Master Thesis:

Travelers' Route Choice Decisions in the Context of Public Transport with Special attention to the role of Main and Side Train Stations

Sofia Tzouli

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Supervisors:

dr.ing. P.J.H.J. van der Waerden (TU/e)

dr. G.Z. Dane (TU/e)

ir. J. Hoogenboom (BonoTrafficsBV)

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Personal Information

Student:	S. (Sofia) Tzouli
Student ID:	0927369
E-mail address:	stzouli@gmail.com

Graduation committee

prof. dr. ir. B. (Bauke) de Vries	(Chairman master CME, TU/e)
dr. Ing. P.J.H.J. (Peter) van der Waerden	(Graduation Supervisor TU/e)
dr. G.Z. (Gamze) Dane	(Graduation Supervisor TU/e)
ir. J. Hoogenboom	(Graduation Supervisor BonoTrafficsBV)

Institute:

University:	Eindhoven University of Technology
Faculty:	Faculty of the Built Environment
Department:	Construction Management and Engineering

Graduation company:

Company name:	BonoTrafficsBV

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Preface

The current report represents my graduation project of the Master program Construction Management and Engineering (CME) at Eindhoven University of Technology (TU/e). The aim of the study was to investigate the choice behavior of the public transport travelers regarding the route choices that are available with focus on the role of side and main railway stations. The thesis was performed in cooperation with BonoTraffics BV.

Studying at TU/e was a very important experience for me and carrying out this research was one of the most valuable components of this experience. Life in the Netherlands is definitely associated with traveling by train and as I have personally spent many moments in the railway stations, I was motivated to strengthen my knowledge on this specific topic.

First of all, I would like to thank dr. ing. Peter van der Waerden for his unlimited support from the very first moment, his enthusiasm, his valuable guidance and comments, and his important help throughout my graduation. I would also like to thank dr. Gamze Dane and prof. Bauke de Vries for their helpful comments and the nice cooperation we had. Also, I would like to thank Joris Hoogenboom for his insights and advices of a technical point of view and I am grateful for the opportunity to conduct my thesis at BonoTrafficsBV. I want to thank Stephan Metz from OV-bureau Groningen-Drenthe for his comments and help and ir. Joran Jessurun for helping me build my online questionnaire. I also want to thank the respondents whose input was essential for my results. Finally I want to thank my family and friends, who made the difficult path of the MSc look much easier, especially my parents, because nothing would have happened without their unconditional support.

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Abstract

Transportation planners in the Netherlands have been constantly trying to provide high-quality public transport. Multimodal mobility holds a large part of public transportation and this means that transfers need to me made while traveling. However, transfers cause high disutility to the travelers. In order to attract more passengers into the public transportation mobility and at the same time decongest the most crowded railway stations, it is aimed to find out what influences travelers' decision making process regarding the route choices they have. Therefore, the current research investigates the characteristics that have an impact in the route choice behavior of public transport travelers with special attention to the role of the main and side railway stations. For this purpose, a stated choice experiment was designed and data was mainly collected in the area of the Zernike campus in the city of Groningen. The analysis of data was conducted by a Binary Logistic Regression Model and the results show that time-related and crowding-related characteristics were proved to be significant. The estimated model showed that the facilities of a railway station are not influential. However, some additional models with separate groups were estimated, showing that some socio-demographic attributes and travel-experience characteristics proved to have an impact on the outcome as well.

Summary

The travel behavior of the public transport users has been extensively studied in the past because it can give understanding about what are the crucial measurements that the travelers are in need of. In order to provide a good quality of transportation, the travelers' perceptions and thoughts must be understood. In the Netherlands the public transportation system is generally characterized of a high quality, with the train playing the dominating role. The Dutch railways have passed through different phases already since the nineteenth century, resulting in an extensive and well-organized railway network nowadays. However, the main focus still lies in the centralized lines, who offer service of high capacity and high frequency, facilitating mainly the Randstad area in the north-west, while in the rest of the network keeps a rather steady course.

Moreover, the Dutch urban system has been organized in a way that avoids the urban sprawl and the flows of passengers have formed a polycentric system. For the purpose of a successful and efficient interaction of the separate systems and the fast mobility of the passengers, the necessary measurements must be taken from the involved authorities. These circumstances lead to multimodal mobility, that holds a large part of the Dutch public transportation. A multimodal journey is a trip that consists of two or more vehicular modes and therefore at least one intermodal transfer is necessitated during the journey. Research has been repeatedly proved the high disutility that is received due to these transfers.

Since the Dutch network is organized in such a way, it means that the travelers often have more than one option to arrive at their journey's end. When their trip cannot be seamless and a transfer needs to me made, then they can choose the route that is the optimal for them based on personal tastes and perceptions. Despite the plentiful body of research about the route choice behavior of drivers and car users, little insight has been gained for the public transport travelers. Transfers are perhaps the most distinctive characteristic that has been found to have a negative effect in the route choice decision making process. An extensive literature review is carried out in order to find the influential attributes on the route choice behavior of public transport users.

At the same time, the main railway stations often suffer from congestion, as they are dominantly chosen by the travelers as starting points or transfer points of the trip. The governmental agencies in the Netherlands are aware of these dissatisfactions and in an effort to result in content customers, they are searching the factors that can create a pleasant experience to the traveler. Therefore, the aim of this research is to explore the factors that play a role in the decision making process regarding the public transport route choices, by giving special attention to the role of main and side railway stations, in order to find the way to decongest the most crowded of them and direct a portion of passengers to smaller transfer points.

In order to realize what influences the public transport route choice behavior, a stated choice approach is selected, because it can predict the future demand and foresee how the travelers would react in possible changes. Through a stated choice experiment, the most influential attributes can be identified. For this purpose, a questionnaire was designed in the 'Berg Enquete System' of Eindhoven University of Technology, which consists of three main parts.

The first part includes questions related to the travel experience of the participants, the second part contains the stated choice experiment with an explanation and a trial choice set and the third part includes questions related to sociodemographic information in order to get a clearer idea of what sample is approached.

The collection of data took place mainly in the area of Zernike campus, which is situated in the north-west of the city of Groningen. The selection of this case was based on the fact that travelers from the city of Leeuwarden face two routes that can choose from in order to arrive in Zernike campus, so the participants were familiar with the investigated case. The participants were approached in the bus and were invited to take part in the survey through a flyer which contained a QR code that was directing to the online questionnaire. In order to increase the sample size, more respondents from similar cases in other regions of Netherlands were asked to participate through social media networks. Finally, 204 people took part in the survey, and 170 of them filled in the main part, i.e. the choice experiment.

The cohort that participated was rather young, as four of five participants had an age lower than 25 years, which was anticipated because of data collection in university areas, but the gender distribution was quite representative of the Dutch population. The data was analyzed by estimating a binary logistic regression model, which showed a satisfactory statistical fit. The attributes that proved to be significant for the route choice decision making process were time-related and crowding-related. It is noted that the investigated case pertained to a route which included the use of a train and then transferring at a railway station and embarking on a bus. More specifically, it was found that headway of the bus, transfer time from train to bus, crowding at the station, in-vehicle time in the bus and walking distance from train to bus were the characteristics with the highest influence. Some facilities, namely information service, toilets, a kiosk and a heated waiting area, were also examined but they were not found to be significant. However, estimation of different models by taking into account some separate groups showed some different results, with presence of a kiosk having an impact on the route choice of women, frequent travelers and travelers who do not make use of the train before embarking to the bus.

Therefore, it is perceived that time-related attributes dominate in the route choice behavior, since public transport passengers seek ways to minimize the overall time. Moreover, crowding at the station also proved to be important, which should be taken into consideration by the station planners, as well as the short walking distances to the bus. The involved stakeholders are advised to include a kiosk, which offers some basic needs to the station users, in the side railway stations, since it was found to influence some groups' decisions making. It is also recommended that when a good time planning of the routes is ensured along with a good collaboration of trains and buses, the design of the stations and the presence of facilities should not be overlooked, as they can improve the overall experience at a transfer station.

1. Introduction

This chapter introduces the topic of the thesis by defining and stating the problem, formulating the research questions, explaining the theoretical and practical relevance and finally, providing a reading guide of the entire report.

1.1. Transportation planning and travel behavior in the Netherlands

Nowadays, urban scientists are not unfamiliar with the fact that people tend to increasingly move to the bigger cities. Human population will probably be larger by 2 to 4 billion people by 2050 (Cohen, 2003) and public transport is considerably taken into account in the context of urban and transportation planning, especially due to the strict environmental demands and the emission reduction commitments (UNECE, 2012a; UNECE,2012b). This definitely leads to many challenges that urban development faces and will face in the future. Zhang et al. (2004) stated that despite the abundant literature which “has shown that task complexity and choice environment affect individual choice behavior”, most of the existing transportation models do not explain this relation, so they suggest that the behavioral mechanisms of individuals, which lead to specific choices, should be interpreted adequately.

The transportation planners in the Netherlands, through their enduring discussions about resolving any kind of qualitative or quantitative problems that might appeared in the Dutch transportation system and their focus on the constant improvement of the quality and the policy aims, have managed to provide very important guidelines for a high-quality result (Alpkokin, 2009). The governance of public transport incessantly takes care of the system’s development and transportation planning is well established in the country, so there is a constant need of identifying all the important characteristics of the transportation system in order to make it functional and profitable (Veeneman and van de Velde, 2014). Many Dutch public transport authorities and operators have to cooperate for that purpose and therefore understanding the trends and needs within the urban environment becomes more crucial than ever before. Moreover, data are frequently collected due to various transportation visions which are related with developing transportation applications and designing travel diaries (e.g. Melnikov et al., 2015; Hoogendoorn-Lanser et al., 2015).

This extensive and thorough effort of many Dutch authorities to provide high-quality transportation services and willingness to investigate the elements that play a crucial role in urban travelers’ decision making processes reveals the spectrum of importance that characterizes the Dutch transportation system. It is realized that the travel behavior in the Netherlands is definitely influenced by the actions of the planning authorities, which tried to restrict the urban sprawl in the past decades (Vos, 2015).

1.2. Problem Statement

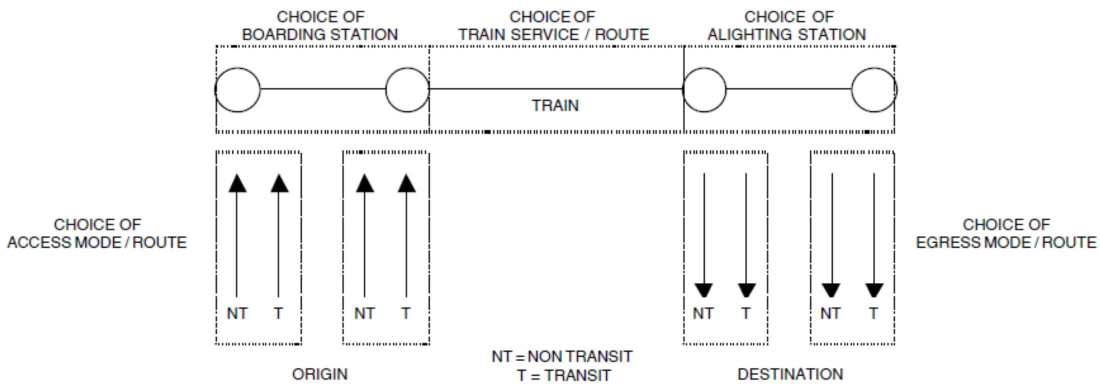
The overall Dutch urban system was developed on the basis of flows between the separate urban systems according to Limtanakool et al. (2009). They found that the flows of commuters established a polycentric system, although the developments were mainly occurring faster within the regions rather than between the regions. Leisure flows showed different results, since they did not contribute to a polycentric, but more to a fragmenting system. Therefore, it becomes apparent that the commuting flows show the necessity of interaction between the local systems, but at the same time improvements towards that direction might produce a pattern of change for flows of different nature as well. However, this interaction cannot be enabled exclusively with direct connections and for that purpose transfers need to be made, which inevitably “are seen as a necessary evil in public transport” as Guo and Wilson(2011) described them. In an effort to keep the Dutch cities accessible and livable, the multimodal movement is stimulated in the Netherlands, where for the sake of efficiency and cost consideration, the lines of the network are bundled instead of being direct, creating a hierarchical network, consisted of higher and lower-order lines (ECORYS, 2006). However, “disutility associated with the non-seamless stages and connections that characterize public transport are very much to blame”, as Krygsman et al. (2004) stated, expressing the additional inconvenience that the public transport travelers receive from the transfers, beside the effort that they have to make in order to reach and leave the system, compared to the door-to-door automobile traveling.

