Analysis of travel planner use, route choice behaviour and passenger predicitions on the Dutch railway

a case of the Nederlandse Spoorwegen

by Lara Witte

TU Delft

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Preface

Dear reader,

With this thesis in cooperation with NS I am ending my Master Transport & Planning of Civil Engineering at the Technical University of Delft. When starting with my Bachelor of Civil Engineering, I had no idea where I would end up. I am incredibly pleased with the massive development I have undergone in my 7 years at the TU Delft. A development which culminated in this graduation project.

First of all, I want to thank my graduation committee of the TU Delft. Marjan, for being the chair of my graduating committee. Niels, for being my daily supervisor. The meetings were always very relaxed and each meeting I had the feeling you understand really well what graduating students are going through. Sander, for you constructive and clear feedback during the meetings and after reading my report. You all motivated me to keep going and keep improving my project.

Furthermore, I want to thank my colleagues at NS. I am grateful for the opportunity to get to know NS. The main person I want to thank is Heleen, for supervising me on a daily basis. We had meetings every week during these past 10 months in which we always had a nice chat and discussed all the details of my project. It sometimes felt as if we were doing this project together, this was a major support for me. Aside from helping me with the content, you taught me a lot about writing technical reports by proofreading my texts. Moreover, I want to thank Niek for being my second supervisor from NS. With your experience you were always able to give really helpful and remarkably positive feedback. Furthermore, I want to thank team Vervoer for including me in the team as a real colleague. I learned a lot during my time at NS.

Lastly, I would like to thank my family and friends and fellow students for their support. We were all mainly working from home so the lunch walks were always a good idea to share our graduating experiences. In special, I want to thank Bart for believing in me and helping me to stay positive. You could always listen to me but also distract me and make me laugh. I want to thank my roommates as well, for the necessary company and distraction during this thesis period mostly in a lockdown situation. I am a real fan of our coffee moments together where we could share our study struggles and achievements while discussing whose turn it is to make the coffee.

Enjoy reading!

Lara Witte
Delft, july 2021

Summary

As a result of population increase and economic growth, public transport is increasingly being used. A positive impact of this increase is the expanded use of an energy-efficient mode compared to car use. However, the downside is trains becoming more crowded. With this increasing number of passengers, the transport service needs to maintain the same level in terms of crowdedness and available travel options. Otherwise, public transport operators will lose passengers because of passengers being dissatisfied. To reassure this level of service, it is essential to predict the passenger count accurately. Predicting passenger ridership and allocation is a challenge for public transport companies. They need to estimate passenger demand beforehand to plan the suitable amount of vehicles. The better the prediction, the more efficient and hence profitable a travel company can operate. With a better prediction, the level of service probably also increases. Passengers often plan their journey using a travel planner. So, the passenger prediction must be aligned with the travel planner and passenger behaviour. Therefore, the main research question to answer in this research is: 'How do train passengers use travel planner route advice and how can these insights be used to improve alignment of the passenger prediction with passenger route choice behaviour?'. The research focus lies on the Dutch railway and Dutch passenger behaviour. It will give the Nederlandse Spoorwegen (NS) practical information concerning their route travel planner and prediction model. Furthermore, this research will contribute to knowledge about route travel advice in public transport and choice route behaviour on rail of different user groups. In the current literature, only little is known about the compliance rate and the influence of route travel advice of prescriptive tools like the travel planner of NS.

For this research, a case study of the NS is used, the travel planner and the prediction model of NS are studied. To answer the research question, a questionnaire to collect data is executed in the passenger panel of NS. In the questionnaire, data about travel planner use and passenger route choice behaviour is collected. Route choice cases are presented to the respondents. A sophisticated selection of routes was needed because only real routes are used to be able to compare the results with the prediction model. Furthermore, the routes should consist of two visible travel options and should involve only one trade-off. Two different trade-offs are selected for this study, the Intercity versus the Sprinter and a transfer options versus a direct train. For the passenger prediction of NS, VISUM is used. VISUM is a program with a distribution procedure to model all the travelling passengers in five steps. It allocates passengers to trains taking the timetable and passenger demand into account. A perceived journey time per route is calculated to determine how attractive the different route options are. The passenger behaviour found in the questionnaire is compared with the passenger distribution of VISUM.

In this research, looking at what influences on route choice behaviour, findings about the choice moment and age are done. The moment a passenger selects a route, the choice moment, is found as an essential factor in choice behaviour. The choice behaviour differs substantially between making the route choice from home and making the route choice from the station. Passengers take the shortest and most comfortable travel option from home, and if passengers are already at the station, they tend to take the first available travel option. For example, on the route Den Haag Centraal - Leiden Centraal, as is visible in figure 1, from home 88% of the respondent would take the Intercity.

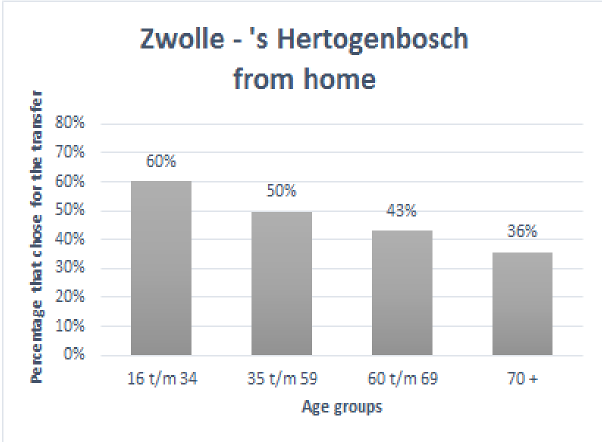


Figure 2: Choice behaviour per age group, Zwolle - 's Hertogenbosch, transfer/direct trade-off

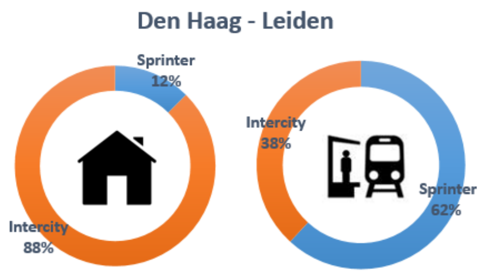


Figure 1: Passenger choice distribution Den Haag Centraal - Leiden Centraal from home(left) and from the station(right)

If the respondents are already at the station and the Sprinter departs first, only 38% of the respondent will wait 9 minutes longer at the station to take the Intercity. This difference in choice behaviour is influenced by the fact that from home passengers can exactly plan their departure and if passengers are already at the station, they take the waiting time at the station into account.

Moving on to the factor age, if the travel time difference is significant, the younger age groups seem more inclined to take the faster travel option when making the route choice from home. In the case of Zwolle - s' Hertogenbosch, the travel time difference between the two travel options is 15 minutes. In this case, as is visible in figure 2, from the youngest age group 60% choose for the transfer. While in the highest age group only 36% choose for the transfer instead of the direct train.
Furthermore, when passengers are already at the station, the younger age groups are inclined to take the first train while the older age groups are waiting for the Intercity or the direct train. For example, at Den Haag Centraal - Leiden Centraal, making the choice from the station, shown in figure 3. From the youngest age group, 71% choose for the Sprinter while from the oldest age group only 31% choose for the Sprinter. The reason for the difference in choice behaviour between age groups is probably to a difference in desire to comfort and travel time. Younger passengers often seem more in a rush, so they want to travel in the fastest way possible and not want to wait at the station. Secondly, their hesitance, so disutility, for making a transfer is probably lower than for older passengers. It is essential to take these influencing aspects on choice behaviour into account when making the passenger prediction. It would be useful to incorporate the choice moment and age influence in passenger allocation models. Especially when there are events or disruptions, the influence of these factors on choice behaviour could be bigger than usual.

When comparing the passenger distributions resulting from the questionnaire with the distributions of VISUM they align properly, the difference runs from 2 - 22 %. So evaluating the allocation of VISUM, no big problems arise and the forecast seems accurate in an average situation. For the Sprinter/Intercity consideration, the fit of VISUM is better than for the transfer/direct train consideration. Furthermore,

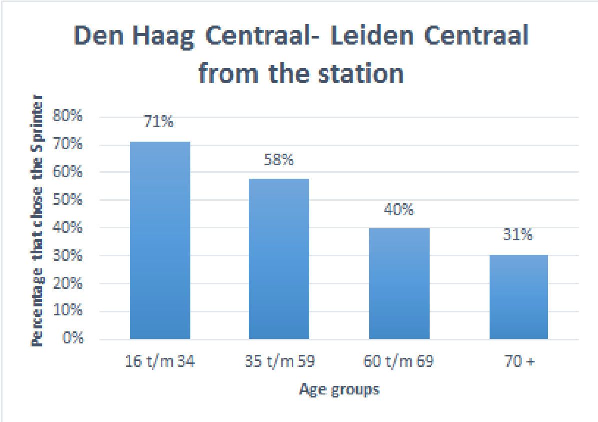


Figure 3: Choice behaviour per age group, Den Haag Centraal - Leiden Centraal with a Sprinter/Intercity trade-off from the station

the combination of waiting time and a possible transfer penalty gives the worst fit. VISUM allocates more passengers to the direct train than is found from the questionnaire. The reason for this can be a too high transfer penalty or a too low waiting time penalty. However, concluding from the other cases, both parameters separately performed well.

Considering travel planner use, 52% answers that they always use the travel planner when travelling by train. If passengers are using the travel planner, the compliance rate is high, 41% always follows one of the adviced routes and 51 % follow more than half of the times an adviced route. Furthermore, from the questionnaire is concluded that passengers have trust in the travel planner and find it a user-friendly tool. This extensive use and trust in the travel planner makes the travel planner of NS a really powerful tool. Which gives opportunities to possibly influence the route choice of passengers.

All together, The most important findings are summarized and visualized in figure 4. Answering the main question, travel planner route advice is used extensively, and most passengers follow the route advice. The passenger predictions of NS are already properly aligned in an average situation. In specific situations as events or disruptions, VISUM is expected to be less accurate due to the influence of choice moment and age. In these situations, passengers are expected to make the choice from the station more often. Considering the good fit in an average situation, no direct measures are needed for NS. However, the prediction can be improved by separately evaluate the different parameters used in VISUM to value the influence of one parameter. Another recommendation is to further research the influence of age and choice moment to make a well-considered decision to incorporate this into the prediction of VISUM or not. When implementing this, the increasing complexity and run time of the model should also be taken into account.

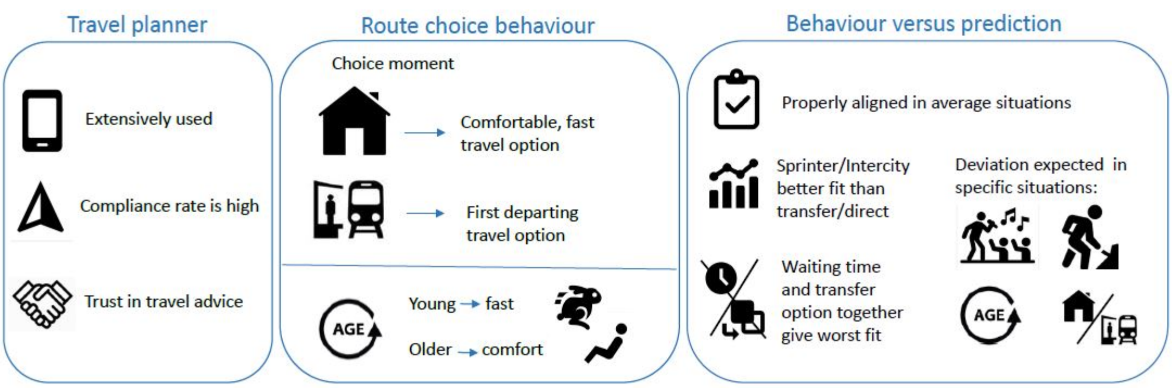


Figure 4: Overview of findings visualised in an infographic

Dutch summary for the Nederlandse Spoorwegen

Door de bevolkingsgroei en de economische groei reizen er steeds meer mensen met de trein. Tussen 2010 en 2018 is de totale reisafstand in Nederland met 14% per jaar gestegen [Ministry of Infrastructure and Water Management, 2019a]. Daarnaast is er meer aandacht voor het milieu wat energy efficiënte vervoersmiddelen zoals de trein steeds interessanter en populairder maakt. Wel kan dit een nadelig effect hebben op de drukte in de treinen. In de huidige situatie met het Covid-19 virus zijn reizigers extra alert op het mijden van drukke situaties. Om te voorkomen dat reizigers ontevreden worden en minder gebruik gaan maken van het openbaar vervoer is het belangrijk dat het serviceniveau wat betreft zitplaatskans en reismogelijkheden naar wens blijft. Om dit zo goed mogelijk te doen is het belangrijk om nauwkeurige prognoses te maken van het aantal verwachte reizigers. Hoe beter deze voorspelling is, hoe efficiënter een vervoerder materieel kan inzetten wat de klanttevredenheid waarschijnlijk positief zal beinvloeden. Reizigers plannen hun reis vaak in de reisplanner. Het is belangrijk dat dit advies en het keuzegedrag aan de hand van dit advies overeenkomt met de voorspellingen. Daarom is het hoofddoel van dit onderzoek om reizigersgedrag aan de hand van de reisplanner te analyseren en te vergelijken met de reizigersvoorspellingen van NS. Dit onderzoek is gefocust op het Nederlandse spoornetwerk en is uitgevoerd in samenwerking met de Nederlandse Spoorwegen (NS).

Om de hoofdvraag te kunnen beantwoorden is er een enquête uitgevoerd in het reizigerspanel van NS. Hiermee is er informatie over reisplannergebruik en routekeuzegedrag verzameld. In een deel van de vragen is er een routekeuze voorgelegd waarbij de respondenten moeten kiezen welke route ze zouden nemen. Er zijn twee verschillende afwegingen voorgelegd, een Sprinter/Intercity afweging en een overstap/directe trein afweging. De gevonden resultaten wat betreft de reizgersverdeling over de verschillende reisopties zijn vergeleken met de prognoses van NS. NS maakt een voorspelling waarin de reiziger worden verdeeld over de verschillende reisopties. Hiervoor wordt de dienstregeling en het aantal verwachte reizigers per herkomst-bestemming relatie gebruikt. Daarnaast wordt er per reisoptie een ervaren reistijd berekend aan de hand van reistijd, wachttijd en een mogelijke overstap.

De twee meest opvallende factoren van invloed op het keuzegedrag die naar boven komen in dit onderzoek zijn keuzemoment en leeftijd. Het moment dat een passagier een reis selecteert, het keuzemoment, is van grote invloed op het keuzegedrag. In de enquête is dit opgesplitst in twee verschillende locaties, vanuit huis en vanaf het station. Vanuit huis kiezen de meeste passagiers de kortste en meest comfortabele route. Daarentegen, als passagiers al op het station staan nemen ze de eerstvolgende reisoptie. Bijvoorbeeld op het traject Den Haag Centraal - Leiden Centraal, wat zichtbaar is in figuur 5. Vanuit huis neemt 88% de Intercity en vanaf het station als de Sprinter eerst vertrekt neemt nog maar 38% de Intercity. Dit verschil wordt waarschijnlijk veroorzaakt doordat passagiers vanuit huis precies hun vertrek kunnen plannen en ze dus niet hoeven te wachten. Als passagiers al op het station staan speelt de wachttijd op het station een grote rol. De andere opvallende factor is leeftijd, de passagiers van de jongere leeftijdsgroepen kiezen vaker voor de snelste reisoptie al zit daar bijvoorbeeld een overstap in. In figuur6 is het percentage dat voor de overstap kiest per leeftijdsgroep op het traject Zwolle - s' Hertogenbosch te zien. Op dit traject is de reisoptie met de overstap 15 minuten sneller. Wachttijd speelt geen rol want beide reisopties vertrekken tegelijk. Van de jongste leeftijdsgroep kiest 60% voor de kortste reisoptie met een overstap terwijl van de oudste leeftijdsgroep maar 36% voor deze optie kiest. Als de reistijden van de reisopties vergelijkbaar zijn maken de leeftijdsgroepen nagenoeg dezelfde keuzes behalve als de reizigers al op het station staan. Bijvoorbeeld op de route Den Haag Centraal - Leiden Centraal, als passagiers al op het station staan, kiezen de jongere leeftijdsgroepen vaker voor de eerstvolgende reisoptie, zie figuur 7. De jongere leeftijdsgroepen willen blijkbaar zo kort mogelijk op het station wachten en zo snel mogelijk bij hun bestemming aankomen. Waarschijnlijk komt dit doordat jongere reizigers een hogere waarde voor tijd hebben dan oudere reizigers. Daarnaast hebben ze aan-

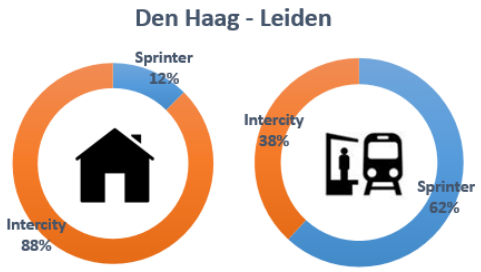


Figure 5: Keuze verdeling Den Haag Centraal - Leiden Centraal vanuit huis en vanaf het station

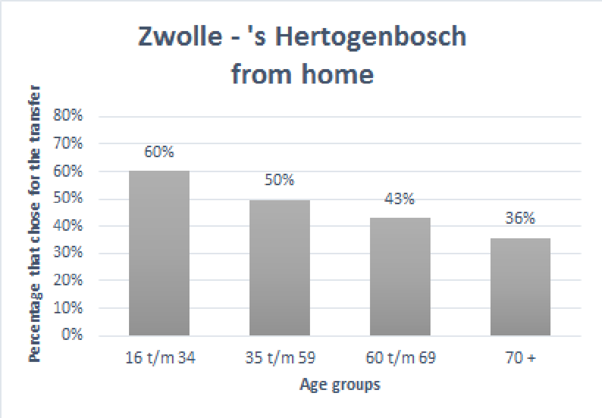


Figure 6: Keuzegedrag per leeftijdsgroep, Zwolle - ’s Hertogenbosch, overstap/direct afweging

nemelijk een lagere overstapweerstand omdat een overstap maken hen relatief gemakkelijk af gaat. Het is belangrijk om dit verschil in keuzegedrag wat betreft keuzemoment en leeftijd mee te nemen in de voorspellingen.

Naast het analyseren van het keuzegedrag zijn de uitkomsten van de enquête ook vergeleken met de voorspellingen van NS. Deze twee reizigersverdelingen over de twee verschillende reisopties komen goed overeen in een gemiddelde situatie. Wel geeft de voorspelling van NS voor de Sprinter/Intercity overweging een betere schatting van de reizigersverdeling dan in de overstap/direct overweging. De combinatie tussen een optionele overstap en wachttijd op het station geeft de minste overeenkomst tussen de voorspelling en het gevonden keuzegedrag. In die situatie worden in de voorspellingen meer passagiers aan de directe trein toegedeeld dan in de uitkomst van de enquête is gevonden. De reden hiervoor kan een te hoge overstapweerstand of een te lage weerstand voor wachttijd zijn. Echter geven de parameters los van elkaar wel een goede voorspelling. Om dit nader te kunnen verklaren is er meer onderzoek nodig.

Wat betreft het reisplanner gebruik, 52% van de respondenten geeft aan dat ze altijd de reisplanner gebruiken als ze een treinreis maken. De respondenten die de reisplanner niet gebruiken geven in de meeste gevallen aan dat dit komt doordat ze gebruik maken van 9292OV uit gewoonte. De meeste reizigers volgen vaak een van de geadviseerde routes, 41% volgt altijd een van de aangegeven reisopties en 51% volgt meestal een van de aangegeven reisopties. Op het moment dat reizigers aangeven het advies niet te volgen komt dit in een deel van de gevallen doordat ze op een snellere manier met de trein op de bestemming kunnen komen door bijvoorbeeld een kortere overstap. Uit de enquête resultaten is ook gebleken dat reizigers de reisplanner vertrouwen en gebruiksvriendelijk vinden. Dit uitgebreide gebruik en vertrouwen maakt de reisplanner een waardevol instrument wat in de toekomst misschien mogelijkheden geeft om reizigers te sturen in hun routekeuze.

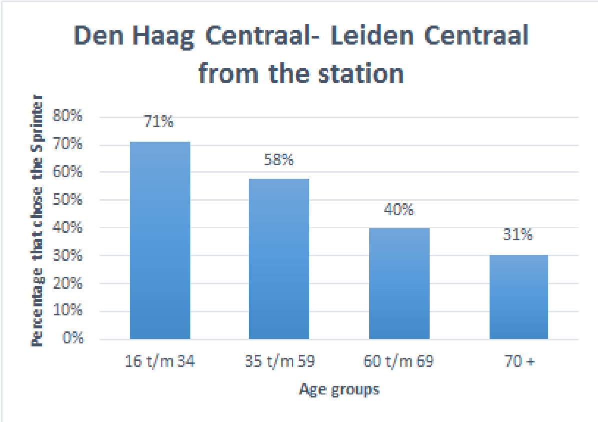
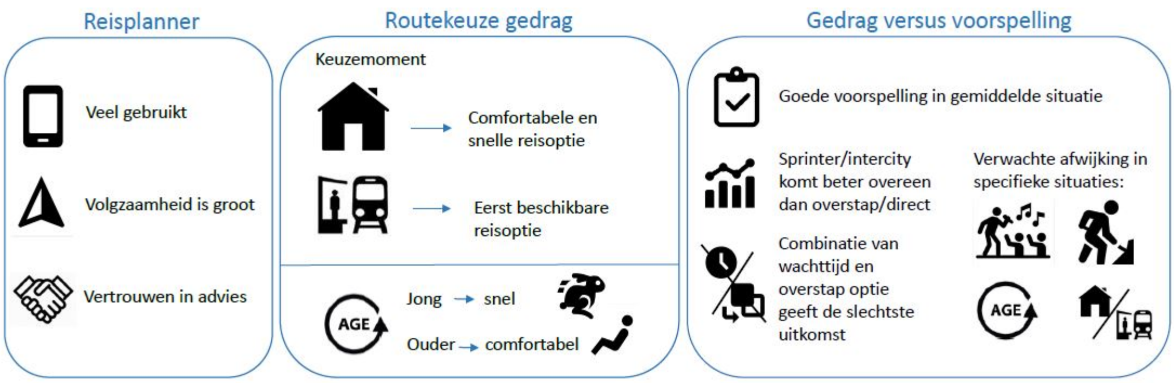


Figure 7: Keuzegedrag per leeftijdsgroep, Den Haag Centraal - Leiden Centraal, Sprinter/Intercity afweging vanaf het staion

Uit dit alles blijkt dat NS goede prognoses maakt voor een gemiddelde situatie wat betreft reizigers verdeling over de reisopties. Dit kan nog verbeterd worden door verschillende parameters gescheiden te analyseren en zo nodig te corrigeren. Daarnaast is het waardevol om de invloed van het routekeuze-moment en de leeftijd te mee te nemen in de voorspellingen. Dit zal de meeste invloed hebben in bijzondere situaties, bijvoorbeeld gedurende een evenement of tijdens een verstoring. Vooral in het geval van evenementen waar veel jonge mensen aanwezig zijn en alle reizigers hun routekeuze vanaf het station maken kan het keuzegedrag erg afwijken van een gemiddelde situatie. Echter moeten de nadelen van een groter en complexer model worden afgewogen tegen de voordelen in de voorspelling.



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1 Introduction

The use of public transport has significantly increased over the years. For example, in the Netherlands, the total distance travelled each year increased by 14 % between 2010 and 2018 [Ministry of Infrastructure and Water Management, 2019a]. Different factors play a role in this increase. First of all, population growth has a direct impact. Secondly, economic development increases the need for people to travel for work or recreational purposes, the quality of public transport has improved, making traveling by train easier. The positive aspect of this increase is that public transport is the most energy-efficient way of passenger transport. However, the number of car trips are not directly decreasing when more train trips are made. Nevertheless, public transport gives travellers an opportunity for a sustainable way of travelling because travelling by train instead of car cuts emissions by 80% for medium-length trips [Ritchie, 2020].

The downside of this increase in public transport use is that the crowding in the train increases. Especially trains during peak hours are often overcrowded, transport experts call this ''hyperspits''. This ''hyperspits'' is a short period within the peak hour in which double the number of people are entering the train compared to the start or end of the peak hour [Daalen et al., 2017]. The government of the Netherlands, Ministry of Infrastructure and Water, foresees growth of 30 to 40 percent in public transport use at the latest by 2040 [Ministry of Infrastructure and Water Management, 2019b]. This growth makes it essential to predict the passenger demand accurately. Predictions are beneficial if they could help determine the sufficient and cost-efficient amounts of rolling stock. In this way, the transport service does not decrease with an increasing amount of passengers. Prediction models use historical passenger data to estimate the passenger amount a year to a few weeks beforehand for the material deployment to be adapted to the expected number of passengers. With a passenger assignment algorithm, the forecast model assigns the expected passengers from origin to destination to the designated vehicles to analyse the crowdedness in vehicles.

When passengers are traveling by public transport, they often use a travel planner to plan their journey. A travel planner gives different travel options from origin to destination and can be found on a website or an application on your mobile phone. There are various travel planners available in the Netherlands. For example, Google maps has a planner option in which different modes are shown. The planner of 9292OV and the travel planner of NS give an overview of all the public transport travel options. This research focuses on the travel planner of NS. On an average day, NS' travel planner gets approximately 1.5 to 3 million requests between 6:00 and 23:00 (NS-app team). However, before the passenger looks up his or her journey, the public transport company already had to determine its schedule and rolling stock. This represents a problem for the public transport companies, which will be discussed in more detail in the next section, after which research questions regarding this problem are formulated and the way in which these questions are answered is outlined.

1.1. Problem statement

As described earlier, public transport passenger forecasts are getting more important, this represents a big challenge for public transport companies. They are estimating passenger demand beforehand to determine the suitable rolling stock. So they want to be able to predict passenger's route choice behaviour. The better this prediction, the more efficient and hence profitable a travel company can be. Furthermore, a good prediction will give the best level of service for the passengers. If the demand and the supply do not match, the rolling stock will not fit the passenger demand. Too much rolling stock will be costly for a company and too little rolling stock will make passengers dissatisfied. Currently, the travel planner of NS in which a lot of passengers plan their train journey is not aligned with the forecast model. Both models have their algorithms and are not developed together. The advice of a travel planner is not adjusted to the forecast of that moment. The better the prediction and the advice match, the more passengers are satisfied and the more efficient NS can operate. If more information about the passenger choice process and the impact of a travel planner is known, this would be very helpful to make a more accurate passenger's behaviour prediction. To achieve this, knowledge and understanding of passenger route choice behaviour on rail is needed. Therefore, this study investigates passenger route choice behaviour on the Dutch railway with respect to a travel planner. Their is a lack of literature that specifically focuses on travel planners and the influence of this on passenger choice behaviour. Furthermore, little is known about the compliance rate of route travel advice.

