service-car and to have a late arrival time. Additionally are private facilities preferred. Sadly are no significance found that gives more insights into the membership characteristics of this class.
- **Class 4: ’Newborn night train lovers - mode shifter’**: With a share of 40%, this is the greatest class among the 5. This class has a relatively high positive systematic utility difference like class 2. This class stands out because it is the only one where the comfort level ’couchette’ was found relevant for choice-making. It also has a relatively high estimate value which is even higher than the comfort level ’sleeper’. Comfort level ’capsule’ has the highest value although all three comfort estimates are close together. These travellers are the only class that prefers to arrive later in the morning. Travellers who have a high probability of belonging to this class are who prefer to fly (positive ’Preferred mode Plane’ constant) to their destination. These travellers seem to switch to rail travel with the offered service on the night train since the preferred mode question was asked before the choice experiment. Travellers who have a high probability of being in this class are highly educated (positive ’Academic Master’ constant) and French-speaking Belgians (negative ’State’ constant).
- **Class 5: ’Autotrain users’**: In the second smallest class belong 13,1% of the travellers. These travellers have a favour for night train as well. The ASC value is not as high there is still a significant positive systematic utility difference. The comfort level ’couchette’ does not have an influence on the choice of night trains since it is not found to be statistically significant. The comfort level ’capsule’ has the highest preference again followed by the comfort level ’sleeper’. However, the difference between the two comfort levels does not differ much as in the other classes. The attribute ’cost’ is not found to be statistically significant which suggests that for these travellers the cost does not influence their choice. They have a relatively high preference for private facilities since the parameter (β_{Fac}) is twice as high as in classes 3 and 4. This class stands out since it is the only class that has a preference for taking their car on the night train. The travellers who prefer an aeroplane as their favourite mode have a higher probability of belonging to this class.

A visualisation of the 5 classes is shown in figure 5.3.

5.6. WtP for service attributes per class

To compare all classes with each other in terms of service attributes, the willingness to pay (WTP) is calculated like in the earlier section 5.3.1 with the formula 5.4. The calculated WTP is presented in table 5.12. As well are the WTP shown which were calculated from the MNL model with interaction at section (5.8). These are found as an average for the population since the MNL model assumes that all travellers have the same preferences.

No attribute parameters were found significant for class 1. This class did not want to use the night train either. Therefore was were no WTP values found. Class 2 is the price-sensitive class. Only the comfort level ’capsule’ and ’sleeper’ were found significant. These travellers are willing to pay €61 for a capsule cabin and €56 for a sleeper cabin. For these travellers are a capsule more preferred. Compared to the average population are these low values. Class 3 are price-insensitive and this is found in the price these travellers are willing to pay. They find a sleeper cabin more preferred and are willing to pay €238. Compared to the average is this more (€206). For the capsule cabine are they willing to pay €134 which

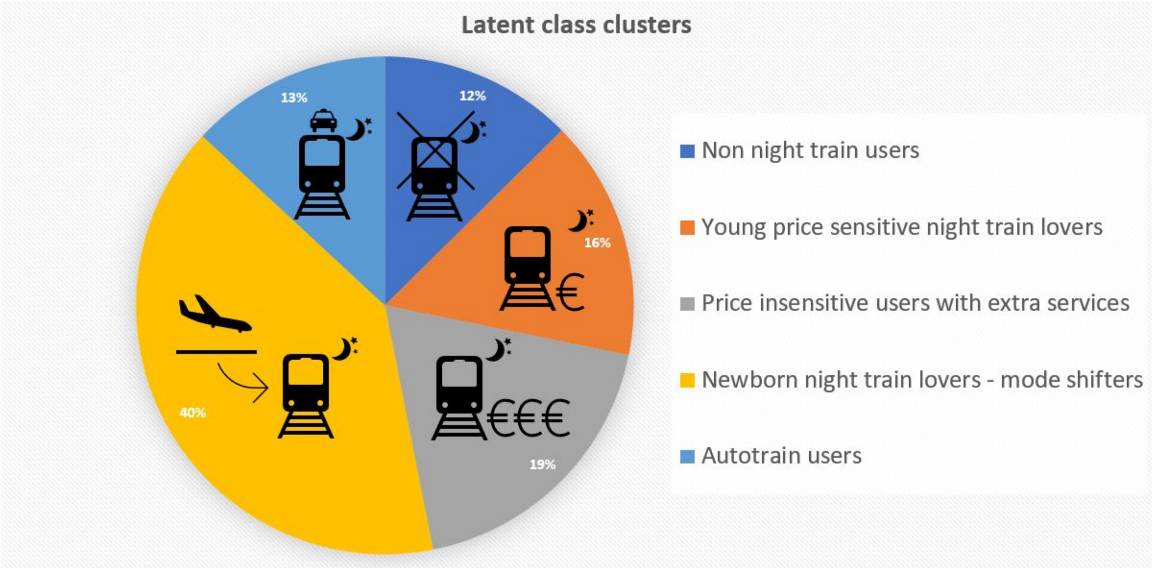


Figure 5.3: Visualisation of the Latent Class Clusters

is a lot lower than the average population (€200). This is the only class that prefers a sleeper cabin more over other comfort levels. These travellers are also willing to pay the most for a sleeper cabin compared to other classes. In order to have a service-car available within the train are they willing to pay €28 which is a lot more compared to the average population (€10). This is also the only class where this service-car is preferred. Arriving late is worth €26 which is simular to the average (€21). Having private facilities is worth a lot more than the average which is €64 compared to €34. Class 4 have also high WTP values. A couchette cabin is worth €202 compared to €127 for the average population. This is a lot more. A capsule cabin is ranked the highest with €212 whereas a sleeper cabin is lower valued at €189. Compared to the MNL model are these values similar (respectively €200 and €206). To have the availability to have stops over the night is worth €33 which is twice as high as the average population (€14) where they have valued private facilities on average (€30 compared to €34). Since no cost parameter was found significant for class 5, it is not possible to calculate the WTP for this class.

Table 5.12: Willingness To Pay of service attributes for each class

Attributes	MNL model with interaction [€]	Class 1 [€]	Class 2 [€]	Class 3 [€]	Class 4 [€]	Class 5 [€]
β_{COMcou}	127	-	-	-	202	-
β_{COMcap}	200	-	61	134	212	-
β_{COMsle}	206	-	56	238	189	-
β_{NSTOP}	14	-	-	-	33	-
$\beta_{ServCar}$	10	-	-	28	-	-
$\beta_{ArrTime}$	21	-	-	26	-	-
$\beta_{CarCarr}$	20	-	-	-	-	-
β_{Fac}	34	-	-	64	30	-

6 Application

The Latent Class model is used to explore the effect of the service attributes on the probabilities to choose the night train in section 6.1. In section 6.2 are multiple scenarios constructed to model realistic night train options and their market share. Section 6.3 summarises the main findings from this chapter.

6.1. Exploring effect of the service attributes

The models have been estimated to explore the night train utility contribution of the service attributes and their background variables. The estimated Latent Class model from section 5.5 is used in this chapter. This information can now be used for various attribute combinations to determine the probabilities of choosing the night train. For each combination, the levels are varied for one attribute. Other attributes remain fixed on their middle or lowest level (lowest level when the middle level is not possible). The background and socio-demographic variables of the collected respondents are used. The variables which are included in the Latent Class model are state, age, income, academic master, car as preferred mode and aeroplane as preferred mode. The input variables (from the collected respondents) can be found in table 5.3 and figure 5.1. This results in the following input variables for the respondents:

- State: 53%
- Age: 33
- Academic master: 38%
- Preferred mode car: 19%
- Preferred mode aeroplane: 38%

The probability of choosing the night train per attribute level can be found in figure 6.1. It must be noted that these probabilities only hold for the given context which was described in the survey. The trip duration takes 12 hours and European destinations can be reached at a distance between 800 and 1200 km from Brussels. Any other mode to travel besides the night train is possible.