Hence, it is often the case that passengers have to make one or more transfers during their journey. Multimodal trips had a 3% share of the total trips in the Netherlands in 2002. This seems minimal, but the share of the multimodal mobility among the trips longer than 30 kilometers and the trips to and from the four main cities of the country was quite noteworthy, representing 15% and 20% of the total trips respectively (Van Nes, 2002). Therefore, the final percentages show the high importance of multimodal traveling and the special attention that should be paid to the optimal design of this kind of transportation. This argument is further supported when train trips are looked separately; 80% of the total amount of them is multimodal according to Van Nes’ findings and this shows the prominent role of train traveling in the multimodal mobility. Furthermore, it is often the case that the interchange occurs from one mode of transport to another. Related to that, there is evidence that bus-based modes cause higher transfer disutility in comparison to rail-based modes (Currie, 2005). Currie stated that the reason for the higher transfer penalties that ensue from the use of bus services are related to open-air waiting, lack of available facilities and crossing roads, pointing out the significance of transfer locations’ design to the perceived transfer disutility. As a result, it is relevant to investigate whether a combination of different modes might reveal new relationships, since different factors seem to have an effect on travelers’ decision making process across different modes. It also emerges that the transfer locations play a crucial role as well. In multimodal transport networks, choosing the most suitable transfer stations is often a difficult task, as it is the outcome of a good coordination between the modes and pertains to an essential element of the process (Wang et al., 2009).

Most of the studies related to the concept of multi-modal transport, typically define the multi-modal trips as journeys which are consisted of three distinctive parts, the access, the egress and the main leg (e.g. Van Nes, 2002). Therefore he approach the topic by focusing on one mode which pertains to the main leg and assign the trip towards and after this leg to the additional modes. However, there is a different concept of multi-modal transport, which focuses on the interchange that happens between two modes during a non-direct trip. Therefore, the connection of this fragmented route takes place in one transfer point (Mahrous, 2012). This was introduced from Lu (2010) as “Switch Point”, where the people who are planning a multimodal route can switch from one mode to another mode. Public transit stations were expectedly included in the list of switch points, where travelers can perform this action. So it becomes evident that the stations which serve as transfer nodes, as already mentioned above, play a crucial role.

Bovy and Hoogendoorn-Lanser (2005) in their analysis about multimodal traveling, distinguished the home-end and activity-end of the trip and formulated the behavioral hypotheses of Figure 1, showing the choices that a multimodal traveler has to make, adopting the idea of Van Nes (2002) that the train trip covers the main route of the entire trip. Figure 1 reveals that a multimodal traveler has to choose, apart from the train route, the access and egress route as well as the boarding and alighting station

Figure 1. Choice dimensions in multi-modal train alternatives. Source: Bovy and Hoogendoorn-Lanser (2005)



Therefore, multimodal traveling requires a plethora of decisions about the routes and stations. On top of that, attention should be paid to the design, use and planning of the railway stations. It is not surprising that the stations compete with each other about dominating in one area by having more passengers as it is quite often the case that people in the same region have the possibility to choose different train stations. Givoni and Rietveld (2014) state that even in the periphery of Amsterdam, people mostly tend to use the central railway station as the starting point of their trip instead of the closest located station. They suggest that congestion in the most crowded hubs can be relieved by opening more stations or letting the trains stop in more stations. Hence, it can be perceived that stations' overcrowding is an issue that is holding attention in the transportation planning science. The traffic flows of passengers must be managed effectively in the congested places in order to avoid inconvenience. In addition, safety issues are usually arisen in the areas that allow multimodal transportation (Tasic and Porter, 2016), so facilitating the ridership's movement to railway stations that do not face the problems of overcrowding, could also enable the magnitude of these concerns to be reduced.

Therefore, the outstanding importance of the topic in combination with personal interest on the factors that underlie this kind of decisions stimulated the author to study the relationship between the chosen multimodal routes within public transport and the various attributes of both the travelers and the transportation system.

But how willing are the passengers to adjust their trip in a way that they will avoid a main train station and choose a smaller one while making a transfer? During this research project, the way of choosing a multimodal train trip in the Dutch railway system will be investigated in order to understand the nature of the decisions regarding route choice of public transport travelers. Cities with more than one railway station will be observed in order to make the comparison of the different routes between the various stations. Randstad, which comprises over 5 million inhabitants, has definitely a polycentric system and offers developed services (Van der Burg and Dieleman, 2004). The Dutch Railways (NS) is accountable for the majority of railway transport in the Netherlands (Ministerie van Infrastructuur en Milieu, 2015) and investigation of the possible stations and routes in the official website of the company made it clear that except for Amsterdam and other cities of Randstad, which possess quite a large number of stations, several smaller Dutch cities have more than one train station as well. For instance, in the city of Eindhoven, there are the main train station in the center and the Strijp-S station in the north, facilitating the newly developed Strijp-S area. Tilburg has two train stations, apart from the main central one, facilitating the Tilburg University and the Reeshof district in the west. Groningen used to have two railway stations, one in the center and one in the north of the city, but a new station was opened in 2012 near the Euroborg football stadium in the south east. Nijmegen is also facilitated by five train stations in total spread around the city. These are just a few examples and it appears that this is quite common in the Netherlands. In addition, as already mentioned, there is interest in investigating the situation out of the main Randstad area, which apart from densely populated, is also an economic center of advanced financial and business services (Limtanakool et al., 2009). Lower density areas often hold importance, due to the fact that the public transport system has to be managed in a way that is not cost-inefficient, mainly because of the lack of massive flows that are met in the large centers (De Jong et al., 2011).

It can be very likely that the neighborhoods served by the smaller stations are also approached by travelers from different cities or areas for various reasons, and not exclusively from the inhabitants of the neighborhood itself. It is of a certain interest that travelers to these lower-density neighborhoods might be confronted with two choices; arriving by train to the main railway station and continuing their trip by bus or tram to get at their final destination or changing from fast to slow train some stops before arriving in the main railway station and heading to their destination with a different vehicle. For instance, people who travel between Rotterdam and Tilburg University can choose to take the train to the central station of Tilburg and then arrive at the University of Tilburg by bus (Figure 2) or they can go by train to Breda and then take a local train that arrives at Tilburg University (Figure 3). Choosing the second option enables them to avoid walking at the main train station of Tilburg as well as avoid making use of a different transport mode (bus) and in addition, the time spent during the second option can be less than the one spent during the first option. This is just one of many examples with similar route choice combinations which appear in Dutch cities and towns.

Figure 2. Multi-modal trip Rotterdam-Tilburg University with a transfer in Tilburg station.

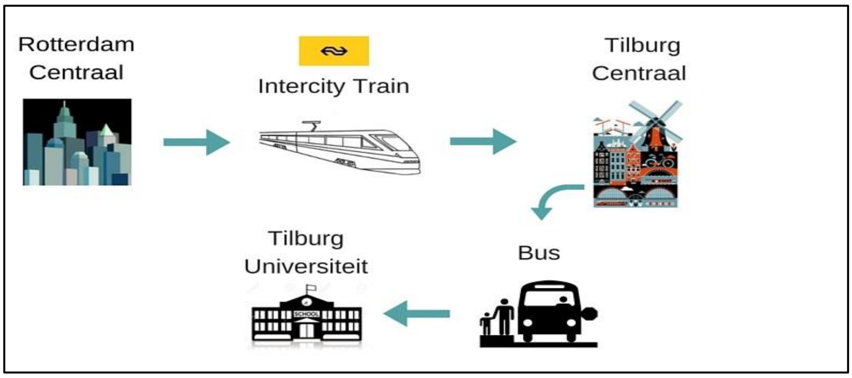
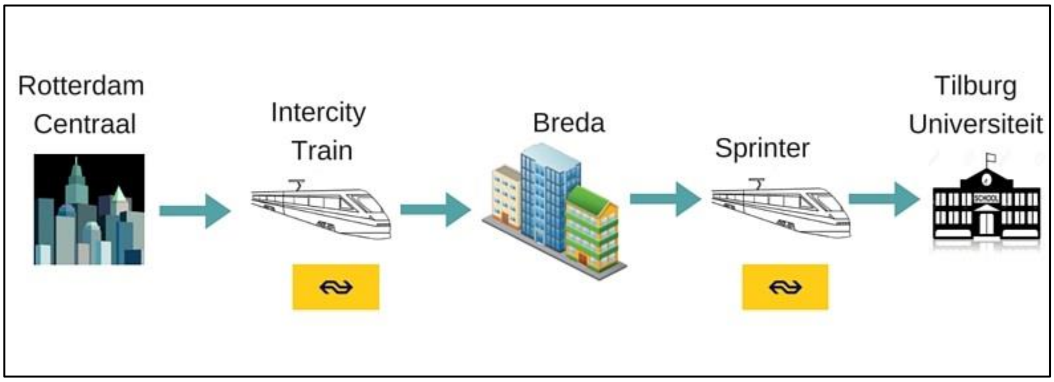


Figure 3. Train trip Rotterdam-Tilburg University with a transfer in Breda station.



It should kept in mind that when passengers, and especially commuters, have to make transfers, their dissatisfaction increases. Therefore they would readily walk longer distances in order to avoid transfers (Alshalalfah and Shalaby, 2007). A transfer between train and local public transport feeder modes (such as bus, tram and metro) was perceived as counterproductive, when Schakenbos et al. (2016) tried to examine this transfer disutility in a public transport trip. Hine and Scott (2000) also studied the passengers' perception about interrupting trips and found out that interchange is generally not appreciated, especially by commuters, due to various reasons such as delays, lack of information on changing points or long walking distances. Similar findings appeared in the study of Wardman et al (2001), where convenience and cleanliness proved to be crucial requirements for avoiding negative feelings towards interchanges in the trip. Therefore, evidence emerges about general dissatisfaction regarding necessity of changing from one conveyance to the other. It needs to be clarified which characteristics have a positive impact on travelers' decision making processes while they have to make these transfers. It needs to be identified whether, by avoiding the congested railway stations, this option seems to be more ideal than choosing the interchange in a crowded station. In addition, it is necessary to identify the attributes that could attract passengers to a change in their behavior. However, it can also be the case that passengers decide to make a transfer in a major train hub due to several needs they have during the trip, which probably cannot be satisfied at a station of a lower level.

As the reasons that a passenger chooses a specific railway station can be very complex, gaining understanding in that direction can obviously help the railway planners to manage the railway system more effectively. Debrezion et al. (2009) showed that the derived rail service quality index (RSQI) had a positive effect on the choice of a railway station, and although the study was about departure station choice, it provides an evidence that a good accessibility to other stations increases the possibilities that a station will be chosen. Similarly, Shaoa et al. (2015) supported that it should not be assumed that every commuter chooses to travel efficiently. They found that the railway station in the vicinity of origin is not necessarily chosen from the total amount of commuters, indicating that station service and facilities had a stronger impact instead.

Ridership's choice decisions can also be affected by broader factors such as urban evolution and new forms of city development. For instance, growth and decentralization of population and employment has caused changes in the patterns of transit customers as well as in their behavior, such as decrease of transit patronage in the traditional centralized lines, demand growth in more far-flung regions and tendency to return to personal motorized vehicles (Brown and Thompson, 2008). As a result, taking into account all the new circumstances, identifying the important characteristics of this procedure can be quite complex.

According to Van Acker et al. (2010) there is not yet a theoretical framework justifying the relationships between daily travel behavior and spatial, socio-economic and socio-psychological characteristics, pointing out the importance of understanding the complexity of the transportation systems and choices and the magnitude of factors underlying travelers' decisions in regard to this. They considered travel behavior as an outcome of short-term activity decisions, medium-term location decisions and long-term lifestyle decisions (adapted from (Handy, 1996), showing the intricacy of interrelations that exist during decision making process of each individual. Therefore, despite the accumulated evidence, exploring the reasons behind these decisions is deemed to be very interesting, yet quite convoluted.

In a nutshell, it becomes apparent that multimodal transport is necessary in order to serve a polycentric system, where for various reasons people can easily move from one place to another. This kind of transport demands various decisions to be made from the travelers. These decisions pertain to the chosen travel modes, routes, railway stations and a combination of all of them. Also, constant efforts of the Dutch planners to result in satisfied users and provide a well-functioning transportation system, prescribes that the transfer nodes should be carefully designed and become more appealing, relieving in that way the undesired congestion of the most crowded hubs. However, the motives behind the various choices of the public transport travelers are difficult to identify clearly, since many and complex factors underlie their decisions. So, understanding the nature of these decisions and realizing which attributes play a crucial role in the choices related to multimodal traveling will be a valuable aid to the overall planning of routes' and stations' characteristics.

1.3. Research questions

The problem that needs to be identified is which attributes of a trip and railway station have an influence on public transport travelers' route choice behavior and therefore how travelers can be triggered to choose a certain railway station and a certain route, when they have to make one or more transfers to reach their destination. The main research question that arises is the following:

- Which are the influential characteristics in the public transport passengers' decision making process while choosing the route and the railway station(s) that they will use during a multimodal trip?

More specifically, the objective of this research is to shed light on public transport users' behavior regarding the choice of a specific multimodal route when one or more transfers are necessary to be made. In addition, it is tried to understand why a main or a side railway station is preferred as transfer point. This will provide understanding in the attributes that are important for the travelers when they have to change transport modes to reach their final destination. In addition, knowledge needs to be gained in the combinations of modes that passengers prefer to choose, when taking only one train is not an option to arrive at their journey's end, and therefore perceive how they can be motivated to make combinations of modes and routes that are facilitated by side train stations. For the purpose of that, more research questions arise and are presented below.

- How can railway stations be characterized?
- How can travelers' route choice behavior be investigated?
- Do the sociodemographic characteristics or the travel experience of the public transport passengers have an impact on the route choice behavior?