1.2. Research questions

Considering the described problem, this research aims to develop new insights to inform the Dutch railways on possible improvements of the travel planner and passenger prediction. The research focus lies on the Dutch railway and Dutch passenger behaviour. It will give practical information to NS concerning their route travel planner and prediction model. Furthermore, this research will contribute to knowledge about route travel advice in public transport and choice behaviour on rail of different user groups. The questions and sub-questions are formulated as follows:

'How do train passengers use travel planner route advice and how can these insights be used to improve alignment of the passenger prediction with passenger route choice behaviour?'

1. Which train passengers are using route advice?
2. Do passengers follow route advice?
3. How does the prediction model of NS assigns passengers to trains?
4. Which route choices do passengers make using the travel planner of NS?
5. To what extent does the passenger assignment algorithm of NS match the route choices passengers are making?

1.3. Research design

To answer the previously formulated research questions, NS is used as a case study. First, a literature review is performed in which information on route choice behaviour of travellers and travel advice is gathered. Then, a questionnaire is designed to collect information about the use of the travel planner and the route choice behaviour of passengers. The use of travel advice, together with the user groups and willingness to follow the travel planner, will give new insights into the influence of NS's travel planner. Furthermore, the route choices of the passengers are researched with a stated choice experiment in the questionnaire. With this information, a view on passenger route choice behaviour is gained. The passenger assignment algorithm of NS will be compared with the outcome of this experiment to see how the route choice behaviour match the passenger allocation of the forecast. Knowing this, the passenger assignment algorithm and travel planner can be further analysed to see where they can be improved to align them with passenger route choice behaviour. In figure 1.1 a schematisation of the research design is given. The way the different steps of the research are connected to the chapters in this report is shown. First, the methods used in the study are described. Secondly, a literature review is executed, after which the case study of NS is explained and the questionnaire design is described. Then, the collected data is analysed in chapter six en seven. At last, in chapter eight, the conclusions and recommendation are described.

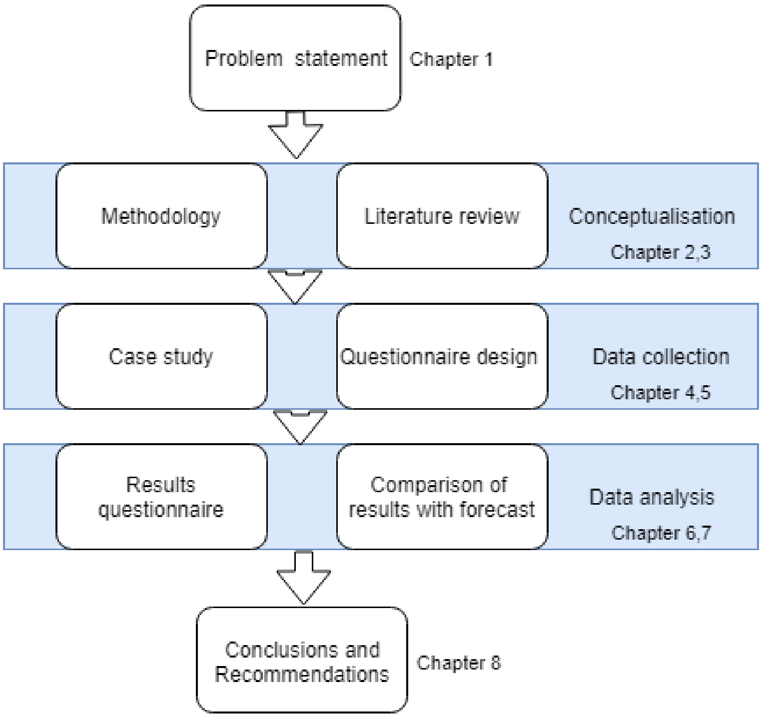

Figure 1.1: Schematisation of research design

2
Methodology

In executing this research, a case study of NS is used, the travel planner and the prediction model of NS are researched. The travel planner of NS is analysed and used in a questionnaire to learn more about the use and view of passengers on the travel planner. Also, different travel options to travel from origin to destination are presented in the questionnaire, participants are asked to indicate which route option they would take. The found choice behaviour is compared with the passenger allocation of the assignment algorithm of NS. In this chapter, the different methods used in this research are presented. In table 2.1, an overview of the sub-questions and the method used to answer this sub-question is shown. The motivations for the use of the different methods named in the table is described in the sections below. The sections are split up in a literature, data collection part and a data analysis part.

Table 2.1: Research method per sub-question

Sub-question	**Research method**
1. Which train passengers are using route advice?	Literature research Questionnaire
2. Do passengers follow route advice?	Literature research Questionnaire
3. How does the prediction model of NS assigns passengers to trains?	Research into the NS prediction model
4. Which route choices do passengers make using the travel planner of NS?	Stated choice part of the questionnaire
5. To what extent does the passenger assignment algorithm of NS match the route choices passengers are making?	Visual comparison with bar graphs Statistical analysis: chi-square test

2.1. Literature research

A literature review is executed to answer part of the sub-questions and find research gaps. The first and second research questions are in first instance researched in a literature review to determine what is already known about using route advice and the compliance rate of travel information. This literature research forms the basis for assumptions further in the study. Moreover, with this information expectation on the questionnaire results can be made. Furthermore, influencing aspects on choice behaviour can be further analysed and added to the questionnaire to either confirm or deny the finding.

2.2. Data collection

The data used for this research will be collected using the prediction model of NS and executing a questionnaire among train passengers. A questionnaire is chosen because the influence of the travel planner can not be identified using for example in- an out check data. It is important to ask passengers to make a route choice using the travel planner. This is done in the questionnaire by showing the passengers two travel options in travel planner format and ask them to choose a route. Furthermore, the travel planner use and trust in the travel planner is also important to take into account to see how passengers are using this tool. These aspects are also easily asked in a questionnaire.

In collecting the data the timetable and the prediction of November 2019 are used to overcome the changes in the timetable because of Covid-19. A travel planner test environment is used to come to the travel advice of November 2019. The timetable is also loaded into the prediction model of NS to simulate the prediction of November 2019. Another reason for using the data of November 2019 is that this gives the possibility to in future research compare the found results with the realisation of November 2019, which is the last normal month before Covid-19.

2.2.1. NS panel

The questionnaire is executed in the NS panel, NS has 80.000 panel members, at which NS can send out a questionnaire once a month. The panel consists of different kind of travellers, every traveller can join the panel if they want to. The questionnaires are always sent out to an NS representative group, so all types of travellers and all age groups are represented as they are in the whole passenger population. The questions are programmed in the standard NS questionnaire layout, NS uses a research platform called MWM2. MWM2 is an abbreviation of 'Meer Weten van Mensen en Markten', which can be translated as 'know more about people and markets'. In MWM2, the questions are programmed, the invitation is sent out to the selected panel members and the result can be downloaded. The NS panel's advantage is that the respondents' personal data is already known, so this does not have to be asked in the questionnaire, which leaves more room for substantive questions. To the respondent is communicated that Covid-19 is not involved, so they should answer as if Covid-19 is not existing. The duration of the questionnaire is around 10 minutes.

2.2.2. Questionnaire

In the questionnaire, passengers are asked about their travel planner use and a stated preference part with route choice cases is incorporated. Passengers are asked how often they use the travel planner and if they are following the travel advice. Furthermore, three statements about trust, user ease and user friendliness are shown. Respondent can indicate on which level they agree or disagree with the statement. The second part of the questionnaire consist of a stated choice part in which route choice cases are shown. In the route choice cases, the respondents are asked to choose which travel option they would take when travelling at the shown route. Different routes on which there is a route choice trade-off are selected.

Sub-question one, two and four are answered with the result of the questionnaire. The collected data is downloaded in Excel from MWM2. Every row represents one respondent and in the columns the answers to the questions are stored. A data management plan is made and approved by the ethical commission of the TU Delft to make sure the privacy of all the respondent is guaranteed.

2.2.3. Stated preference experiment

The route choice questions are asked in a stated preference format. There are different stated preference techniques. In this section, the different and used techniques are discussed. The two versions of stated preference methods are, contingent valuation (CV) and Multi-Attribute Valuation (MAV)[Merino-Castello, 2011]. Since making a route choice consists of more than one attribute, the MAV is used. The MAV has the advantage that it could look at more than two alternatives simultaneously, which makes it more efficient than the CV if more than two attributes are involved. Furthermore, the multi-attribute design reduces severe multicollinearity problems and response difficulties. The analyst can assume that all attributes offered in a choice experiment are relevant. In addition, the analyst assumes that the respondent has complete familiarity with the alternatives. The analyst needs to make sure that this is the case[Hensher, 2015]. There are two different types of MAV, preference-based approach and choice-based approaches. The first one asks the participant to rate or rank the alternatives and in the second one respondents are asked to select one [Merino-Castello, 2011]. Since choice-based is a more realistic task for respondent in making a route choice this method is chosen.

2.2.4. Prediction model of NS

The distribution of passenger allocation of the prediction model VISUM of NS is analysed. The timetable of November 2019 is used to come to the passenger allocation of November 2019. The passenger distribution over the used routes is executed from VISUM. This distribution is compared with the questionnaire results, as is asked in sub-question five. In chapter 5, research into the passenger allocation of the passengers assignment algorithm of VISUM is executed, sub-question three is answered with this information.

2.3. Data analysis

After the data collection, the data needs to be checked for missing data and if it correctly represents the traveller population of NS. The data are analysed in Excel. If some user groups or age categories are not fully represented a weight factor is used to make the sample representative to the train traveller population. In 2019, NS did a research in which they determined the dimensions and composition of their train passenger population [NS, 2019]. This is a research that is executed once every 5 years. In this research the composition of age groups and travel purpose of the passenger population of NS is determined. Furthermore, the composition of passengers in an average train is determined. Both compositions are used in this research. With this knowledge, the dataset is made representative to the passenger population of NS to analyse the travel planner use. Furthermore, the composition of passengers in an average train is used in analysing the result of the choice distribution of the stated preference experiment. To answer sub-question five, first, the comparison between the passenger distribution of the prediction model and the results of the stated preference experiment is made visually where after a Chi-Square test is executed and a choice model is estimated. The distribution of the prediction and the stated choice experiment are plotted next to each other in a bar chart to visually see the difference. A Chi-square test is used to see the relative difference and test the goodness of fit in a numerical way. The choice model estimation is done to see if the resulting data from the questionnaire gives a realistic values for predicting route choice behaviour.

2.3.1. Chi-square test

After the visual comparison of the passenger distributions over the travel options, a numerical comparison is executed. The collected data is nominal and two outcomes are compared with each other. So, a Chi-square goodness of fit test is used to compare the predicted passenger distribution, the expected outcome, with the observed outcome from the questionnaire. With this test, the relative difference between the expected and observed amount of passengers is tested. The null hypothesis is that the expected results are equal to the observed results. The X^2 per route is calculated to test this hypothesis.

$$X^2 = \sum (O - E)^2 / E$$

Respondents have on degree of freedom in choosing a travel option because they are asked to chose between two travel options. A probability level of 0.05 is used so the null hypothesis cannot be rejected if X^2 is smaller than or equal to 3.841. The outcomes of this test are compared to the visual comparison findings to see if the same results are visible.

2.3.2. Choice model estimation

Next to analysing the result of the data, predictive power of the data is also tested. However, this is not the main goal of the research, it is still executed to see if the results using the questionnaire data are logical. With the choice model estimation the willingness to pay for an intercity in minutes is calculated. Furthermore, the transfer resistance is calculated to see if this resistance match the transfer penalty of VISUM. Since the data is collected using only real trajectories, possibly the data is not ideal for estimating a choice model. However, an attempt is made to estimate a choice model using Biogeme. The input of Biogeme is a dataset with the difference choices and the programmed utility functions. Utility functions for different situations are made including the travel time, waiting time, train type and the possibility of a transfer. For example, the utility function of the Sprinter/Intercity consideration is shown.

$$UtilityAlternativen = \beta_{time} * TravelTime_{alternativen} + \beta_{sprinter} * traintype_{alternativen}$$

The dataset consist of the travel time, waiting time, train type and transfer possibility of the two different route options together with the choice a passenger made. Every row represents one respondent, in the first columns the data of the two options are stored and in the last column the choice this respondent make is stored. With this information Biogeme estimates the impact and so the value of the different $beta$ parameters. The $beta$ values represents the positive or negative impact of the variable on the utility of a travel option.

3 Literature review

In this chapter, an overview of current knowledge about passenger route choice behaviour in public transport is given. Furthermore, information provision to travelers is researched. The goal of this literature research is to create an overview of travellers' behaviour using travel information. Also, the first two sub-questions are partly answered with the information gathered in this literature review. The first two sub-questions are:

1. Which train passengers are using route advice?
2. Do passengers follow route advice?

To answer these questions, this chapter consists of eight parts, the first section is about the search strategy. The second covers travel choice strategies of passengers, the third is about different information provision ways following by elaboration on how travelers use travel information. The fifth section is about how to influence travellers choices with travel advice. Then the route choice factors and passenger characteristics that could influence route choice are discussed. In the last part the findings are discussed and conclusions are drawn.

3.1. Search strategy

The information for this chapter is collected via different sources. The search engines Google Scholar and Scopes are used to find literature. The following search terms are used as a starting point on this literature research:

’public transport’ AND ’travel planner’ OR ’route information’ OR ’pre-travel information’

Variations on the composition of these search terms are made to search the whole field. Furthermore, sometimes the term ’literature review’ was also added to found literature overviews of this knowledge field. New relevant papers were also found in references of papers found in the search. Papers are mainly selected on their title, keywords and published year. Furthermore, a couple of publications of NS are used, as well as some master thesis reports of other students to find relevant sources in a faster way.

3.2. Travellers route choice strategy

Travel choice behaviour has become interesting since forecasting travellers is seen as a crucial element in planning and managing transport systems [Avineri, 2009]. In most researches is assumed that individual travellers are ’homo economicus’, they always maximize their utility. Nevertheless, other studies say that travellers are typified by bounded rationality, ’homo psychologicus’. However, the limited cognitive resources of travellers have a forceful effect on travel choice behaviour and it is hard to predict how much information different travellers collect. If choices cannot be explained, cognitive psychological models can be used to make a prediction [Avineri, 2009].

As mentioned, the individual perspective of utility maximization is often used. It is called utility maximisation if travellers are rational in their choices, which means exploring every alternative and choosing the alternative with the highest pay-off against the lowest costs [Dicke-ogenia, 2012]. This implies that all route options perform differently on certain attributes. These attributes and scores together are making the utility function to 'calculate' which option gives the highest utility to an individual. However, there are a lot of influencing factors in determining this utility. To cope with individual random errors, random utility theory adds a stochastic error term to the utility function [van Essen et al., 2016]. Next to individual random errors, individuals are limited to the knowledge that they have available. Furthermore, passengers often choose what they like and support these choices by rational considerations. Due to limited available knowledge and emotional influences, biases arise in people's choice behaviour. Besides, individuals also simplify decisions, they go for a satisfactory solution instead of an optimal solution. This satisfactory solution is often a habitual manner route choice, travellers repeat a route that provided the most positive experiences in the past [van Essen et al., 2016]. This finding is confirmed by the statement of Hensher [2015]: 'individuals could be described as creatures of habit with a tendency to rather follow instead of lead'. This lead to herding behaviour in making a route choice, travellers will be doing what others are doing rather than using their information. The research of Grotenhuis et al. [2007] also states that habitual behaviour makes people less stressed and makes them use their time and cognitive capacity effectively. However, nudging behaviour can help to overcome a cognitive bias by highlighting better choices and increase the effect of behavioural change without restricting choices [Hensher, 2015]. As a result, sometimes options that conflict with a travellers objective are chosen. Concluding, individuals maximize their profit in determining a travel route but are influenced by knowledge availability, emotional influences, simplification and habit.

If all individuals want to use the same low-cost option these options could get congested. Spreading individuals over the options can reduce or prevent congestion on the network. To achieve this, individuals need to behave socially [van Essen et al., 2016]. Actual choice behaviour is often based on an individual degree of rationality and degree of selfishness. Nowadays, the travel advice aims at individual benefit. To achieve a system-optimal network state, were the system is used in the most efficient way, part of the travelers need to act non selfish. This means these individuals choose a route that is not optimal for themselves but it is optimal for the system. They sacrifice some of their own profit to contribute to an optimal use of the system. There are some system beneficial information strategies to create a system-beneficial travel information. However, empirical findings on these methods does not exist yet [van Essen et al., 2016]. For this system personalized travel information is needed in order to assign each individual to a route alternative matching their level of rationality and selfishness.

3.3. Travel advice characteristics

Travel information has changed over the years, it has transferred from analog information from the newspaper or television to advanced traveller information systems (ATIS) [van Essen et al., 2016]. With these systems, information is provided to everyone without any lag. Travel information consists of a lot of different aspects. Overall, for all different kind of travellers is concluded that the most effective travel advice is an advice that is prescriptive, predictive, qualitative and gives real time delay [van Essen et al., 2016]. However the information needs to stay simple because travellers want information that makes the travelling easier instead of types that facilitate advanced search options. Only the basic information as travel time and cost are wanted because the traveller wants to minimize the non monetary costs, which are the cost of thinking[Chorus, 2007].

This upcoming information technology is a chance to make the use of transportation more efficient due to the design of persuasive information systems that could motivate travellers to make a cooperative and efficient choice[Ben-Elia and Avineri, 2015]. In the literature review of Ben-Elia and Avineri [2015] three different kind of information types are distinguished: experimental information, descriptive information and prescriptive information. Experimental information (EI) is information gathered from own experience, out of previous choice experiences. Travel information will help travellers in the short term to learn through EI. However, as long as travelers are satisfied with their current habitual route their sensitivity to information decreases [Ben-Elia and Avineri, 2015][van Essen et al., 2016]. Thus, non-frequent travellers are more in need of travel information in comparison with frequent users[Grotenhuis et al., 2007]. Descriptive information (DI) gives a view on the current travel conditions for example travel or departure time. Prescriptive information (PI) gives guidance to travel from A to B with recommended alternatives. The hard part of PI is that relatively little is known about the compliance rate of the advice, although there are a lot of applications providing this information. From a mixed logit model estimation of Ben-elia and Pace [2012] is concluded that PI has the largest effect on route choice, so the suggested routes are more likely to be chosen. However, perceived unreliability has a negative effect on the compliance rate [Chorus et al., 2009] [Ben-elia and Pace, 2012]. Reducing the reliability will shift choices towards risk aversion. All together, prescriptive information is the information type with the most effect but the compliance rate of the advice is not known. However reliability has a substantial impact on the compliance rate.

In the research of Hagen [2003] the translation from customer wishes to measures are studied. The core needs of passengers are control, appreciation, and freedom. A good operating route planner can add value to the core need control. The design principles of the core need control are offering help, predictability of the journey, and accessibility of the journey. The route planner helps the passengers to plan and predict their journey.

Travel information adds quality to public transport. The main effects of good travel information are time savings, effort savings and collecting certainty [Grotenhuis et al., 2007] [Zhang and Levinson, 2008]. Information about a trip can be gathered before or during the trip. In this literature research the focus lies on the pre-trip information. Gathering information pre-trip, before departure, is the most popular stage to collect the information. With having access to pre-travel information passengers are able to optimize their waiting time. Especially for long trips with low frequencies this makes a significant difference [Berggren et al., 2019]. Similarly, from an earlier research of Farag and Lyons [2008] it is concluded that most of the time people are consulting public transport information before their trip, unless there are no time constraints, the service runs frequently or the journey is local. Most users have their standard source which they are used to and will always use. Nevertheless, there are also some negative effects of travel information. For example, it could lead to oversaturation, overreaction and concentration of passengers, although personalized information can overcome these effects [van Essen et al., 2016]. If there is too much information, travellers can also suffer from information overload so they start ignoring it to make lower cognitive efforts. However, information strategies are designed to overcome information overload and still have an impact on habitual decision makers who are hard to influence. Designers of travel information must find a balance in providing as much useful information as possible and minimizing the risk of information overload [Dicke-ogenia, 2012].

From a web survey of Chorus [2007] a positive relationship between destination familiarity and perceived resourcefulness is found. Knowing the destination has more impact on the resourcefulness than the level of experience with a given mode. Furthermore, familiarity of the destination also has an impact on the perceived reliability. If incidental circumstances appear, which are impacting the travel time, this causes a more negative impact than recurrent circumstances as for example peak hour. So, this gives away that meeting expectations is really important considering travel time.

3.4. Passengers usage of travel information

From the research of Yeboah et al. [2019], in a British urban environment, it is concluded that there is a significant difference in pre-travel use between passengers that are making less than one trip a week and travellers that are making five or more trips a week. The chance of looking for pre-travel information is 2.5 times higher for the passengers that use public transport less than once a week. The research of Farag and Lyons [2012] also shows that people are mostly using public transport information for infrequent and unfamiliar trips. Moreover, arrival time-sensitive trips are found as a trip for which passengers obtain pre-trip public transport information. According to the trip purpose, respondents consult information more often when making a business trip in comparison with a leisure trip. This is related to the time-sensitivity of a business trip. Another factor that has influence the pre-trip public transport use are socio-demographics as gender, age, education, income and internet access. Females as well as highly educated people and persons that have access to internet more often use pre-trip public transport information. Furthermore, for unfamiliar or long trips males compare car less often with public transport option. In short, the factors most affecting the use of the travel planner according to the research of Farag and Lyons [2012] are travel behaviour and socio-demographics.

The research of Berggren et al. [2019] came to four aspects that increase the use of pre-planning. Again, it is established that pre-planning is used more among infrequent public transport travellers. The three other aspects that increase the use of pre-planning Berggren et al. [2019] found are: travellers that make long trips, trips in urban areas, and trips with a reliable first public transport leg. However, from the research of Mulley Mulley et al. [2017] it is concluded that regular users are more aware and use the application more often. Although the route planner application is the most frequently used source and is the main element that influence traveller satisfaction, infrequent users are also influenced by the printed timetable leaflets while frequent users also use government and operators websites. Overall pre-trip public transport information is mostly used by infrequent trips but socio-demographics and the length of the trip also play a role.

3.5. The influence of travel advice on people's travel behaviour

There are different ways in which travel behaviour can be influenced. The behavioural change approach is an approach that could be a cost effective method in comparison with an infrastructural change [Dicke-ogenia et al., 2011]. Dicke-ogenia [2012] researched the psychological aspects of travel information presentation in car traffic. Although this research is not about public transport specific, the psychological principles of information processing are still relevant because this could work the same way. The different processing steps of McGuire [1972] are used in this study. The information processing steps are: presentation of the information (1), attention to the information (2), comprehension of arguments and position the information advocates (3), yielding to the message contents and its conclusions (4), retention of the changed attitude (5), behaviour based on the changed attitude (6). Some psychological principles that may have an effect on the information process steps are: habit, the elaboration likelihood model and attitudes [Dicke-ogenia, 2012]. In the following alinea is elaborated on this three different principles.

Firstly, Dicke-ogenia [2012] confirms the finding described in 3.2, habit has a lot of influence on route choice. Even without the person's awareness this behaviour may be activated. If a journey is performed successfully and satisfactorily it is likely that the route taken will become a habit. With a continuously changing infrastructure a habit route could become no longer the most efficient route. If travellers have a strong habit they acquire less information than other travellers. A strategy to change this is making a travellers habit impossible by changing the circumstances [Jager, 2003]. Another possibility is to confront habitual travelers with the negative outcomes of a route choice. Nevertheless, the ignorance of travel information stays a problem. The second psychological principle that could have effect on the information processing steps is elaboration likelihood model. The elaboration likelihood model is the way to which extent a person thinks about the issue-relevant arguments contained in a message before making a route choice. Sometimes, the traveller does not have sufficient time to process information so a consideration is not totally executed. If the elaboration is made, the message will be accepted which will lead to a change in attitude and behaviour. The last psychological principle that could have influence is attitude. Attitude is a way in which people have learned to respond in a consistently favourable or unfavourable manner [Dicke-ogenia, 2012].

The effect of behavioural change is dependent on the effect of travel information. The aspects that are of influence are the size of the target group, attitude towards the alternatives, feelings of uncertainty as a result of unclear information and the willingness to change plans during the on-trip stage[Dicke-ogenia, 2012].

All together, psychological strategies seems a possibility to steer passengers instead of only changing infrastructure. So, travel information via travel planner can play a role in this. An important factor to take into account in doing this is that habit, the elaboration likelihood model and attitudes could have an influence on the processing of travel information.

3.6. Route choice factors

In this section, attributes affecting a route choice are discussed. In the research of Mulley et al. [2017], a trip is separated into hard factors and soft factors. The hard factors are travel time, frequency, and fare. The soft factors are quality of access, information, waiting experience, and in-vehicle experience. The soft factors are not easy to measure but are proved to be all relevant. Also, there can be a gap between perception and facts, which can affect the way in which the provision of information is given in the right format. From the research of van Hagen and van Oort [2019] is stated that people are choosing the options of the least resistance which means the cheapest, fastest and most reliable way to travel. All public transport services want to give passengers a relaxing and pleasant journey. This is translated in level of service and perceived quality or comfort. The research of Guis and Nijënstein [2015] confirms that the three most important factors that determine the attractiveness of a journey are the travel time, necessity and difficulty of a transfer (transfer resistance) and lastly the departure time of the train (frequency). Below, the different attributes concerning a route choice for a train journey are presented.

3.6.1. Time

The travel time is one of the most important aspects of the route choice, passengers want to optimize their route and will always start by looking at the travel time. The travel time can be split up in waiting time, in-vehicle time and transfer time. The waiting time is the time that the passenger needs to wait from the moment the passenger wants to depart until the train leaves, which is dependent on the frequency of the train. The in-vehicle time is the time spend inside the vehicle and the transfer time is the time it takes to switch to another vehicle. The waiting time (on a transfer station) is experienced more negatively than in-vehicle time [Keizer, 2013].

3.6.2. Transfer

When passengers need to transfer in their public transport journey from one train to another they experience a discomfort. This discomfort is also named transfer resistance or transfer penalty. This value depends on the ease of the transfer. The transfer penalty can differ per station en person, because transfer stations and transfer ease are perceived very differently by passengers [Guo and Wilson, 2011]. Different researches are done considering the value of a transfer penalty in minutes. From the research of Guo and Wilson [2007] a rail-to-subway transfer is estimated between 8.5 - 17 minutes of walking time, the transfer penalty for a subway is usually estimated lower than the penalty for a rail-to-rail transfer. [Guo and Wilson, 2011],[Guo and Wilson, 2007]. Hunt [1990] and Yoo [2015] both did a transfer penalty estimation for multimodel trips, this resulted in a transfer penalty of 17 minutes in vehicle time for Hunt [1990] and 11,24 minutes was the result of Yoo [2015]. Focusing on rail transfer penalties, Algers et al. [1975] did a research in Stokholm and found a rail-to-rail transfer penalty of 14.8 minutes of in- vehicle time. While Wardman et al. [2011] did a research in Edinburgh, a penalty of 8 minutes is vehicle time was concluded.