Table 6.1 shows that cost has the biggest influence on the night train share. It ranges from 34% at a cost of €360 to 81% at a cost of €40. The relative broad cost range results in a wide range of probabilities for choosing the night train as well. The price of €360 is rarely asked for a night train trip. It is only asked when a car is taken on a journey where an additional cost is asked of 100-200 euros. The second biggest influence is comfort. The probabilities vary between 23% for having a seat and 60% for having a capsule cabin. As discussed in section 5.3.1 was it expected that having night stops would result in a lower probability. Since the night stop estimate is positive, the opposite is true. It results in an increase of 3%. Having private facilities instead of shared ones has a similar increase of 4%. The inclusion of the other service attributes such as 'Service car', 'Arrival time' and 'Car carriage' does not change the probability of choosing the night train much. It is less than 1% for these attributes.

Table 6.1: Probability of choosing night train per attribute level

Attribute	Level	Prob. Nighttrain [%]
Comfort	Seat	23
	Couchette	54
	Capsule	60
	Sleeper	57
Cost	40	81
	120	70
	200	60
	280	48
	360	34
Nightstop	No stops during the night	60
	6 stops during the night	63
Service car	Not included	60
	Included	60
Arrivaltime	8:00	60
	10:00	60
Car carriage	Not included	60
	Included	60
Facilities	Shared	60
	Private	64

6.2. Scenario application

Some scenarios are constructed to model realistic night train options. These scenarios make it possible to see which night train configuration attracts the most travellers and to which extent. The scenarios are described below.

1. **Reference**: This scenario is the base scenario. It is the most common service which is offered on night trains. The couchette cabin is offered in this scenario at a price of €80. This was found as an average price for a couchette when searching for similar night train journeys 2-3 months in advance.

2. **Low cost and low comfort**: This scenario represents a cheap night train option with only seats. It is offered for a price of €40. It is the average starting price of existing night train services where the comfort level is a seat.

3. **High comfort**: The highest comfort level is served in this night train which is the sleeper cabin. To accommodate this increase in comfort is the price set to €160. No other service attributes are included.

4. **High comfort with luxury**: The sleeper cabin is offered to accommodate the high comfort in this scenario as well. Additionally, this train includes a service carriage, private facilities and it arrives later in the morning. To accommodate these extra services, the price is increased to €220.

5. **Privacy with medium comfort**: To accommodate the preferences for additional privacy, the capsule is included in this night train. The additional privacy comes with a slightly higher price than the couchette cabin. The price is set to €120.

Different user groups are defined to calculate their market share. The average Belgian population and young Belgian travellers who have a lower income such as students. The average Belgian population has two additional subgroups where one group prefers to travel with a car and one group prefers to travel with an aeroplane. The average Belgian population is chosen to calculate the total market share of the night train for the total Belgian population. The three other user groups are added to find shifts in market shares. The user group variables can be seen in table 6.2. No data was found on the Belgian population about their preferred mode (car or aeroplane) to travel. Therefore are the values used of the respondents. It can be found in the previous section 6.1.

Table 6.2: User groups

	Average Belgian population	Young Belgian with low income	Average Belgian population who prefers the car	Average Belgian population who prefers the aeroplane
State	60%	60%	60%	60%
Age	41	25	41	41
Income	€30600	€15000	€30600	€30600
Academic master	18%	18%	18%	18%
Prefers car	19%	19%	100%	0%
Prefers aeroplane	38%	38%	0%	100%

6.2.1. Distribution of the classes

Each class from the Latent Class model depends on the background variables. Therefore, different user groups lead to a shift in the probability of belonging to each class. The class probability of the respondents from section 5.5 are:

- Class 1 ’Non-night train users’: 12.6%
- Class 2 ’Young price sensitive night train lovers’: 15.6%
- Class 3 ’Price insensitive users with extra services’: 18.7%
- Class 4 ’Newborn night train lovers - mode shifter’: 40%
- Class 5 ’Autotrain users’: 13.1%

The probability of belonging to each class for the different user groups can be seen in table 6.3. It is interesting to see how the distribution among the classes is formed per user group. From that information can be concluded who (most likely) the users are of the night train.

A shift of the probabilities is noted when the average Belgian population is used. Class 4, which are the newborn night train lovers, is still the largest class and is even larger compared to the respondents. The probability of belonging to class 4 is almost 54% and represents therefore more than half of the user group. Class 2, which represents the young price-sensitive night train users, has become smaller compared to the respondents’ distribution. This is expected since the average age of the Belgians is higher than the average of the respondents. Other classes remain similar to the respondents’ distribution. The Average Belgian population will be used as a reference to the other user groups.

The ’Young Belgians with a low income’ user group is a major shift seen from class 3 and 4 to class 2. Since this user group has a low income, price-insensitive users lose their share (class 3) to class 2 who are the price-sensitive users. Class 4 loses a major share to class 2 as well.

The average Belgian population who prefers the car is a major shift noticeable from class 4 to class 1 and 3. Class 1 are the ’Non-night train users’ and is expected that more users would shift to this class since they prefer to take the car. It was not expected that car lovers can shift to the night train when extra services are offered. This can be concluded since many users shifted to class 3. This means that extra services offered on night trains can still attract car lovers.

The user group ’Average Belgian population who prefers the aeroplane’ are classes 1,2 and 3 shifted to class 4. This user group has a notable high share of ’Newborn night train lovers - mode shifter’. The probability for this user group to belong to this class is 71.2%.
From the different distribution among the classes for the different user groups can be concluded that class 4 has a major impact on the distribution. Depending on the user group, users are shifted to or from class 4.
Users who prefer the aeroplane result in a high probability of using the night train compared to users who prefer the car. This can be due to the fact that whether you travel by aeroplane or by train, at the destination does the traveller not have their own transportation. Travelling by car has the advantage to have your own transportation.

Table 6.3: Probability of belonging to each class

	Average Belgian population [%]	Young Belgians with low income [%]	Average Belgian population who prefers the car [%]	Average Belgian population who prefers the aeroplane [%]
Class 1	9.8	8.4	18.3	3
Class 2	6.2	19.7	4.3	2.4
Class 3	9.8	8.4	18.3	3
Class 4	53.8	46.1	40.8	71.2
Class 5	20.4	17.4	18.3	20.4

6.2.2. Market shares

The market shares are determined for different scenarios and for different user groups. This can be seen in table 6.4.

As seen for the average Belgian population, scenario 5 has the highest share for the night train which is 70%. This means that 70% would choose to travel with the night train and not for other possible modes. Since this scenario has the highest share, users prefer a capsule cabin with a reasonable price of €100 compared to all other scenarios.
The night train with the highest comfort together with additional luxury services offered (scenario 4) has a lower share. It attracts almost 4% fewer (66.3%) travellers compared to the night train with the capsule cabins. Similar to this scenario are scenarios 1 and 3. These scenarios have a similar share which is respectively 65.3% and 64.4%. Offering a couchette cabin at a price of €80 results in the same share for the night train offering a sleeper cabin at the higher price of €160. The same holds for the luxury night train at a price of €220. This suggests that travellers are willing to pay more for these additional services although it does not lead to a higher ridership.
Offering a low-cost (€40) night train with only seats results in a noticeable decrease in ridership. Only 52.2% of the travellers would choose this option.

These findings hold for all user groups. Offering a low-cost night train leads to the lowest ridership whereas offering privacy and medium comfort leads to the highest ridership. Offering medium comfort at a reasonable price leads to similar ridership compared to night trains with extra comfort or luxury at a higher price.
Young Belgians with a low income have lower ridership on night trains compared to the average population. Only the low-cost scenario does not lead to a significant decrease in ridership. It still has the lowest share compared to other scenarios, but the gap between the scenarios decreased.
The background variable of the preferred mode has a major effect on the ridership of the night train. When a car is preferred, ridership significantly decreases. As stated earlier, this is most likely due to the fact that the traveller has their own transportation at the destination which is not the case when taking the night train.
This might be the reason as well why users who prefer to take the aeroplane are willing to take the night train as well. It does not affect the plans in terms of transportation at the destination. This user group has the highest ridership compared to other user groups. 83.8% of the travellers would choose to travel with the night train in capsule cabins followed by 80.3% in couchette cabins. Medium comfort is therefore preferred by this user group.