1.4. Practical and theoretical relevance

Conducting research on this topic holds both theoretical and practical relevance, since it can provide contribution to the scientific knowledge of the investigating field and at the same time it can yield findings that are important to the related stakeholders that are directly involved in the subject.

Regarding the theoretical relevance, this study will attempt to provide a concrete insight into the consequential characteristics of the public transportation system, the station environment and the route choices context, trying to consider and measure their influence on the final route choice behavior of public transport passengers. In addition, to the author's knowledge, the scientific information that is available today is mainly approaching the route choice matter from a more general viewpoint including driving and other means of transport. The focal point of this research is the public transport, so the study aims in increasing the knowledge related to this specific kind of transportation.

Besides, the study results in a practical contribution as the outcome can prove to be very informative for all the involved stakeholders. Tracing the relations between the passengers' behaviors and the characteristics of the transport system can be a powerful tool for both the Dutch railways operator and the regional public transport companies, which in cooperation can be aware of the necessary conditions that their ridership is in need of. Furthermore, the regional governments can get benefit by possessing some insightful comments regarding the opinion of their residents. In this way, formation of their policies related to use of public transport and regional mobility can be improved according to the passengers' needs.

1.5. Thesis outline

The thesis consists of five distinctive chapters, where different topics are discussed. The first one pertains to the introduction of the thesis's objective, including the problem statement, the research questions that arise from this problem and the practical and theoretical relevance of the thesis. The second chapter includes the outcomes of the literature study about multimodal traveling and route choice behavior. Various previous studies related to multimodal transport and ridership reactions toward transfers in public transport are reviewed. In addition, a literature study related to route choice decision making process is conducted in order to retrieve the most valuable attributes, crucial for constructing an experiment.

Next, the third chapter follows where the research method is selected and presented. The advantages and disadvantages of the method are described, the experimental design process is explained and the case that is examined in this study is introduced. Moreover, the design of the experiment is thoroughly outlined and the data collection is shown. The forth chapter includes information about the outcome of the data collection, describing the data that is gathered, the sample that is obtained and the outcome of the analysis. The built model is explained and the research questions are answered through the results that emerge from the analysis. In addition, a simulation example is shown in order to understand how the results can be applied.

Finally, there is a conclusion that arises in the fifth chapter, along with some recommendations. This is the point where the final results are collectively explained in order to draw the conclusions, while recommendation is helpful for the stakeholders and the potential future researchers. Last but not least, the limitations of the current research are discussed, explained by possible flaws and possible improvements of this study.

2. Theoretical framework

This chapter presents all the important and relevant subjects that this research project deals with. First, the chapter provides some general information about the Dutch public transport, giving a historical overview of the Dutch railways and explaining some characteristics of the train, the bus and the railway stations. Next, multimodal transport is introduced and the disutility of transfers is explained. Finally, the route choice concept is explicated and the attributes that were found in the literature study to play a crucial role in the route choice decision making process are recorded.

2.1. Dutch public transport

2.1.1. History of Dutch Railways

The Dutch railway network has been developed through various phases since 1839, when the first railway was created between the cities of Amsterdam and Haarlem. Kasraian et al. (2016), on their research about the impact of the Dutch railway system on the urbanization in the Randstad area, explained this development by presenting four main periods, that fundamentally influenced the railway growth in the Netherlands. A closer look to these periods can be found in Appendix 1 , where Figure 25 depicts the most prominent features of the Dutch railway development across these years.

The Memorandum Infrastracture and Space that was approved by the Dutch governement in 2012 gives some guidelines for the Dutch spatial planning by 2040, with an aim to bring the local authorities to the frontline of the spatial development (Vos, 2015). In this manner, the concept of urban network will be neglected for the sake of a new plan with clustering areas, depicted in Figure 4.

Figure 5. Desired Dutch urban networks according to the Memorandum Space. (Source: MVROM (2004), retrieved from (Vos, 2015))

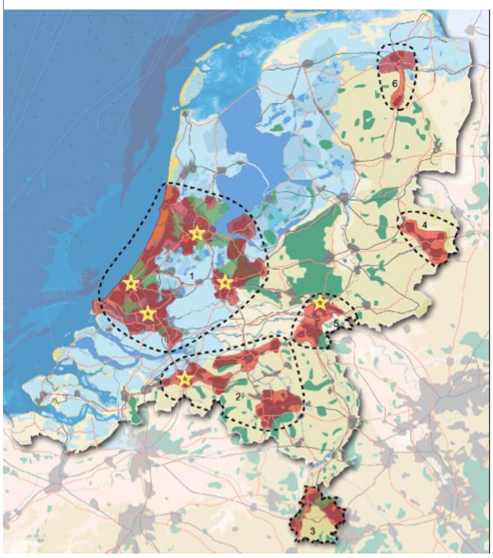


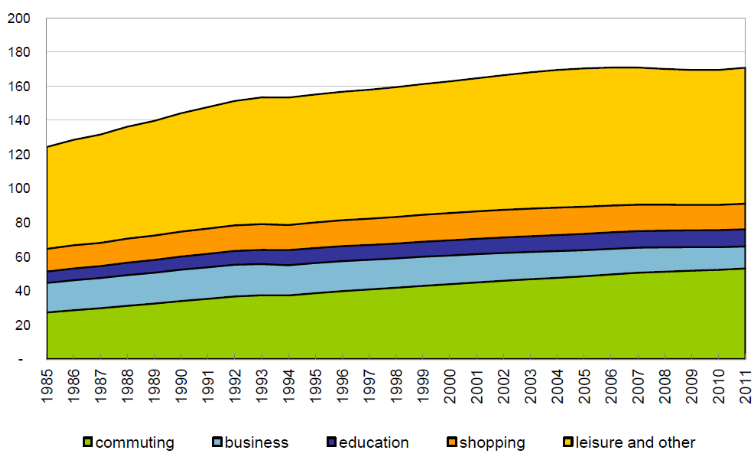
Figure 4. Main connecting corridors for rail roads. Source: MVW (2004), retrieved from (Vos, 2015)

The Memorandum shows that the main focus of the rail traffic is apparent in some specific connecting corridors, shown in Figure 5. It is quite remarkable that the priorities of the public transportation lie in these corridors, resulting in their optimization and improvement, instead of expansion of the network, which means that less attention is given to the lines that do not belong in this group. Therefore, there is high quality of public transportation provided in the main areas of the Netherlands, but since the focal point is the infrastructure that facilitates the largest group of passengers, this leaves less space for enhancement of the systems that serve areas with smaller potential for travelers (Vos, 2015).

2.1.2. Current situation

The changes that have occurred throughout this period have inevitably caused alterations in the way the Dutch population travels. There is a considerable increase in the kilometers traveled per person for each purpose (Van der Waard et al., 2012). The main reasons of mobility are leisure, shopping, education, business and commuting. Commuting shows a remarkable increase from 1985, as can be seen in Figure 6.

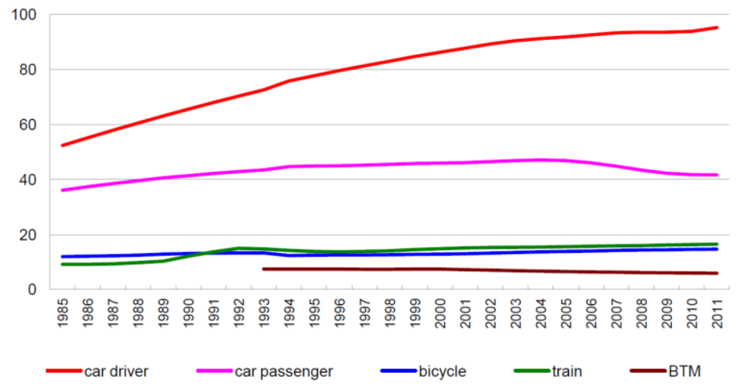
Figure 6. Kilometres by trip purpose per person. Source: (Van der Waard et al., 2012)



It can be observed that business, education and shopping trips have had a rather steady course. The new conditions of urban growth in the end of 20th century, with development and creation of job opportunities taking place around the transport hubs led to the augmentation of the work-related trips. In total, mobility for commuting, business and education, which can be divided from the shopping and leisure trips, possesses around 40% of the kilometers being covered.

These distances are traveled by car, train, BTM (Bus/Tram/Metro) and bicycle. Available data show the progress of these modes' use since 1985, depicted in Figure 7. The total amount of distance covered by public transport reaches the substantial number of around 23 billion kilometers in 2011, representing 13% of the total distance traveled but it can be observed that the use of car has a prominent role (Van der Waard et al., 2012). A notable increase in the use of public transport in the last 30 years has been recorded, but this increase actually pertains to travelers who changed their previously walking and cycling trips as well as to students who acquired free transportation cards for public transport traveling (Alpkokin, 2009). Therefore, there is still much room for improvement concerning the stimulation of public transportation use, since the use of car still holds a predominant portion.

Figure 7. Kilometres per mode (in billions). Source: (van der Waard et al., 2012)



On the other hand, looking closer to the car travelers more specifically it appears that the young adults between 18-30 years old have decreased the use of car between 1995 and 2009 according to analysis of data from the Transportation Behavior Survey 1995-2003 and the Netherlands Mobility Survey 2004-2009, possibly due to the fact that more women are involved in the working environment or because there is an increase in the young adults studying and working (Jorritsma et al., 2013). Specifically, young adults have reduced the use of every mode of transport, apart from the train, according to Van der Waard et al. (2012), which they used 31% more in 2009 compared to 1995. However, it should be kept in mind that students, who form a big amount of young adults, are supplied with a free public transportation card while they are studying in the Netherlands, therefore this feature might be a determinant of young adults' traveling behavior (Van Nes, 2002).

2.1.3. Train and bus in the Netherlands

The vast majority of rail transport in the Netherlands, specifically around 95%, is facilitated by the Dutch Railways (Nederlandse Spoorwegen - NS), while the rest of traveled kilometers is accounted for other operators (Veolia, Arriva, Connexxion and Syntus), which take care of the so-called decentralized railway lines (Ministerie van Infrastructuur en Milieu, 2015).

Figure 8. Overview transport companies on decentralized lines. Source: (Ministerie van Infrastructuur en Milieu, 2015)

The Dutch railway network is divided into the main rail lines and 22 decentralized. The process of decentralization began in 1998 with the Almelo-Mariënberg railroad and completed in 2014 with the line Zwolle-Enschede. NS has the responsibility for transportation to most of the main rail network on the basis of a transport concession from the government and is also accountable for four decentralized lines, i.e. Rotterdam-Hoek van Holland, Gouda-Alphen aan den Rijn, Zwolle-Kampen and Zwolle-Enschede. The other four operators serve mobility of the rest of the decentralized railway lines, as can be seen in Figure 8 (Ministerie van Infrastructuur en Milieu, 2015).

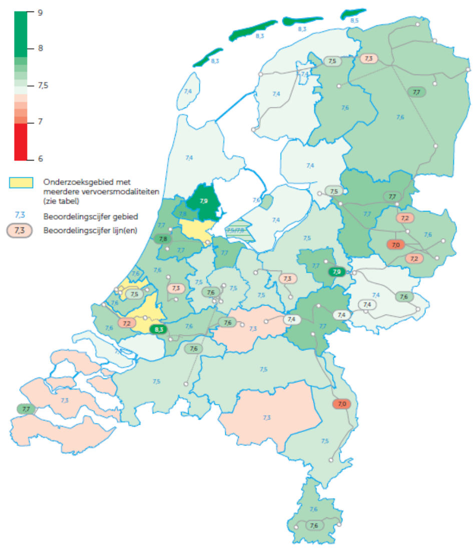
Due to lack of public data since 2012, caused by the full implementation of the OV-chip card system, 2011 is the last year for which a complete list is available on the volume of traffic on the decentralized lines. Roermond-Nijmegen (130 million kilometers) and Leeuwarden Groningen (140 million kilometers) had the largest share, partly due to the longer average travel distances on these lines (Van Ooststroom and Savelberg, 2008). Between 2002 and 2006, the rise in train usage was much larger in these lines in comparison to the rest of the Dutch network. Some quality improvements, such as increase of frequency and integration of train and bus, were the possible causes. Moreover, the Netherlands Institute for Transport Policy (KiM) assigns the fourteen regional public transport authorities, which are responsible for the development of public transport in their region, to implement their own policies for 2020, which are tailored to the specific situation in each area (Ministerie van Infrastructuur en Milieu, 2015).

Because of the integration of the OV-chip card system and cessation of the WROOV research that was taking place in the bus, there is not a clear view available for the development of bus, tram and metro (BTM). The use of BTM increased from about 6.3 billion kilometers in 2004 to 7 billion in 2011. This growth took place mainly between 2009 and 2011 (Ministerie van Infrastructuur en Milieu, 2015).

The emphasis on high-quality public transportation in the Netherlands has resulted in railways of high frequency and high capacity. However, these characteristics mainly apply to some centralized lines between the major cities, while the public transportation system is more limited in smaller cities or the countryside (Vos, 2015). So, two types of trains can be distinguished in the Dutch public transport network (TransTec adviseurs BV, 2009):

- Intercity trains, which are mainly met in the fast and long-distance routes of the main corridors;
- Stop trains, which are available in the local routes and can be met in every station.