A transfer time of 5 minutes is experienced as optimal. A longer transfer time leads to useless waiting time and less time leads to stress [Keizer, 2013]. According to the research of Navarrete and Ortúzar [2013] the most penalised time component of a trip including a transfer is the transfer waiting time. Transfers have a lot of impact on the travel journey. Improving the transfer action could significantly benefit the public transport experience [Guo and Wilson, 2011]. From a case study of Santiago the Chile of Navarrete and Ortúzar [2013] was concluded that the willingness to pay for avoiding a transfer is approximately one-fourth of the travel fare. This reflects the greater walking and waiting time required for a transfer.

3.6.3. Cost

Cost is also an important aspect in determining a route to travel from A to B. For a train journey, if the begin and end station are fixed, the train route does not make a difference in the costs at NS. However, in the Netherlands there is a high-speed line for which passengers need to pay surcharge to user this connections. The high speed line goes from Schiphol Airport, to Rotterdam, to Breda and then follows it's way to Antwerpen. Furthermore, in general, train journeys are perceived as more expensive than car journeys especially for infrequent train travellers without a subscription. However, travelling with public transport, travellers are more confidence about their cost than travelling by car [Chorus, 2007].

3.6.4. Comfort

As stated above the soft factors of a journey are also important in making a route choice. Passengers want a pleasant experience while travelling. This implies a good quality of access to the station, information provision, a save and warm station atmosphere to wait and a clean train.

3.7. Passenger characteristics

Next to the route attributes, also passenger characteristic could influence the route choice. Individuals could have a personal preference because of their mobility, amount of luggage and experiences. To collect the preferences of different travellers, travellers are separated in different user groups. This can be done on sex and age but also motivation to travel, stress level or travel experiences [Hagen, 2014]. In public transport passengers are mostly split up in must and lust travellers. Must travellers are the business or commuter travellers while the lust travellers use the train to visit family, friends or a day out. Another segmentation is the separation by motivation, this is a segmentation in which passengers are separated by their emotional layer. These are six types which indicate the context of the journey: life enricher, individualist, functional planner, security seeker, fun seeker and convenience seeker. Someone's type in a journey can differ per journey a passenger is making[Hagen, 2014].

Personality traits could also have a lot of influence on the choices people make. The most famous method used is the five-factor model. This model consists of the following five factors: extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience[McCrae and John, 1992][Soto and John, 2017]. In the research of Yazdanpanah and Hosseinlou [2016] the role of personality traits in future preference of public transport use is studied. An indirect link between personality traits and the future use of public transport is suggested in the results. Neuroticism has a slightly negative association with future public transport use while extraversion has a positive influence on future public transport use.

3.8. Conclusion

In this section, the main findings of the literature research are presented. In table 3.1, a short overview of the findings is presented. Also, the first research questions are partly answered in the second paragraph of this section.

Due to the psychological strategies to steer passengers being effective in steering passengers, it is helpful to gather more knowledge on the influence of passenger information, focusing on the travel planner. Following the theories, the travel planner of NS is a good information source. As for all different kind of travellers, the most effective travel advice is an advice that is prescriptive, predictive, qualitative and gives real-time delay. Another aspect of an effective travel advice is that travel advice needs to be simple instead of types that facilitate advanced search options. However, to create optimal use of a transport system, personal travel advice is suggested to overcome concentration of passengers. Furthermore, people want to optimize their waiting time, keep their cognitive efforts low and get certainty about their journey. However, only little is known about the compliance rate of prescriptive advice. Nonetheless, that perceived unreliability has a negative effect on the compliance rate is known. In this research, the research gap of compliance rate of prescriptive travel advice is studied. Furthermore, there is a lack of literature that specifically focuses on travel planners and the influence of this on passenger route choice behaviour.

In this paragraph is elaborated on the answers to the first two sub-questions. The first sub-question is formulated as: 'Which train passengers are using route advice?'.
Answering the first part of this question, pre-travel information is mainly used by infrequent train travellers, although the frequent travellers are more aware of the available information. Furthermore, pre-trip information is used for long and time-sensitive journeys. These aspects make it interesting to look at the difference between commuter/business travellers and recreational travellers since commuter/business travellers are often frequent travellers. In analysing the questionnaire results, these

different groups are separated to either confirm or deny this finding.
The second sub-question is formulated as: 'Do passengers follow route advice?' Since the compliance rate is not known it is not possible to give a complete view of the effect of the travel planner. In general, individuals are making their route choice by choosing the route with the highest utility, but individuals make errors in their utility determination. Furthermore, personal experiences and habits are impacting the route choice. In this research, the compliance rate of the travel planner of NS is researched. Due to the influence of habit, during the questionnaire, participants are asked if they are familiar with the trajectory to see how this influences their choice behaviour.

Table 3.1: Short overview of literature findings

Subject	**Findings**
Passenger route determination method	Utility maximization [Avineri, 2009], [Dickeogenia,2012] while minimizing search effort [Chorus et al., 2007]
Substantional findings on passenger route determination	There are always errors in the utility maximization, influences by: Available information, ersonal experience and habit [van Essen et al., 2016], [Hensher, 2015].
To what extent do travellers follow given travel advice?	Compliance rate is not known from current literature [BenElia and Avineri, 2015].
Substanstial findings on following travel advice	Perceived reliability has a negative effect on the complaince rate [Chorus et al., 2009],[Benelia and Pace, 2012] .
Who are using the travel advice?	Infrequent travellers, travellers with a long and time sensitive journey and travellers that make an unfamiliar route are making more use of the travel planner [Grotenhuis et al., 2007], [Yeboah et al., 2019],[Berggren et al., 2019].
Travel advice	Best travel advice is prescriptive, predictive, gives real time delay and is simple [van Essen et al., 2016].

4 Case study

In this chapter is elaborated on the case study of NS. In this case study, the travel planner and the passenger assignment algorithm of NS are used. The components of this case study are described in this chapter. Furthermore, this chapter elaborates on selecting the routes for the stated choice part of the questionnaire.

4.1. Travel planner of NS

As described in the introduction, the NS travel planner application is widely used by train passengers. The travel planner of NS gives prescriptive information, which means it gives guidance to passengers how to travel from origin to destination with recommended alternative as is described in section . The travel planner of NS is a good information source, as for all different kind of travellers, the most effective travel advice is an advice that is prescriptive, predictive, qualitative and gives real time delay [van Essen et al., 2016]. With this application, it is possible to plan a trip from station to station and also from address to address. The planner could take walking, cycling, tram, bus and metro into consideration as access and egress modes. There is also a possibility of planning a journey via a particular station or adding 5, 10, 15 or 20 minutes additional transfer time. The application is online available via www.ns.nl see figure 4.1 and it is also possible to install the application on a smartphone. The travel planner is a prescriptive travel information source because it advises on how to travel from A to B. Over time, the selected travel options are shown, and the passengers can choose their desired option for which the departure or arrival time fits best. Furthermore, the route travel planner of NS blocks backward travelling. Passing a station twice is not allowed to prevent passengers from traveling kilometers for which they do not pay. The travel planner also gives real-time delay of trains per minute, so passengers can see if the transfer or journey they want to make is still possible considering the delay.

More about the background algorithm that selects the travel planner's shown routes is explained in this section. In the background, the route travel planner of NS calculates the fastest travel option and the most comfortable option. The fastest travel option is when the total travel time from origin to destination is the lowest. The most comfortable option is the most convenient route, so the route with the

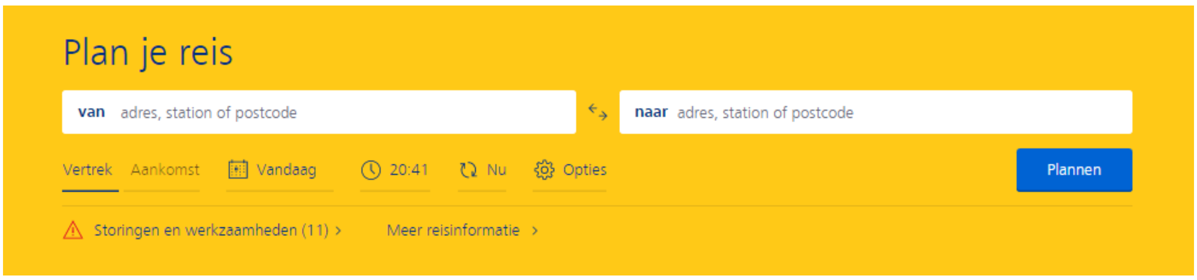

Figure 4.1: NS travel planner website

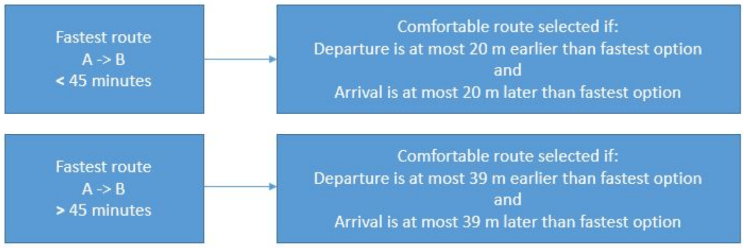

Figure 4.2: Route selection of travel planner

least amount of transfers. The perfect transfer time is 5 minutes, transfer times more or less than 5 minutes are seen as inconvenient. The next steps of the algorithm to select appropriate route options are as follows. They are also shown in figure 4.2. If the duration between departure and arrival time of the faster route is less than 45 minutes, the departure of the most comfortable alternative may be maximally 20 minutes earlier than the departure 20 minutes later than the arrival of the fastest advice. For a journey longer than 45 minutes, this threshold lies at 39 minutes. It stays there even when the duration of the journey increases.

If there are different transfer options with almost the same travel time the interchange priority is used (CP). This is a value between 0 and 16 in which 0 means highest priority and 16 lowest priority. A cross-platform, for example, gets a lower value than a station where passengers have to walk a lot or need to take stairs.

4.2. Prediction model: VISUM

NS works with different models to design the timetable, test the timetable, and use the information of in- and out- check data to determine the passenger amounts. This research focuses on the prediction model that executes the passenger assignment to trains, VISUM. VISUM is a transportation model which can allocate origin-destination matrices to travel options. Since 2013 NS and Prorail are using the software VISUM which is developed by German PTV [Banninga et al., 2016]. VISUM is a program with a distribution procedure to model all the traveling passengers in five steps. The inputs of the model are the origin destination matrices with the expected amount of passengers and the timetable. VISUM is used at the basis of timetable studies.

So, VISUM is the core of the transportation model of NS. On top of VISUM, a user-friendly program TRENO is built in Python by NS. TRENO makes the result of VISUM insightful and relevant features for NS are added. TRENO works with different levels: the network, timetable, rolling-stock and travel options [NS, 2020]. TRENO can process the timetable and transport demand outcomes of VISUM to achieve a level of service for the passengers. Then a distribution is made in which the response on this (new) timetable is predicted. From this prediction is visible how many passengers will make different use of the train or leave the train. With this result, the origin destination prediction matrix can be adapted to the new timetable. The yields, distribution and material that are needed are calculated. For all this analysis, the passenger allocation is made in VISUM.

The five steps in which VISUM allocate the expected amount of passengers over the travel options are described below. The parameters used in this model are trade secret of NS so these are not incorporated in this report. All the variables used in this model by NS are determined with a calibration study executed in 2016 by NS using the check-in and check-out data [Banninga et al., 2016]. The check-in and check-out data does not directly tell in which train a passenger travels so an allocation model is used to make the data suitable for the calibration with VISUM.

1. Search algorithm for travel options
   A Branch and Bound searching algorithm is used to determine the travel options. This algorithm systematically adds routes and determines when a route is not added anymore.

2. Filter travel possibilities
   Then the not realistic travel options are deleted. These are travel options in which the travel time is a specific factor bigger than the shortest travel time or the amount of transfers is way more than the travel option with a minimum amount of transfers.

3. Calculate the perceived travel time of the travel options
   For every travel option, the generalized travel time is calculated. This is not the real travel time but the experienced travel time by the passenger. This consists of the travel time in the train, transfer penalties, and the waiting time at a transfer. The following formula is used:

   $$PerceivedJourneyTime(PJT) = In{-}vehicletime*\beta_{vehicle}+Amountoftransfer*\beta_{trasfer}+transfertime$$

   The $\beta_{vehicle}$ is a value that differs per train type, depending on the comfort of this train. For a Sprinter this value is higher than for the Intercity because travelling with the Sprinter is seen as lees comfortable, giving a higher perceived journey time. A penalty is added for making a transfer because this is seen as a big disutility for the passenger.

4. Calculate the resistance of the travel options
   Now VISUM calculates the resistance for every minute that a passenger would like to leave the station. In this calculation the PJT, travel costs and the time between the departure of the train and the desired departure time of a passenger are used. Each value that is used in the resistance calculations can be individually Box-Cox transformed. A Box-Cox transformation, depending in the value of λ, can be used to increase or decrease the effect of one component. In the settings of NS the PJT is individually Cox-Box transformed. The following formulas are used for the resistance and Box-Cox transformation:

   $$Resistance = PJT + \frac{costs}{VOT} + \delta * \Delta T$$

   $$f(x) = (x^{\lambda} - 1)/\lambda$$

   in which

   PJT is the value calculated at step 3, individually Box-Cox transformed

   $Costs$ are the travel cost including a possible surcharge

   VOT is the value of time of the societal report about travel time of Warffemius [Warffemius, 2013].

   ΔT is the time between the departure time of the train and the desired departure time of the passenger. The ΔT could be earlier or later than the desired departure time, $\Delta Tearly$ and $\Delta Tlate$.

   δ The resistance to depart earlier or later than the desired departure time. This value differs between an early and late departure.

5. Distribution of the travellers over the travel options
   After calculating this resistance, the shares are calculated with the distribution functions. In VISUM there are four possible distribution function to choose from. BoxCox(β ,τ), Kirchhof(β), Logit(β), Lohse(β). The value of β determines to what extent the resistance leads to difference in passengers between the route options. In the forecasts of NS the Logit function is used. In Logit, only the absolute differences between the resistance are taken into account. The value of β determines to what extent the resistance leads to a difference in passengers between the route options. If β is zero, all choice options are chosen equally. The Logit function is as follows:

   $$Utility, U = e^{-\beta*Resistance}$$

Now some assumptions of VISUM and the effect of them are described. The starting point of VISUM is that passengers are making their route choice decision after arriving at the station. The expected amount of passengers per half an hour are distributed over time. So if thirty passengers per half an hour are expected, VISUM assumes that every minute one passenger arrives. After arriving at the station, passengers determine which train they take. Furthermore, as described above, with the $\Delta Tearly$ passengers are able the go back in time with a penalty of δ. This implies that at least part of the passengers should be informed about this travel option. Otherwise, they are not able to take this journey back in time. This compensates for the two rough assumptions at the beginning of the choice process. Namely, passengers are making their route choice at the station and arriving at the station distributed over time.

So VISUM assumes that passenger are making their route choice decision at the station however they are able to take a train earlier, so go back in time. The values used for $\Delta Tearly$ and $\Delta Tlate$ in VISUM are determined, as described earlier, in the calibration study of NS from 2016 [Banninga et al., 2016]. The values are estimated using the check-in and check-out data, which makes it as close to reality as probably possible. However this makes it hard to say something about the individual parameters of VISUM. The choice process route of passengers as used in VISUM is not explicitly followed. For example, the consideration if and how much passengers are already informed or not is not made in determining these parameters.

Furthermore, in the passenger allocation of VISUM every transfer has the same penalty. There is no difference between a cross-platform transfer and cross station transfer. In reality is expected that people take the ease of a transfer into account. As described in 4.1 the travel planner takes the ease of a transfer into account in determining the best travel option. Another difference between the travel planner and the allocation of VISUM is that VISUM allows backward travelling, so passengers that are passing an station twice are incorporated. However, it is not allowed, it is important to take it into account in the prediction if passengers are dong this.

VISUM is usually used to make the forecast for a whole day or a few hours. However, to illustrate the choice process of one passenger, that is already at the station, the settings can be changed. VISUM is run as if all passengers are arriving at the station in one minute and it is not possible to go back in time. In figure 4.3 an illustration of the PJT, resistance and utility of a Sprinter/Intercity consideration is shown. Four minutes before the departure of the Sprinter the passenger arrives at the station. Because of the trade secrecy of the parameters, the route, departure times and travel times are not shown. Also, the values on the x-as are removed. On the y-as the kind of train and the time between arrival time at the station in minutes and departure of the travel option are shown. An IC stands for Intercity which is a train that only stops ad bigger station which makes it a faster connection if you travel from and Intercity station to another Intercity station. A Sprinter, also called a stop train, stops at intermediate stations which make the travel time a bit longer as can be seen in figure 4.3. In the figure is visible that to the already longer travel time of the Sprinter a penalty is added, as is following from $\beta_{vehicle}$, described in step 3 of the calculations. However, due to the delta T late, the earlier travel options are more favorable than the later options. The prediction is that the most passengers will choose the first travel option, a way smaller part will go for the Intercity and a really small part is assigned to the Sprinter 19 minutes later.

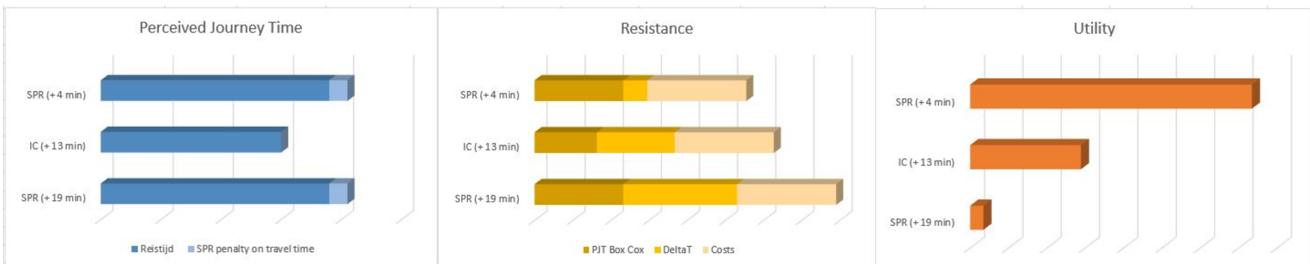

Figure 4.3: Visualisation of calculation steps of the allocation of VISUM

4.3. Selection of routes

A sophisticated selection of routes is crucial for this research because different requirements needs to reach the research goal. To answer the research questions, real routes of the Netherlands are used because of the comparison with the prediction model. However, another goal of this research is to analyse choice behaviour. The case studies presented in the questionnaire must be trade-offs with two realistic travel options to reach these goals. However, on many routes in The Netherlands, one travel option dominates so an extensive search is needed.

For the stated choice study, routes in The Netherlands are selected, at which two travel options are possible. These options need to be realistic travel options, so people need to make a trade-off before choosing. The different travel options need to lay close together in time because otherwise, the choice is influenced by the departure or arrival time of the travel option. It is not reasonable to wait 30 minutes at the station before the departure of a better travel option. In this way, the choice pattern of passengers can be researched and compared with the distribution of the choice model. Furthermore, to analyse different aspects of the prediction model and choice behaviour it is important to isolate different choice options to disentangle individual effects.
The different aspect to which the route should comply are:

1. It needs to be a real route in The Netherlands
2. There need to be two realistic travel options
3. The travel options need to lay close together regarding departure time
4. Only one choice factor is involved

To make a good analysis, as mentioned above, preferably this trade-off only consists of one aspect. If there are many aspects involved, it is hard to see the individual impact of an aspect. The trade-off between different travel options can consist of:

1. Taking the Sprinter or wait for the intercity
2. Making a transfer to reach the destination faster or take the direct train
3. Paying surcharge for a faster connection or not
4. Making a route choice, if there are different transfer stations possible

In the Sprinter versus the Intercity, the Sprinter is always the choice with a longer travel time. Nevertheless, if the Sprinter departs or arrives at a passenger's preferred time, this could still be a preferred journey. However, passengers can also dislike the Sprinter because of frequent stops, which could be uncomfortable because of the braking and accelerating and entering and leaving passenger frequently. Moving on to the second trade-off, on some routes it is possible to take a direct train. However, there is also a possibility to make a transfer and arrive earlier at the destination. Some passengers want to avoid a transfer, while others are more interested in the possibility of a lower travel time. Considering the third trade-off, a surcharge is asked for a faster travel time on the high-speed route of the Netherlands. For this trade-off, it is important how much money the passenger has to spend, how much value of time the passenger has and if the passenger's employer is paying for a business trip. The last trade-off mentioned in the list above is route choice, which means that there are different options to make a transfer. An example of a route choice option is travelling via Rotterdam or Den Haag from Delft to Utrecht. The transfer station could for example differ on kiosk facilities or walking distance between platforms.

Since generic insights are searched, trade-off 4 is not used since every route choice option is different because of the influencing factors of the transfer station. Furthermore, there is only one trajectory of NS in which the surcharge is the only variable. This gives too little insight for trade-off 3, so the surcharge is also not taken into consideration. So the route choice variables in this research are: taking the Intercity or the Sprinter and make a transfer or take a direct train.

Table 4.1: Selected routes for the case study

Routes	Train	Travel time difference	Departure time difference	Transfer option	Transfer time	Frequentie per hour
Amersfoort C.- Zwolle	IC/Sp	20 min	24 min			IC 2x Sp 2x
Haarlem – Amsterdam C.	IC/Sp	4 min	9 min			IC 4x Sp 4x
Den Haag C.– Leiden C.	IC/Sp	6 min	9 min			IC 4x Sp 4x
Eindhoven C.- Amsterdam C.	IC	0 min	10 min	Yes	3 min	No transfer 2x Transfer 2x
Schiphol Airport – Arnhem C.	IC	1 m	12 min	Yes	6 min	No transfer 2x Transfer 2x
Zwolle – ‘s Hertogenbosch	IC	15 min	0 min	Yes	13 min	No transfer 2x Transfer 2x

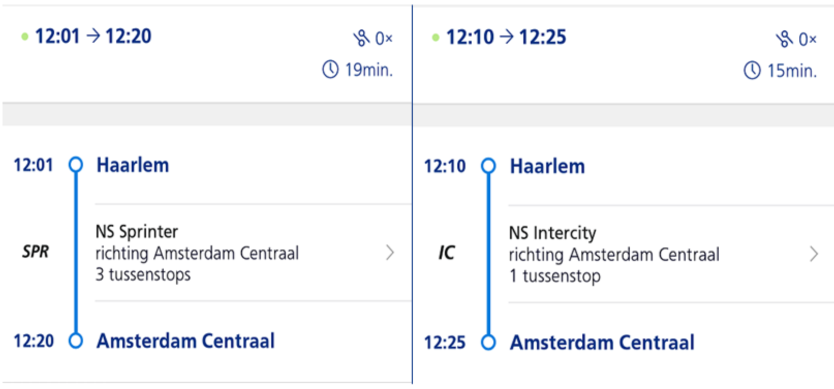

Figure 4.4: Example of route choice on Haarlem - Amsterdam Centraal

In table 4.1 the chosen trajectories with the travel time difference between the options and attributes are shown. In an ideal situation, the variation in travel time difference and departure time would be bigger. However, this is not possible because only real trajectories are used. In the found routes the two travel options are repeated in time, for example every half an hour a sprinter departs and always 9 minutes later the intercity departs. So only one sequence of the two travel options per route are shown in the stated choice cases. The less profitable choice is always shown first to create a trade-off. If the route choice is made from the station and the Intercity departs first, there is no trade-off. So, to learn something about the choice behaviour of passengers, the Sprinter departs first, so the passengers need to make a trade-off. Passengers could wait on the Intercity or depart earlier with the Sprinter. A test travel planner of NS is used regenerate the travel advice from November 2019. Data of November 2019 is used to overcome the possible influences of Covid-19 on the timetable. After collecting this data, figures of the travel planner application on a mobile phone are used. In this layout, the route choice cases are presented to the passengers. So passengers recognise that it is coming from the travel planner app and the choice feels as realistic as possible. An example of a choice like this is shown in 4.4.

4.4. Conclusions

The travel planner and the prediction model of NS, VISUM, have both their own algorithm. However, in the end, on the selected routes they considered the same travel options, so they negate the same choice set. VISUM assumes that passengers make the route choice at the station. However, passengers can go back in time which indicated that passengers are not always making the choice from the station because is reality passengers are not able to go back in time. Nevertheless, the parameters are estimated using the check-in and check-out data so the base of the model is simulating the passenger behaviour of the in- and out-check data. Generally, the working of VISUM is not easy to capture. Furthermore, VISUM predicts passenger distribution for an average daily situation, making it hard to analyse one specific situations separately. For example, if passengers are already at the station, they cannot go back in time, and the Sprinter departs first. The goal of this study is to compare the results of the case studies with the distribution of the prediction model, so only real trajectories are used. This makes that there is not an ideal of variation between the cases. However, six suitable cases are selected for the stated choice part. The timetable of November 2019 is used to overcome timetable changes because of Covid-19.

5 Questionnaire design

After selecting the routes in Chapter four, in this chapter, the design of the questionnaire is described. The two main goals following from the research questions are learning more about the travel planner use and comparing the choices passengers make with the passenger forecast of NS. Furthermore, interesting points that came up during the literature and forecasting model research are added to the questionnaire. The questionnaire will consist of two parts. The first part is about the travel planner use and the second part consists of the stated choice part in which respondents are asked to make a route choice. Before the final questionnaire, a pilot questionnaire is executed to tests all the questions and sees if the results meet the expectation.

5.1. NS panel

As described in the methodology, the questionnaire is executed in the passenger panel of NS. NS works with the research platform MWM2 in which the questionnaire is designed and send out to the selected panel members. The questionnaire is in Dutch because this is what the panel members are used to. The questionnaire is executed among an NS traveller representative group, so all age groups and travel purpose groups are represented in the data set. Profile information about the participants is already known because all the NS panel members already filled-in personal information about themselves when they joined the panel. The personal data of the NS panel member is updated every year. The profile data used in this research are age, travel frequency and main travel purpose. Passengers are asked to fill in the survey as if Covid-19 is not existing.

5.2. Findings from literature

In the literature review, chapter3 section 3.2, the influence of habit on choice making is found [van Essen et al., 2016], [Hensher, 2015]. In the questionnaire, this is tested by analysing if there is a difference in choice behaviour between respondents that are familiar with the route and respondents that never travelled over the route before. Another aspect found in the literature is the expected difference between frequent and infrequent train travellers, section 3.4. Concluding from the literature, pre-travel information is mostly used by infrequent travellers [Berggren et al., 2019], [Yeboah et al., 2019], this makes it interesting to look at the difference in choice behaviour between frequent and infrequent travellers. So the difference between commuter/business travellers and recreational travellers is studied since commuter/business travellers are often frequent travellers. These two different travel groups are also called Must and Lust travellers. Must travellers are the commuter/business travellers who must make the journey for work. The Lust travellers are recreational travellers. They travel in their free time to go somewhere for recreational purposes.