Table 6.4: Market share per scenario for each user group

	Average Belgian population [%]	Young Belgians with low income [%]	Average Belgian population who prefers the car [%]	Average Belgian population who prefers the aeroplane [%]
Scenario 1 ’Reference’	65.3	60	52.5	80.3
Scenario 2 ’Low Cost, Low Comfort’	52.2	51.2	42.7	61.2
Scenario 3 ”High Comfort’	64.4	58.3	53.8	76.9
Scenario 4 ’High Comfort with High Luxury’	66.3	59.5	56.2	78.7
Scenario 5 ’Privacy with Medium Comfort’	70	65.5	57.4	83.8

6.3. Summary

The estimated Latent Class choice model is applied in this chapter to predict the potential market share of the night train.
An exploration of the service attributes showed that cost has the biggest influence on the market share followed by comfort. The biggest difference in the market share resulting from the variation of the cost is 47%.

Scenario analysis showed that introducing a night train for the average Belgian population with couchette cabins of €80, which is the most common service offered, would result in a potential ridership of 65.3%. The highest ridership would be for the night train offering just capsule cabins at a price of €120. The lowest ridership would be for the night train offering low comfort at a low cost. 52.2% of the travellers would choose this option. The preferred mode seems to be a great influence on the ridership of the night train. When a car is preferred, this leads to low market shares. When an aeroplane is preferred, and still no train, a high market share results. This is most likely to the fact that taking a train or an aeroplane does not influence the transportation possibilities at the destination. Travelling with a car has more flexibility at the destination in terms of transportation.

7

Conclusion, discussion and recommendations

7.1. Conclusion

The objective of the research was to gain more insight on the service attributes that influence the night train usage of the Belgian population. As well was it important to find relating socio-demographic and journey context characteristcs that influence the usage of the night train. More insight was gained in individuals' preferences and trade-offs based on a choice experiment carried out by Belgian domestic train users. The presented results could be used for further research on travel behaviour for the mode choice for European international travel. As well can the results be used by rail opeators who want to make their existing night train services more attractive for their users or operators who have an interest in operating night train services to develop their new services to the expectations of their new users. The sub questions and main research questions are answered in this section.

Which night train service attributes are relevant for night train services?
From the literature is found that comfort is the most important attribute that contributes to the utility of the night train. The already existing comfort attributes 'seat', 'couchette' and 'sleeper' are therefore included as attributes. since the night train operator of Nightjet OBB introduces a new comfort attribute 'capsule' is chosen to include this attribute as well. This comfort attribute should answer the need for more privacy during the journey. Privacy is found to be the most important factor for perceived comfort, which is found in the literature. Other important attributes like 'cost', 'arrival time' and private or shared 'facilities' were found as important as well. Therefore are these included as well. When looking into excisting services was not found what the preferences were about the ability to take a car on to the journey. However, this option is served on some night train services. Since this service attribute still exists is it chosen to include in the choice experiment.

Besides service attributes is found from literature that trip purpose and travel companions influence the mode choice for international travel. Therefore are these variables included as context variables in the choice experiment.

Which night train attributes are most important for the Belgian population, and to which extent?

In the night train choice experiment were 9 service attributes included. Three comfort attributes: 'couchette', 'capsule' and 'sleeper' together with 'cost', 'nightstop', inclusion of a 'service-car', early or late 'arrivaltime', inclusion of a 'car-carriage' and shared of private 'facilities'. These attributes were applied to two night train alternatives where a third alternative is a base alternative which can be any other mode besides the night train to undertake an international journey such as a car, bus and aeroplane. From the base MNL model is found that all attribute estimates are positive except for the cost estimate. An overview of the parameter estimates is given in table 7.1. Therefore is the inclusion of the attributes experienced as positive, except the attributes 'cost'. The comfort attributes have the

highest value compared to the other attributes. This suggests that it has the highest relevance for choice-making between the night trains and the base alternative. The attribute 'sleeper' has the highest estimate followed by 'capsule'. Although the differences are small between the two attributes. It suggests that the travellers have an almost as high preference for a capsule as for a sleeper, which has the highest comfort offered. 'Couchette' has the lowest estimate of the three comfort attributes where the difference is more noticeable between the 'capsule' and the 'couchette'.
The attribute 'cost' has the second highest importance of relevance for the travellers by choice making for the night train. It is the only parameter which has a negative estimate which means that it is experienced as negative when a higher value is assigned to the attribute level. It has a bit lower absolute value compared to the lowest comfort attribute 'couchette'. Compared to the comfort attribute 'sleeper' is the importance of attribute 'cost' almost two times lower.
Following by having private 'facilities' instead of shared with other passengers. Shared facilities are all available at the end of each carriage. Travellers prefer to have their own facilities within their own cabin. Compared to 'cost' is the importance of 'facilities' more than two times lower and compared to the comfort attribute 'sleeper' 6 times lower.
The remaining attributes have similar importance of relevance. Having a late 'arrival time' is followed by (with almost the same relevance) having the possibility to take a car on the journey with the inclusion of a 'car carriage'. These attributes are almost 5 times less relevant than 'cost'. These are followed by 'night stop' and the inclusion of a 'service car' where drinks and food are served. These attributes are respectively 7 to 8 times lower in relevance compared to 'cost'.
The ranking (high to low) of the service attributes is summarized in the following list.

- Comfort 'Sleeper'
- Comfort 'Capsule'
- Comfort 'Couchette'
- 'Cost'
- 'Facilities'
- 'Arrivaltime'
- 'Car carriage'
- 'Night stops'
- 'Service carriage'

Table 7.1: Attribute estimates from the base MNL model

Attributes	base MNL model
ASC	-0.11
β_{COMcou}	0.92
β_{COMcap}	1.44
β_{COMsle}	1.49
β_{Cost}	-0.72
β_{NSTOP}	0.10
$\beta_{ServCar}$	0.08
$\beta_{ArrTime}$	0.15
$\beta_{CarCarr}$	0.14
β_{Fac}	0.24

To which extent does heterogeneity in preferences exist among the Belgian population regarding the values of night train attributes, and to which socio-demographic characteristics and context variables can this heterogeneity be attributed?

The heterogeneity in preferences regarding to socio-demographic characteristics and context variables was examined in two ways. First was the MNL model used with the inclusion of the socio-demographic characteristics and the context variables. Second was a Latent Class Choice model estimated with a class membership function.
From the MNL model with interaction effects are only some socio-demographic effects found significant. On the other hand, no significant effects were found on the context variables which determine the journey that attributed to the heterogeneity. Included context variables were regarding to trip purpose and travel companion.

- **Couchette & Household with adults (student-house)**: Students who live in a student house are more likely to choose a couchette cabin.
- **Capsule & Household with adults (student-house)**: A capsule is more likely to be chosen by students who live in a student house. This is more likely than for a couchette cabin.
- **Cost & Age**: The older the travellers are, the less sensitive they are to price.
- **Service car & Employed**: Travellers who earn money (employed) find it important to have a service car included in the night train.
- **Car carriage & Academic Master**: Travellers who are higher educated are more willing to take a car on their journey.
- **ASC & Personal Car**: Travellers who own a personal car result in a higher systematic disutility for the night train.

By estimating the heterogeneity in preferences with the Latent Class Choice model were socio-demographic characteristics found to be significant as well. Although this model has revealed a more detailed heterogeneity in the form of 5 classes instead of 1 population of the MNL model with interaction effects. 12.6% of the Belgian population belongs to the first class, 15.6% to the second class, 18.7% to the third class, 40% to the fourth class and 13.1% to the fifth class.
This model did not reveal any context variables that attributed heterogeneity either. Included context variables were regarding to trip purpose and travel companion.