Figure 9. Passengers' scores of the regional public transport in the Netherlands. Source: (CROW, 2016)



Stadsvervoer Amsterdam		Stadsvervoer Rotterdam		Stadsvervoer Den Haag	
bus	7,5	bus	7,6	bus	7,7
tram	7,4	tram	7,8	tram	7,4
metro	7,4	metro, RandstadRail	7,6		

It should be mentioned that the local operators of the decentralized lines tend to call these two types "sneltrein" and "stoptrein" respectively.

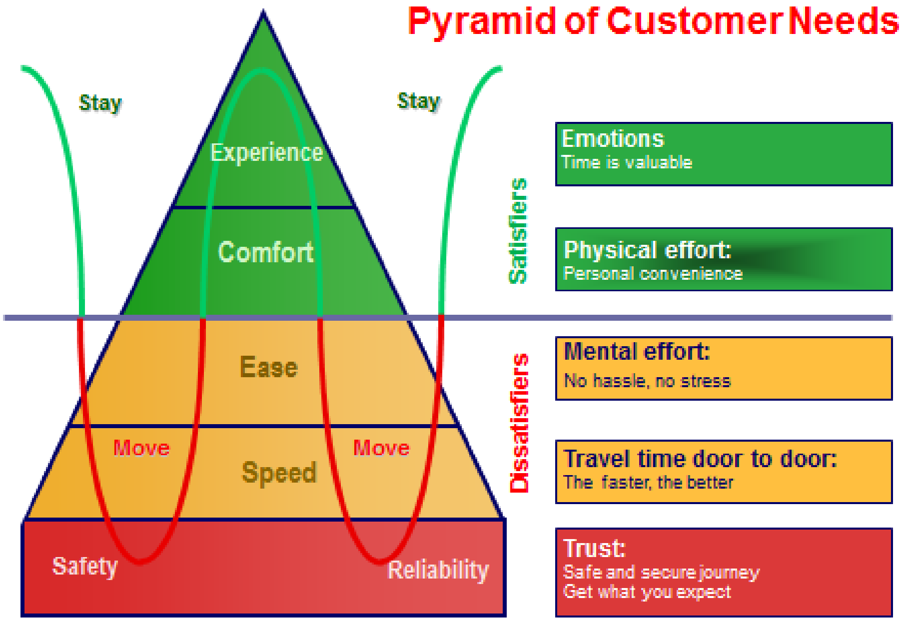
The bus service in the Netherlands is available both at a regional and city public transport level, but there is minimal long-distance bus service provided due to the high quality and broad use of railway services throughout the country. Overall, passengers are satisfied by the regional public transport because of the quality improvements that have occurred in the last fifteen years (CROW, 2016). Figure 9 shows the total scores for the entire country. The results show an increase in the valuation of the BTM, especially in comparison with the related figures of previous years, which shows that BTM is gaining recognition as improvements are established in the organization of the service.

2.1.4. Railway stations

ProRail is a government agency, responsible for the maintenance of the Dutch railway network infrastructure (apart from metro and tram) as well as for traffic control and allocation of rail capacity. In a partnership with NS-stations, they are in charge of providing clean, reliable, durable and comfortable stations along with good transfer facilities that make the trip of the passengers as comfortable as possible (ProRail(a), 2015). They are aware that the experience of travelers is determined by a combination of factors and not only the quality of the transfer is of importance, but the quality of the station as a whole.

Because the basic facilities are not enough in order to make the customers, i.e. the passengers and the users of the stations, satisfied, NS has formulated ten basic commandments in order to become a customer-driven railway operator and thus result in content users (Van Hagen and Bruyn, 2012), shown in Figure 10. They presented these commandments in the form of rules which lead to a high-quality service and therefore to satisfied users. For this reason, the customers are the center of attention, so their expectations, wishes and needs are defined in order to achieve the desired result. These needs are depicted in a hierarchical pyramid that reflects the way the customers realize and measure the quality that is offered to them by the railway operators.

Figure 10. Hierarchical pyramid of the various quality dimensions. Source: Van Hagen and Bruyn, 2012).

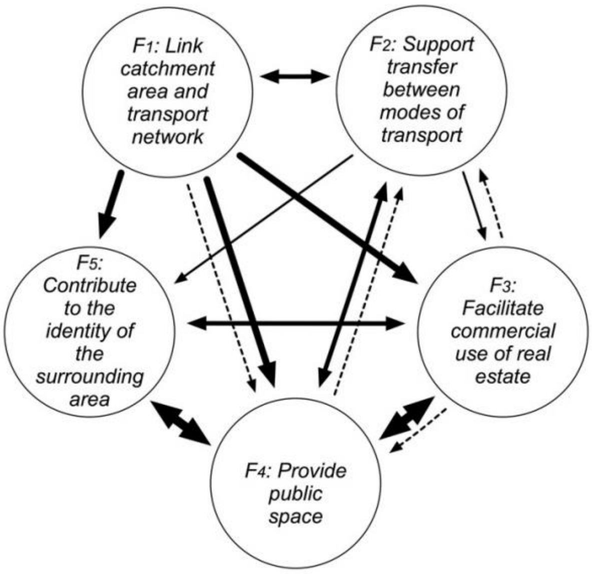


Safety and reliability create the foundation of the offered qualities, implicating that these are the cornerstones of satisfaction while using a railway service. When this basis is ensured, the customers measure the received quality in more aspects. Speed and ease are the next prerequisites that they demand, and when these are not elements of the offered service, this leads to dissatisfaction. This is why they are called dissatisfiers; it is substantial that a trip is fast and that little effort has been made from the traveler. On top of that, the structure of this hierarchical pyramid is complete when comfort and experience are provided; the so-called satisfiers. This is due to the fact that when these characteristics define a trip, the customers perceive an extra gratification. Therefore, not only has the trip to be safe, reliable, fast and easy, but the conditions must also be comfortable and pleasant, such as non-crowded environment in trains and stations, where various facilities are also offered, that enable the users to experience a complete service (Van Hagen and Bruyn, 2012).

The extent to which these preconditions will be applied at a railway station certainly depends on the degree of necessity that exists there. There are differences between the railway stations, which in the Netherlands are classified into five categories, namely ‘cathedral', 'mega', ‘plus’, ‘basic’ and ‘stop’, which is based on the number of passengers per day, with values of <1000, 10,000, 25,000, 75,000, >75,000 respectively (ProRail(b), 2015). Classifying the railway stations into groups means that the attributes and the facilities of each station will vary depending on the level of the station and undoubtedly, the higher the level, the more carefully will the pyramid of customer needs will be implemented.

However, classifying the stations solely by their passenger frequencies forbids the consideration of other crucial characteristics, which are not comparable between stations and allow for inclusion of functioning, context and system structure (Zemp et al., 2011). This statement is further supported by Zemp et al. (2011) who argue that in order to achieve a strategic planning in the area of railway stations, these need to be classified according to the

Figure 11. Possible interactions between functions of railway stations. Source: (Scholz et al., 2011)



relevant demands instead of the current indicator of "passenger frequencies". Scholz et al. (2011) identified a framework of five generic functions of the railway stations, shown in Figure 11, in order to develop assessment criteria on a more solid basis rather than simply looking at the station from a passenger frequency perspective. This enables the integration of more factors in the development of the railway stations, taking into account all the interactions that exist in the catchment area. Transfer between modes of transport is one of them, as well as the overall transport network, so the multimodal transportation can definetely have an impact on the stations' design and development.

2.2. Multimodal transport

As mentioned above, the Dutch public transportation is tightly linked with multimodal mobility. A multimodal journey is a trip that consists of two or more vehicular modes in order to reach the trip's end and therefore at least one intermodal transfer is necessitated during the journey (e.g. Carlier et al., 2003; van Nes, 2002 etc.). In addition, a specific mode or service serves as the main one, covering the biggest distance, while the rest of the modes or services are the ones used to access and/or egress from the main mode. Thus, the transport networks are characterized by a hierarchical aspect.

The main focus of this research is to investigate multmodal trips where the main part of the journey is covered by train. Therefore, the most important definitions are adopted from the study of Hoogendoorn-Lanser and Van Nes (2005) where the main parts of such a trip are defined. They describe that a trip where the origin or destination is the traveler's home address is called homebound and in the specific case that the train is the main means of transport that the traveler uses, then the journey is divided into three elements; a train trip part and two non-train trip parts.

However, Hoogendoorn-Lanser and Van Nes propose two different ways of distinguishing the two non-train trip parts, but only one is adopted here, namely a distinction between *access* and *egress.* The former refers to the trip being made from the origin of the traveler to the railway station while the latter refers to the trip being made from the railway station to the final destination. The reason of such a selection lies in the willingness to examine cases of trips being made specifically from origin to destination and the adoption of the athors' second distinction, i.e. *home-end* and *activity-end* parts, would dictate the inclusion of exclusively direction-free atrributes in the utility specification.

2.3. Transfers

Inevitably, making a multimodal trip prescribes that the traveler is obliged to make at least one transfer. Necessity of transfers in a public transport network is often more than apparent since they offer the possibility of various connections within the network and therefore they enlarge it. However, this opportunity is probably not appreciated by potential users, since they can compare it with an undisturbed car trip that offers a door-to-door mobility (Guo and Wilson, 2011).

Transfers may cause an additional disturbance to the passengers in cases of extra delays or lost connections, which decreases the attractiveness of public transport in general (Arentze and Molin,2013), so a transportation network designed with transfers needs to be accurate and reliable. In the beginning of 2006, 1 out of 8 trains of the Dutch railway system were reported with a belated departure (Molin et al., 2009), which implies that in cases of short connections or transfers to low frequency trains, the final delay might be quite longer.

Hence, transfers play a crucial role in travelers' perception and pertain to one of the most determining elements of a multimodal trip. The importance of transfers on passengers' decision making became evident almost 30 years ago when Hunt (1990) formulated a logit model and found out that minimizing the transfer waiting times can prove to be unsuitable, especially at the expense of increasing the need to transfer, implying that number of transfers is much more influential than the transfer waiting time. At the same time, it becomes apparent here that the "ideal" transfer time is difficult to be identified with certainty. However, his findings were quite preliminary and pertained to traditional characteristics such as, apart from number of transfers and transfer time, headway, in-vehicle time, walking distances from home and to final destination, repeatedly examined from following researchers.

Taking into account the disutility that passengers receive while making transfers, some advantages must be offered to them in such a case. Reduction in travel time and cost seems to counteract the dissatisfaction that a transfer can cause as it has been found in an attempt to gain patronage for a new route which includes a transfer and abandon an already existing route option (Chowdhury et al., 2015).

In addition, this perceived disutility can be reduced by other means of improvement, related to the environment that the passengers make their transfer. Public transport in general or specific multi-modal routes could significantly benefit by improving the transfer experience, so taking care of the facilities that the ridership can enjoy would reduce the figurative cost that somebody pays while making transfers (Guo et al., 2011). Train station attributes play a significant role in the users' choice decisions, which calls for thoughtful awareness of which facilities should be available in the transfer hubs (Anderson, 2013).

2.4. Route choice background

One of the main questions that arise is how travelers are making their decisions in cases where more than one routes are available for their trip. The individuals' attitudes and beliefs have certainly a determining effect on every choice being made. However habitual behavior is noticed when a chosen action is repeated, leaving doubts about the well-reasoning nature of these decisions (Van Acker et al., 2010). He et al. (2014) reflected the travelers' route choice generally and described the diversity of route choice behaviors also by giving special attention to the habitual or deliberate aspect of these decisions.

Lindsey et al. (2014) showed the importance and effects of pre-trip information on route-choice decisions, but referred to driving conditions and adopted a ''two-route network'' model by treating drivers and non-public transport users. Manley et al. (2015) also dealt with route choice complexity in urban areas but outlined a heuristic rule to reflect the drivers' route choice decision as well. Similarly, Prato and Bekhor (2007) estimated the important parameters in the actual route choice behavior of habitual commuters that drive on an urban network. Although focused on driving as well, their results can be auxiliary for route choice modeling since they suggest guidelines for prediction of route choice behavior, while observing the actual one. Freijnger (2007) proposed a stochastic path generation algorithm, trying to propose the number of necessary paths to obtain objective estimates, focusing on drivers as well.

Bekhor and Albert (2014) also analyzed route choice behavior of drivers and tried to show which latent variables, especially those related to sensation seeking, can be included in the models and combined with the traditional ones, such as pre-trip travel information, can give more valuable and realistic results. Physical feelings and emotional impressions were therefore incorporated in the models, in an effort to realize to which extent human sensations can play a prominent role to this kind of decisions. However, it can be assumed that the above attributes can only be apparent in driving choice decisions, where there is more freedom and variety of choosing the different routes. Route options in public transport are somehow pre-defined, leaving small space for sensation seeking variables, which cannot be included that easily, since public transport users act more passively by default.