5.3. Pilot

Before the final questionnaire, a pilot is executed among thirty people who volunteer to fill in the pilot version of the questionnaire. The people who filled in the pilot are not part of the NS panel. The goal of the pilot was to test the questions and see if the results are as expected. Respondents of the pilot were asked to give their opinion about the questionnaire in the last question. Respondents gave suggestions for word choice and spelling. They also indicate that some questions were difficult to answer. Furthermore, some respondents named their considerations in making a route choice, several times the influence of the weather was named. Another thing that stood out was the question about the choice moment. Most respondents indicate that they choose their route from home. However, following the way VISUM works, most route choice cases were asked as if passengers were already at the station.

5.4. Choice moment

When designing the questionnaire, the passengers' route choice moment using the travel planner is important. The choice moment is split up in travellers that make their this choice at home before the journey starts or make the choice at the station. The moment of this decision has much impact on the travel option passengers take. VISUM takes as starting point that passengers are already at the station. However, passengers can go back in time. The pilot suggests that most passengers are making the route choice from home. In reality, a mix of the two choice moments is expected on the train. Some passengers make their choice at home, while others do this at the station or at a moment in between. As a result of this expected mix, both decision moments are incorporate in the questionnaire. Furthermore, to get some more insight into the choice moment, respondents are asked to indicate when they usually make the route choice using the travel planner.

5.5. Travel planner use questions

In the first part of the questionnaire, participants are asked about their general use and opinion of the travel planner. Specifically, they are asked if they use the travel planner of NS when they are planning their journey. If they answer this question with: 'I never use a travel planner', they will not get the next questions about the NS travel planner. Secondly, if they answer the question with: 'I use another information source', in the next question, they are asked which information source they use and why. When participants are using the travel planner, they are asked to which extent they follow the travel advice of the travel planner to get an indication of the compliance rate. If passengers indicate that they do not always follow the travel planner, they are asked to indicate why they do follow it in an open question. In the following question, they should indicate to which statement their answer is applicable. This technique is used to let respondents think about their answers before they see the given options. Since the moment a passenger makes the decision has a lot of influence, participants are also asked to indicate how often they choose their journey at home and at the station. The choice moment of the outbound journey, as well as the homeward journey, are asked. In figure 5.1 a scheme of the questionnaire is shown. With the arrows is also indicated with which answers certain questions are skipped. Questions two to eight and twenty-two are about travel planner use.

Question twenty-two about the travel planner is placed in between the stated choice cases to give the participants some variety. Three statements about the travel planner are shown. Participants need to indicate how much they agree with this statement. The statements are about trust in the advice of the travel planner, if the travel planner makes travelling by train easier and the user-friendliness of the travel planner. These statements are used because these are all characteristics of good travel information according to the literature.

At the end of the questionnaire, an open question is added in which respondents can put their tips or remarks about the NS travel planner. If needed, using this information, a general view of the participants on the travel planner can be specified. For the participants, it is also pleasant that they can share their opinion if they want to. The final Dutch version of the questionnaire is visible in appendix A.

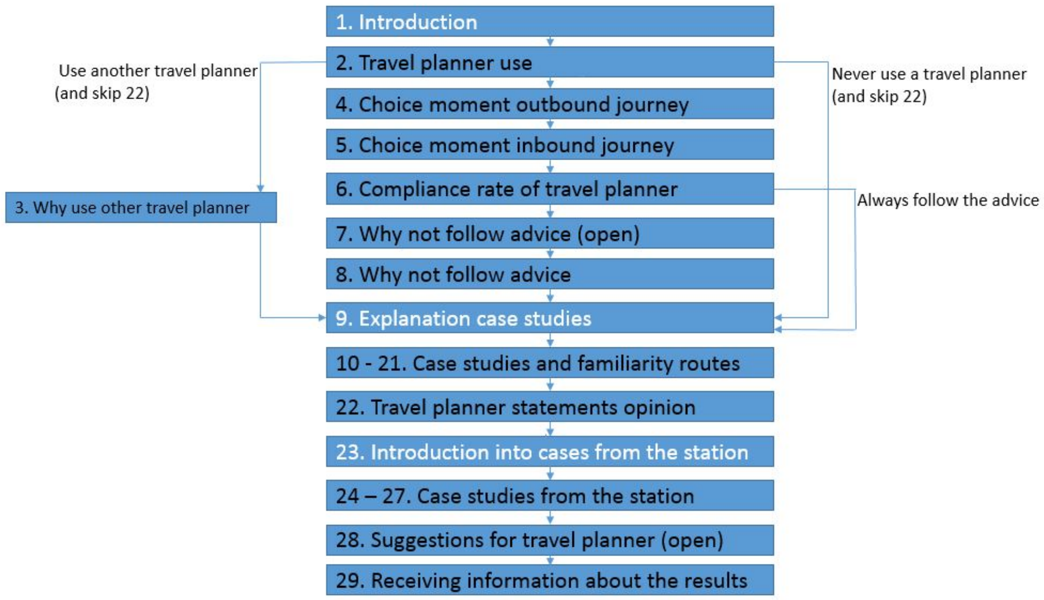

Figure 5.1: Schematisation of questionnaire, questions and order

5.6. Stated choice cases

In the stated choice part, respondents were asked to choose between the two travel options of the selected routes. These cases are prescribed to them in two different ways. First, they are asked what they would choose if they are planning their journey from home. Later on, participants get the same case again when they are already at the station, four minutes before the departure of the first travel option. The expectation is that passengers who are already at the station are more inclined to take the first travel option. In contrast, the passengers who decide at home take the most profitable travel option because they can still plan their departure time. The assumptions that it is an average temperature on the station and in all trains there are seats available are made. Passengers are also asked to indicate if they are familiar with the route. This could impact the choice behaviour because of positive, negative experiences or habits, as was found in the literature.

In table 5.1 the order of the different cases are shown. The route Zwolle - 's Hertogenbosch is only asked from home because both trains depart simultaneously. So the assumption is made that making the choice from home does not differ from the choice at the station because waiting time does not play a role. Amersfoort-Zwolle is also only asked from home because the two travel options lie 24 minutes apart, so waiting on the station for the IC is not seen as a realistic option. An example of one case question, in Dutch, when the choice is made from the station is shown in 5.2. The final version of the questionnaire in Dutch is visible in appendix A.

Table 5.1: Order of stated choice cases in the questionnaire

Case nr.	Route	Trade-off
1	Amersfoort C. -Zwolle	IC/SPR
2	Schiphol Airport - Arnhem C.	Transfer/direct
3	Den Haag C. - Leiden C.	IC/SPR
4	Eindhoven C. - Amsterdam C.	Transfer/direct
5	Haarlem - Amsterdam C.	IC/SPR
6	Zwolle- s' Hertogenbosch	Transfer/direct
	Interruption	
From station 7	Schiphol Airport - Arnhem C.	Transfer/direct
From station 8	Haarlem - Amsterdam C.	IC/SPR
From station 9	Eindhoven C. - Amsterdam C.	Transfer/direct
From station 10	Den Haag C - Leiden C.	IC/SPR

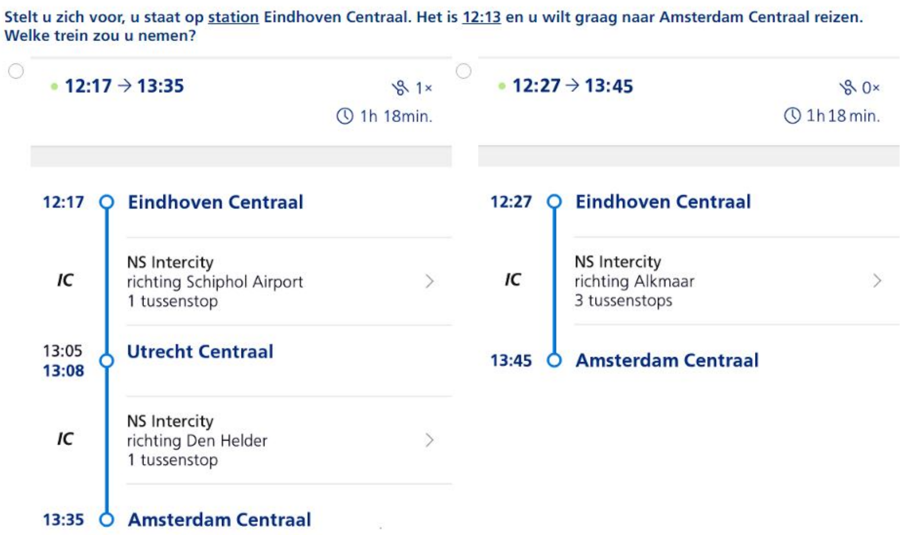

Figure 5.2: Example case questions with choice from the station, Eindhoven C. - Amsterdam C.

6

Results questionnaire

In this chapter, the results of the questionnaire are shown and discussed. Firstly, the respondents and method to create a representative data set for the passenger population of NS is explained. Then, the relevant results of the questionnaire are shown and discussed, ending with the overall conclusions of the results.

6.1. Respondents

The questionnaire was sent to 2510 respondents of the NS panel and completed by 672. 102 respondents opened the questionnaire without completing it, the majority only reaching the first or second question. The data of the dropouts are not used. The average lead time of the questionnaire was, as expected, about 10 minutes. A passenger representative group of respondents was selected. However, the older age groups have a higher response rate, hence are overrepresented. After a few days, a reminder was sent out to all the selected panel members under the age of 40 to get some more responses for the younger age groups. This helped a bit, but still, older age groups are overrepresented in the dataset. Hence, the raw data set of the questionnaire is not representative of the NS population.

6.2. Creating a representative dataset

In the initial dataset, the older age groups are overrepresented. As was already mentioned in Chapter 2, NS researched their passenger population in which the composition in age groups and travel purpose is determined [NS, 2019]. NS estimated the composition of the whole passenger population as well as the passenger population on an average trip. So there are two compositions, the passenger population and the trip population. The trip population is different from the total passenger population because some train travellers are travelling more often than other train travellers. These two compositions are used to make the dataset suitable for the analysis that is done. These compositions are trade secrecy of NS so compositions are not shown.

The the passenger population and the trip population two compositions are needed because the analysis of the questionnaire data is split into two parts. In the first part, the travel planner use and the opinions about the travel planner are analysed. For this analysis, a passenger population representative groups of NS is used. So the data set is weighted to the passenger population of NS according to age groups and travel purpose. For travel purpose, only two groups, Must and Lust travellers are used. In the second analysis, the route choices of the respondents are studied. For this analysis, a data set representative of the average passenger population in a train is needed, so the average trip population.

Therefore the data set needs to be scaled to two different compositions. This scaling is done in Excel by assigning a weight factor to every respondent, which fits their age category and primary travel purpose. Respondents are divided in 12 different passenger groups depending on their age and travel purpose,

Table 6.1: The respondent are divided in 12 different passenger groups depending on their age and travel purpose

	Must	Lust
16 t/m 24 year	x	x
25 t/m 34 year	x	x
35 t/m 49 year	x	x
50 t/m 59 year	x	x
60 t/m 69 year	x	x
70 + year	x	x

see table 6.1. From KLIMAAT 2019 [NS, 2019], the percentage of the total population per combination is known. To estimate the weight factors for the sample of the questionnaire, the ideal number of respondents per cell is calculated using the total amount of respondents as a hundred percent of the population. Then, the actual number of respondents per cell is calculated by using a pivot table in Excel. The weight factor per cell is determined by dividing the wanted number of respondents per cell by the actual number of respondents. By weighting to the whole passenger population, the highest weight factor is assigned to the Lust travellers of the youngest age group. The young age groups are underweight, the factor assigned to this groups is 3.67. The lowest weight factor is assigned to the Must travellers of the highest age group, a factor of 0.28. When weighting to the average trip population, the highest weight value is assigned to the Must traveller of youngest age group, a factor of 4.97. The lowest weight factor of 0.21 is for the Lust travelers of 60 t/m 69 year. Some of these weight factors are high, which means the response of one young respondent has a lot more impact on the results than the response of an older respondent. Still, this is the best method to deal with this response inequality in the data set because without making the data set representative, the results are not of value. Furthermore, these high weight factors are not assigned to one respondent, the weight factors are always assigned to 25 respondents or more.

For this method, respondents of which age or travel purpose are not known are deleted from the data set because the relevant weight factor for this respondent is unknown. This concerned ten respondents, so the data set reduces from 672 respondents to 662 respondents. In all the figures where n is not mentioned n = 662. In all the figures and analyses in the following steps, four age groups are used because the younger age groups do not have 100 responses. Therefore, the two lowest age groups and the third and fourth age groups are taken together.

6.3. Travel planner use

The first part of the questionnaire is about the travel planner use. For this part the data is weighted to the passenger population of NS. First the participants are asked about their travel planner use and most respondents sad they always use the travel planner when travelling by train, see 6.1. The Lust travellers and older age groups make slightly less use of the travel planner than the Must travellers and younger age groups, see appendix B. If participants indicate they do not use the travel planner of NS they mainly use the 9292 application. The most named reasons to use another travel planner are habit and the completeness with all the public transport modes like bus and metro. If passengers travel less frequently, they are more inclined to always use the travel planner. Furthermore, Lust travellers also make more use of the travel planner, as shown in appendix B.

If passengers use the travel planner, the next question is if passengers follow one of the advised routes, also called the compliance rate. Figure 6.2 shown that 41 percent of the respondents always follows one of the travel planner options. Furthermore, 51 percent of the passengers answers that they follow the travel advice more than half of the times. When splitting up the results for the different user groups, there is no large difference in compliance rate between the groups. This may imply that the found compliance rate applies to all the users. There is not one group for which the travel planner is not suitable at all. For the infrequent and Lust travellers the compliance rate is slightly higher than for the other users. In the literature, the compliance rate of prescriptive travel advice was unknown. Most passengers that they are always or more than half of the time following the travel advice of the NS.

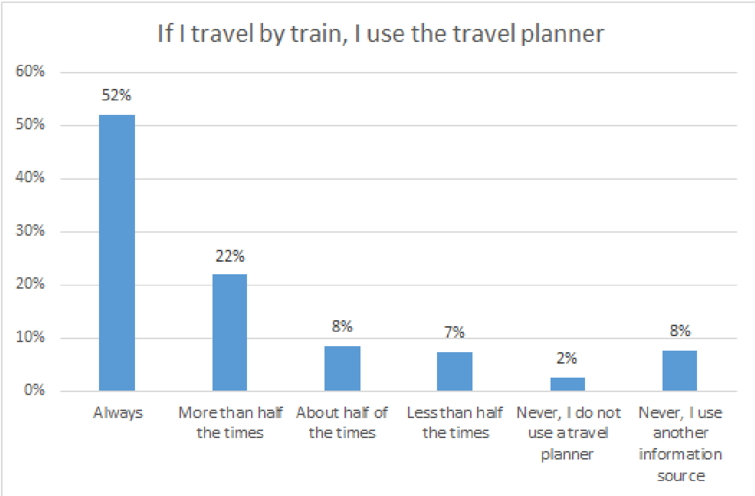

Figure 6.1: Travel planner use by train passengers (n=662)

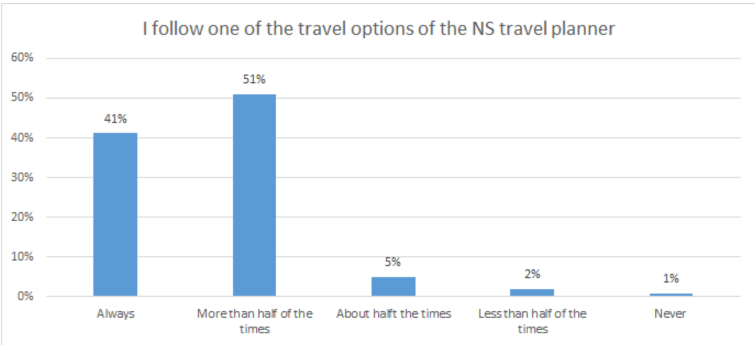

Figure 6.2: Travel planner complaince rate of train passengers (n=601)

This implies that their information service is working good and the service influences people.

If respondents do not always follow the travel planner, they are asked for explanation in an open question. A lot of different reasons are mentioned in this open question. After the open question, respondents are choosing to which statement their answer was applicable. The result of this question is visible in figure 6.3. Most passengers who are not following one of the advised routes indicate that they take a faster travel option than one of the advised ones. This faster travel option mainly consists of a transfer that is not visible in the travel planner because it is a transfer of less than 5 minutes. 19% of the passengers that do not always follow one of the travel options check the travel planner but do not select a route, they just go to the station. Other reasons that are mentioned in the open question are costs, walking distance, comfort and another option is more fun.

From the pilot was concluded that the moment a passenger makes the route choice has a lot of impact on choice behaviour. To get an indication of this choice moment, passengers are asked to indicate how often they make their route choice at the station and how often they choose from home. A difference was expected between the homebound and outbound journey, so they are both asked. In the homebound journey more passenger are expected to plan from the station because if passengers travel back home they usually have no time restriction, they just want to travel home after their activity or job has ended. The results are shown in figure 6.4 and 6.5, for the home bound journey it is also possible to plan your journey back home at your destination. Respondents could indicate if they always, sometimes or never make their route choice at the named moment. The figures shown that passengers plan their travel journey more often from home than at the station. A difference is found between the homebound and outbound journey. On the homebound journey, more passengers are planning their journey at the station. However, for the homebound journey still most passengers plan their journey at their

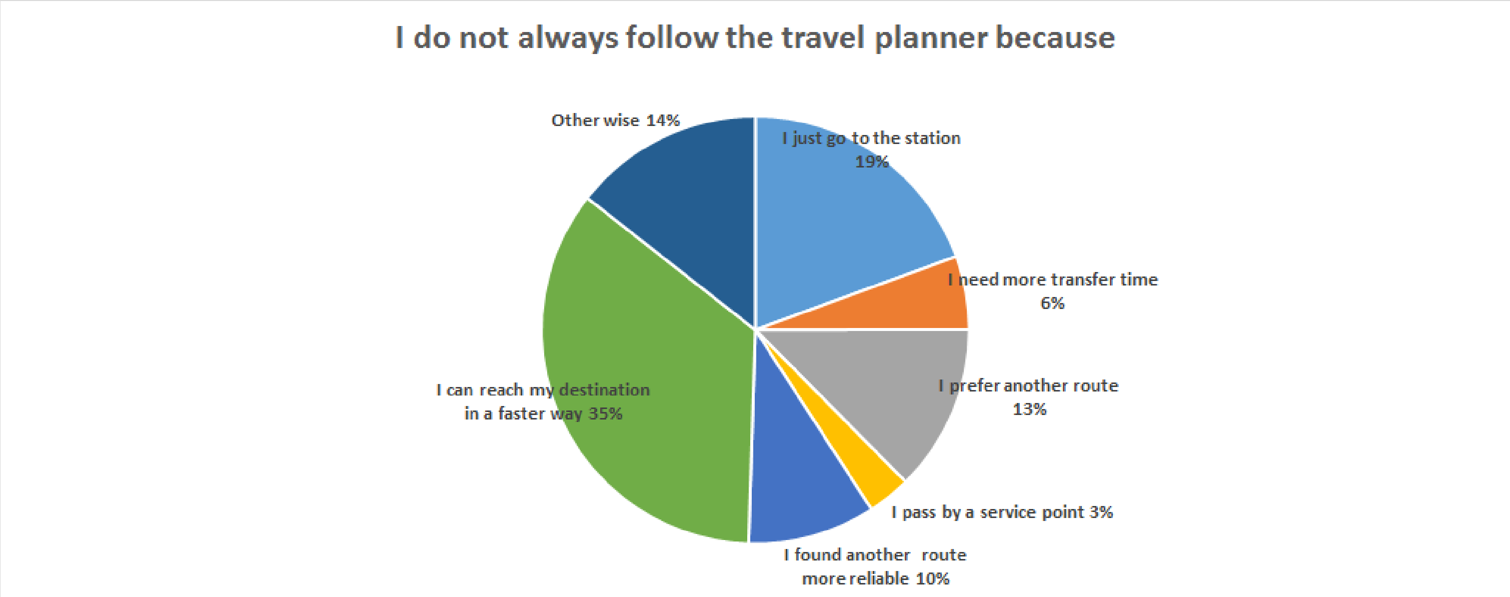

Figure 6.3: If passengers do not always follow the travel planner advice their are asked to indicate why (n=356)

destination. The conclusion that most passenger are planning their journey before arriving at the station can be drawn. An aspect that could be of influence on this is the departure frequency of the train, if the train departs often passengers can just go to the station because they know there will be a train, for example, every 5 minutes. If the train only departs once in an hour it is important to plan your journey before departure to the station.

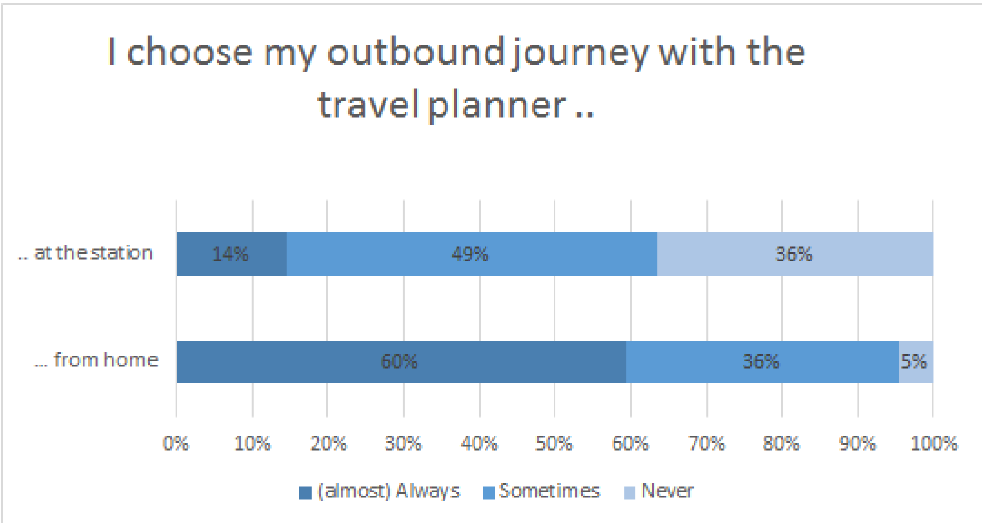

Figure 6.4: Passenger choice moment of outbound journey (n=662)

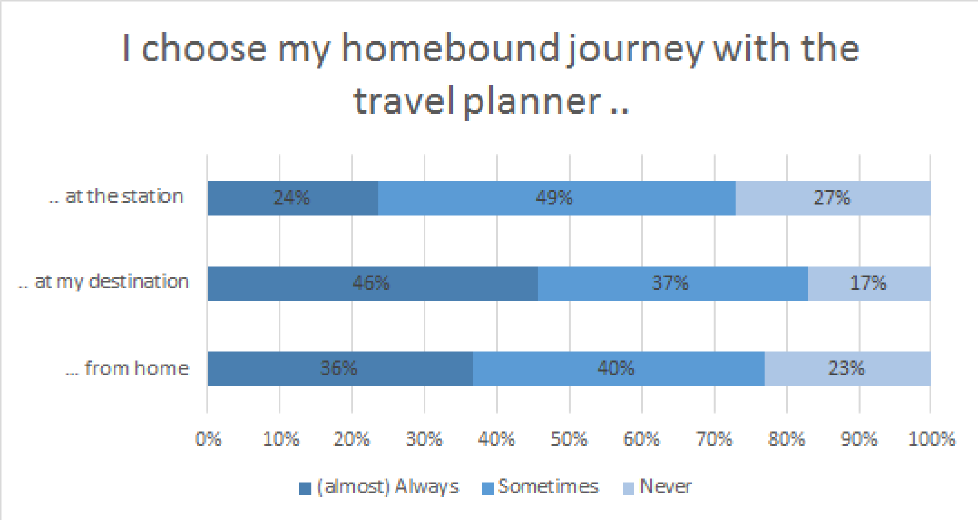

Figure 6.5: Passenger choice moment of homebound journey (n=662)

6.4. Opinion about the travel planner

To get an impression of the passenger's opinion about the travel planner, three statements are presented to the respondents. They can indicate how much they agree or disagree with the statements, the results are shown in figures 6.6, 6.7, 6.8. Most passengers agree with the statements, which is a positive result. Passengers trust the travel advice from the travel planner, the travel planner makes traveling easier for them and they find the travel planner user friendly. In general, the younger travellers are slightly less positive but still agree with the statements. Furthermore, no difference in opinion is found between user groups.

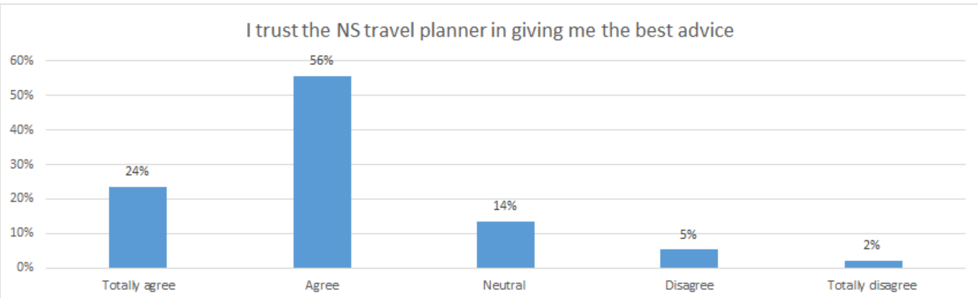

Figure 6.6: Travel planner statement, I trust the NS travel planner giving me the best advice (n=601)

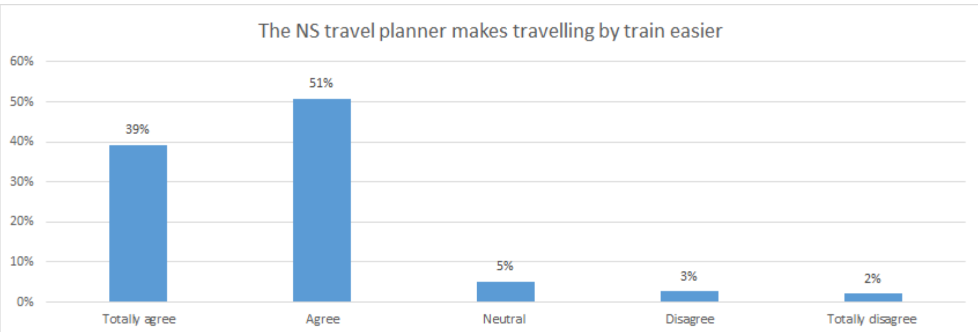

Figure 6.7: Travel planner statement, The NS travel planner makes travelling by train easier (n=601)

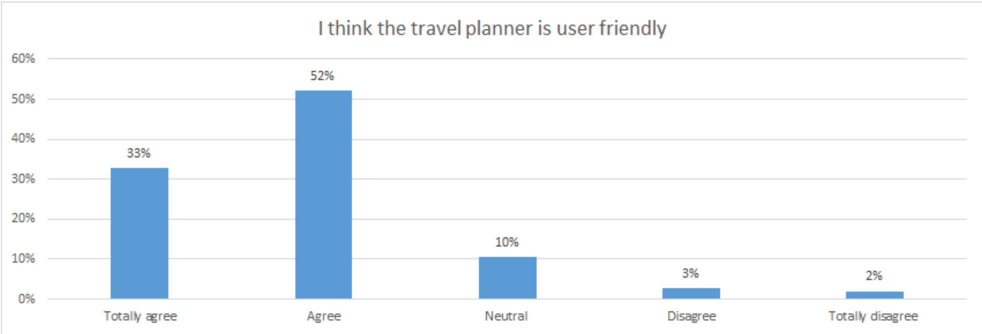

Figure 6.8: Travel planner statement, I think the travel planner is user friendly (n=601)

After all these closed pre-determined questions, an open question where passengers can give their opinion and tips about the travel planner is stated. Most respondents had no suggestions. Hence, the most mentioned suggestions are:

1. Give better advice in a disrupted situation, actualise the advice more often
2. Give the possibility to select a preferred transfer time
3. Make a tool in which passengers can select if they are in a hurry or want a touristic route
4. Give a sign if it is possible to still make a travel option with a tight transfer
5. The connections with the bus or tram are not always visible and right.