- **Class 1: 'Non night train users'** do not prefer to take the night train. None service attributes, except for cost, were found insignificant which results that the night train is not an option to travel with for these travellers.
- **Class 2: 'Young price sensitive night train lovers'** have a high preference for the comfort attribute 'capsule' followed by 'sleeper' and must be low valued in price. Other service attributes are not relevant for these travellers. Young and high aducated travellers who are from the French speaking part of Belgium have the highest probability to belong in this class. As well have these travellers not a high income and do not prefer a car as their preferred mode.
- **Class 3: 'Price insensitive users with extra services'** is the second largest class. These travellers have the highest preference for the comfort attribute 'sleeper' followed by the 'capsule'. Which stands out in this class is that the 'capsule' is found half as important than 'sleeper' whereas other classes find these two comfort attributes nearly as important. These travellers are not sensitive for 'cost' and do prefer a service car in their night train. Late arrival time and private facilities are preferred as well. The class membership parameter was not found significant which means that this class is not significant larger than class 1. As well were other socio-demographic factors not found significant resulting that the probability of belonging to this class being the same as class 1.
- **Class 4: 'Newborn night train lovers - mode shifter'** is the biggest class with 40% of the population. They are relatively sensitive to 'cost' and prefer the comfort attribute 'capsule' the most. Although all comfort attributes, including 'couchette' are found similarly as important. Having night stops and private facilities is preferred as well. Travellers who are from the French-speaking part of Belgium and are high educated have the highest probability to belong in this class. As well do these travellers prefer to travel by aeroplane which is not seen at the positive ASC estimate. This suggests that these travellers shifted to night train.

- **Class 5: 'Autotrain users'** are the only class who prefer the ability to take a car on the journey. The comfort attribute 'capsule' is most preferred followed by 'sleeper' together by the private facilities. The class membership parameter was not found significant which means that this class is not significantly larger than class 1. Other socio-demographic factors were not found significant as well resulting that the probability of belonging to this class being the same as class 1.

Scenario analysis showed that introducing a night train for the average Belgian population with couchette cabins of €80, which is the most common service offered, would result in a potential ridership of 65.3%. The highest ridership would be for the night train offering just capsule cabins at a price of €120. The lowest ridership would be for the night train offering low comfort at a low cost. 52.2% of the travellers would choose this option. The preferred mode seems to be a great influence on the ridership of the night train. When a car is preferred, this leads to low market shares. When an aeroplane is preferred, and still no train, a high market share results. This is most likely to the fact that taking a train or an aeroplane does not influence the transportation possibilities at the destination. Travelling with a car has more flexibility at the destination in terms of transportation.

Since all the subquestion has been answered can the main question be answered to conclude the conclusion.

"Which factors influence the preference and use of night train services among the Belgian population and what is the corresponding heterogeneity"
The inclusion of context variables regarding to trip purpose and travel companion could not influence the preference and use of the night train services. Besides this could the socio-demographic factors do influence the preference and use of the night train. 'Household with adults (studenthouse)', 'age', 'employed', 'academic master' and 'personal car' influence the preferences and use of the night train services. The socio-demographic factors that influence the heterogeneity in preferences among the Belgian population are 'state', 'age', 'income', 'academic master', 'preferred mode car' and 'preferred mode plane'. Five classes among the Belgian population could be found with different night train preferences. Class 1 (12.6%) who do not prefer the night train at all. Class 2 (15.6%) are French-speaking, high educated, young travellers, who do not prefer to take a car and have a low income. They prefer a capsule cabin (followed by a sleeper cabin) and are highly price sensitive. Class 3 (18.7%) prefer a sleeper cabin (followed by a capsule cabin) and are not price sensitive. They also prefer to have a service car, late arrival and private facilities. Class 4 (40%) prefer all comfort attributes similarly but capsule cabin the most. They prefer night stops and private facilities. French-speaking travellers with high education who prefer an aeroplane as mode have a high probability to belong in this class. Class 5 (13.1%) have the capsule cabin as the preferred comfort attribute followed by sleeper. They prefer private facilities and are the only ones who prefer to take a car on their journey. Those who prefer an aeroplane to travel with have a higher chance of belonging to this class. Scenario analysis has shown that the night train with high privacy and medium comfort offered is preferred above night trains with higher comfort and more luxury offered. Low-cost night trains result in the lowest ridership. The preferred mode has the biggest influence on ridership as a background variable.

7.2. Discussion

The most important service attributes in this research were the three comfort attributes. This was also found at an earlier study carried out by Heufke Kantelaar (2019) where comfort was found an important preference for night trains. Its study revealed that the highest preference was found with a private cabin for 2 people, which is a sleeper cabin. This was also the case at this study where a sleeper has the highest preference. It was followed by a capsule cabin which had almost the same importance. Heufke Kantelaar (2019) also found that privacy contributes a lot to the perceived comfort which would explain the high preference for a capsule. The attribute cost is found to be the most important negative contributor to the utility of the night train. This is found in many studies as well (Heufke Kantelaar, 2019) (Curtale et al., 2023) (Li et al., 2019). Extra service attributes such as service car, private facilities, arrival time and night stops are found less important preferences which is also the case from earlier research Heufke Kantelaar, 2019. The attribute 'arrival time' has the expected amplitude compared to other studies but it does not have the expected sign. More night stops would suggest having a less comfortable night which was also found by Heufke Kantelaar (2019). The reason for this unexpected sign might be that the respondents were focused on other attributes (since 9 attributes were included) or that they prefer the possibility to embark and to alight the train. The other service attributes (night stop and car carriage) were found with the same importance as the last mentioned. These investigated attributes could not be found in the literature and can therefore not be compared.

The aim of the research was also to find heterogeneity regarding socio-demographic characteristics and context variables in a more detailed manner. More socio-demographic characteristics and context variables were therefore included in the survey. The comfort attribute 'couchette' is found to be used by young adults and especially students who live in a student house. That young adults are more likely to use a couchette is also found in an earlier study by Heufke Kantelaar (2019). The inclusion of context variables was expected to be found significant to attribute to the heterogeneity in preferences. The same study of Heufke Kantelaar (2019) was the trip purpose included as business or leisure trip and was found as an important variable for the mode choice between night train and aeroplane. In this study, the trip purpose is included as well with an additional trip purpose variable, visiting friends or family and with travel companions. It was expected that for certain trip purposes and travel companions, certain service attributes would have been preferred or another mode. However, this was not the case.

The data for the stated choice experiment has been collected on the IC trains within Belgium. This means that the respondents travel more often by train which could lead to a correlation to the night train use of the experiment. This correlation between regular train travellers and night train use was found by earlier studies (Heufke Kantelaar, 2019) (Curtale et al., 2023). There is a risk that the respondents were not familiar enough with the choiceset where to choose from. Night trains are not in service on a large scale which results that most of the respondents had never used a night train before. Their choices were therefore hypothetical which could lead to choices they would not make in reality. As well is a new service attribute included in the choice experiment which is the capsule cabin. This has never been used on night trains yet in Europe which leads to hypothetical choices as well. The survey was circulated by using a QR-code which interested respondents could scan and this lead to the online survey. However, this method lead to more younger respondents since older people where not familiar with the QR-code, did not have a smartphone or did not want to fill in a whole survey on their small smartphone. This was aimed to be solved by giving an URL-website which interested respondents could lead to the online survey at home on their computer. Although not many potential respondents made use of this. The experiment exists of two night train options and a base alternative which can be any other possible mode to undertake a long-distance journey. When respondents chose the base alternative, no information is known about which mode they wanted to use.

7.3. Recommendations

7.3.1. Recommendations for further scientific research

This research only considered the choice between two night train options and a base alternative as described in the discussion. Therefore is not much known about the other modes. Some studies has been carried out already with a partial mode choice with the inclusion of some modes. It would be interesting to include one night train together with other alternatives within the choice set. Therefore a full mode choice can be estimated.

Other service attributes could be included in the choice experiment. For example is frequency not used as an attribute to limit the complexity of the choice experiment. Although, frequency is found as an important attribute for long-distance travel (van Goeverden, 2009). If a night train does not run daily, are people less interested in taking a night train compared to a daily service? The effect of frequency is known yet on the use of night trains.

This research is carried out with respondents from Belgium who are regular train users. This research could be carried out with different data samples. Travellers from an airport could be used or data can be collected in another country. It could be interesting of a difference in night train usage could be observed.