Handy (1996) classified the choices made by individuals into long-term, intermediate and short-term, namely life-style choices (e.g. family formation, labor force participation, orientation toward leisure), mobility choices (e.g. employment, residential location, housing type, automobile ownership, mode to work) and daily travel choices for non-work purposes (e.g. activity type, activity duration, destination, route, mode) respectively, explaining that the short-term choices are made in order to satisfy the long-term. Therefore, there is a link between every choice that is made by the individuals and it can prove very useful to realize the factors that underlie the observed relationships. It can be seen in the above classification that route choice decisions are part of the short-term group of choices. The link between this specific short-term decision and the factors that motivate it has not been studied thoroughly from previous researchers. There is great abundance of research about transportation choices and there has definitely been an extensive effort to draw conclusions about mode choice decision motives in general and about route choice decisions as well, but as stated before not about the choice between routes within public transport solely. Attention is therefore drawn about how the choices are been made exclusively in the public transport context and the question that arises here is not whether e.g. a commuter goes to work by car or by train, but how a public transport passenger decides on which of the routes, available to him between his fixed origin and fixed destination, to take.

Route choice in a public transport network is defined by Guo and Wilson (2011) as a choice among various services, even in cases where they follow the same physical path, for instance the choice of a passenger whether to board in the arriving vehicle or to wait for a later one, which will have a lower in-vehicle time or else taking a slow or a fast train for the same route.

Since public transport traveling entails distinct features than driving experience, these users' behavior is significantly different than the one of drivers and dissimilar approach might be necessary. Undoubtedly, common general characteristics appear in these cases, but attention should certainly be devoted in the way of treating each scenario. Moreover, necessity to include multiple modes in the models of public transport route choices and combine them for the various route options, instead of introducing inflexible separations between them while making the models, is frequently proposed in transportation studies (e.g. Brands et al., 2014).

2.5. Route choice influential attributes

A thorough research of relevant to the route-choice-behavior characteristics has been carried out in an effort to reveal relationships between these attributes and the decision making of the travelers. An abundance of pertinent scientific papers is available nowadays, since examining the complex associations between the main features of route choice behaviors was always of particular interest in the field of transportation planning. It becomes quite evident from previous researches that the authors fervently support the need to focus on explanations from a behavioral perspective and not only justify the travel choices by looking at the time and fare differences. Some of the most important findings are presented below.

2.5.1. Transfer related attributes

Transfers concern the travelers of multimodal trips, since they constitute one of the main elements of these journeys. Guo and Wilson (2011) conclude that "the transfer cost comes from three different sources: transfer walking, transfer waiting, and transfer environment", so attributes related to these three pillars can definitely be expected. As already mentioned, transfer disutility is one of the biggest ones that the passengers seem to receive. Therefore, it needs to be examined which are the most influential attributes related to transfers while traveling.

The *number of transfers* is one of the most important attributes for the route choice models in the regional and long distance railway traffic (e.g. Axhausen and Vrtic, 2002; Bovy et al., 2005; Axhausen et al., 2006; Jánošíková et al., 2014; Hoogendoorn-Lanser et al., 1988). There are plenty of more researchers who agree that not only the total number of transfers, but the *time* that is necessary for the transfer is the least appreciated part of a trip (e.g. Schakenbos et al.; 2016, Carlier et al., 2003; Anderson, 2013). Investigation on multimodal transport by using a fuzzy logic approach (Hoogendoorn-Lanser et al., 1988) and by deriving data from a smart card-based fare payment system (Jánošíková et al., 2014) showed that *walking time* at transfer points is also influential.

Therefore, it becomes clear that there is a variety of attributes, associated with the necessity to make transfers that are included in the models of route choice studies. However, Hoogendoorn-Lanser (2005) suggests that attention is demanded on their inclusion due to expectancy of high correlations between the parameter estimates. This is the reason that a limited number of transfer variables should be included in travel choice models. Attention is specifically called to the number of transfers, because they might highly correlate with other transfer characteristics, therefore careful inclusion of a combination of these attributes should be considered in order to result in smaller correlations.

It should also be remembered that transfer disutility varies significantly between different trip purposes and various groups of passengers. For instance, travelers aged more than 60 years, probably perceive short transfer times as stressful due to fear that they will lose the transfer (Schakenbos et al., 2016). Therefore, in order to improve the quality of public transport by reducing the transfer disutility, consideration must be taken on the various groups and needs that are associated with the specific public transport lines, connections and time slots. Short transfers might be desired during peak hours, while more time might be necessary on the off-peak hours (Schakenbos et al., 2016). Indeed Axhausen and Vtric (2002) state that seasonal ticket holders find transfer time more important than other groups of travelers. Consequently, a *travel card possession* is implied to be one attribute that can be considered in the route choice modeling. Findings of Van Nes (2002) support this further, as availability of the students public transport card, which is provided in the Netherlands, found to have a substantial (positive) influence, compared to socio-demographic characteristics, in the determination of multimodal travel share. More examples of a different transfer valuation can be found in other aspects as well, such as between low and high quality level of traffic supply or between a frequent and non-frequent service (Axhausen and Vtric, 2002).

2.5.2. Travel attributes

The *in-vehicle time***,** as anticipated, is also highly relevant in the context of multimodal choice decisions. It was mentioned as a major factor in various studies, where the route choice decision making process was investigated using a Multi-Nested GEV model (Bovy and Hoogendoorn-Lanser (2005), a stated choice experiment to evaluate the travel time savings in Switzerland (Axhausen et al., 2006), a comparative study between the metro systems of London and Santiago (Raveau et al., 2014), or a qualitative study in an effort to determine the factors of the passenger transport (De Jong and Van de Riet, 2008). Hence, the in-vehicle time that the passengers spend while traveling is definitely one of the leading determinants in their decision making, since it defines in a large extent the final travel time and consequently the total time that they lose by making a specific choice.

The aforementioned studies reveal a considerable number of other influential attributes, able to determine the public transport travelers' opinions and choices. *Headway* appears quite frequently to be one of them (Axhausen and Vrtic, 2002; Jánošíková et al., 2014; Hunt, 1990, Anderson, 2013). This refers to the frequency of the connecting vehicle that a passenger needs to board in after the transfer. Therefore, it is expected that large headways, i.e. vehicles arriving infrequently, are not embraced by the ridership, due to the potential increase that this can mean for the duration of their entire trip.

Similarly, as with the transfer attributes, valuation of each characteristic might be interpreted differently between various groups, for instance commuters showed a significantly higher price parameter, probably stemming from their lower willingness-to-pay for improvements.

Travel costs and fares appeared to be significant as well in the conclusions of the previous researchers, which is not surprising, since somebody would expect that one route would be preferred over another if there was a difference in costs. However, Hoogendoorn-Lanser et al. (1988), while studying interurban multimodal trips in the Netherlands, excluded cost variables and socio-economic characteristics from their models. The considered route choice problem was with respect to public transport and the cost of urban public transportation in the Netherlands solely depends on the trip's origin and destination, regardless of the transportation mode that the traveler takes (for instance fast or slow train). Hence, the researchers wanted to examine the problem without including influences from cost differences between alternatives and income of the travelers and as the current research will be conducted in the same area, the same consideration will be taken.

The research done by Axhausen and Vtric (2002) unveils more attributes that influence public transport users trade-off during their route choice decision making. Apart from the aforementioned ones, *reliability* and *type of train* seem to be included in the most prominent, showing that passengers care for the high quality offered to them, while number of station stops, in-train services, landscape views, and general cleanliness of the system become a second priority.

In the study of Raveau et al. (2014), apart from the traditionally significant attributes, some more important attributes that proved to have an influence refer to the *conditions in the train and the station* (i.e. mean occupancy, possibility of getting a seat, possibility of not boarding the first train) as well as to the *transfer environment*. Hence, not only the time and fare related characteristics can play a prominent role in the travelers' opinion but the ridership also cares for the environment that is encountered while making the trip (both in the train and in the railway station). In addition, sociodemographic characteristics were found to be significant in this study, such as gender and age.

2.5.3. Socio-demographic attributes

So, sociodemographic characteristics also form a group of attributes that might have an outstanding influence in individuals' decisions. In the draft of RSG Inc. et al. (2015) about Intercity Passenger Rail, research has shown that passengers using buses tend to be younger and have less income than the general population, therefore it is apparent that *age* and *income* are two of socio-demographic variables that play a role in mode choices and as a result in route choices as well. Some more findings of the research with respect to bus traveling, suggest a few more attributes that are relevant with public transport choices, such as *level of education* and *employment*. Specifically, it was found that "bus behaves as an inferior good" to passengers who are employed and/or highly educated (RSG Inc. et al., 2015). Bus is also ranked lower than other modes from passengers who are accompanied by more passengers, hence it should be investigated what behavior is encountered whether travelers move in groups and if so, if there are exact formations of groups or number of accompanying travelers that lead to a change in travel behavior**.**

Household income appears to have an influence of route choice decisions due to the fact that people with higher incomes seek fast routes without paying special attention to the price of the trip, but, instead, caring more about the increase in the value of time (De Jong and van de

Riet, 2008). De Jong and van de Riet also stated that although travelers' sociodemographic characteristics affect the route choice and other decisions as well, many of these attributes may work through car availability or income, therefore in order to avoid further correlations, it can be supposed that income is one of the most important sociodemographic attributes that can be included in the route choice modeling.

2.5.4. Advanced technology/information attributes

Van Acker et al. (2010) developed a conceptual model in an effort to justify the individuals' trip decision making by assessing and explaining the reasoned and unreasoned factors influencing the choices made by travelers. Supporting the idea that travel choices are made based upon individuals' preferences and the relative costs associated with these choices, they generated a model to unravel the link between the observed daily travel behavior and the combination of attributes related to spatial, socioeconomic and socio-psychological nature. Some important findings promulgate the emergence of *telecommunication technologies* and the new circumstances of individuals' interaction with each other that follow this condition. Thus, travel choice behavior is definitely modified, since the recently intensive use of these technologies has altered joint activities with other individuals such as colleagues and friends quite impressively and as a consequence it has led to an alteration in the travel behavior.

Not only this advanced technology environment has an influence on passengers' action individually, but it also has an important effect on people's interaction. Nowadays, smartphone ownership is booming in most developed countries and the Netherlands rate reaches 59%, outperforming Germany, France, Finland, Belgium and even the United States (Deloitte, 2013). This fact combined with smartphone applications, which inform about transportation alternatives that a user has from origin to destination, form a new base of mobility, since travelers are equipped with all the available tools that enable them to instantly be aware of various options they have while traveling, enriched with plenty of information about fares, times, durations and transfers. These circumstances, emerged and settled in the beginning of the 21st century, probably have an impact on travelers decision making process that should not be neglected. The importance of using information technology has already been highlighted and a difference between trains and buses has been discovered, with train users showing more interest on this attribute, probably due to the fact that train passengers have a more business profile and show a bigger propensity to train than to bus (RSG et al., 2015). Therefore, as railway services offer quite often the possibility to information technology access, there is an even higher value that passengers receive, a situation that does not count many years in the forefront of transportation systems. It should be tested whether advanced technologies, for instance available in-vehicle Wi-Fi connection, are influential in the choice of modes and routes.

2.5.5. Station/environment/facilities attributes

Despite the recent trends and the tendency to frenetic use of wireless internet, it is found that this is not the only amenity that public transport passengers care about. *Facilities* offered during the transfers are also a determining nature as already mentioned above. "Transferring is a less significant barrier to travel when quality stations and interchange facilities are provided", as Currie (2005) mentioned. He also showed that penalties associated with transfers decrease when higher quality interchange facilities such as platforms and protected walkways are provided. The travelers anticipate a certain degree of physical comfort, while making use of the stations and the trains. Protected waiting areas and food facilities, shops and cafes at the station are elements that can increase the user satisfaction and the overall experience.

In spite of the extensive transfer experience, there is lack of knowledge about how specific investments within the station environment need to be managed in an effective way (MIMIC, 1999). Solutions regarding the offered facilities and investments at the transfer points must be proposed in respect to the needs of the users and should not emerge as opportunistic decisions.

Some important findings about the role of railway stations and train service in passengers' choice behavior were presented in the research done by Fiorenzo-Catalano et al. (2003), namely a strong preference for both boarding and alighting at train stations that are served by Intercity train services, although Intercity train is not necessarily used. What is indicated here is that some characteristics of these stations might be important for the travelers even if they do not make use of the main Intercity service component, which is the use of Intercity train itself, meaning that these stations are preferred due to the facilities being offered. Bovy et al. (2005) also mentioned that the stronger preference that is recorded for the Intercity railway stations is not only related to the observed level-of-service attributes but to unobserved variables as well, such as availability of various facilities or safety in the station.

Certain aspects of the built environment, such as *passenger densities* and the physical *characteristics of the stations*, were also proved to have an influence. Raveau et al. (2011) have shown that inclusion of non-traditional variables in public transport route choice experiments is quite beneficial for consequential results. Valuable findings of this study reveal that user knowledge of the network's route alternatives and the way in which network information of a transit system is presented are also of a great importance, reinforcing the statement made before, that the way information is presented and provided in the railway stations can contribute with a considerable impact. In addition, providing accurate information is essential while making transfers due to anxiety that a non-direct trip causes, especially in comparison to a convenient and direct automobile trip (RSG et al., 2015). Information was also proved to be an important facility on the research of Wardman et al. (2001) about travelers' perception of interchanges on public transport traveling. In addition, a *good shelter* was also included in the findings of the aforementioned study, showing that a protected area is quite important while travelers need to wait while making the transfer.