A positive result is that all the suggestions are points to improve the travel planner further instead of complains about the current travel planner. Most of the recommendations are about updating the planner more so the advice is as accurate as possible, which would improve the planner's power if it is possible. The other suggestions are about adding extra functions. These functions seem helpful although, the planner's simplicity should be preserved. Moreover, not all passengers are aware that there is also a possibility in the NS travel planner to plan from address to address. Furthermore, passengers suggested the option to get advice in English, but this is already possible. Therefore, on some functions of the planner passengers are not aware which could be improved by informing them better or promote these functions. Other more general remarks about the questionnaire were that the route choice of passengers also depend on the weather and which kind of appointment passenger are travelling to.

Altogether, the travel planner of NS is used extensively. The results suggests that passengers trust the travel planner and follow the advice. This is a positive result and makes the travel planner a powerful tool for NS.

6.5. Route choice behaviour

Ten cases are presented in the questionnaire to get more insights into the route choice behaviour on train passengers. As described in Chapters 4 and 5, three trajectories with a Sprinter/Intercity trade-off and three with a transfer or direct route choice are presented. For four of them, the choice from home and the choice from the station are asked. The case questions are answered by all the respondents so n=662.

After the route choice, for every route was asked if passengers are often travelling over this route because this could influence their choice behaviour. They could answer this question with: never, sometimes or often. Most people responded to this question with never. Not enough respondents answered that they often use the trajectory to draw conclusions with this data. However, with the data available it seems that being familiar with the route has minor impact on route choice behaviour.

6.5.1. Intercity or Sprinter trade-off

First, the Sprinter/Intercity trade-off is discussed. In figures 6.9,6.11 and 6.13 the distribution over the Sprinter and the Intercity of the weighted answers from the questionnaire are visible. From these figures can be concluded that as expected, the choice behaviour from home is different from choice behaviour at the station. As described in Chapter 5, Amersfoort-Zwolle is only asked from home. From home, most passenger choose for the Intercity. However, if passengers are already at the station, they are more inclined to take the first travel option instead of waiting at the station. as is visible in figure 6.9 and 6.11. This implies that waiting time at the station plays a significant role in route choice behaviour. Furthermore, The time difference between the Sprinter and the Intercity is of influence on the choice behaviour. At Amersfoort - Zwolle, the time difference between the Sprinter and the Intercity is the biggest which lead to more passenger choosing for the Intercity.

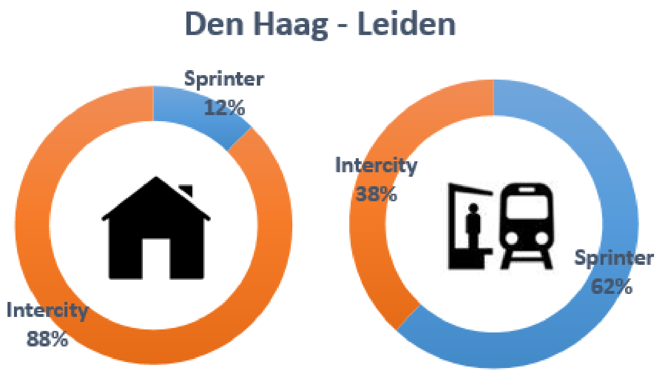

Figure 6.9: Choice distribution Den Haag Centraal - Leiden Centraal from home and from the station

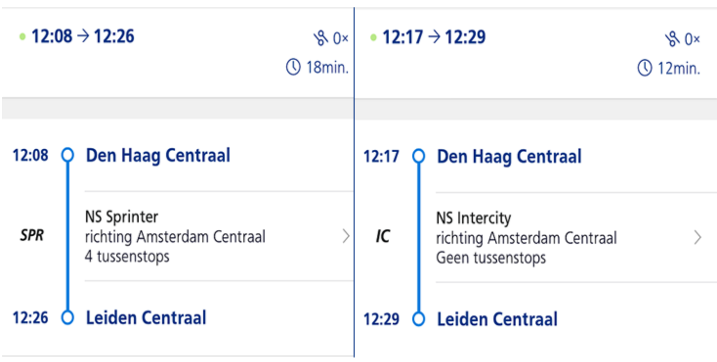

Figure 6.10: Travel planner advice Den Haag Centraal - Leiden Centraal

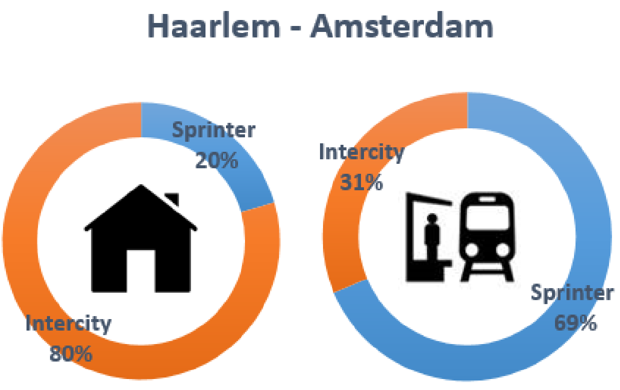

Figure 6.11: Choice distribution Haarlem -Amsterdam Centraal from home and from the station

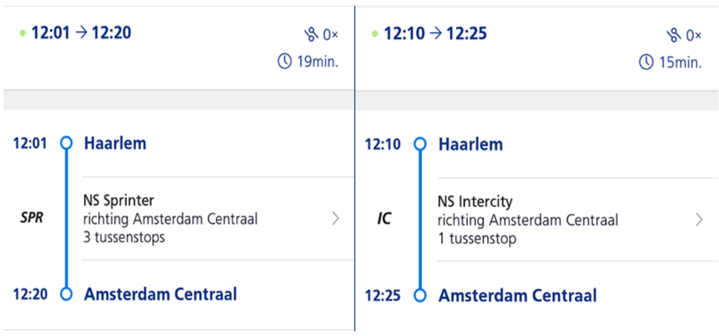

Figure 6.12: Travel planner advice Haarlem -Amsterdam Centraal

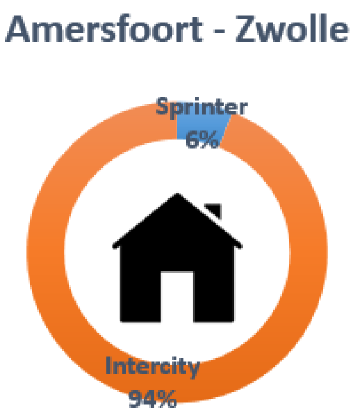

Figure 6.13: Choice distribution Amersfoort Centraal - Zwolle from home and from the station

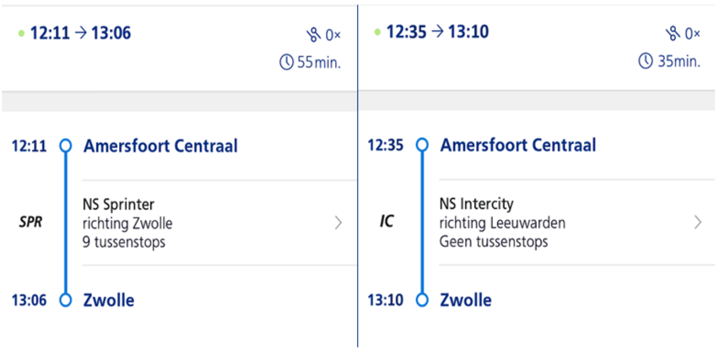

Figure 6.14: Travel planner advice Amersfoort Centraal - Zwolle

Furthermore, the distribution per age group and travel purpose are examined. In figures 6.15 and 6.16 the choice behaviour per age group is visible. At the y-axis, the percentage that choose for the Sprinter option is shown. From home, all age groups make the same route choices,as can be seen in figure6.15. However, when making the route choice from the station, the younger age groups are more inclined to take the first train while the older age groups are waiting for the Intercity or the direct train, 6.16. This is an interesting finding because it implies that the route choice behaviour differs per age group. Reasons for this behaviour could be that younger people are more in a hurry, they dislike the waiting time at the station. Secondly, possibly older people value comfort more so they wait for the Intercity. The Intercity stops less often and has a different design with usually more comfortable chairs.

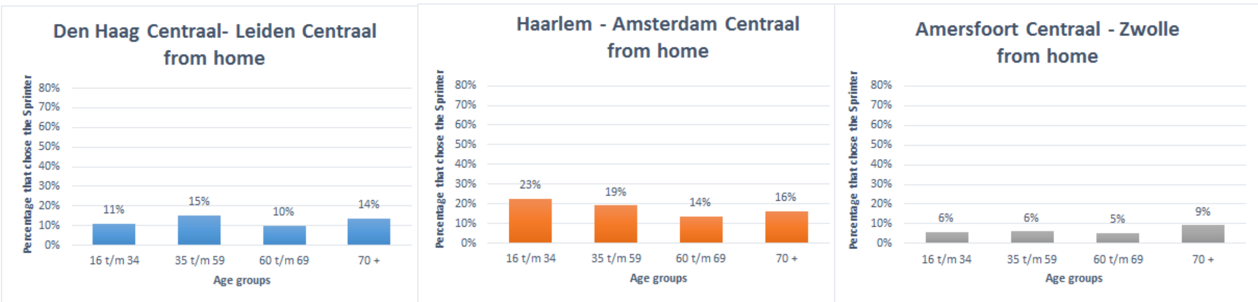

Figure 6.15: Percentage that choose for the Sprinter per age group when making the route choice from home

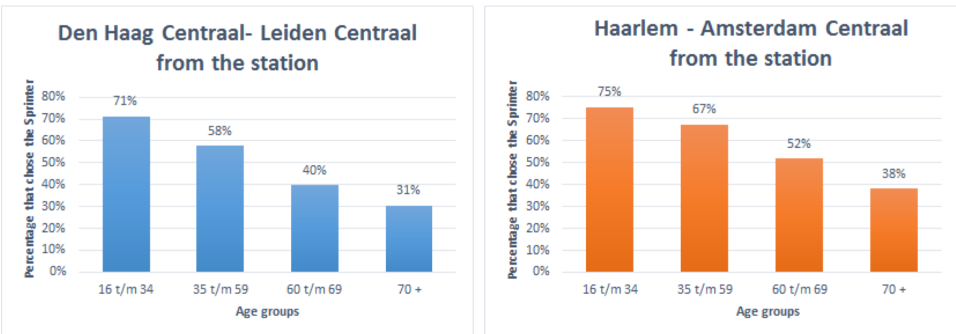

Figure 6.16: Percentage that choose for the Sprinter per age group when making the route choice at the station

Next to age, the route choice of Must travellers is also compared to that of Lust travellers. In 6.17 and 6.18 the percentage choosing for the Sprinter per Must and Lust traveller from home and at the station is shown. The Must and Lust travellers are almost making the same choice when choosing from home. When choosing from the station, it is visible that more Must than Lust travellers take the Sprinter. Probably, because Must travellers are more in a hurry. Furthermore, this finding could be correlated with the finding of the different choice behaviour between age groups because in the younger age groups there are more Must travellers than Lust travellers.

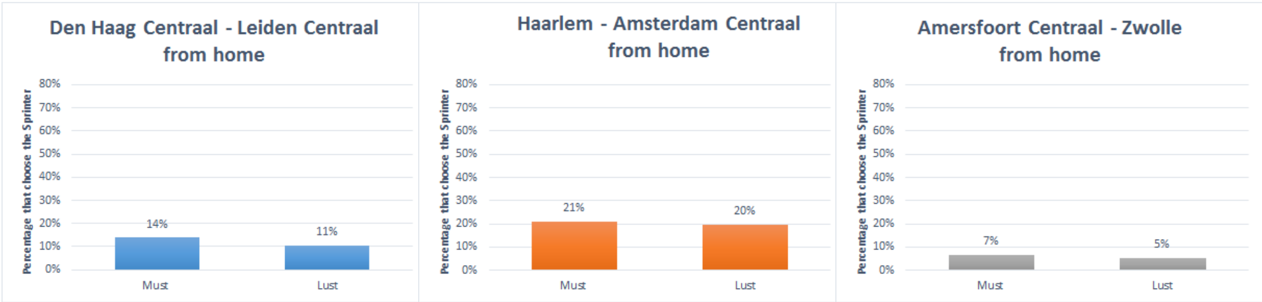

Figure 6.17: Percentage that choose for the Sprinter when making the route choice from home

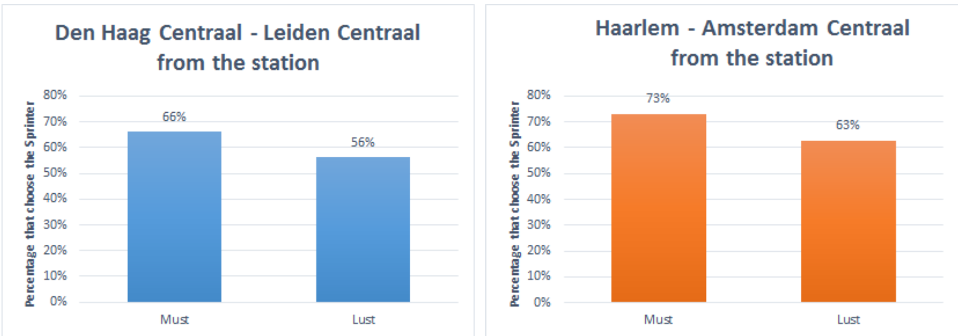

Figure 6.18: Percentage that choose for the Sprinter when making the route choice at the station

6.5.2. Transfer or direct train trade-off

To continue, the three trajectories with the transfer/direct trade-off are discussed. In figures 6.19, 6.21 and 6.23 the choice distributions are shown. As well as in the Sprinter/Intercity trade-off, the choice behaviour from home is different from the choice behaviour at the station. From home, passengers choose the most comfortable option, so the direct train in this case. On the route Zwolle-'s Hertogenbosch, the two travel options depart simultaneously, so the waiting time does not play a role and the trade-off from the station is the same as the trade-off from home. So, this trajectory is only asked from home and the same choice distribution is assumed at the station. At Zwolle - 's Hertogenbosch, the time difference between the transfer and the direct train is significant. This time difference has impact on the route choice behaviour because 54 percent of the passengers choose for the transfer instead of the most comfortable option, the direct train. Moreover, the transfer time at Zwolle - 's Hertogenbosch is longer than at the other transfer options, which could be of influence. Passengers could be more comfortable with taking a transfer that has more transfer time.

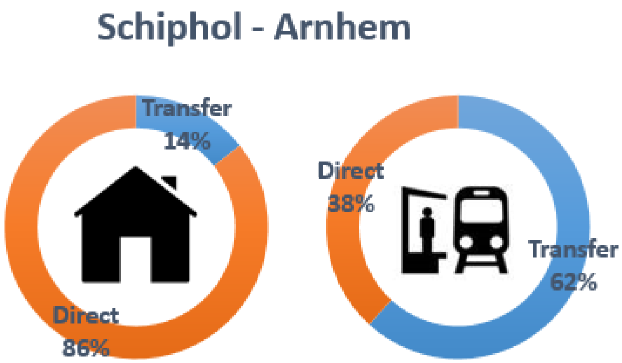

Figure 6.19: Choice distribution Schiphol Airport- Arnhem Centraal from the home and at the station

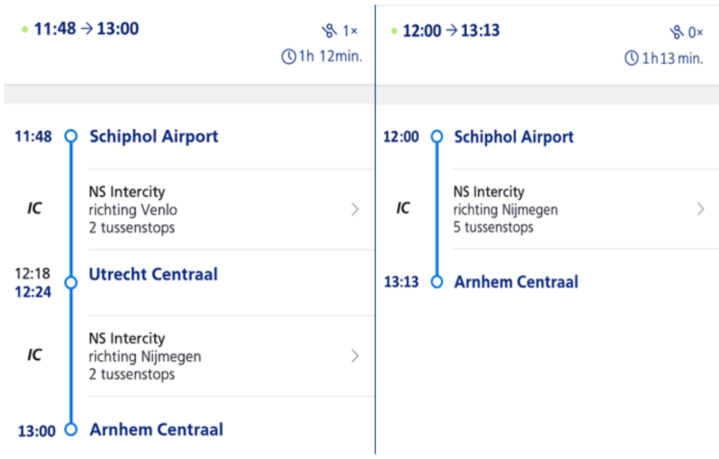

Figure 6.20: Travel planner advice Schiphol Airport- Arnhem Centraal

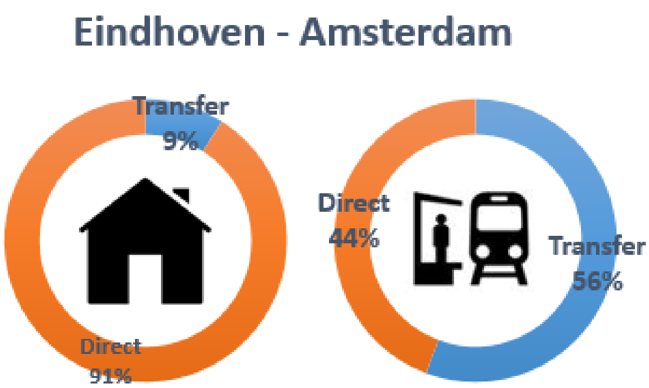

Figure 6.21: Choice distribution Eindhoven Centraal - Amsterdam Centraal from the home and at the station

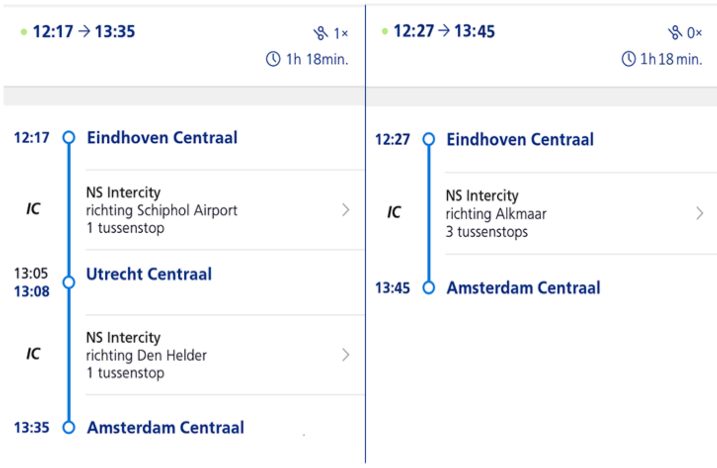

Figure 6.22: Travel planner advice Eindhoven Centraal - Amsterdam Centraal

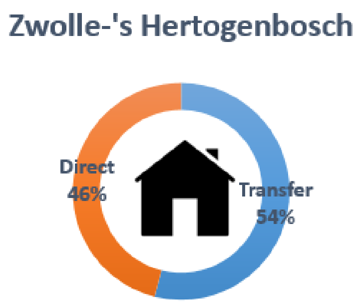

Figure 6.23: Choice distribution Zwolle - 's-Hertogenbosch from the home

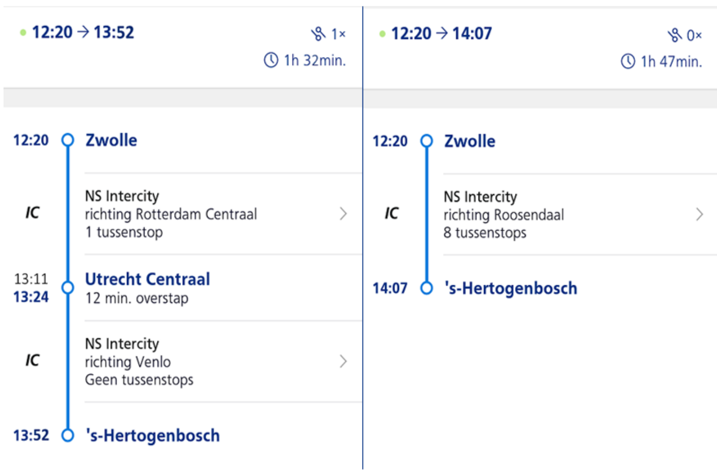

Figure 6.24: Travel planner advice Zwolle - 's-Hertogenbosch

As well as in the Sprinter/Intercity trade of, the difference per age groups is analysed. The percentage that chooses for the transfer per age group is shown in figures 6.25 and 6.26. On the vertical axis, the percentage choosing for the transfer option is visible. When selecting a route from home, it is visible that for Schiphol Airport - Arnhem Centraal and Eindhoven Centraal - Amsterdam Centraal, the difference in choice behaviour between age groups are small. The older age groups choose slightly more often for the transfer than the younger age groups. This difference is contradictory to the other findings. However, the increase is small, hence may be statistically insignificant. At Zwolle-'s Hertogenbosch, a significant downward slope over the age groups is visible. The younger age groups are choosing more often for the transfer, which is an effective faster travel option. In this case the travel option including a transfer is 15 minutes faster than the direct travel option. In the other two cases, Schiphol Airport - Arnhem Centraal and Eindhoven Centraal - Amsterdam Centraal, the time difference between the two travel options are zero or one minute. This implies that the turning point of young age groups to choose the travel options with a transfer from home lies somewhere below 15 minutes. The reason for this could be that younger passengers have less hesitance to a transfer than older passengers. Moreover, it could be that younger passengers have a higher value of time, so they prefer the fastest route.

When looking at the choice distribution per age group when passengers are choosing at the station, the same thing as from the Sprinter/Intercity trade-off is visible. If passengers choose when they are already at the station, it is clearly visible that the younger age groups choose more for the transfer 6.26. At Schiphol Airport - Arnhem Centraal, the highest percentage of young people choose for the transfer. The reason for this could be that at Schiphol Airport - Arnhem Centraal, the waiting time before the direct train departs is the longest, 12 minutes. It seems that the younger age groups have a lower resistance to making a transfer and do not want to wait at the station.

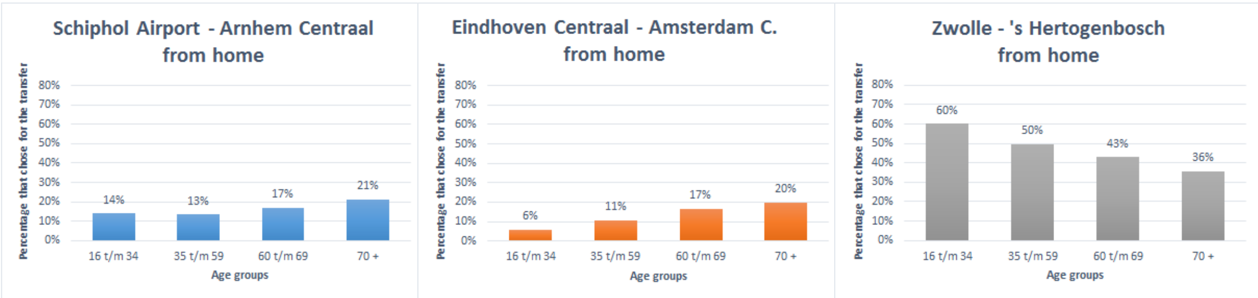

Figure 6.25: Percentage that choose for the transfer options per age group when making the route choice from home

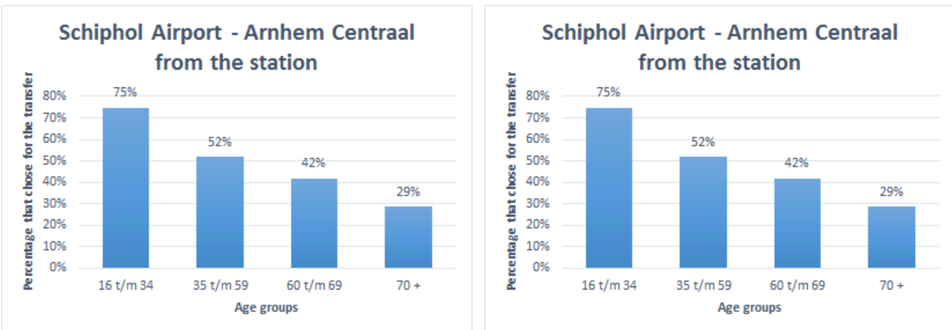

Figure 6.26: Percentage that choose for the transfer options per age groups when making the route choice from the station

Again, also the travel purpose is considered. The choice behaviour difference between Must and Lust travellers is shown in figures6.27 and 6.28. When passengers decide at home Must and Lust travelers are almost the same, a horizontal line is visible. Similarly as at the Sprinter/Intercity consideration, when passengers are making the choice from the station, there is a small difference between Must and Lust travellers. At the routes Schiphol - Arnhem and Eindhoven - Amsterdam, a little more Must than Lust travellers are taking the transfer options. A reason for this could be that Must travellers are more in a hurry. However, at Zwolle-'s Hertogenbosch, the travel time difference between the two travel options is bigger and Must and Lust travellers make the same choice at that trajectory. This implies that the difference in arrival time does not directly influence the difference in choice between the Must an Lust travellers. Moreover, another reason could be the waiting time. Probably, Must travellers dislike waiting at the station, so they take the first travel options, which is in this case the transfer. Comparing this result with the result of the age distribution, more Must travellers choosing for the transfer seems a logical finding because Must travellers are often younger people.