7.3.2. Recommendations for practice

If train operations are interested in creating night train services could it be most interesting to focus on the biggest group of the results. Class 4 which are the mode shifter explains 40% of the data. This class seem to shift from aeroplane to night train with a good offered service except for a service carriage and car carriage. The inclusion of these carriages would anyway increase the operational cost en increase operational complexity. Some of the socio-demographic factors are known which makes it possible to target certain user groups.

7.3.3. Recommendations for policy

Since price plays an important contributor to the disutility of the night train can policy makes decisions in terms of lowering the price for travellers who are taking the night train. This can be done by lowering the tax on the tickets. Some countries are considering it for domestic services but not yet for international services. As well can it be considered to lower the train path price which is found to be one of the highest operational cost. This is already implemented by the Belgian parlement. Another option is to let the policy set up concessions where rail operators can sign up to exploit the service. The winning operator get in return subsidies to operate the service which makes it possible to lower the price. It is difficult if each country implements their own measures to make night train travel more attractive. Night trains mostly cross several countries where it could be more helpful if the European parliament implement measurements to make night train travel more attractive.

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A

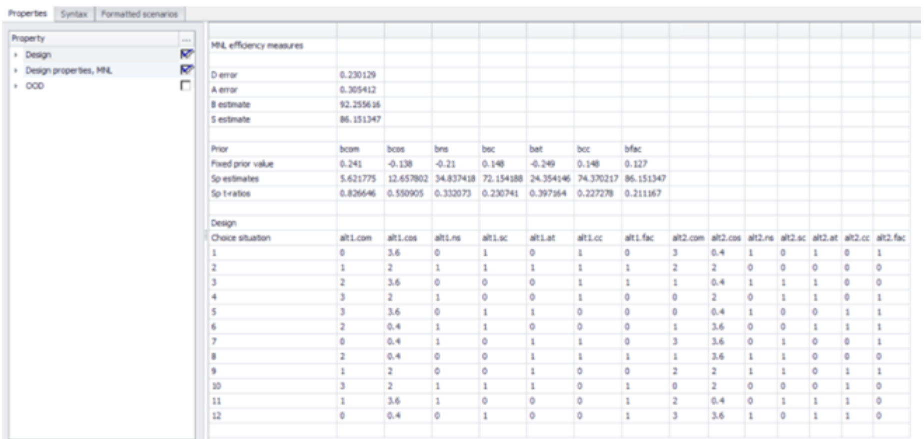
Ngene model

To model the choice set, these Ngene models are used.

A.0.1. Input Ngene model

```
Design
;alts = alt1*, alt2*
;rows = 12
;eff = (mnl,d)
;model:
U(alt1) = bCOM[0.241] * COM[0,1,2,3] + bCOS[-0.138] * COS[0.4,2,3.6] + bNS[-0.21] * NS[0,1] +
bSC[0.148] * SC[0,1] + bAT[-0.249] * AT[0,1] + bCC[0.148] * CC[0,1] + bFAC[0.127] * FAC[0,1]/
U(alt2) = bCOM[0.241] * COM[0,1,2,3] + bCOS[-0.138] * COS[0.4,2,3.6] + bNS[-0.21] * NS[0,1] +
bSC[0.148] * SC[0,1] + bAT[-0.249] * AT[0,1] + bCC[0.148] * CC[0,1] + bFAC[0.127] * FAC[0,1]
$
```

A.0.2. Outcome Ngene model



MNL efficiency measures							
D error	0.230129						
A error	0.305412						
B estimate	92.255616						
S estimate	86.151347						

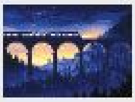
Prior	bcom	bcos	bns	bsc	bat	bcc	bfac
Fixed prior value	0.241	-0.138	-0.21	0.148	-0.249	0.148	0.127
Sp estimates	5.621775	12.657802	34.837418	72.154188	24.354146	74.370217	86.151347
Sp t-ratios	0.826646	0.550905	0.332073	0.230741	0.397164	0.227278	0.211167

Design

Choice situation	alt1.com	alt1.cos	alt1.ns	alt1.sc	alt1.at	alt1.cc	alt1.fac	alt2.com	alt2.cos	alt2.ns	alt2.sc	alt2.at	alt2.cc	alt2.fac
1	0	3.6	0	1	0	1	0	3	0.4	1	0	1	0	1
2	1	2	1	1	1	1	1	2	2	0	0	0	0	0
3	2	3.6	0	0	0	1	1	1	0.4	1	1	1	0	0
4	3	2	1	0	0	1	0	0	2	0	1	1	0	1
5	3	3.6	0	1	1	0	0	0	0.4	1	0	0	1	1
6	2	0.4	1	1	0	0	0	1	3.6	0	0	1	1	1
7	0	0.4	1	0	1	1	0	3	3.6	0	1	0	0	1
8	2	0.4	0	0	1	1	1	1	3.6	1	1	0	0	0
9	1	2	0	0	1	0	0	2	2	1	1	0	1	1
10	3	2	1	1	1	0	1	0	2	0	0	0	1	0
11	1	3.6	1	0	0	0	1	2	0.4	0	1	1	1	0
12	0	0.4	0	1	0	0	1	3	3.6	1	0	1	1	0

B Survey

To model the MNL model is the given Apollo syntax used.



Voorkeursonderzoek: langeafstandsvervoer binnen Europa met de nachttrein

Beste deelnemer,

Deze enquête is onderdeel van mijn thesis onderzoek voor de Master Transport, Logistiek en Infrastructuur aan de TU Delft in samenwerking met de NMBS. Het doel van dit onderzoek is om meer inzichten te krijgen over het gebruik van nachttreinen voor langeafstandsvervoer in Europa. Uw deelname zal het mogelijk maken om een simulatiemodel te maken over het keuzegedrag van nachttreinreizigers.

De enquête kan op elk moment onderbroken worden. Enkel anonieme informatie wordt verzameld en kan hierdoor nooit herleid worden tot individuen. De verzamelde data zal enkel gebruikt worden voor dit onderzoek over verplaatsingsgewoontes. De antwoorden van deze enquête en de resultaten van dit onderzoek zal door de TU Delft gepubliceerd worden.

U moet minimum 18 jaar zijn om deel te nemen en de enquête zal ongeveer 10 minuten duren.

In ieder geval hartelijk bedankt voor uw deelname!

Wouter Moors
w.p.m.moors@student.tudelft.nl

Onderdeel 1 - Reizigersgedrag en persoonlijke kenmerken

In het eerste onderdeel zijn we geïnteresseerd in uw reisgedrag binnen Europa ongeacht met welk vervoersmiddel u hiermee uw reis maakte. Ook vragen we enkele persoonlijke kenmerken.

1

Wat is uw geslacht? *

- ◯ Vrouw
- ◯ Man
- ◯ Anders
- ◯ Zeg ik liever niet

2

Wat is uw geboortejaar? *

De waarde moet een getal zijn

3

Wat is uw postcode (optioneel)?

De waarde moet een getal zijn

4

Hoe ziet de samenstelling van uw huishouden eruit? *

- ◯ Alleen mezelf
- ◯ Ikzelf en partner
- ◯ Ikzelf met partner en kinderen
- ◯ Ikzelf en ouders
- ◯ Ikzelf, ouders, broer(s) en of zus(sen)
- ◯ Ikzelf met meerdere volwassenen (18 jaar of ouder) (bv. studentenhuis)
- ◯ Anders
- ◯ Zeg ik liever niet

5

Heeft u een rijbewijs? *

- ◯ Ja
- ◯ Nee

6

Bent u in het bezit van een auto? *

- ◯ Ja
- ◯ Nee

7

Van welke auto maakt u het meeste gebruik? *

- ◯ Persoonlijke auto
- ◯ Bedrijfswagen

8

Wat was uw (netto) inkomen van afgelopen jaar? *

- ◯ Minder dan €10 000
- ◯ €10 000 - €20 000
- ◯ €20 000 - €30 000
- ◯ €30 000 - €40 000
- ◯ €40 000 - €50 000
- ◯ €50 000 - €60 000
- ◯ €60 000 - €70 000
- ◯ €70 000 - €80 000
- ◯ €80 000 - €90 000
- ◯ €90 000 - €100 000
- ◯ €100 000 - €200 000
- ◯ €200 000 of meer
- ◯ Zeg ik liever niet