Crowding is also a determinant factor of station users' satisfaction and has an impact on the travel experience (Van Hagen and Bruyn, 2012). Since a crowded situation might be tolerated to a limited extent, the passenger density in the stations is an important element of the travelers' perception. But how can the users' tolerances regarding a crowded condition can be measured? Versluis (2010) conducted research about pedestrian interaction behavior and some important features that influence the pedestrian interaction process have been stated. Age, gender, body size, cultural aspects are some of them. Travel purpose is also mentioned as influential on the walking speed, with business-traveling pedestrians showing the highest one, followed by commuters, shoppers and pedestrians walking in leisure. However, not much evidence has been gathered about influence of the travel purpose in the interaction process. In addition, familiarity with the environment also plays a significant role in the pedestrian interaction process (Fruin, 1971) retrieved from (Versluis, 2010). Users of public infrastructure tend to focus their attention on understanding the surrounding environment rather than on their interaction with other users, so it can be comprehended that when pedestrians are familiar with the space, their mutual interaction process is smoother.

2.6. Conclusions

It is realized that the Dutch public transportation has been developing since the nineteenth century with constant efforts of optimizing it. There is however a lot of room for improvement because the car still holds the leading position of mobility in the Netherlands. Despite the focus on quality of all aspects of public transportation mobility, the increase in public transport use the last decades has only been recorded for young adult travelers who are equipped with free transportation cards. In addition, the most of improvement actions are concentrated in the main corridors which facilitate the biggest cities of the Randstad area, while the rest of regions come next. In any case, the planning authorities always seek for the reasons of station users' satisfaction and surveys take place every year in all means of transport in order to observe the course of public transport use and understand the demanded improvements.

At the same time, the urban formation in the Netherlands has been organized on the basis of flows between the separate urban systems so a polycentric system has been developed. This entails that quite often the public transport passengers cannot travel seamlessly to their destination, because few network lines are direct, while the majority of them are bundled. Transfers need to be made from one vehicle to another, which cause a disutility to the ridership. In addition, due to inability of traveling directly from origin to destination, various route options can be available, with different combinations of used vehicles and/or transfer stations. Because of the disturbance that is caused by the transfers and based on the continuous effort of optimizing the Dutch public transport network, the route choice behavior is tried to be investigated. Special attention is given to the role of main and side railway stations in order to understand how this differentiation affects the decision making process of the public transport passengers. Acknowledgement of the most influential factors that are related with the environment of the railway stations can lead to policy making which can allow the redirection of travelers to the side railway stations and decongest the main ones.

A literature review about route choice behavior has been carried out and it was tried to identify the influential characteristics of the public transport travelers' decision making process. The attributes related to in-vehicle travel times and transfers appear to be the ones with the highest impact. The environment in the stations, the crowd conditions and the facilities that are provided have also been reported to be of a considerable influence and can mitigate the dissatisfaction that is received with interchanges. The costs and fares are inevitably influential as well for the route choice decisions. Moreover, the headways of the required vehicles have been continuously stated from previous researchers to highly affect the route choice behavior. Some more elements that have proved to be important for this behavior are the age, the income, the travel card possession, and the level of education and employment of the travelers as well as the reliability of trains, the way of presenting information and the presence of telecommunication technologies.

3. Research approach

This chapter provides information about the research approach that is chosen in order to answer the research questions. It is explained why stated choice approach is selected. In addition, the case study is described and the experiment is explained thoroughly. Details of the questionnaire, which was designed in order to conduct the experiment, are also provided as well as the way the data was collected. Finally, the chosen method for the data analysis and the proposed model is introduced.

3.1. Stated choice

Route choice modeling has been approached by many researchers due to its complexity and various methods have been used in order to get a valuable insight in this process (e.g. Guo et al., 2011; Frejinger et al., 2009; Vitetta, 2016; Jayasinghe et al., 2016; Vrtic et al., 2007). But finding the right approach which will help in drawing the desired results is the key ingredient of a valuable outcome. In the current research the aim is to find out what are the key characteristics that influence the route choice behavior of the public transport travelers. According to Arentze and Molin (2013), “the stated choice method is a well-established method to estimate travel choice models empirically”.

When there is need of predicting how various transportation policies would affect the travel demand, then employing stated choice surveys proves to be a powerful tool (Fujii and Garling, 2003). The current study seeks to identify the attributes that have an impact on route choice decision making process, in order to realize how would the public transport users be triggered to redirect from main to side railway stations and establish successful policies based on these findings. The stated choice approach has been deployed in various transportation studies that aimed to predict the future demand and foresee how the involved travelers of each case would react in possible changes, such as the study of Mabit et al. (2013) who investigated international long-distance travel preferences. Therefore, since it needs to be captured how the individuals make their specific choices, hypothetical situations will be presented to them in the form of a stated choice experiment.

But a question that sometimes arises in similar approaches is whether stated preference should be preferred over revealed preference. Stated-preference data are gathered by presenting hypothetical situations to respondents, where they have to *state* their choice in the given circumstances. On the other hand, revealed-preference data refer to the ones gathered through the actual choices that people make, by *revealing* their real preference (Train, 2009).

Janosikova et al. (2014) estimated a public transport route choice problem by using archived data from a smart card-based system and showed that it is modeled with higher accuracy. But Hoogendoorn-Lanser et al. (1988), who considered a similar problem in urban areas, after classifying the travelers to regular and incidental, recognized the problem that arises from collecting revealed preference data only. Regular travelers are more familiar with a specific trip alternative than incidental travelers, but on the other hand, habitual behavior is likely to bind them from exploring different travel alternatives. As a result, observed travel behavior of regular travelers may not correspond to their actual preferences, so setting revealed preference questions exclusively prevents the researcher from approaching the topic thoroughly and understanding how ridership will react in possible alterations, not only by relying on their repetitive behavior, which is probably driven by habitual forces. The most prominent advantages and disadvantages of stated preference compared to revealed preference are presented below.

Advantages of SP

- While RP only shows choice results, SP shows ranking, rating and choice information;
- While RP only captures existing alternatives and observable behavior, SP captures non-existing alternatives and hypothetical behavior;
- There is not measurement error in SP data;
- While the range of attributes in RP is limited, in SP situations it can easily be extended;
- In SP it is possible to control multi-collinearity among attributes;
- More responses can be obtained from each respondent due to brevity and clarity of the choice set

Disadvantages of SP

- While there is consistency in RP since it is obtained from observed behavior, this might not be the case in SP because there is not real correlation between real behavior and answers;
- Because respondents might try to justify their actual behavior or to control policies, biases are likely to occur;
- In order to avoid biases, SP data must be collected in a highly specific fashion. (Adapted from Sanko, 2001 in (Lem, 2014)

Therefore, stated choice approach is selected and various individuals will be invited to participate into a stated choice experiment in which they will have to choose between a specific set of hypothetical alternatives. Each alternative is described by its attributes which in turn are explained by their levels. Hensher (1994) stated that choice responses are directly translated into predictions and that making a choice is relatively easier for the respondent. First, it is important to clarify the procedure that a researcher needs to follow in order to generate valuable choice alternatives and sets, and in consequence useful data and results. Hensher et al. (2005) summarized the process to generate stated preference experiments in an experimental design process scheme, as can be seen in Figure 12. First of all, the research problem is clarified, so it is unambiguous what results need to be achieved at the end of the research. In this case, as mentioned above, the factors that influence passengers' route choices in the context of public transport is the main research goal. It is also underlined that attention will be given to the role of side and main railway stations as well. Hence, the research problem is properly refined.

Next, stimuli refinement follows in the process. The researcher has to refine the list of alternatives and attending the location of the study can be an initial step. In addition, the alternatives need to be further limited down in order to result into a manageable size of choice alternatives. In this way, each decision maker is presented with a different sub-set of alternatives. A second approach of limiting down the alternatives is to exclude the "insignificant" ones. In this case, the researcher has to act somehow subjectively and place more weight in practical considerations.

The next task of the stimuli refinement refers to attribute and attribute level identification. The relevant attributes need to be assigned carefully to each alternative because the conditions are rather vague. For instance, one researcher might attach a different marginal utility to time spent walking to a station than they do to time spent waiting at the station. As a result, this is a very crucial step and literature review can give an important insight into the issue. At this point, inter-attribute correlation must also be considered, which refers to the cognitive perceptions the decision makers bind to the attribute descriptions provided. This means that while an experimental design is generated by estimating some attributes independently, the respondents may not necessarily treat these attributes as being independent, so in this case nested designs might be dictated. If nested structures are not used, then a rather safe solution is to identify the attributes that probably act as proxies for other attributes and choose the most appropriate ones for the research.

The identification and refinement of the attribute levels and attribute level labels is the next important step, which also requires much attention. We are forced to compromise in terms of the number of attribute levels to use and we also have to identify the extreme ranges of the attribute levels. Examining the experiences related to the attributes of the decision makers being studied is very helpful to attribute level labeling, as well as deriving the extremes of them. However, if it needs to be examined which the travel behavior will be in case of alterations of the current situation, attention has to be kept because using values outside of the identified range might cause respondents' skepticism.

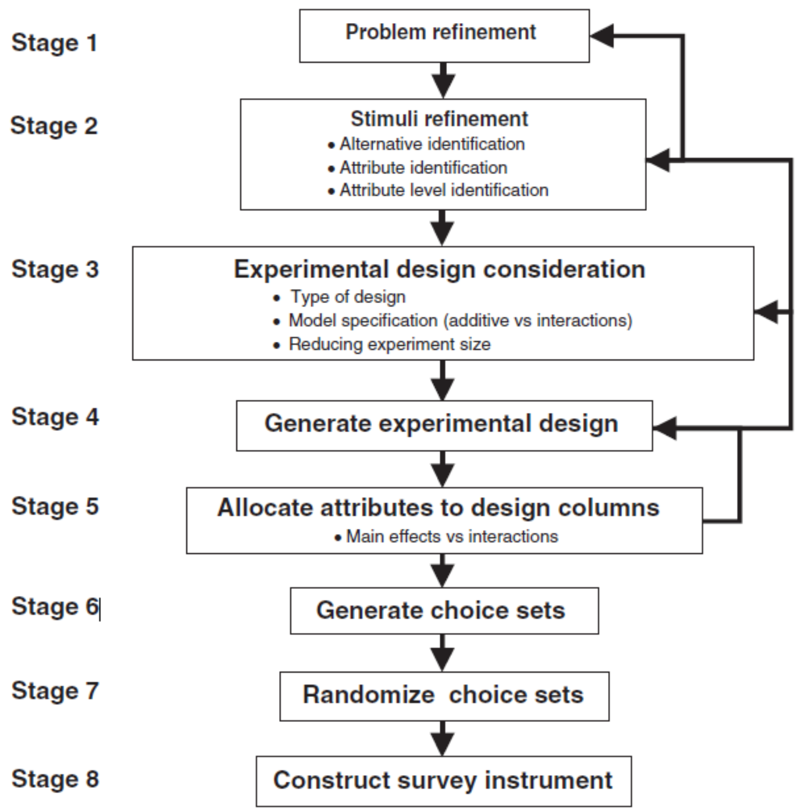
After having identified the aforementioned elements, the next step that the researcher needs to take pertains to the consideration of the experimental design. This is the moment when the type of design is chosen and the model is specified so the analyst needs to take decisions such as whether to use a full factorial design or not, whether to present a labeled or unlabeled experiment, whether the number of levels should be reduced or not etc. In addition, the reduction of the experiment size should be considered here, since it is possible that a fraction of the treatment combinations is used and the degrees of freedom are also calculated.

The fourth and fifth step occur simultaneously and refer to the actual generation of the experimental design, so the design strategy is adopted, and the attributes are allocated to design columns, so the attribute levels are coded. As a consequence, the sixth step takes place, which means that the choice sets are generated.

The choice sets that can be recognized are the subjective and the objective choice set, consisting of the alternatives known to the traveler and of all the feasible alternatives considered relevant by the researcher for the traveler respectively (Bovy and Stern, 1990). Fiorenzo-Catalano et al. (2003) studied the characteristics of multimodal choice sets by generating objective alternative sets for each individual and realistic alternative sets for groups of travelers. They explained Bovy and Stern's (1990) classification of alternatives into the feasible, the known, and the considered sets both from a traveler's and a researcher's perspective, showing the differences in the two approaches and the difficulties that might stem from the different information obtained from the two groups or the lack of researchers' knowledge about the travelers' preferences. A procedure was developed to generate estimated objective choice sets and there was a comparison done between them and the reported subjective choice sets. However, the big number of possible alternatives involved means that generating objective choice sets might not be quite appropriate and therefore Fiorenzo-Catalano et al. (2003) developed an alternative approach, estimating subjective choice sets and comparing these with the reported sets.

Subsequently the choice sets are randomized in order to result in a random selection and to be presented to the respondents, which refers to the seventh stage of the procedure. When all the steps are followed and completed it is time for the survey to be constructed. The experimental design process instrument can act as a "compass" during the researcher's effort to result in a valuable outcome, by providing a sequence of steps that facilitate a careful design.