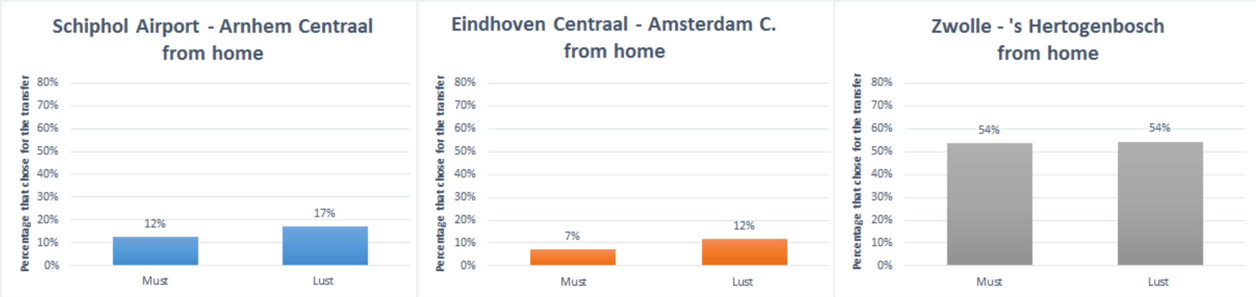

Figure 6.27: Percentage that choose for the transfer options when making the route choice from home

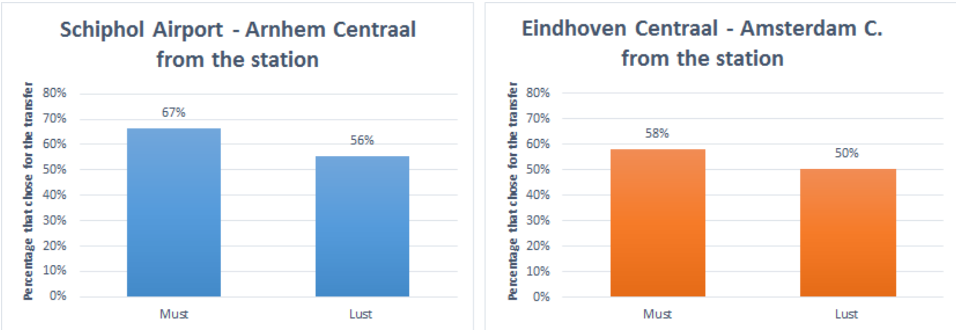

Figure 6.28: Percentage that choose for the transfer options when making the route choice from the station

6.6. Conclusion

The passengers are asked about their NS travel planner use, and overall they are really positive about the travel planner. This makes the travel planner a really powerful tool, most passengers use the travel planner of NS, 52% answers that they always use the travel planner when travelling with the train. If passengers are using the travel planner, the compliance rate is high, 41% always follows one of the adviced routes and 51% follow an adviced route more than half of the times. The choice moment, the moment the passenger selects a route is found as an essential factor in choice behaviour. The route choice can be made from home before departing to the station or the route choice can be made at the station. The results of the choice behaviour of the respondents are as expected. The choice behaviour differs substantially between the two choice moments that are used. From home, passengers take the most beneficial travel option and if passengers are already at the station, they tend to take the first available travel option. It is important to be aware of this and take it into account in prediction model. This choice moment depends on the kind of journey and situation. For the outbound journey 60% of the respondent (almost) always make the route choice from home, 14% (almost) always makes the route choice from the station. For the homebound journey more passengers maker their route choice from the station, this is 24%.

Furthermore, all age groups make the same route choices from home if there is not much time difference between the two travel options. If the travel time difference is significant, the younger age groups seems more inclined to take the faster travel options. In the case of Zwolle - s' Hertogenbosch, the travel time difference between the two travel options is 15 minutes, and waiting time does not play a role. In this case, from the youngest age group 60 % choose for the transfer, while in the highest age group only 36% choose the for the transfer instead of the direct train. Probably because younger passengers have a higher value of time and a lower resistance for making a transfer. Considering the choice moment from the station, when passengers are already at the station the younger age groups are also more inclined to take the first train while the older age groups are waiting for the Intercity or the direct train. For example at Den Haag Centraal - Leiden Centraal making the choice from the station, in the youngest age group 71% choose for the Sprinter while from the oldest age group only 31% choose for the Sprinter. This could be because the younger age groups dislike waiting at the station. Additionally, as also mentioned above, it could be that their hesitance, so disutility, for making a transfer and travelling with the Sprinter instead of the Intercity is lower.

7

Comparison of the questionnaire results with the forecast of NS

In this chapter, the route choice distributions resulting from the questionnaire are compared to the distributions of the passenger allocation of VISUM, the results are shown and discussed. This comparison is made visually and statistically, using a Chi-square test. In the fourth sections a choice model is estimated with the available data to see if this is possible and if the results are logical.

7.1. Distribution of VISUM

In the questionnaire, the route choice of the passengers is split up in passengers that make the route choice from home and passengers that are making the route choice from the station. In the forecast of VISUM both choice moments are captured in the passenger allocation. However, no explicit distinction is made so it is not possible to split up the passenger allocation of VISUM for the two choice moments. The prediction of VISUM is expected to lie between the two limits of the questionnaire. The two limits of the questionnaire are the the choice from home where most people choose for the fastest most comfortable route and the choice from the station where most passengers take the first travel option available.

The distribution of VISUM is compared with the choice the respondents made from home assuming that most passengers make their route choice before departing to the station as is found from figures 6.4 and 6.5. The disadvantage of this is that in the VISUM distribution, all passengers are included, instead of only passengers making the route choice at home. The comparison is made, taking this into account. To approach the route choice from the station with VISUM, some setting are changed. A run is made in which all passengers are arriving at the station in one minute and passengers are not allowed to go back in time. In this way, the waiting time of waiting at the station is corporate.

7.2. Visual comparision

To get more insight into the difference between VISUM and the questionnaire results, per route, the distribution of the questionnaire results and the passenger allocation of VISUM are compared. In all the following figures, first, the choice behaviour from home resulting from the questionnaire next to the passenger allocation of VISUM is presented. Then, the choice from the station and a VISUM run of one minute is presented. In figure 7.1, 7.2 and 7.3 the Sprinter Intercity trajectories are shown. As is visible the distributions match, which means the prediction of VISUM lies close to the results of the questionnaire. Comparing the choice from home with VISUM, VISUM assigns in general more passengers to the Sprinter than the results from the questionnaire. However, this is accountable to the fact that the results of VISUM consists of all passengers. This means that the passenger allocation of VISUM of the Sprinter/Intercity trade-off is accurate. The sprinter and waiting time penalty together make and accurate prediction on a Sprinter/Intercity route for the choice from home and the choice from the station separately.

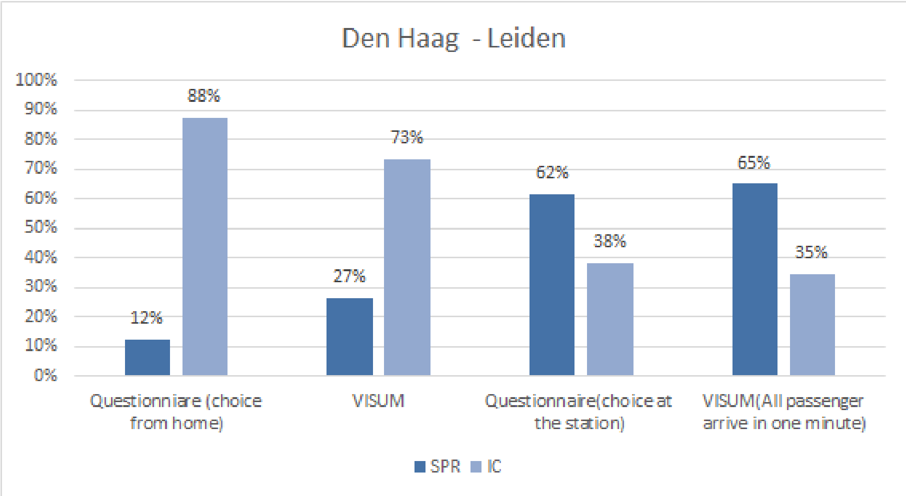

Figure 7.1: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Den Haag Centraal - Leiden Centraal

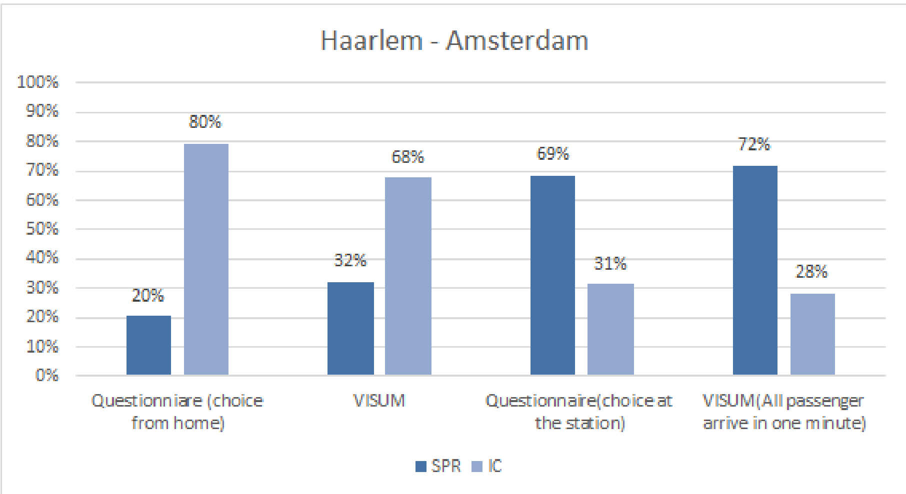

Figure 7.2: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Haarlem - Amsterdam Centraal

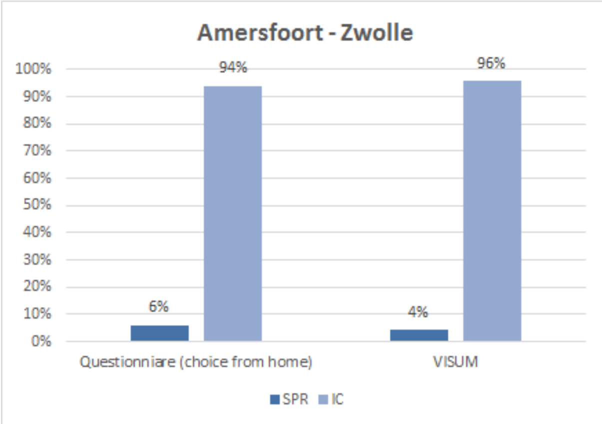

Figure 7.3: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Amersfoort Centraal - Zwolle

Next to the Sprinter/Intercity trade-off the transfer/direct trade-off is analysed. In figure 7.4, 7.5 and 7.6 the transfer/direct trade-off routes are shown. Comparing the choice from home and VISUM, the same as at the Sprinter Intercity trajectories is visible. VISUM allocates more passengers to the transfer, which seems logical because VISUM also includes passengers who choose from home. Furthermore, in the comparison of the choice from the station, a difference is found. In 7.4 and 7.5 is visible that VISUM assigns fewer passengers to the transfer than the results of the questionnaire. This difference could follow from a too high transfer resistance in VISUM or a too low penalty for waiting at the station. For the direct train, passengers need to wait at the station. This result would imply that more passenger are taking the transfer options than expected which makes the transfer route more crowded than expected.

Nevertheless, in figure 7.6 where both travel options depart at the same time VISUM matches good with the questionnaire result, so this implies the transfer resistance is suitable. Waiting time is not of influence on Zwolle - 's Hertogenbosch because both travel options depart simultaneously. Therefore, it seems that the transfer penalty gives a good estimation however the combination of waiting time and transfer penalty gives a worse fit.

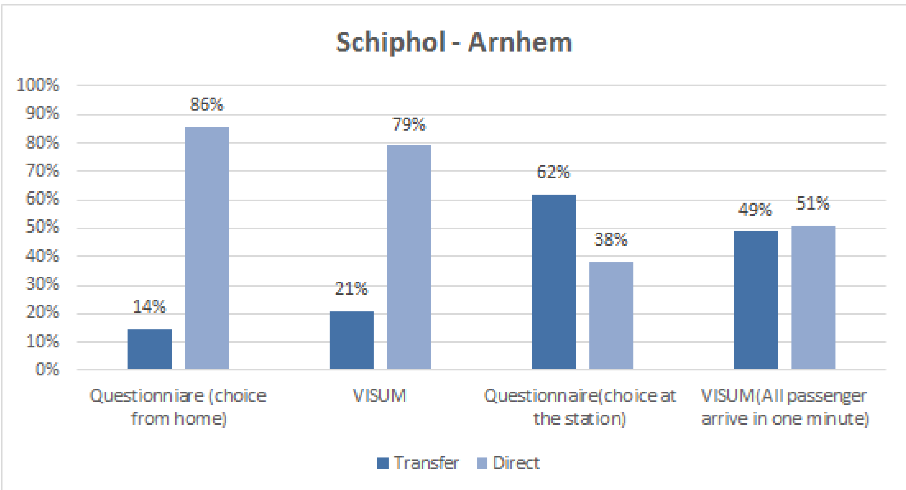

Figure 7.4: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Schiphol Airport - Arnhem

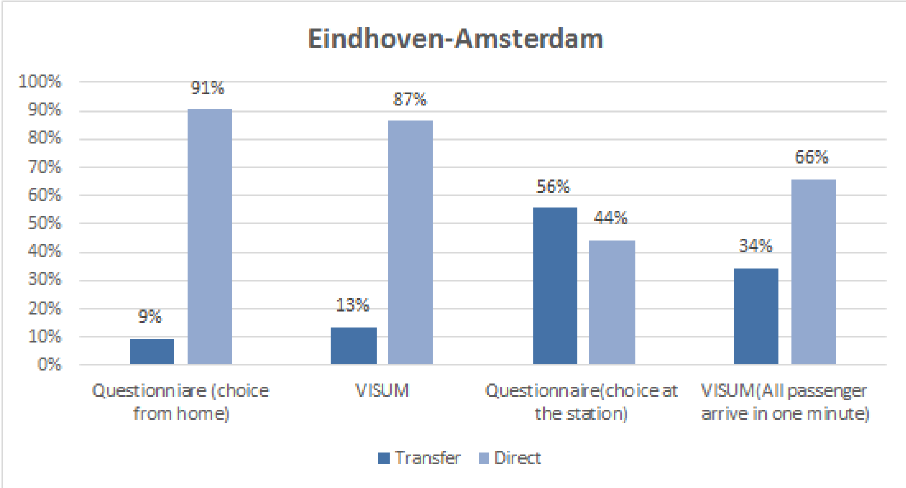

Figure 7.5: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Eindhoven Centraal - Amsterdam Centraal

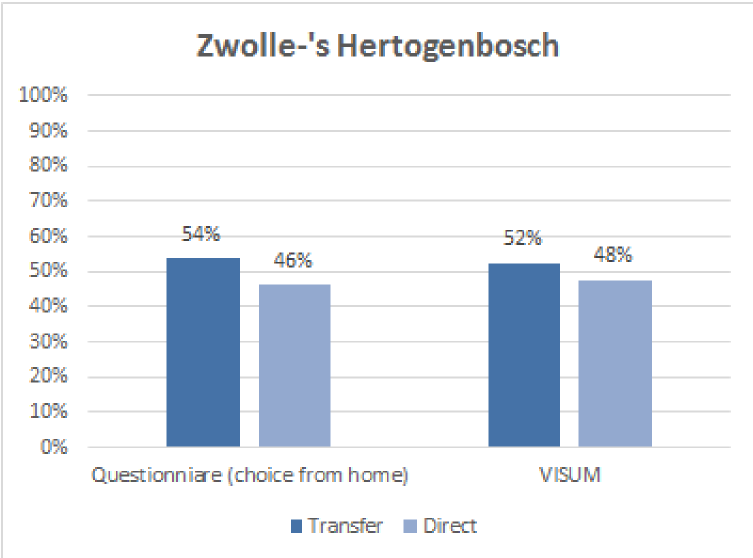

Figure 7.6: Comparision of the passenger distribution of VISUM with the distribution resulting from the questionnaire on Zwolle - 's Hertogenbosch

7.3. Chi-square test

To get more insights into the relative difference between the questionnaire result and VISUM, the goodness of fit Chi-square test is used. This test is suitable because it compares two distributions. With this test, the relative difference between the observed and expected amount of passengers is tested. The observed number of passengers results from the questionnaire, while the expected amount is the passenger distribution of VISUM. The null hypothesis is that the results from the questionnaire are equal to the distribution of VISUM. With the following formula, the X^2 per route is calculated to test this hypothesis:

$$X^2 = \sum (O - E)^2/E$$

With a probability level of 0.05 and one degree of freedom, the null hypothesis cannot be rejected if X^2 is smaller than or equal to 3.841. In table 7.1 the Chi-square values per trajectory are shown. On the route, Den Haag Centraal - Leiden Centraal (from the station), Haarlem - Amsterdam (from the station) and Zwolle - 's Hertogenbosch the null hypothesis, that the expected and the observed values are equal, is not rejected. This means that these three trajectories give the best fit, which confirms the finding from the visual analysis. Overall, the fit is the best at the Sprinter/Intercity routes. Zwolle - 's Hertogenbosch gives the best fit of all routes. The difference between Zwolle - 's Hertogenbosch and the other routes is that at Zwolle - 's Hertogenbosch waiting time does not play a role. This implies that probably the waiting time penalty is not completely right. Moreover, for all the choices from home, the null hypothesis is not accepted. This is an expected result since the distributions from home are compared with the total allocation of VISUM. This total allocation of VISUM also includes the choices passengers make from home, which makes the fit not perfect.

Table 7.1: The X^2 values calculated per route

Route	X^2	H0 Rejected?
Sprinter/Intercity		
Den Haag - Leiden from home	71,21	Yes
Den Haag - Leiden from the station	2,90	No
Haarlem - Amsterdam from home	40,47	Yes
Haarlem-Amsterdam from the station	3,67	No
Amersfoort - Zwolle	7,17	Yes
Transfer/direct		
Schiphol - Arnhem from home	17,48	Yes
Schiphol-Arnhem from the station	43,56	Yes
Eindhoven-Amsterdam from home	9,05	Yes
Eindhoven-Amsterdam from the station	139,45	Yes
Zwolle-'s Hertogenbosch	0,86	No

7.4. Choice models

To investigate if the collected data is also suitable for predicting what passengers would do in a particular situations, some simple choice models are estimated in Biogeme as is described in section 2.3.2. Four different situations are following from the questionnaire:

1. Sprinter/Intercity trade-off from home
2. Sprinter/Intercity trade-off at the station
3. Transfer/direct train trade-off from home
4. Transfer/direct train from the station

For these four situations a choice model is is made. However, the second en fourth model estimation did not succeed.The data of making the choice from the station is not suitable to estimate a choice model. The passengers often choose for the first travel option if they are already at the station. Even when the waiting time is added to the utility function, the rho-square value is too low, the complete result tables are visible in Appendix C. Rho-square gives a value that indicates the statistical measure of fit of the choice model. So Biogeme does not estimate a reasonable choice model with the available data when passenger are making their route choice from the station. The results of the two other models, so the route choices from home, are described and shown below.

For the first situation, the Sprinter/Intercity consideration from home, the following utility function is used:

$$UtilityAlternativen = \beta_{time} * TravelTime_{alternativen} + \beta_{sprinter} * traintype_{alternativen}$$

For every case, there are two alternatives, the Sprinter and the Intercity, so n is two.$traintype_{alternativen}$ is zero for the Intercity option and one if it is a Sprinter. The rho-square of the results of this estimation is 0.48, which makes it a good fit. The complete result tables are visible in Appendix C. The results of the estimated parameters are visible in table 7.2. The order of the estimated beta parameters is as expected, logical values are find. The disutility for one minute extra travel time is -0,07 and the disutility for a sprinter instead of an intercity -1,39. The Sprinter disutility can be converted to minutes by dividing the disutility for a Sprinter by the disutility for an extra travel minute. $1,39/0,0679 = 20,47$ minutes. So, the disutility of travelling with the Sprinter is equal to 20,47 extra travel minutes. This implies that the if the sprinter would be 20 minutes faster than the intercity, they would be equally attracted. However this is never the case so almost all passengers will choose for the intercity if they make the route choice from home.

Table 7.2: Estimated βvalues of the Sprinter/Intercity consideration from home

Name	Value	Std err	t-test	p-val
$\beta_{sprinter}$	-1,39	0,114	-12,17	0.00
β_{time}	-0.0679	0.0118	-5,76	0.00

For the third situation, the transfer/direct train from home the following utility function is used:

$$UtilityAlternativen = \beta_{time} * TravelTime_{alternativen} + \beta_{transfer} * transfer_{alternativen}$$

For every case, there were again two alternatives. $transfer_{alternativen}$ is one for the transfer options and zero if it is a direct train. The rho-square of this test is 0.25, which makes it an acceptable fit. The complete result tables are visible in appendix C. The results of the estimated parameters are visible in table 7.3. The disutility per minute travel time is -0,107 and the disutility for making a transfer is -1,72. This is a logical result, a transfer gives a lot more disutility than an extra travel minute. So a transfer, when making the route choice from home, gives a disutility of $1,72/0,107 = 16,07$ minutes of in-vehicle time. So a travel option with a transfer needs to be 16 or more minutes faster than the direct train to make it an attractive travel option.

Table 7.3: Estimated β values for the transfer/direct consideration from home

Name	Value	Std err	t-test	p-val
β_{time}	-0,107	0,00743	-14,42	0.00
$\beta_{transfer}$	-1,72	0.0775	-22,16	0.00

The found value or the transfer penalty seem a really realistic value. However there was not a lot of data, the order of magnitude of the transfer penalty of the choice model matches the transfer penalty of VISUM. The transfer penalty of VISUM is trade secrecy so this value cannot be mentioned here. Moreover, considering the literature about transfer penalties that are described in section 3.6.2 the found result of 16 minutes seems also plausible. For multimodal trips a transfer penalty of 11 [Yoo, 2015] and 17 [Hunt, 1990] minutes was found in the literature. For train trips a penalty of 14.8 [Algers et al., 1975] and 8 [Wardman et al., 2011] minutes was found. So the found transfer penalty of this research fit the range from the literature but seems a little bit high in comparing it to the train transfer penalties found in the literature.

7.5. Conclusion

Evaluating the allocation of VISUM, no big problems arise and the forecast seems accurate in an average situation. This means that the predictions of VISUM match the behaviour that was resulting from the questionnaire, the deviation runs from 2 - 22%. Problems that could arise are a mismatch between passenger demand and rolling stock which can lead to overcrowded trains or empty trains which costs a lot of money.

More specific findings are that on average, at the Sprinter/Intercity consideration, the fit of VISUM is better than at the transfer/direct train consideration. The transfer penalty gives the worst fit when passengers are choosing from the station instead of from home. In this situation, the waiting time does also plays a role that can influence the result. So the combination of waiting time and a possible transfer penalty does not give a good fit. However, evaluating these two variables separately they perform well. Considering the waiting time penalty, in the Sprinter/Intercity consideration from the station, the waiting time also plays a role and the fit is good. Furthermore, considering the transfer penalty, at Zwolle - 's Hertogenbosch waiting time does not play a role and the allocation of VISUM is really similar to the questionnaire results. On the Sprinter/Intercity consideration from home as well as on Zwolle - ’s Hertogenbosch the null hypothesis of the Chi-square test is accepted so the distribution are considered the same. So the waiting time penalty and the transfer penalty preform good on their own but together they give a the worst fit.

Furthermore, the estimated transfer resistant by the choice model, 16 minutes of in vehicle time, is really reasonable when comparing it to the the used transfer resistance of VISUM and the literature about the values of transfer penalties.

8 Conclusions and recommendations

In this last chapter, the conclusion, limitations, and recommendations of this study are described. The recommendations for NS, as well as general recommendations are explained.

8.1. Conclusions

First, the conclusions of the found route choice behaviour are discussed where after the conclusion of the comparison of the route choice behaviour and the prediction from NS is described. Then, the travel planner use is outlined. Last, the research questions as presented in the chapter 1, the introduction are answered. In figure 8.1 a visual overview of the main findings is visible.

8.1.1. Route choice behaviour

From the pilot questionnaire was concluded that the moment the passengers make their route choice is of impact on their choice behaviour. The results in choice behaviour from the final questionnaire confirms this finding. As expected, if passengers are already at the station, they are more inclined to take the first travel option instead of waiting at the station for a more comfortable and faster travel option. Waiting time plays an essential factor in making a route choice at the station. When passengers make their route choice from home, they are more inclined to take the most comfortable and fastest travel options. So, the Intercity instead of the Sprinter and the direct train instead of a route with a transfer.

Moreover, all age groups make the same route choices from home if there is not much time difference between the two travel options. If the travel time difference is 15 minutes the younger age groups seems more inclined to take the faster travel option. They take the route including a transfer to be 15 of more minutes faster. Furthermore, a significant difference is seen between age groups when passengers choose from the station. In this choice situation, younger age groups are much more inclined to take the first travel option, while older age groups are more willing to wait at the station for the direct train or the Intercity. For example on the route Den Haag Centraal - Leiden Centraal making the choice from the station, from the youngest age group 71% choose for the Sprinter. While from the oldest age group only 31% make the choice for the Sprinter. The reason for this could be that younger people do not like waiting at the station or are more often in a hurry. Another reason could be that the transfer resistance is lower for the younger age groups.

8.1.2. Comparing the route choice behaviour with the passenger prediction

When comparing the questionnaire results to the passenger allocation of VISUM, no alarming differences are found. No direct measures are needed. However, there are still points on which VISUM can be improved. The challenging aspect in comparing the questionnaire choice behaviour to the allocation of VISUM is that VISUM does not split up the route choice per age group and choice moment.

In general, the Sprinter/Intercity trade-off has a better fit than the transfer/direct trade-off. When choosing at the station, VISUM allocates fewer passengers to the transfer than the questionnaire results. A too high penalty for the transfer or a too low penalty for waiting at the station is possibly used. In contrast, the transfer/direct trade-off Zwolle - 's Hertogenbosch gives the best fit from the researched routes. In the Zwolle - 's Hertogenbosch case, waiting time does not play a role because the trains depart simultaneously. This implies that the transfer penalty on its own match with the questionnaire results. On the other hand, the Sprinter/Intercity trade-off from the station gives a good fit, and waiting time does play a role in this case. This indicates that the waiting time penalty also fits the questionnaire results. Therefore, however, the transfer penalty and the waiting time penalty seem to work well when used separately, the combination of both parameters does not give the best fit.

The consequence of different choice behaviour depending on the choice moment, as described in section 8.1.1, makes it useful to incorporate this in the used choice model. On the other hand, adding more complexity to a model could also increase the run time and costs. VISUM predicts the choice behaviour in an average situation and does not distinguish between choice moment and age. As long as VISUM predicts an average situation, this will not cause problems. However, if there is a situation in which one kind of passenger is involved the prediction will not match the realisation. For example, if all passengers are making their choice from the station, the allocation of VISUM is not accurate. This kind of situations could occur during an event where passengers want to depart simultaneously and do not plan their departure time on forehand. In these specific situations, it is essential to take the different behaviour per choice moment into account.