9

Welke onderstaande situatie is het meeste van toepassing voor u? *

- Scholier
- Student
- Werkzaam in loondienst
- Zelfstandige ondernemer
- Werkloos
- Huisman/huisvrouw
- Gepensioneerd
- Arbeidsongeschikt
- Anders
- Zeg ik liever niet

10

Wat is uw (afgerond) opleidingsniveau? *

- Middelbare school
- Professionele Bachelor/graduaat
- Academische Bachelor
- Academische Master
- Anders
- Zeg ik liever niet

11

Ongeacht met welk vervoersmiddel, hoe vaak maakt u vanuit België gemiddeld per jaar een reis naar een Europese bestemming? *

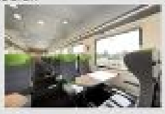
- 0 keer/jaar
- 1-3 keer/jaar
- 4-7 keer/jaar
- 8-10 keer/jaar
- Meer dan 10 keer/jaar
- Zeg ik liever niet

12

Welk vervoersmiddel heeft over het algemeen uw voorkeur mochten alle opties mogelijk zijn om te reizen binnen Europa binnen een afstand van 800-1200 km (Bv. Milaan, Geneve, München, Kopenhagen)? *

- Auto
- Vliegtuig
- Trein
- Anders

Keuze nachttrein

Comfort categorieën	Uitleg
Comfort: stoelen 	De reis wordt afgelegd in een stoel.
Comfort: slaapbanken 	De reis wordt afgelegd in een gedeelde cabine waarbij 6 slaapbanken aanwezig zijn. Kussen en slaapzak worden voorzien om te kunnen slapen.
Comfort: slaapcapsule 	De reis wordt gemaakt op een slaapbank dat d.m.v. luiken afgesloten kan worden langs de zijkanten (capsule). Hierdoor heb je eigen privacy. Kussen en slaapzak worden voorzien om te kunnen slapen.
Comfort: slaap bed 	De reis wordt afgelegd in een cabine dat bestaat uit twee volwaardige opgemaakte bedden. Je kan hier alleen of met je reisgezel comfortabel slapen.

In dit onderdeel van de enquête zijn we geïnteresseerd welke nachttrein u kiest voor lange afstandsreizen binnen Europa vanuit Brussel (afstand ±800-1200 km). Milaan wordt als voorbeeldbestemming gebruikt. 12 keer worden u 2 fictieve nachttreinen getoond waaruit u uw voorkeur kiest. Als u geen gebruik wenst te maken van de nachttrein, geef dan alsnog de keuze aan die uw eerste keuze zou zijn. De nachttreinen verschillen in *'comfort'*, *'prijs'*, *'nachtstop'*, *'service rijtuig'*, *'aankomsttijd'*, *'autorijtuig' en 'faciliteiten'*. Uitleg vindt u onderaan deze tekst.

Elke nachttrein is standaard uitgerust met **wifi** en **stopcontacten** aan uw zit- of ligplaats.
De nachttrein zal **12 uur onderweg zijn** om de bestemming te bereiken.

- **Comfort:** Zie foto.
- **Prijs:** De prijs die betaald wordt om de reis af te leggen.
- **Nachtstop:** 's Nachts zal er wel of niet 6 maal gestopt worden tussen 00 uur en 06 uur om mensen in en uit te laten stappen.
- **Service rijtuig:** De trein heeft wel of geen rijtuig waarin je rustig kan zitten, een drankje kan drinken en kan ontbijten.
- **Aankomsttijd:** De tijd waarbij je aankomt (8 uur of 10 uur 's morgens) in het aankomststation van je bestemming. Hierdoor verschilt ook de vertrektijd: respectievelijk 20 uur of 22 uur (doordat trein 12 uur onderweg is)
- **Autorijtuig:** De trein heeft wel of geen rijtuig waarmee je je auto kan meenemen naar je bestemming.
- **Faciliteiten:** Wastafel, wc en douche kunnen gedeeld worden met andere reizigers of je kan het privé gebruiken in je slaapcabine.

13

Heeft u afgelopen jaren een lange afstand zakenreis gemaakt (±800-1200 km)? Zo ja, maak dan al uw nachttrein keuzes alsof u een zakenreis maakt. *

- ◯ Ja, zakenreis
- ◯ Nee, anders

14

Waarvoor maakte u wel een lange afstandsreis (±800-1200 km)? Vervolgens, maak al uw nachttrein keuzes volgens uw gekozen reis. *

- ◯ Vakantie
- ◯ Bezoek van vrienden of familie
- ◯ Anders

15

Met wie reisde u tijdens deze reis? *

- ◯ Alleen
- ◯ Met partner
- ◯ Met kinderen
- ◯ Met partner en kinderen
- ◯ Met vriend(en)/collega('s)
- ◯ Andere

Nachttrein keuzes

Houd de ingevulde reis en reisgezel in gedachte om te kiezen uit de komende fictieve nachttreinen opties.

16

Keuze 1/12: Welke optie heeft uw voorkeur voor deze reis? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapcabine	Stoelen
Prijs	40 euro	360 euro
Nachtstop	Geen	Wel
Service rijtuig	Geen	Wel
Aankomsttijd	10:00	8:00
Auto rijtuig	Wel	Geen
Faciliteiten	Gedeeld	Gedeeld

- ○ Nachttrein 1
- ○ Nachttrein 2

17

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ○ Nachttrein
- ○ Ander vervoersmiddel

18

Keuze 2/12: Welke optie heeft uw voorkeur voor deze reis? *

	Nachttrein 1	Nachttrein 2
		
Comfort	Stoelen	Slaapcabine
Prijs	200 euro	200 euro
Nachtstop	Geen	Wel
Service rijtuig	Geen	Wel
Aankomsttijd	8:00	10:00
Auto rijtuig	Geen	Wel
Faciliteiten	Gedeeld	Gedeeld

- ◯ Nachttrein 1
- ◯ Nachttrein 2

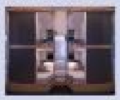
19

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

20

Keuze 3/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1	Nachttrein 2
		
Comfort	Stoelen	Capsule
Prijs	200 euro	200 euro
Nachtstop	Wel	Geen
Service rijtuig	Wel	Geen
Aankomsttijd	8:00	10:00
Auto rijtuig	Wel	Geen
Faciliteiten	Gedeeld	Gedeeld

- ◯ Nachttrein 1
- ◯ Nachttrein 2

:::

21

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

22

Keuze 4/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	**Nachttrein 2** 
Comfort	Slaapcabine	Stoelen
Prijs	200 euro	40 euro
Nachtstop	Geen	Wel
Service rijtuig	Wel	Geen
Aankomsttijd	8:00	10:00
Auto rijtuig	Geen	Wel
Faciliteiten	Privé	Gedeeld

- ◯ Nachttrein 1
- ◯ Nachttrein 2

23

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

24

Keuze 5/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1	Nachttrein 2
		
Comfort	Slaapcabine	Slaapbank
Prijs	200 euro	200 euro
Nachtstop	Wel	Geen
Service rijtuig	Geen	Wel
Aankomsttijd	8:00	10:00
Auto rijtuig	Wel	Geen
Faciliteiten	Gedeeld	Privé

◯ Nachttrein 1

◯ Nachttrein 2

25

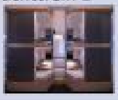
Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

◯ Nachttrein

◯ Ander vervoersmiddel

26

Keuze 6/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1	Nachttrein 2
		
Comfort	Capsule	Slaapbank
Prijs	360 euro	40 euro
Nachtstop	Wel	Geen
Service rijtuig	Wel	Geen
Aankomsttijd	8:00	10:00
Auto rijtuig	Geen	Wel
Faciliteiten	Gedeeld	Privé

◯ Nachttrein 1

◯ Nachttrein 2

27

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

28

Keuze 7/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapcabine	Slaapbank
Prijs	360 euro	40 euro
Nachtstop	Wel	Geen
Service rijtuig	Geen	Wel
Aankomsttijd	10:00	8:00
Auto rijtuig	Geen	Wel
Faciliteiten	Privé	Gedeeld