Figure 12. Experimental Design Process (Hensher et al., 2005)



3.2. Case study

The main case that is selected to be studied in this research pertains to the Zernike campus in the city of Groningen, which accommodates the State University of Groningen (RUG) and the Hanze University of Applied Sciences (Hanze). The route choices that are examined refer to the public transport connection between the city of Leeuwarden and the Zernike campus. This case is chosen due to the fact that the travelers between this pair of origin-destination have more than one route option to choose from. OV bureau Groningen-Drenthe, which is a cooperation entity between the provinces Groningen and Drenthe and the municipality of Groningen (De Jong et al., 2011), is responsible for the organization of public transport in these provinces and needs to identify the motives behind the passengers' behavior in order to facilitate the area in the most proper way.

The target group that will be examined pertains mainly to students and employees who travel between the city of Leeuwarden and the Zernike campus. The total number of students and employees of Hanze exceeds the 30000 (Hanzehogeschool Student Information 2015-2016) while this number is bigger than 43000 for the case of RUG (Annual Review University of Groningen), but there is not a clear figure of the exact number of the students who travel from Leeuwarden.

As stated choice approach is chosen to obtain the desired information regarding the influential factors of passengers' behavior, a questionnaire will be constructed and respondents will be invited to evaluate different choice sets with alternatives between which they will have to choose the one they prefer. Afterwards, the completed questionnaires will be analyzed in order to get results concerning passengers' preferences about available public transport routes.

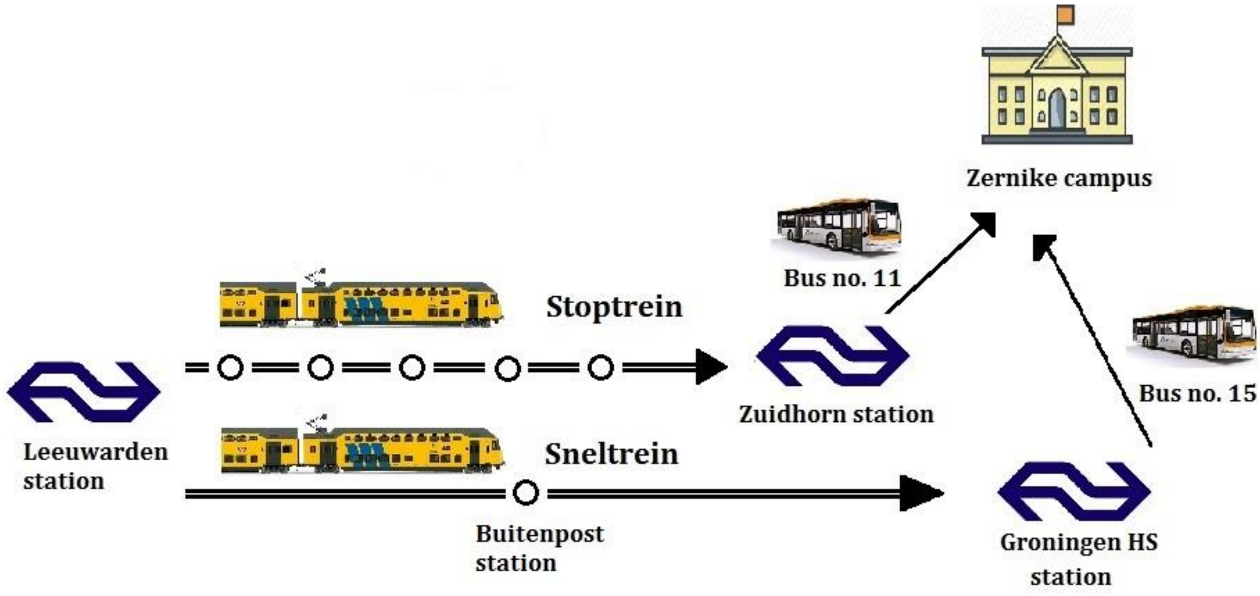
Description of available routes

The experiment is focused on people whose destination is the Zernike campus in Groningen and their origin is Leeuwarden or one of the following stations: Leeuwarden Camminghaburen, Hurdegaryp, Feanwalden, De Westereen, Buitenpost, Grijpskerk, or Zuidhorn. The aforementioned railway stations refer to the intermediate stops that exist between Leeuwarden and Groningen and passengers who make use of them have to choose between different routes in order to arrive at Zernike campus, the end of their trip. The main goal of the research is to clarify all the factors that play a role in the choice behavior of these passengers during their multimodal trip and whether and which of the station characteristics have a strong influence as well on the selection procedure.

The capital cities of Leeuwarden and Groningen are connected by trains from Arriva operator. The line has an increasing function for the accessibility of both centers and is 54 kilometers long, not electrified, secured with the train control system ATB-NG and partially (about 30 kilometers between Grijskerk and Zwaagwesteinde) two-track (Van Ooststroom and Savelberg, 2008).

The two types of train that a passenger can take are: the fast train ("Sneltrein") or the stop train ("Stoptrein"). The former one connects the two cities almost directly, since there is only one stop between them, in Buitenpost and the whole itinerary's duration is 35 minutes. The latter one follows the same railway line, but stops in many points in-between and the whole trip lasts 49 minutes. Connection from Leeuwarden to the Zernike campus in Groningen is therefore dependent on this connection (between Leeuwarden and Groningen) and it is facilitated by two main different routes, which are illustrated in Figure 13.

Figure 13. Route options between Leeuwarden station and Zernike campus in Groningen.

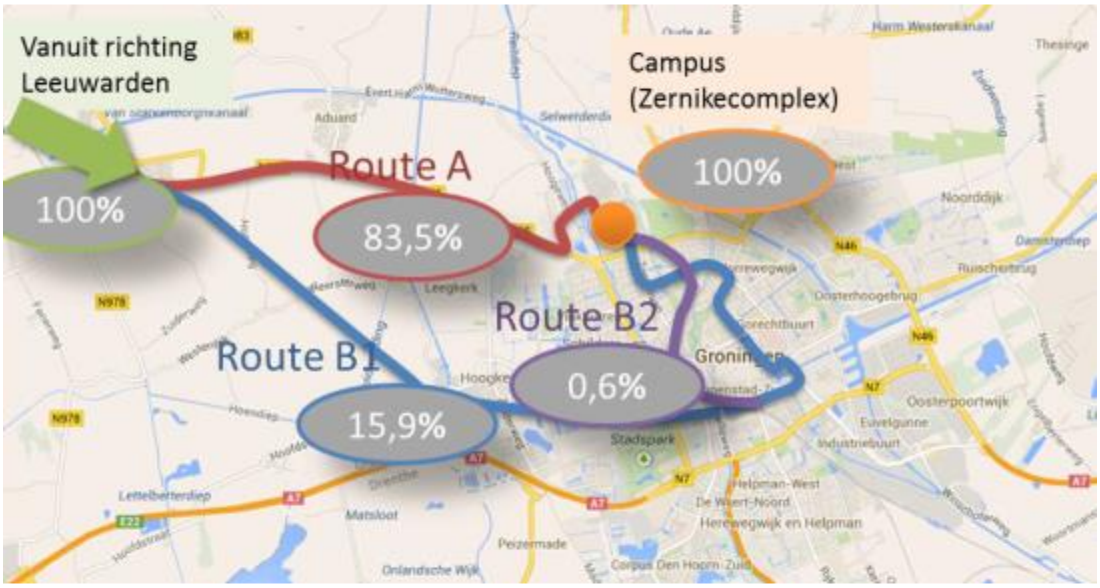


The first option that travelers are given is to take the stop train from Leeuwarden and disembark from the vehicle at Zuidhorn station, after 38 minutes. Afterwards, there is a bus (no. 11) connecting Zuidhorn station with Zernike campus in 13 minutes. It should be noted here that this route takes in total approximately the same time with the second route that will be explained afterwards, which is about 1 hour (embarking in Leeuwarden and disembarking at Zernike campus).

The second choice is to take the fast train from the beginning till the end of the train route (from Leeuwarden to the main station of Groningen) and then continue the trip to Zernike campus by bus (no. 15) from the bus station, which is located next to the railway station, in a walking distance of about 2 minutes. This route's duration is also about 1 hour. It should be noted that stop train can also be used for this route, but this trip lasts 14 minutes more, so it will not be taken into account, since the time difference with the other two routes, compared to the time difference they have with each other, is not negligible.

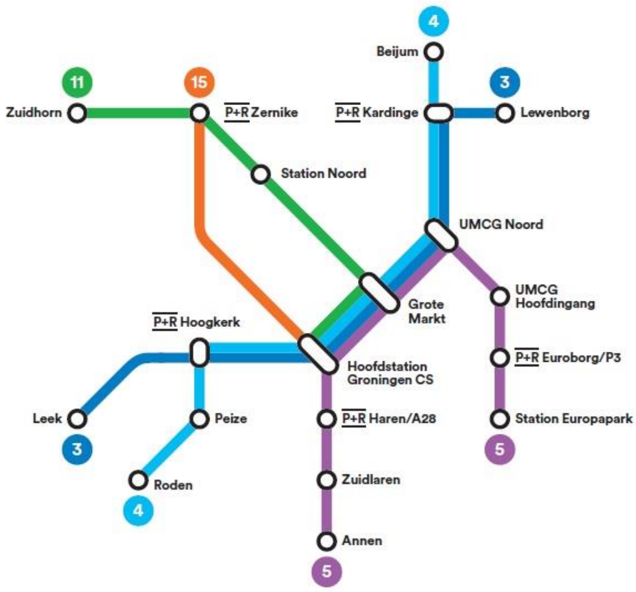
According to data gathered from OV-bureau in 2013, 83.5% of the travelers choose the first option (Route A in Figure 14), therefore travel to Zernike campus through Zuidhorn. 15,9% of them chose the second option (Route B1), selecting to travel through the main train station of Groningen (from now on *Groningen CS*) and taking the bus no.15, while a very small percentage (0.6%) choose to head to Zernike by another route, which is to travel to Groningen CS, but then continue to Zernike campus by taking another train to Groningen Noord station.

Figure 14. Passengers distribution in the available routes. Source: OV-bureau Groningen-Drenthe, 2013



As it can be perceived, both aforementioned routes initially require taking the train and afterwards the bus. The third option that seems to exist in the data from OV-bureau, will not be taken into account in this research due to its low status and because it cannot compete satisfactorily with the other two routes. The situation regarding the buses within the city of Groningen can be more closely looked in Figure 15, where it is visible that the green line represents the route of bus no.11 that starts in Zuidhorn, and the orange line represents the route of bus no. 15 that starts at Groningen CS. The scheme shows roughly the available routes, with Zernike campus on the north-west being represented as "P+R Zernike", which is only one of the four available bus stops in the entire area of the campus.

Figure 15. Buses route scheme in the city of Groningen, Q-link (* retrieved from qbuzz.nl/q-link/)



Finally, the two routes that are investigated refer to the connection from Leeuwarden through Zuidhorn station with bus no. 11 and through Groningen CS with bus no. 15. Choosing the first option allows passengers to leave the train in Zuidhorn, 10 minutes before it reaches the final destination and therefore board in the bus while having covered almost four fifths of the entire route. On the other hand, choosing the latter option means that they have to cover the whole distance till the city of Groningen and then also board in a bus.

One more difference that can be marked between the two choices is the walking distance from disembarking point to the bus stop. In Zuidhorn travelers have to walk 50 meters to reach the bus, while in Groningen CS they have to walk 200-300 meters, crossing the train station, which requires about 2 more minutes walking. However, this fact finally makes the two routes quite equal concerning the waiting time between the train and the bus, since in Zuidhorn the bus leaves 5 minutes after the train arrives, while in Groningen this happens after 7 minutes. Of course, this also depends on each passenger's walking speed, personal capability, conditions in the station etc. In addition, it is important to note that the bus from Zuidhorn (no. 11) departs every 30 minutes, while the headway of bus no. 15 (from Groningen CS) is every 5 minutes in the morning rush hour between 07:50-10:30 (but every 10 minutes before the morning rush hour and every 7-8 minutes after the morning rush hour). The latter one is very frequent, leaving less space for uncertainty and minimizing the waiting times in case of train delays or overcrowding in the bus.

Figure 16. Zuidhorn train station (only two train tracks)

Noteworthy difference can also be observed in terms of available facilities in the transfer points. In Zuidhorn station, which simply facilitates the line Groningen-Leeuwarden, serving the village and the surrounding area, there are no facilities offered to the travelers, since it belongs to the "stop" station category, which is the lowest one, according to the classification of ProRail (ProRail(b), 2015). On the other hand, in Groningen CS, plenty of facilities are offered to the passengers due to the magnitude of the ridership and the quantity of connections and lines that fulfill the needs in the area of Groningen and therefore it belongs to the "mega" category. Shops, cafes, toilets and supermarkets can be found in Groningen CS, giving the opportunity to the passengers to satisfy their most anticipated and common travel needs (food, drinks, toilet, tickets etc.).

The two aforementioned routes have been observed during weekdays and attention has been given on the morning rush hours which proved to be the most problematic. Extensive information about the outcome of the observations is provided in Appendix 2.