8.1.3. Travel planner use

The questionnaire results confirm the statement of chapter 1, the travel planner is used extensively. 52 % of the train passengers always use the NS travel planner and 22 % indicate that they use the travel planner more than half of the times when traveling by train. The compliance rate of a descriptive route advice, as the travel planner of NS, was not found in the literature. From the questionnaire is concluded that the compliance rate of the travel planner is reasonably high, 41% does always follow one of the travel options of the planner and 51 % indicate that they follow a suggested route advice more than half of the times. When asking passengers about their the trust, ease and opinion of the planner, more than half of the passengers agreed with the statements: 'I trust the NS travel planner in giving me the best advice', 'The NS travel planner makes travelling by train easier' and 'I think the travel planner is user friendly'. There are two main suggestions of the respondents to improve the travel planner. Firstly, a tool in which passengers can set a shorter transfer time for a trip is suggested. Secondly, passengers indicate that they want the planner to be updated more frequently, especially in times of disruptions. Altogether, the results are positive for NS, the travel planner is broadly used, and passengers mainly follow the advice. Hence, the travel planner of NS is a powerful tool.

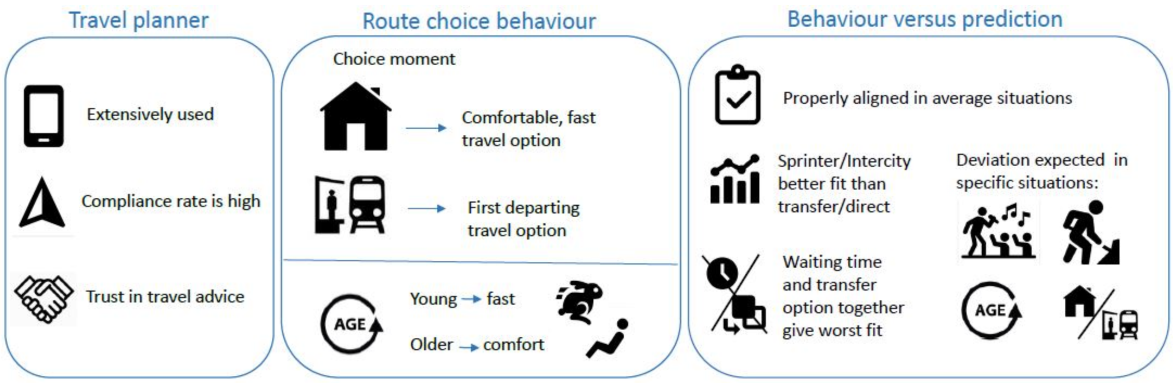

Figure 8.1: Overview of findings visualised in an infographic

8.1.4. Research questions

Now that all the general conclusions are drawn, the concrete answers to the sub-questions are presented. The five sub-questions of this research, specified in Chapter 1, are treated in order.

Starting with the first sub-questions, 'Which train passengers are using route advice?'. In the literature was found that infrequent travellers and travellers with a long and time sensitive journeys use travel

advice. However, from the questionnaire is concluded that most passengers use the travel planner of NS. Furthermore, Lust travellers and older people make a bit more use of the travel planner. Travel frequency had not a significant impact on the NS travel planner use. These findings do not directly confirm either deny the results of the literature.
Moving on to the second sub-question, 'Do passengers follow route advice?' In the literature, the compliance rate of prescriptive route travel advice was not found. Resulting from the questionnaire, 40 % of the respondents always follow one of the travel planner options of the NS and 50 percent follow more than half of the times one of the advised routes of the travel planner. Furthermore, for the infrequent and Lust travellers the compliance rate is slightly higher than for the other users.
The third question is about the prediction model of NS, 'How does the prediction model of NS assign passengers to trains?'. NS uses VISUM to allocate passenger to trains, VISUM is a transportation model. It is a program with a distribution procedure to model all the traveling passengers in five steps. The model inputs are the origin-destination matrices with the expected number of passengers and the timetable. VISUM calculated the resistance for every travel option using the perceived journey time.
Next, the fourth question, 'Which route choices do passengers make using the travel planner of NS?', is answered. Passengers' choice behaviour is depending on the choice moment of the passenger. If passengers choose from home, passengers will choose the most comfortable and fastest travel option. However, passengers will more often choose the first departing travel option from the station, even though this is not the most comfortable journey.
The last sub-question is about the match between the questionnaire results and the forecast, 'To what extent does the passenger assignment algorithm of NS match the route choices passengers are making?' The match between the allocation of VISUM and the passenger behaviour following from the questionnaire is good. No big differences or problems arise. The fit is the best for the Sprinter/Intercity consideration. The transfer/direct train consideration from the station gives the most significant difference. The combination of waiting time and transfer penalty gives this result. Nevertheless, VISUM gives only a general value that does not split up the allocation per choice moment or age group, which probably makes the fit worse in a specific situation as mentioned in section 8.1.1.

With the answers to the sub-questions, the main questions, 'How do train passengers use travel planner route advice and how can these insights be used to improve alignment of the passenger prediction with passenger route choice behaviour?', can be answered. Travel planner route advice is used extensively, and most passengers follow the route advice. The passenger predictions are already properly aligned. This can be improved by separately evaluate the different parameters used in VISUM in a new research using in- and out-check data. An improvement would be to determine various parameters per age group and distinguish between the choice moment from home and the choice moment at the station. Although, the increasing complexity and run time of the model should also be taken into account when implementing this.

8.2. Limitations

In this section, the assumptions and limitations that are made in this research are discussed. The questionnaire is executed in the NS panel, all passengers could apply for this panel. However, the expectation is that especially passengers who are traveling often or feel connected to NS in some way apply for the panel. This does not necessarily mean the results are biased, but it could influence the results. Furthermore, the assumption that passengers in reality, make the choice as they said in the questionnaire is made. This is a reasonable assumption. Nevertheless, respondents also indicated that the weather and the kind of appointment influence their route choice behaviour. Since the young passengers are underrepresented, weight factors are added to all user groups based on their age and travel purpose. In an ideal situation, the sample would already represent the population so all the responses are valued equally in the results. The disadvantage of working with weight values is that one respondent has more influence on the outcome than other respondents.

The biggest limitation of this research is that VISUM does not split up route choices per choice moment and age group, so not all comparisons can be made in an ideal way. The comparisons are made as best as possible, but totally isolating the choice situation in VISUM is not possible at this moment. Another limitation is that only real routes are used so the variations of variables are not very bright, which makes it hard to see the impact of one variable. So it is not possible to, for example, look at the effects of transfer time on choice behaviour.

8.3. Recommendations

In this section the recommendations are discussed. General recommendations as well as recommendations focusing on the NS are done. Also, some suggestions for further research are done in the second subsection.

8.3.1. General recommendations

From this research is concluded that the choice moment and age of passengers is of great impact on their choice behaviour. It would be good to take these aspects into account in passenger route choice models. On average, the influence of choice moment on choice behaviour is expected to be bigger that the influence of age. However, the age of a passenger is easier to track in doing research as well as in prediction models. Furthermore, it is important to weight the advantages against the disadvantages of implementing this aspects in route choice models. The disadvantages could be higher costs and a more complex model with a longer run time. On the other side, this could lead to a better passengers prediction in which rolling stock costs can be saved and more passenger are satisfied.

Another finding of this research is that travel planners are used extensively. Passengers are used to following the advice and trust the given advice. It is interesting to research if it is possible to steer passengers with route travel advice. Possibly, this advice could also be specialised per person to create system-beneficial travel information, as is described in section 3.2. Another possibility is to steer passengers by informing them which routes are busy an on which routes there is more space which probably results in passengers choosing for the route with more space. In this way passenger could be steered to the more quit routes.

8.3.2. Further research

Some points for further research are described in this section. From the literature research, in chapter 3, was concluded that familiarity of a route influences the choice behaviour. In this research no further conclusion where drawn on this subject because not enough respondents were familiar with the used routes. Further research is needed to see whether and how familiarity of a route influences route choice behaviour. Moving on, the impact of the route choice moment is identified in this research. However, to incorporate this into route choice model it is important to gather more information about What influences the choice moment of a passenger. For example, identify why passenger sometimes make their route choice from home and other moments choose from the station. Furthermore, to research the possibility of steering passengers with travel advice this needs to be tested. With more empirical knowledge can be discovered how far travel planners can go to identify when passengers stop following adviced routes that are not the fastest route.

8.3.3. Recommendations for the NS

Considering VISUM, for more research on certain parts or parameters, VISUM needs to be more comprehensible. Detailed research is possible if, for example, the allocation of age groups are split up. Furthermore, as mentioned earlier, the choice moment has a lot of impact on the choice behaviour, so it would be good to implement this into VISUM. Focusing on the transfer penalty, now the transfer penalty is always the same. An improvement would be to adapt the penalty to the kind of transfer, a cross-platform penalty probably gives a lower penalty than a cross-station penalty. Another enhancement could be, adding a transfer penalty per age group. To confirm the findings of this research, the found choice behaviour can be compared with the in an out check data to see if this matches. Furthermore, it would be good to do a new calibration study for VISUM with recent in and out check data. The parameters that are now used in VISUM are from a calibration study of 2016. In this study the difference in choice behaviour per age groups and choice moment can be analysed. In this way, the influence of this factors can be made comprehensible and a well-considered decision can be made whether to incorporate this in VISUM or not.

Focusing on the travel planner use, the travel planner of NS is widely used and the advice is often

followed. This gives the possibility to probably influence the route choice of passengers. The 8% that indicates that they do not use the travel planner often use 9292 out of habit or that 9292 gives better information about the bus, tram and metro. To stimulate these passengers to use the NS travel planner, improving information about the bus, tram and metro in the NS travel planner will be helpful. Promoting the availability of this information is important because not all passengers are aware that planning a trip from door to door is possible in the NS travel planner. Increasing travel planner use will increase the power of the travel planner.
Altogether, if NS, with the NS travel planner, wants to be a door-to-door provider. The door-to-door travel information should be improved and more knowledge about choice behaviour should be collected to understand how passengers are choosing a route and create the possibility to probably steer passengers.

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A

Questionnaire in Dutch

Uitnodigingsmail: Welke trein kiest u?

Welke trein kiest u? In dit onderzoek willen we graag meer weten over uw gebruik van de reisplanner en welke trein u kiest op basis van de getoonde informatie. Hiermee helpt u Lara Witte bij haar afstudeeronderzoek en NS bij het verbeteren van ons informatie aanbod.

Het invullen van de enquête duurt ongeveer 10 minuten.

Klik op onderstaande button (of hier) om het onderzoek te starten.

--

Heeft u technische vragen over het onderzoek? Dan kunt u via ons contactformulier (link) contact met ons opnemen.

Alvast hartelijk dank voor uw deelname!

Met vriendelijke groet,

Brit Moritz
Klant- & Marktadvies
Nederlandse Spoorwegen

Lara Witte
Stagiaire
Nederlandse Spoorwegen

-

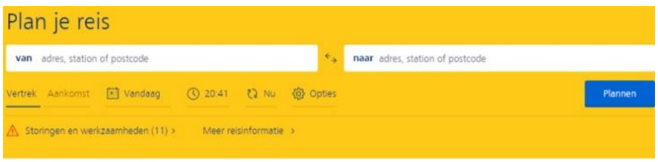
1. <h1 style="color:blue;"> Reisplanner gebruik en keuze gedrag </h1>

Welkom bij mijn enquête, ik ben Lara Witte en voor mijn afstudeer onderzoek bij NS doe ik een onderzoek naar het gebruik van de reisplanner. Door middel van dit onderzoek kijk ik naar de keuzes die reizigers maken met als doel de informatie service en de voorspelling van het aantal reizigers bij NS te verbeteren.

Het invullen van deze vragenlijst is anoniem en de gegevens worden vertrouwelijk behandeld. Het is op elk moment mogelijk om te stoppen, uw deelname is vrijwillig.

We vragen u om <u>geen rekening te houden met corona</u> tijdens het invullen van deze vragenlijst. U kunt uw reisgedrag van voor corona in gedachten nemen.

Onder de NS reisplanner versta ik de mogelijkheid van NS om via de website of de NS App op je telefoon je reis te plannen.



Het invullen van deze vragenlijst duurt ongeveer 10 minuten.

Alvast bedankt voor het meewerken aan dit onderzoek,

Lara Witte

2. Als ik met de trein reis gebruik ik de NS reisplanner (via de website of NS App)
   - Altijd ->4
   - Meer dan de helft van de keren ->4
   - Ongeveer de helft van de keren ->4
   - Minder dan de helft van de keren ->4
   - Nooit, ik gebruik voor mijn treinreizen een andere plannen namelijk .. (open)->3
   - Nooit, ik gebruik nooit een reisplanner ->9

3. Ik gebruik een andere reisplanner omdat ..
   - Open -> 9

Wij zijn benieuwd op welk moment u plant welke trein u wilt nemen en of dit moment varieert.

4. Met de reisplanner <u>kies</u> ik mijn <u>heenreis</u> met de trein …
   (met de heenreis bedoelen we de treinreis van uw huis naar uw bestemming)

	(bijna) Altijd	Soms	Nooit
.. thuis, een dag of meer van tevoren			
.. thuis, op de dag van vertrek			
.. op het station			

5. Met de reisplanner <u>kies</u> ik mijn <u>terugreis</u> met de trein …
   (met de terugreis bedoelen we de treinreis van uw bestemming naar uw huis)

	(bijna) Altijd	Soms	Nooit
.. thuis, een dag of meer van tevoren			
.. thuis, op de dag van vertrek			
.. op bestemming, voor vertrek naar station			
.. op het station			

6. Ik volg een van de reisopties van de NS reisplanner
   - Altijd ->9
   - Meer dan de helft van de keren ->7
   - Ongeveer de helft van de keren ->7
   - Minder dan de helft van de keren ->7
   - Nooit ->7

7. Ik volg niet (altijd) een van de opties van de reisplanner omdat …
   (open)

8. Mijn antwoord bij de vorige vraag gaat vooral over het volgende
   - Ik heb voorkeur voor een andere route omdat deze voor mij bekend is
   - Ik heb voorkeur voor een andere route want daar kan ik langs een service punt op het station zoals een kiosk of winkel
   - Ik heb voorkeur voor een andere route want ik vind deze betrouwbaarder
   - Ik heb meer overstaptijd nodig

- Ik kan op een snellere manier op mijn bestemming komen met de trein (bijvoorbeeld door minder overstap tijd)
- Ik ga naar het station en neem de eerst reis optie op dat moment
- Anders

9. Nu zullen er verschillende keuzes aan u voorgelegd worden. Hierbij kunt u telkens aangeven welke reisoptie u zou nemen.

   U mag uitgaan van een situatie voor de corona crisis. Verder mag u ervan uitgaan dat er geen treinen vertraagd zijn en alle treinen even druk zijn. (tussenpagina)

Overzicht casus vragen

	Volgorde in enquête		**Vraag**
1	Amf -Zl	IC/SPR	9
2	Shl - Ah	Overstap	11
3	Gvc - Ledn	IC/SPR	13
4	Ehv - Asd	Overstap	15
5	Hlm - Asd	IC/SPR	17
6	Zl- Ht	Overstap	19
	Onderbreking		21,22
Vanaf station 7	Shl - Ah	Overstap	23
Vanaf station 8	Hlm - Asd	IC/SPR	24
Vanaf station 9	Ehv - Asd	Overstap	25
Vanaf station 10	Gvc - Ledn	IC/SPR	26

10. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Amersfoort Centraal naar Zwolle reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 12:11 SPR (0:55)
    - 12:35 IC (0:35)

11. Hoe vaak reist u van Amersfoort Centraal naar Zwolle?
    - Nooit
    - Wel eens
    - Regelmatig

12. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Schiphol Airport naar Arnhem Centraal reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 11:48 overstap (1:12)
    - 12:00 direct (1:13)
13. Hoe vaak …

14. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Den Haag Centraal naar Leiden Centraal reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 12:08 SPR (00:18)
    - 12:17 IC (00:12)
15. Hoe vaak ..

16. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Eindhoven Centraal naar Amsterdam Centraal reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 12:17 overstap (1:18)
    - 12:27 direct (1:18)
17. Hoe vaak ..

18. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Haarlem naar Amsterdam Centraal reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 12:01 Spr (0:19)
    - 12:10 IC (0:15)
19. Hoe vaak ..

20. Stelt u zich voor, u plant uw reis vanuit huis. U wilt van Zwolle naar 's-Hertogenbosch reizen. Beide reisopties passen in uw agenda. Welke trein zou u nemen?
    - 12:20 overstap (1:32)
    - 12:20 direct (1:47)
21. Hoe vaak ..

22. Hier worden drie stellingen over de reisplanner gepresenteerd. U kunt aangeven in hoeverre u het eens bent met de stellingen.
    - Ik heb er vertrouwen in dat de NS reisplanner mij het beste advies geeft
    - De NS reisplanner maakt reizen met de trein gemakkelijk
    - Ik vind de NS reisplanner gebruiksvriendelijk

23. <p style="color:red;"> Nu volgen er nog 4 vragen waarbij u al op het station staat bij het maken van de keuze. </p>
    Hierbij kunt u weer aangeven welke reisoptie u zou nemen.
    U mag uitgaan van een situatie voor de coronacrisis. Verder mag u ervan uitgaan dat er geen treinen vertraagd zijn en alle treinen even druk zijn. (tussenpagina)

24. Stelt u zich voor, u staat op <u>station</u> Schiphol Airport. Het is <u>11:44</u> en u wilt graag naar Arnhem Centraal reizen. Welke trein zou u nemen?
    - 11:48 overstap (1:12)
    - 12:00 direct (1:13)
    -
25. Stelt u zich voor, u staat op <u>station</u> Haarlem. Het is <u>11:57</u> en u wilt graag naar Amsterdam Centraal reizen. Welke trein zou u nemen?
    - 12:01 Spr (0:19)
    - 12:10 IC (0:15)

26. Stelt u zich voor, u staat op <u>station</u> Eindhoven Centraal. Het is <u>12:13</u> en u wilt graag naar Amsterdam Centraal reizen. Welke trein zou u nemen?
    - 12:17 overstap (1:18)
    - 12:27 direct (1:18)

27. Stelt u zich voor, u staat op <u>station</u> Den Haag. Het is <u>12:04</u> en u wilt graag naar Leiden reizen. Welke trein zou u nemen?
    - 12:08 SPR (0:18)

- 12:17 IC (0:12)

28. Heeft u nog tips of opmerkingen over de NS reisplanner?
    (open)

29. Als u het leuk vindt om de eind rapportage van mijn afstudeer project te ontvangen kunt u hieronder u email adres achterlaten (de rapportage is in het Engels). Ik zal dan mijn eindrapport opsturen na het afronden van mijn project.
    (open)

Dit was de enquête, bedankt voor het invullen!

U kan deze pagina nu sluiten.