- ◯ Nachttrein 1
- ◯ Nachttrein 2

29

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

30

Keuze 8/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapbank	Slaapcabine
Prijs	40 euro	360 euro
Nachtstop	Geen	Wel
Service rijtuig	Wel	Geen
Aankomsttijd	10:00	8:00
Auto rijtuig	Geen	Wel
Faciliteiten	Gedeeld	Privé

- ◯ Nachttrein 1
- ◯ Nachttrein 2

31

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

32

Keuze 9/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapbank	Slaapcabine
Prijs	360 euro	200 euro
Nachtstop	Geen	Wel
Service rijtuig	Geen	Wel
Aankomsttijd	10:00	8:00
Auto rijtuig	Wel	Geen
Faciliteiten	Gedeeld	Privé

- ◯ Nachttrein 1
- ◯ Nachttrein 2

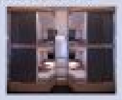
33

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

34

Keuze 10/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1	Nachttrein 2
		
Comfort	Capsule	Slaapbank
Prijs	40 euro	360 euro
Nachtstop	Wel	Geen
Service rijtuig	Wel	Geen
Aankomsttijd	10:00	8:00
Auto rijtuig	Geen	Wel
Faciliteiten	Gedeeld	Gedeeld

- ◯ Nachttrein 1
- ◯ Nachttrein 2

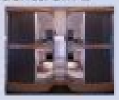
35

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- ◯ Nachttrein
- ◯ Ander vervoersmiddel

36

Keuze 11/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapbank	Capsule
Prijs	360 euro	40 euro
Nachtstop	Geen	Wel
Service rijtuig	Wel	Geen
Aankomsttijd	10:00	8:00
Auto rijtuig	Wel	Geen
Faciliteiten	Privé	Gedeeld

◯ Nachttrein 1

◯ Nachttrein 2

37

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

◯ Nachttrein

◯ Ander vervoersmiddel

38

Keuze 12/12: Welke optie heeft uw voorkeur? *

	Nachttrein 1 	Nachttrein 2 
Comfort	Slaapbank	Slaapcabine
Prijs	40 euro	360 euro
Nachtstop	Wel	Geen
Service rijtuig	Geen	Wel
Aankomsttijd	8:00	10:00
Auto rijtuig	Wel	Geen
Faciliteiten	Privé	Gedeeld

◯ Nachttrein 1

◯ Nachttrein 2

39

Zou u kiezen voor de gekozen nachttrein of een ander vervoersmiddel? *

- Nachttrein
- Ander vervoersmiddel

tie 4

Einde enquête

Hartelijk bedankt voor uw deelname.

Wouter Moors
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+ Nieuwe toevoegen

C

base MNL model

To model the MNL model is the given syntax used in programma Apollo.

```
### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="MNL",
  modelDescr ="MNL results",
  indivID    ="ID"
)

#### LOAD DATA
database = read.delim("samen.dat",header=TRUE)


### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(BETA_COMcou    = 0,
              BETA_COMcap    = 0,
              BETA_COMsle    = 0,
              BETA_COST   = 0,
              BETA_NSTOP   = 0,
              BETA_ServCar    = 0,
              BETA_ArrTime   = 0,
              BETA_CarCarr   = 0,
              BETA_Fac   = 0,
              ASC = 0)

### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use apollo_beta_fixed = c() if none
apollo_fixed = c()


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION

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()
```

```
  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
    V[['A']]  = COMcou1 * BETA_COMcou + COMcap1 * BETA_COMcap + COMsle1 * BETA_COMsle + COST1 * BETA_COST + NSTOP1 * BETA_NSTOP +
      ServCar1 * BETA_ServCar + ArrTime1 * BETA_ArrTime + CarCarr1 * BETA_CarCarr + Fac1 * BETA_Fac

    V[['B']]  = COMcou2 * BETA_COMcou + COMcap2 * BETA_COMcap + COMsle2 * BETA_COMsle + COST2 * BETA_COST + NSTOP2 * BETA_NSTOP +
      ServCar2 * BETA_ServCar + ArrTime2 * BETA_ArrTime + CarCarr2 * BETA_CarCarr + Fac2 * BETA_Fac

    V[['C']]  = ASC


    ### Define settings for MNL model component
    mnl_settings = list(
      alternatives  = c(A=1, B=2, C=3),
      avail         = list(A=1, B=1, C=1),
      choiceVar     = Modal_split,
      V             = V
    )

  ### Compute probabilities using MNL model
  P[['model']] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

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


#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)


#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```

D

MNL model with interaction

To model the MNL model with interaction is the given Apollo syntax used.

```
### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="MNL",
  modelDescr ="MNL results",
  indivID    ="ID"
)

#### LOAD DATA
database = read.delim("samen.dat",header=TRUE)


### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(BETA_COMcou    = 0,
              BETA_COMcap    = 0,
              BETA_COMsle    = 0,
              BETA_COST  = 0,
              BETA_NSTOP   = 0,

              BETA_ArrTime   = 0,

              BETA_Fac   = 0,

              B_COMcou_studentenhuis = 0,
              B_COMcap_studentenhuis = 0,

              B_COST_age             = 0,

              B_ServCar_loondienst   = 0,
              B_CarCarr_acamas       = 0,
              ASC                    = 0,
              ASC_owncar             = 0,
              ASC_prefplane          = 0

```

```
            )

### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use apollo_beta_fixed = c() if none
apollo_fixed = c()


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION

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()

  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
    V[['A']]  = ASC * (1 + ASC_owncar * PersonalCar + ASC_prefplane * PrefMode_plane) +

      COMcou1 * (BETA_COMcou + B_COMcou_studentenhuis * Household_stuhouse) +

      COMcap1 * (BETA_COMcap + B_COMcap_studentenhuis * Household_stuhouse) +

      COMsle1 * (BETA_COMsle) +

      COST1 * (BETA_COST + B_COST_age * Age) +

      NSTOP1 * (BETA_NSTOP ) +

      ServCar1 * (B_ServCar_loondienst * Stat_werk) +

```

```
      ArrTime1 * BETA_ArrTime +

      CarCarr1 * (B_CarCarr_acamas * edu_acamas) +

      Fac1 * BETA_Fac


    V[['B']]  = ASC * (1 + ASC_owncar * PersonalCar + ASC_prefplane * PrefMode_plane) +

      COMcou2 * (BETA_COMcou + B_COMcou_studentenhuis * Household_stuhouse) +

      COMcap2 * (BETA_COMcap + B_COMcap_studentenhuis * Household_stuhouse) +

      COMsle2 * (BETA_COMsle ) +

      COST2 * (BETA_COST + B_COST_age * Age) +

      NSTOP2 * (BETA_NSTOP ) +

      ServCar2 * (B_ServCar_loondienst * Stat_werk) +

      ArrTime2 * BETA_ArrTime +

      CarCarr2 * (B_CarCarr_acamas * edu_acamas) +

      Fac2 * BETA_Fac

    V[['C']]  = 0


    ### Define settings for MNL model component
      mnl_settings = list(
        alternatives  = c(A=1, B=2, C=3),
        avail         = list(A=1, B=1, C=1),
        choiceVar     = Modal_split,
        V             = V
    )

```

```
  ### Compute probabilities using MNL model
  P[['model']] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

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


#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)