B

Figures resulting from the questionnaire data

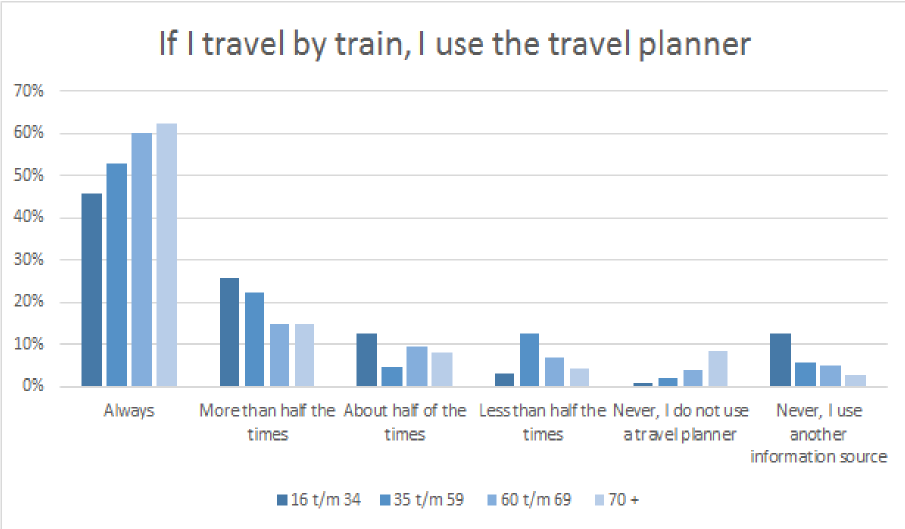


Figure B.1: Travel planner use per age group

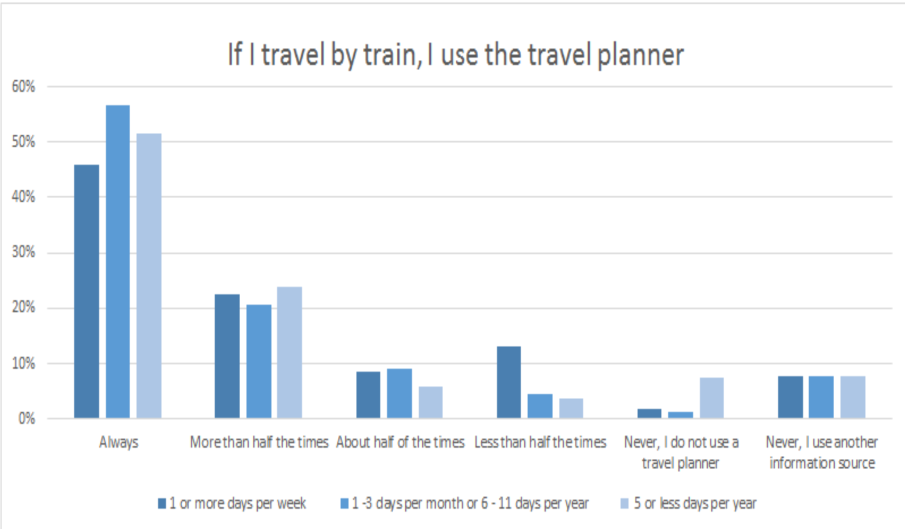


Figure B.2: Travel planner use and travel frequency

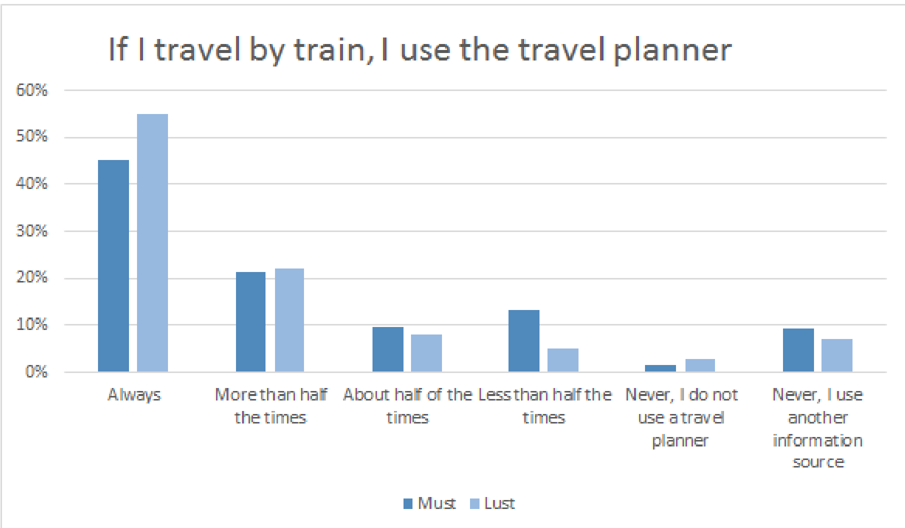


Figure B.3: Travel planner use per travel purpose

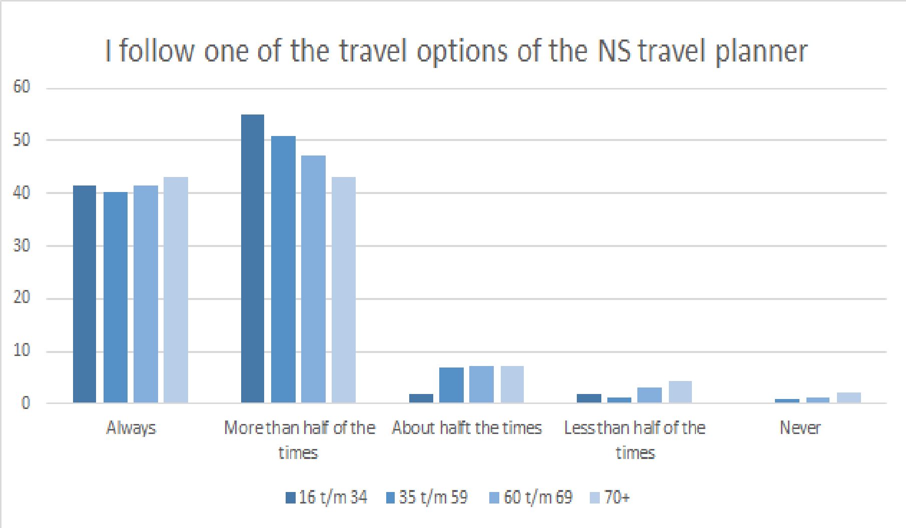


Figure B.4: Compliance rate per age group

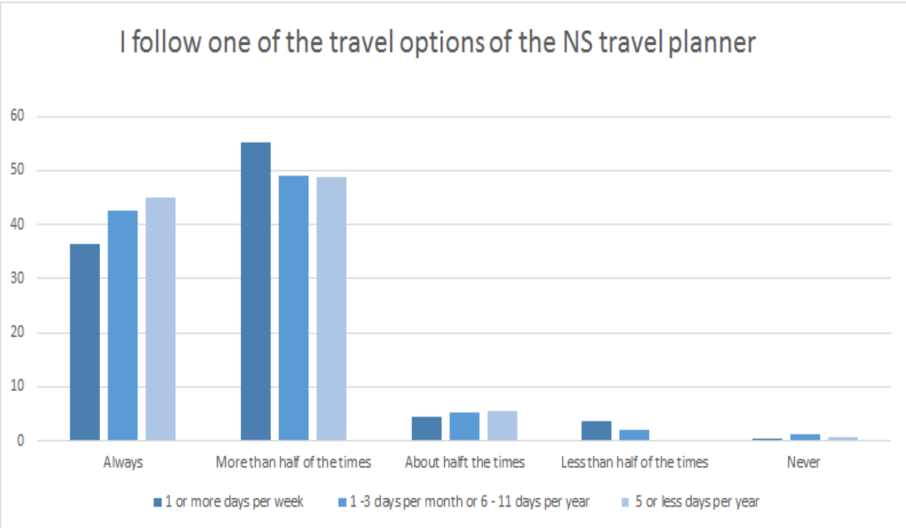


Figure B.5: Complaince rate and travel frequency

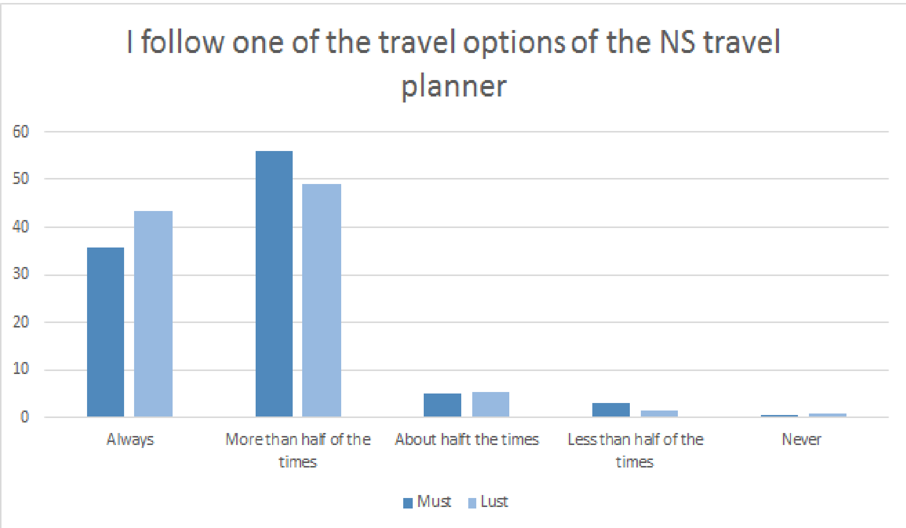


Figure B.6: Complaince rate per travel purpose

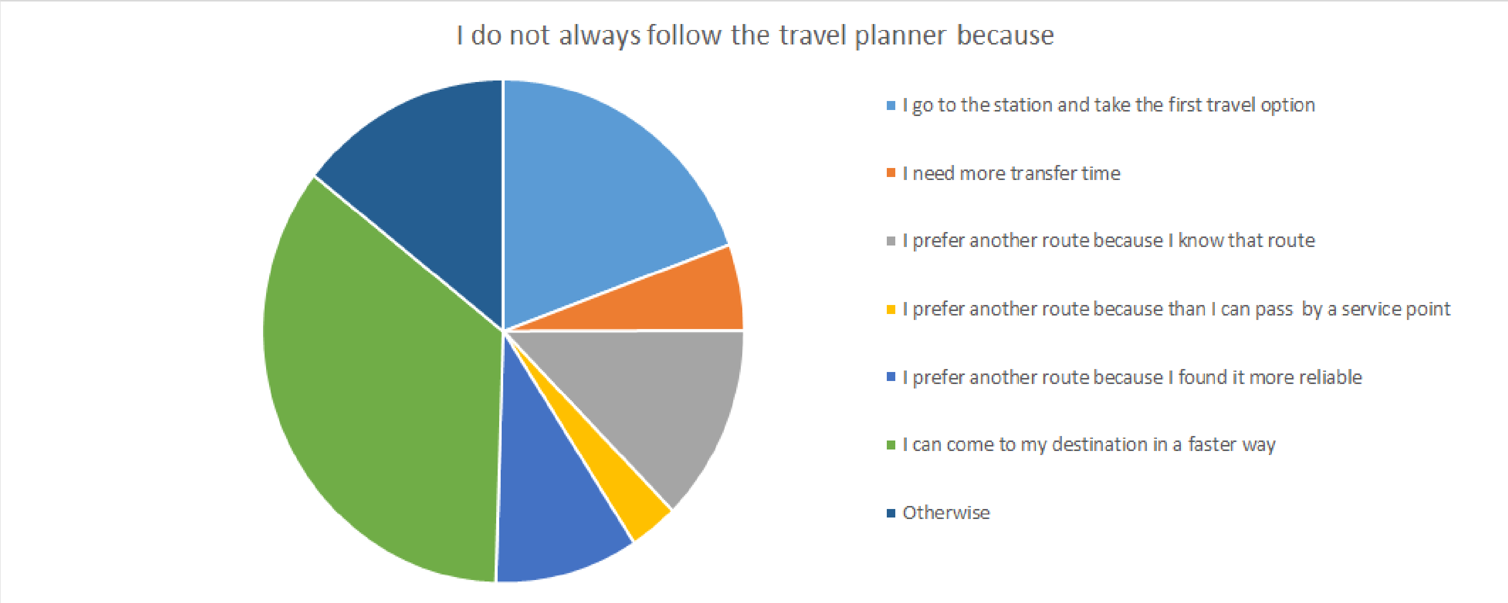


Figure B.7: Reason why passenger do not follow the travel planner with complete legend

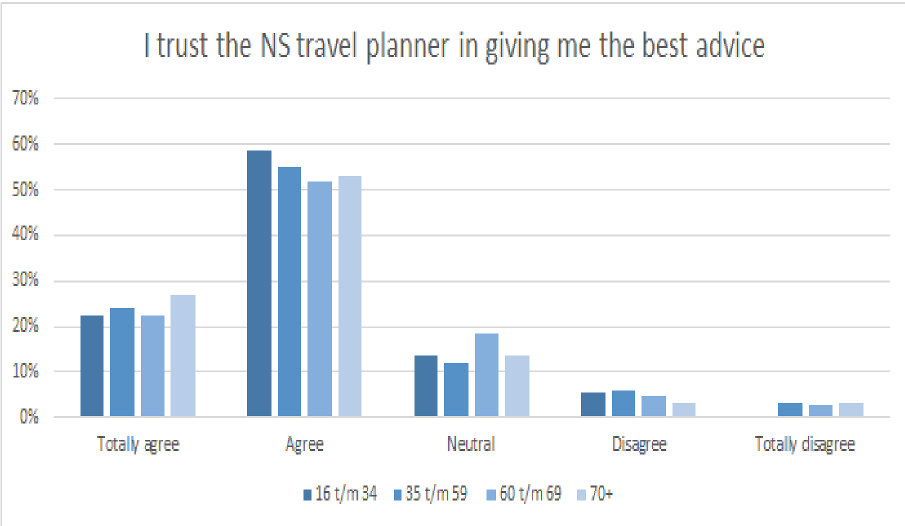


Figure B.8: Travel planner statement: I trust the NS travel planner in giving me the best advice, per age group

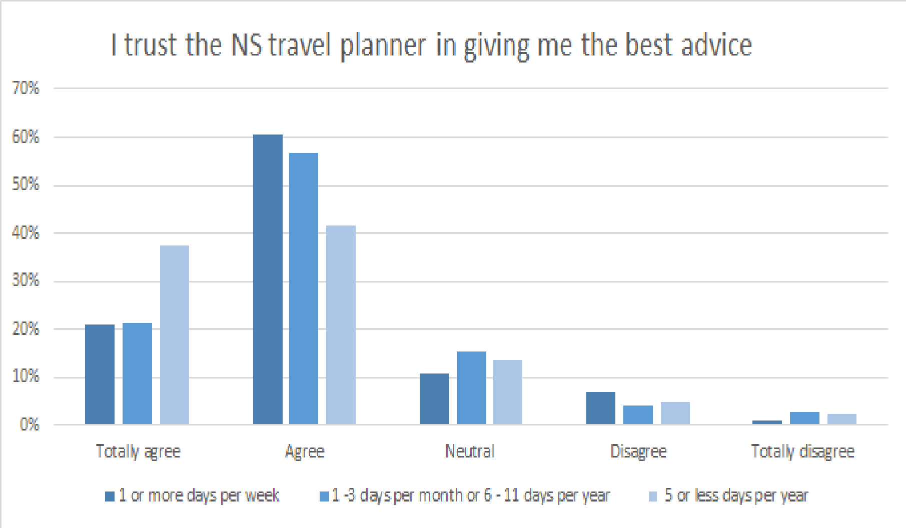


Figure B.9: Travel planner statement: I trust the NS travel planner in giving me the best advice, and travel frequency

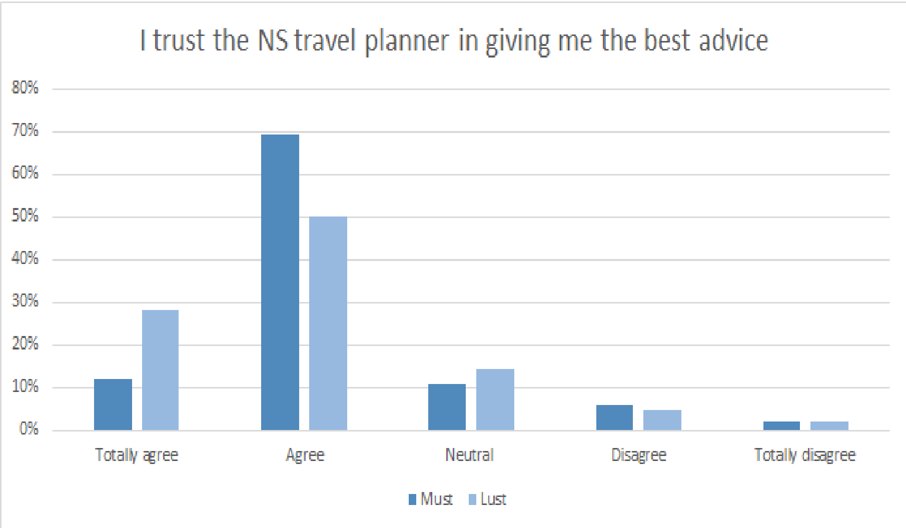


Figure B.10: Travel planner statement: I trust the NS travel planner in giving me the best advice, per travel purpose

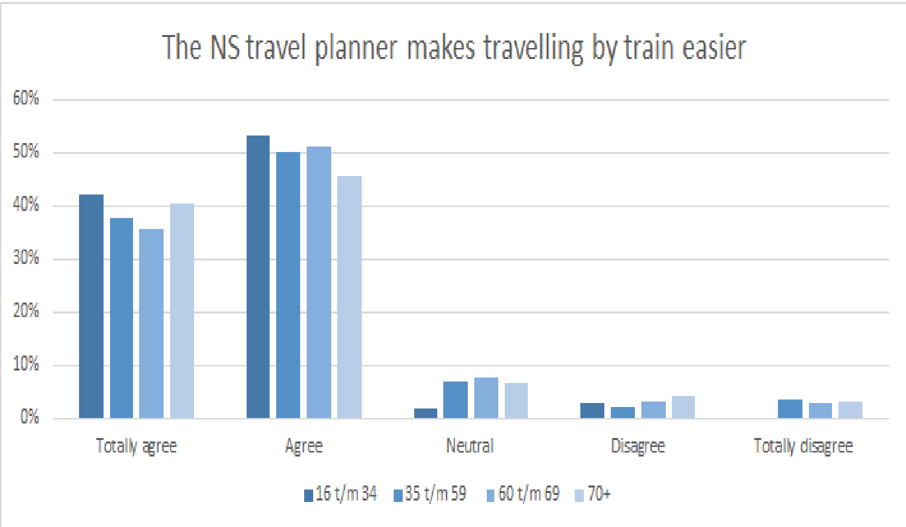


Figure B.11: Travel planner statement: The NS travel planner makes travelling by train easier, per age group

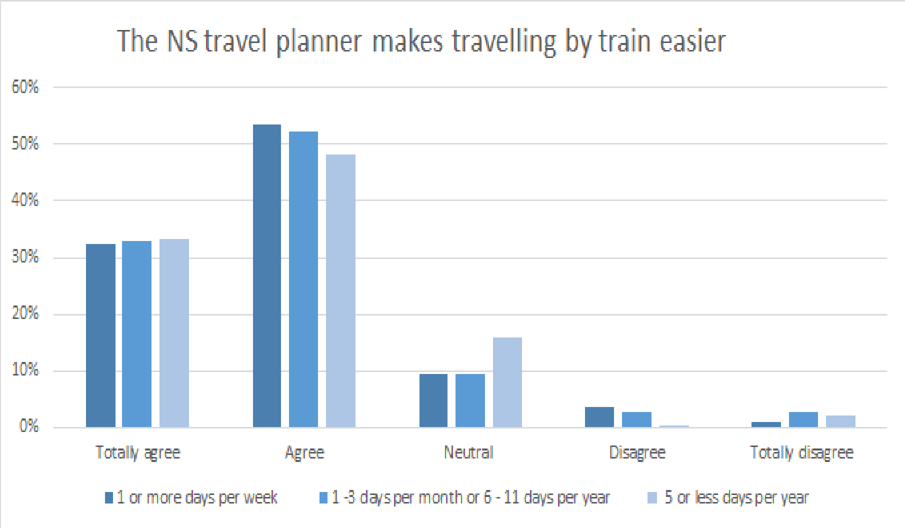


Figure B.12: Travel planner statement: The NS travel planner makes travelling by train easier, and travel frequency

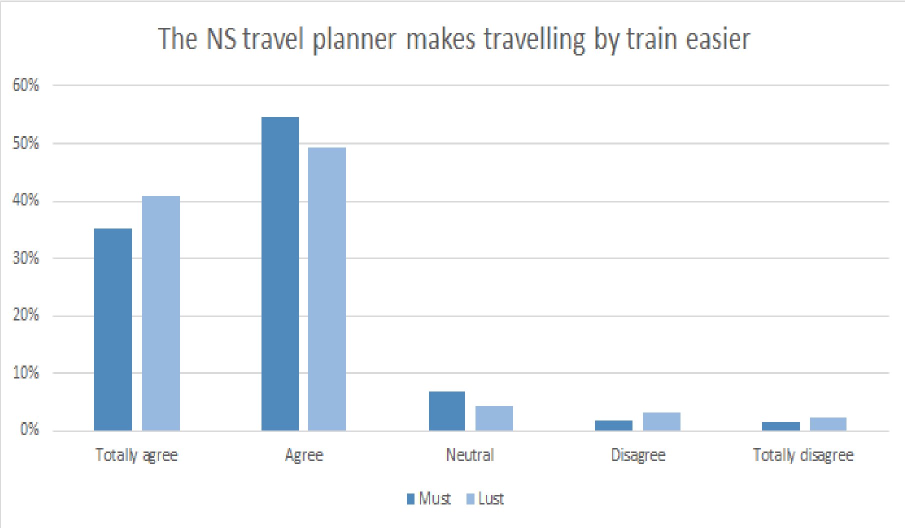


Figure B.13: Travel planner statement: The NS travel planner makes travelling by train easier, per travel purpose

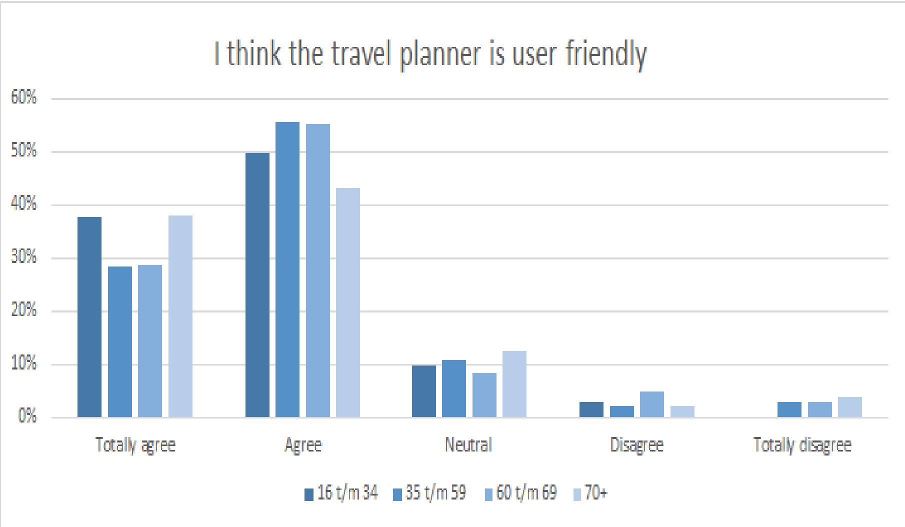


Figure B.14: Travel planner statement: I think the travel planner is user friendly, per age group

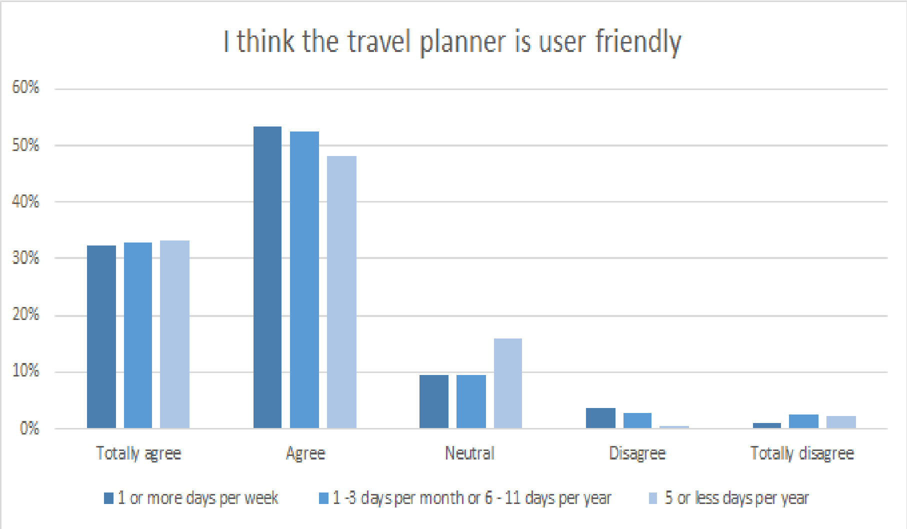


Figure B.15: Travel planner statement: I think the travel planner is user friendly, and travel frequency

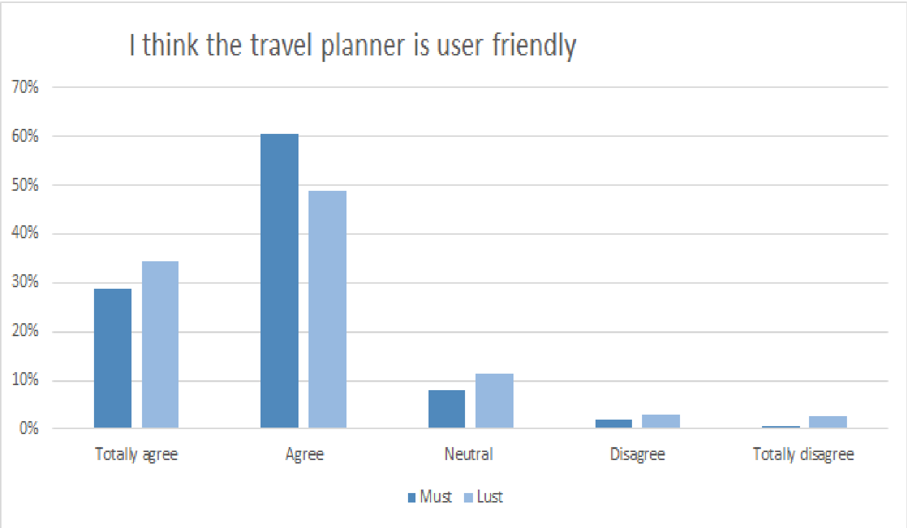


Figure B.16: Travel planner statement: I think the travel planner is user friendly, per travel purpose

C
Results of choice models estimation in Biogeme

Sprinter/Intercity consideration from home

Model: Logit
Number of estimated parameters: 2
Number of observations: 2001
Number of individuals: 2001
Null log likelihood: -1386.988
Cte log likelihood: -737.954
Init log likelihood: -1386.988
Final log likelihood: -718.364
Likelihood ratio test: 1337.247
Rho-square: 0.482
Adjusted rho-square: 0.481
Final gradient norm: +1.676e-003
Diagnostic: Convergence reached...
Iterations: 5
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: IC Sprinter.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val	Rob. std err	Rob. t-test	Rob. p-val
B_sprinter	-1.39	0.114	-12.17	0.00	0.115	-12.03	0.00
B_time	-0.0679	0.0118	-5.76	0.00	0.0121	-5.63	0.00

Utility functions
****

1	Alt1	one	B_time * TT1 + B_sprinter * TR1
2	Alt2	one	B_time * TT2 + B_sprinter * TR2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test	Rob. covar.	Rob. correl.	Rob. t-test
B_sprinter	B_time	-0.00107	-0.795	-10.67	-0.00111	-0.800	-10.54

Smallest singular value of the hessian: 76.4729

Sprinter/Intercity consideration from the station (without waiting time incorporated)

Model: Logit
Number of estimated parameters: 2
Number of observations: 1334
Number of individuals: 1334
Null log likelihood: -924.658
Cte log likelihood: -924.562
Init log likelihood: -924.658
Final log likelihood: -919.336
Likelihood ratio test: 10.645
Rho-square: 0.006
Adjusted rho-square: 0.004
Final gradient norm: +1.233e-005
Diagnostic: Convergence reached...
Iterations: 2
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: IC sprinter station.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val	Rob. std err	Rob. t-test	Rob. p-val
B_sprinter	0.911	0.280	3.25	0.00	0.280	3.25	0.00
B_time	-0.177	0.0550	-3.23	0.00	0.0550	-3.23	0.00

Utility functions
****

1	Alt1	one	B_time * TT1 + B_sprinter * TR1
2	Alt2	one	B_time * TT2 + B_sprinter * TR2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test	Rob. covar.	Rob. correl.	Rob. t-test
B_sprinter	B_time	-0.0151	-0.981	3.25	-0.0151	-0.981	3.25

Smallest singular value of the hessian: 12.2599

Sprinter/Intercity considerations from the station (with waiting time incorporate)

Model: Logit
Number of estimated parameters: 3
Number of observations: 1334
Number of individuals: 1334
Null log likelihood: -924.658
Cte log likelihood: -924.562
Init log likelihood: -924.658
Final log likelihood: -919.336
Likelihood ratio test: 10.645
Rho-square: 0.006
Adjusted rho-square: 0.003
Final gradient norm: +3.180e-005
Diagnostic: Convergence reached...
Iterations: 2
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: IC sprinter station.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val		Rob. std err	Rob. t-test	Rob. p-val	
----	-----	-------	------	-----		------------	-----------	----------	
B_sprinter	-6.90e-016	2.89e+005	-0.00	1.00	*	1.80e+308	-0.00	1.00	*
B_time	-0.177	0.0550	-3.23	0.00		0.0550	-3.23	0.00	
B_wtime	-0.101	3.21e+004	-0.00	1.00	*	1.80e+308	-0.00	1.00	*

Utility functions
****

1	Alt1	one	B_time * TT1 + B_sprinter * TR1 + B_wtime * WT1
2	Alt2	one	B_time * TT2 + B_sprinter * TR2 + B_wtime * WT2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test		Rob. covar.	Rob. correl.	Rob. t-test	
------	------	----------	-----------	------		-----------	------------	-----------	
B_sprinter	B_time	-0.00659	-4.14e-007	0.00	*	-0.0157	0.00	0.00	*
B_sprinter	B_wtime	9.30e+009	1.00	0.00	*	-1.13e+010	-0.999	0.00	*
B_time	B_wtime	0.000910	5.15e-007	-0.00	*	-5.64e-005	0.00	0.00	*

Smallest singular value of the hessian: 1.18009e-011

Transfer/direct consideration from home

Model: Logit
Number of estimated parameters: 2
Number of observations: 2001
Number of individuals: 2001
Null log likelihood: -1386.988
Cte log likelihood: -1154.705
Init log likelihood: -1386.988
Final log likelihood: -1046.331
Likelihood ratio test: 681.313
Rho-square: 0.246
Adjusted rho-square: 0.244
Final gradient norm: +2.274e-003
Diagnostic: Convergence reached...
Iterations: 4
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: TransferDirect.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val	Rob. std err	Rob. t-test	Rob. p-val
----	-----	-------	------	-----	------------	-----------	----------
B_time	-0.107	0.00743	-14.42	0.00	0.00742	-14.44	0.00
B_transfer	-1.72	0.0775	-22.16	0.00	0.0774	-22.18	0.00

Utility functions
****

1	Alt1	one	B_time * TT1 + B_transfer * TR1
2	Alt2	one	B_time * TT2 + B_transfer * TR2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test	Rob. covar.	Rob. correl.	Rob. t-test
------	------	----------	-----------	------	-----------	------------	-----------
B_time	B_transfer	0.000414	0.719	22.26	0.000413	0.718	22.28

Smallest singular value of the hessian: 165.747

Transfer/direct consideration from the station (without waiting time incorporate)

Model: Logit
Number of estimated parameters: 2
Number of observations: 2001
Number of individuals: 2001
Null log likelihood: -1386.988
Cte log likelihood: -1376.053
Init log likelihood: -1386.988
Final log likelihood: -1374.789
Likelihood ratio test: 24.397
Rho-square: 0.009
Adjusted rho-square: 0.007
Final gradient norm: +5.024e-005
Diagnostic: Convergence reached...
Iterations: 2
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: Transfer direct station.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val		Rob. std err	Rob. t-test	Rob. p-val	
B_time	-0.0104	0.00655	-1.59	0.11	*	0.00655	-1.59	0.11	*
B_transfer	-0.266	0.0572	-4.65	0.00		0.0571	-4.65	0.00	

Utility functions
****

1	Alt1	one	B_time * TT1 + B_transfer * TR1
2	Alt2	one	B_time * TT2 + B_transfer * TR2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test	Rob. covar.	Rob. correl.	Rob. t-test
B_time	B_transfer	0.000231	0.617	4.78	0.000231	0.617	4.78

Smallest singular value of the hessian: 199.99

Transfer/direct consideration from the station (with waiting time incorporate)

Model: Logit
Number of estimated parameters: 3
Number of observations: 2001
Number of individuals: 2001
Null log likelihood: -1386.988
Cte log likelihood: -1376.053
Init log likelihood: -1386.988
Final log likelihood: -1374.657
Likelihood ratio test: 24.661
Rho-square: 0.009
Adjusted rho-square: 0.007
Final gradient norm: +2.861e-003
Diagnostic: Convergence reached...
Iterations: 3
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: Transfer direct station.dat

Utility parameters
****

Name	Value	Std err	t-test	p-val		Rob. std err	Rob. t-test	Rob. p-val	
B_time	-0.0258	0.0308	-0.84	0.40	*	0.0308	-0.84	0.40	*
B_transfer	-0.499	0.458	-1.09	0.28	*	0.458	-1.09	0.28	*
B_wtime	-0.0206	0.0401	-0.51	0.61	*	0.0401	-0.51	0.61	*

Utility functions
****

1	Alt1	one	B_time * TT1 + B_transfer * TR1 + B_wtime * WT1
2	Alt2	one	B_time * TT2 + B_transfer * TR2 + B_wtime * WT2

Correlation of coefficients
****

Coeff1	Coeff2	Covariance	Correlation	t-test		Rob. covar.	Rob. correl.	Rob. t-test	
B_time	B_wtime	0.00121	0.977	-0.44	*	0.00121	0.977	-0.44	*
B_time	B_transfer	0.0139	0.986	1.10	*	0.0139	0.986	1.10	*
B_transfer	B_wtime	0.0182	0.992	-1.14	*	0.0182	0.992	-1.14	*

Smallest singular value of the hessian: 4.70888