#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```

E

Latent class model

To model the Latent Class model with interaction is the given Apollo syntax used.

```
### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="LCCM Night train preferences",
  modelDescr ="LC night train preferences",
  indivID    ="ID"
)

#### LOAD DATA
database = read.delim("samen.dat",header=TRUE)


### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(ASC_a = 0,
              ASC_b = 0,
              ASC_c = 0,
              ASC_d = 0,
              ASC_e = 0,
              BETA_COMcou_a   = 0,
              BETA_COMcou_b   = 0,
              BETA_COMcou_c   = 0,
              BETA_COMcou_d   = 0,
              BETA_COMcou_e   = 0,
              BETA_COMcap_a   = 0,
              BETA_COMcap_b   = 0,
              BETA_COMcap_c   = 0,
              BETA_COMcap_d   = 0,
              BETA_COMcap_e   = 0,
              BETA_COMsle_a   = 0,
              BETA_COMsle_b   = 0,
              BETA_COMsle_c   = 0,
              BETA_COMsle_d   = 0,
              BETA_COMsle_e   = 0,
              BETA_COST_a  = 0,
```

```
            BETA_COST_b   = 0,
            BETA_COST_c   = 0,
            BETA_COST_d   = 0,
            BETA_COST_e   = 0,
            BETA_NSTOP_a   = 0,
            BETA_NSTOP_b   = 0,
            BETA_NSTOP_c   = 0,
            BETA_NSTOP_d   = 0,
            BETA_NSTOP_e   = 0,
            BETA_ServCar_a    = 0,
            BETA_ServCar_b    = 0,
            BETA_ServCar_c    = 0,
            BETA_ServCar_d    = 0,
            BETA_ServCar_e    = 0,
            BETA_ArrTime_a   = 0,
            BETA_ArrTime_b   = 0,
            BETA_ArrTime_c   = 0,
            BETA_ArrTime_d   = 0,
            BETA_ArrTime_e   = 0,
            BETA_CarCarr_a   = 0,
            BETA_CarCarr_b   = 0,
            BETA_CarCarr_c   = 0,
            BETA_CarCarr_d   = 0,
            BETA_CarCarr_e   = 0,
            BETA_Fac_a   = 0,
            BETA_Fac_b   = 0,
            BETA_Fac_c   = 0,
            BETA_Fac_d   = 0,
            BETA_Fac_e   = 0,

            delta_a =0,
            delta_b =0,
            delta_c =0,
            delta_d =0,
            delta_e =0,

            State_a = 0,
            State_b = 0,
```

```
            State_c = 0,
            State_d = 0,
            State_e = 0,
            age_a = 0,
            age_b = 0,
            age_c = 0,
            age_d = 0,
            age_e = 0,

            household_stuhouse_a = 0,
            household_stuhouse_b = 0,
            household_stuhouse_c = 0,
            household_stuhouse_d = 0,
            household_stuhouse_e = 0,

            income_a = 0,
            income_b = 0,
            income_c = 0,
            income_d = 0,
            income_e = 0,

            edu_acamas_a = 0,
            edu_acamas_b = 0,
            edu_acamas_c = 0,
            edu_acamas_d = 0,
            edu_acamas_e = 0,

            prefmode_car_a = 0,
            prefmode_car_b = 0,
            prefmode_car_c = 0,
            prefmode_car_d = 0,
            prefmode_car_e = 0,

            prefmode_plane_a = 0,
            prefmode_plane_b = 0,
            prefmode_plane_c = 0,
            prefmode_plane_d = 0,
```

```
              prefmode_plane_e = 0
              )

### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use apollo_beta_fixed = c() if none
apollo_fixed = c("delta_a", "State_a", "age_a", "household_stuhouse_a", "income_a", "edu_acamas_a", "prefmode_car_a", "prefmode_plane_a")


### Define latent class components
apollo_lcPars=function(apollo_beta, apollo_inputs){
  lcpars = list()
  lcpars[["ASC"]]=list(ASC_a, ASC_b, ASC_c, ASC_d, ASC_e)
  lcpars[["BETA_COMcou"]]=list(BETA_COMcou_a, BETA_COMcou_b, BETA_COMcou_c, BETA_COMcou_d, BETA_COMcou_e)
  lcpars[["BETA_COMcap"]]=list(BETA_COMcap_a, BETA_COMcap_b, BETA_COMcap_c, BETA_COMcap_d, BETA_COMcap_e)
  lcpars[["BETA_COMsle"]]=list(BETA_COMsle_a, BETA_COMsle_b, BETA_COMsle_c, BETA_COMsle_d, BETA_COMsle_e)
  lcpars[["BETA_COST"]]=list(BETA_COST_a, BETA_COST_b, BETA_COST_c, BETA_COST_d, BETA_COST_e)
  lcpars[["BETA_NSTOP"]]=list(BETA_NSTOP_a, BETA_NSTOP_b, BETA_NSTOP_c, BETA_NSTOP_d, BETA_NSTOP_e)
  lcpars[["BETA_ServCar"]]=list(BETA_ServCar_a, BETA_ServCar_b, BETA_ServCar_c, BETA_ServCar_d, BETA_ServCar_e)
  lcpars[["BETA_ArrTime"]]=list(BETA_ArrTime_a, BETA_ArrTime_b, BETA_ArrTime_c, BETA_ArrTime_d, BETA_ArrTime_e)
  lcpars[["BETA_CarCarr"]]=list(BETA_CarCarr_a, BETA_CarCarr_b, BETA_CarCarr_c, BETA_CarCarr_d, BETA_CarCarr_e)
  lcpars[["BETA_Fac"]]=list(BETA_Fac_a, BETA_Fac_b, BETA_Fac_c, BETA_Fac_d, BETA_Fac_e)

  V = list()
  V[["class_a"]] = delta_a + State_a * State + age_a * Age + household_stuhouse_a * Household_stuhouse + income_a * Income_or +
    edu_acamas_a * edu_acamas + prefmode_car_a * PrefMode_car + prefmode_plane_a * PrefMode_plane

  V[["class_b"]] = delta_b + State_b * State + age_b * Age + household_stuhouse_b * Household_stuhouse + income_b * Income_or +
    edu_acamas_b * edu_acamas + prefmode_car_b * PrefMode_car + prefmode_plane_b * PrefMode_plane

  V[["class_c"]] = delta_c + State_c * State + age_c * Age + household_stuhouse_c * Household_stuhouse + income_c * Income_or +
    edu_acamas_c * edu_acamas + prefmode_car_c * PrefMode_car + prefmode_plane_c * PrefMode_plane

  V[["class_d"]] = delta_d + State_d * State + age_d * Age + household_stuhouse_d * Household_stuhouse + income_d * Income_or +
    edu_acamas_d * edu_acamas + prefmode_car_d * PrefMode_car + prefmode_plane_d * PrefMode_plane

```

```
  V[["class_e"]] = delta_e + State_e * State + age_e * Age + household_stuhouse_e * Household_stuhouse + income_e * Income_or +
    edu_acamas_e * edu_acamas + prefmode_car_e * PrefMode_car + prefmode_plane_e * PrefMode_plane



  mnl_settings = list(
    alternatives  = c(class_a=1, class_b=2, class_c=3, class_d=4, class_e=5),
    avail         = 1,
    choiceVar     = NA,
    V             = V
  )

  lcpars[["pi_values"]] = apollo_mnl(mnl_settings, functionality="raw")
  lcpars[["pi_values"]] = apollo_firstRow(lcpars[["pi_values"]], apollo_inputs)
  return(lcpars)

  }


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION

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(A=1, B=2, C=3),
    avail = list(A=1, B=1, C=1),
    choiceVar = Modal_split
  )
  ### Loop over classes
  for (s in 1:length(pi_values))
    {
    ### Compute class-specific utilities
```

```


  V = list()
  V[['A']]  = ASC[[s]] + COMcou1 * BETA_COMcou[[s]] + COMcap1 * BETA_COMcap[[s]] + COMsle1 * BETA_COMsle[[s]] + COST1 * BETA_COST[[s]] + NSTOP1 * BETA_NSTOP[[s]] +
    ServCar1 * BETA_ServCar[[s]] + ArrTime1 * BETA_ArrTime[[s]] + CarCarr1 * BETA_CarCarr[[s]] + Fac1 * BETA_Fac[[s]]

  V[['B']]  = ASC[[s]] + COMcou2 * BETA_COMcou[[s]] + COMcap2 * BETA_COMcap[[s]] + COMsle2 * BETA_COMsle[[s]] + COST2 * BETA_COST[[s]] + NSTOP2 * BETA_NSTOP[[s]] +
    ServCar2 * BETA_ServCar[[s]] + ArrTime2 * BETA_ArrTime[[s]] + CarCarr2 * BETA_CarCarr[[s]] + Fac2 * BETA_Fac[[s]]

  V[['C']]  = 0

  mnl_settings$V = V
  mnl_settings$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)
  s=s+1}
  ### 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)
}


#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)


#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```