3.3. Stated choice experiment

The questionnaire has a special focus on students, since the vast majority of the travelers to the university campus are expected to belong in this group. Indeed, a customer satisfaction survey that took place in the entire country about the city and regional transport shows that quite an outstanding percentage of passengers using the Q-line buses in Groningen (both lines 11 and 15 are Q-line) refers to people younger than 27 years old (79% in 2015) and the percentage of Q-line travelers that was using the OV-student card (free transportation) is 48% in 2015 (CROW, 2016).

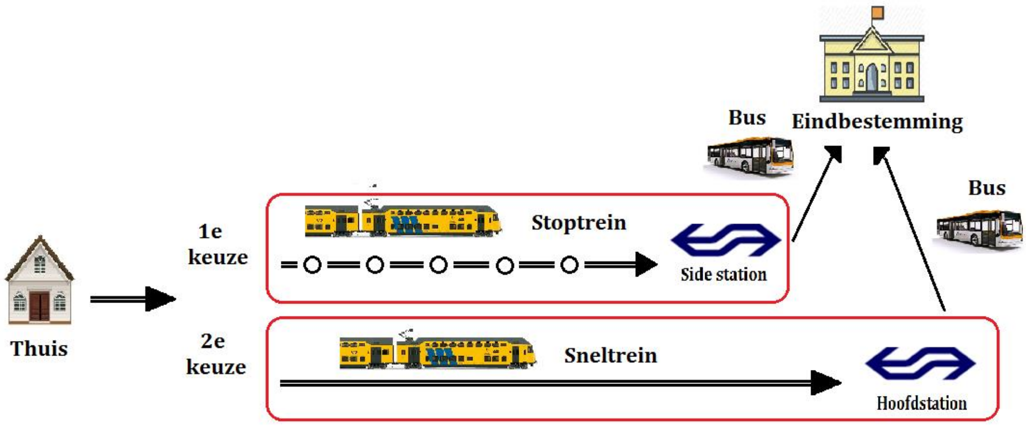
Personal and trip-related questions are included in addition to the stated choice experiment. The survey is written in Dutch and the study is case-specific with young participants, since the questionnaire is designed to be distributed mainly to students who travel to and from university and have to take the relevant route choice decisions as mentioned above.

According to Kløjgaard et al. (2012), who demonstrated the significance of a thorough qualitative process in a discrete choice experiment and the necessary steps during this procedure, it is very important to include the most noteworthy attributes that are relevant to the majority of the respondents, because validity of the experiment should not be affected. The combined set of attributes is presented in a clear and concise manner to the respondents, who have to make trade-offs between the attributes. It has to be ensured that individual characteristics reveal the respondents' true motivations. Moreover, individuals' valuation depends on the levels of these attributes, which are changed across the sets. They have to be defined carefully in order to guarantee the willingness of the respondents to make trade-offs.

Therefore, the questionnaire was constructed according to the aforementioned guidelines. Design of the questionnaire took place in the 'Berg Enquete System', specially designed for Built Environment students of TU/e. The survey presented different choice situations to the respondents, for which they have to make a choice of one out of two alternatives. In every choice situation, the first alternative pertained to a route with a transfer at a side railway station and the second alternative alluded to the connection through a main station (representing the cases of transferring at the station of Zuidhorn and Groningen respectively). It was made clear that the first case concerned a route with use of *stop train*, while the second alternative dealt with use of *fast train.* The two alternatives were roughly presented in a picture in order to give an estimation of the choice situation, as can be seen in Figure 17.

Flügel et al. (2015) also used binary stated choices in order to build a forecasting model, which would help them predict the future demand of a non-existing travel mode in comparison to a current one. Similarly, the current experiment is built in such a way that it tries to understand which characteristics should be given to a route choice with transfer at a side station in order to surpass the probability of an existing route choice through a main railway station.

Figure 17. The 2 different choice situations as presented to the respondents of the survey.



Therefore, the respondents were asked to make a choice between two alternative routes from home to their final destination, where the cases were similar, showing a trip initially by train and then changing to bus. The main difference lies in the type of train, showing that the stop train alternative covers a shorter route than the fast train one. For the purpose of unbiased results, the two choices were presented solely by mentioning the type of train and not the names of the real train stations. Since the focus of the experiment was to understand how the public transport users could be redirected to a side railway station and how this choice can be more appealing, it was decided to keep the second alternative always the same, with specific and predefined attribute levels. These levels were selected from the situation that can be met in Groningen CS. The idea behind this decision is that the characteristics that are apparent in a station like Groningen CS are difficult to alter, as they depend on a large quantity of multiple, complex and already decided factors, and on the other hand it was desired to investigate how we could instigate the passengers to be more keen on stations similar to the one in Zuidhor. Hence, it was tried to elicit information by showing only one level of the fast train variables and manipulating 2 or 3 levels of the stop train variables.

The various profiles were generated by combining attribute levels of each attribute with other attribute levels. The total number of attributes, included in the questionnaire, was 10, however the first one (*time in train*) was always 35 minutes and was only presented in order to make the respondents aware that the two options had exactly the same 'in-train' travel time. As a result the attributes included in the experiment were 10 in total. More specifically 5 of them had 3 levels and 5 of them had 2 levels. This means that 480 (2^5*3^5) treatment combinations would arise with a full factorial design. This would enable the estimation of all possible main and interaction effects, but it could not be easily handled by the respondents (Hensher et al., 2005). It is possible to use partial profile experiments with only a subset of the studied attributes (Chrzan and Orme, 2000), therefore, a fractional factorial design is preferred and the number of profiles that were finally generated was 27.

Each respondent was introduced to the choice situations with one example and then they were invited to evaluate 5 random profiles. Orme (1998) proposed a rule of thumb to estimate the required number of respondents while conducting a stated choice experiment (retrieved from Rose and Bliemer (2013). The proposed equation is the following:

$$N \geq 500 * \frac{L_{max}}{J * S}$$

where,
N is the required sample size;
L_{max} is the largest number of levels for any of the attributes;
J is the number of alternatives included in the choice experiment; and
S is the number of choice sets that are presented to each respondent.

As will be explained in the following section, the largest number of levels was L_{max}= 3, the number of alternatives for each set was *J*=2 and there were five choice sets presented to each participant so *S*=5. As a result, the desired minimum sample size for the current research is equal to 150 respondents.

3.3.1. Setting up the experiment

Attributes

The selection of attributes that were included in the stated preference experiment was based on the most important features that needed to be examined for the case. Based on the literature review of the previous researches about route choice behavior, the most important attributes that were related with the investigated problem were added in the experiment. As already mentioned above, the first attribute, which was not varied in the analysis but was only presented to the respondents, is the *time in the train.* The only reason to display this factor is to make clear that there is no difference in the total in-vehicle time (in the train).

Next, ***transfer time*** between train and bus was included. Passengers are generally disturbed when there is need of making transfers, as already stated in the literature review (e.g. Schakenbos et al.; 2016, Carlier et al., 2003; Anderson, 2013). The examined case involves one transfer in the route between the boarding train station and the destination, therefore number of transfers is not included as an attribute, but the time necessitated for this transfer is investigated.

Hereupon, the ***in-vehicle bus time*** attribute follows. In that way, it needs to be examined whether the time spent in the bus is substantial for a route choice decision like this and therefore, if passengers can be attracted to a route due to smaller times spent in the bus. Concerns about convenience personal safety issues have been reported in relation to bus traveling (RSG, Inc. et al., 2015). So, the purpose of including this attribute is to realize whether the statement is true and indeed makes a difference in the choice behavior.

After these three time-related attributes, the ***total travel time*** was also added in the choice set in order to let the respondents be instantly aware of the entire time difference between the two alternatives. This was the second and last attribute, apart from the *time in the train,* which was only depicted in the choice set to let the respondents have a concrete idea of the travel times, and was not included in the analysis. Therefore, only the ***transfer time*** and the ***in-vehicle bus time*** were the ones really inserted in the experiment.

The following attributes were related to the features of the station and the characteristics of the bus service. Overcrowding situations, met in the platform of Zuidhorn station during the rush hours, led to the consideration of ***occupancy rates (crowding at the platform)*** within the research, which was also found in previous researches (e.g. Raveau et al., 2014; Van Hagen et al., 2012) and investigation of this characteristic's influence in the decision making process of the passengers while making a transfer during their trip, that is to realize the magnitude of effect of crowded platforms. In order to make it clear and unambiguous to the respondents, this attribute was presented by the word "***drukte"*** (bustle, fuss). This informal term was opted for to avoid any misunderstandings.

Next, due to absence of any facility at the station of Zuidhorn and similar side stations in the Netherlands, it was decided to examine whether passengers' behavior would be influenced by some facilities' presence. Previous studies have mentioned the importance of facilities that are apparent in the railway stations because they satisfy some basic needs and improve the overall experience of a station user, as it was reported in section 2.5.5. From the variety of facilities normally offered at a railway station, four of them were selected and included in the experiment; namely, presence of:

- ***Toilets***
- ***Information desk***
- ***Kiosk***
- ***Heated waiting area***

Instead of the four different attributes, it would be possible to include only one that could explain the level of the station, possibly derived from the distinction that Prorail (2015) has indicated. However, it is quite dubious whether the respondents would be able to realize the differences between types of stations and it would also definitely need more time to describe the characteristics of the types as well as more effort on behalf of the respondents to interpret this variation. It is certainly required to provide easy and comprehensible questionnaires that do not provoke respondents' fatigue; therefore these facilities were simply presented as different independent attributes. It was sought to understand if there is any precise preference on a specific facility, so if all the facilities were included as a unique attribute, no insights would be gained about which of them is indeed necessary at a side railway station. This concern is supported by Hensher et al. (2005), who pointed out the attention that needs to be kept in cases like these. More specifically, they stated that attribute ambiguity should be avoided, because different respondents might interpret differently on one single attribute. As a consequence, this will also lead to difficulty in using the results regarding this attribute after model estimation and in providing meaningful recommendations.

Jánošíková et al. (2014) showed that the walking time during the transfers is influential for the route choice behavior. So, the next attribute that was included is the ***walking distance*** from train to bus. This refers to the distance that a passenger needs to walk after disembarking from the train in order to board the bus and continue their trip. There is a small but not negligible difference between the distance that a passenger needs to walk to catch the bus in Zuidhorn and the distance that they need to cover in Groningen CS. In the former case the buses set out almost a few steps further than the entrance of the small Zuidhorn station, while in the latter case, passengers need to traverse a bigger distance in order to walk out of the station. Passing through Groningen CS is undeniably greater in extent and in duration. Similar cases might resemble the above station designs.

Afterwards, the attribute ***headway of the bus*** was included. This pertains to the frequency of the vehicle after the transfer, which was found to be a very important characteristic (Axhausen and Vrtic, 2002; Jánošíková et al., 2014; Hunt, 1990, Anderson, 2013). Regarding the investigated case, there is a substantial difference between the headways of the buses offered in Groningen CS and in Zuidhorn. While, in the former station the bus runs quite often (almost every 5 minutes), in the latter one there are only two buses per hour heading off to the university. Hence, it was decided to test out whether more frequent bus service would attract more passengers to Zuidhorn station or other side stations.

The last attribute is related to the bus experience and more specifically, to the **level of the bus service**. Since the type of train was found to be a prominent attribute by Axhausen and Vrtic, 2002), it will be investigated if this also applies for the case of the bus. It is looked into if travelers can be triggered to use a specific route due to a better level of the running buses. Attention is necessary here, in order to avoid the ambiguity issues mentioned while describing the station facility attributes above. Since it is decided to make use of this attribute in the survey, it is necessary to make clear that it is conceived in a similar manner from the entire group of respondents. Luckily, this attribute, expressing the *level of buses*, has a more limited extend than the one expressing the *level of station*. Presence of a Wi-Fi connection seems to increasingly influence the route choice behavior of travelers nowadays, as mentioned in 2.5.4, so this can be one of the included features.

Attribute levels

The two alternatives that the respondents had to make a choice from are similar in terms of transport modes and core characteristics. Therefore, the attributes that are assigned to each of them are exactly the same. Thereby, it is easier for the respondents to make a direct comparison. In addition, it is reminded that the attribute levels of the second alternative are unchanging, further facilitating the choice procedure, since the respondents are presented various pairs of choice options, where the description of the second option of the pair is always the same. The attribute levels that are assigned to the attributes of the constant alternative simulate the real situation of Groningen CS. It should be recalled that this decision was based on readiness to realize what changes can be made in Zuidhorn (and in similar side stations examples all over the Netherlands) taking into account the predefined and considerably difficult-to-change conditions of a relating main station. The included attributes were given 2 or 3 levels. It should be noted that inclusion of 2 levels only will lead to estimation of linear effects, so inclusion of 3 levels might seem appropriate for a more realistic estimation. However, the decision to include 2 levels was made for the facility attributes, because it was simply presented to respondents that these facilities were present or not.

The attribute levels of each variable are presented below. The reasoning behind the selection of these specific levels stems from the case study that is used in the Zernike campus, and is provided in Appendix 3.

Transfer time:

- 3 minutes
- 6 minutes
- 9 minutes

Time in the bus:

- 12 minutes
- 14 minutes
- 16 minutes

Headway of the bus:

- Every 10 minutes
- Every 20 minutes
- Every 30 minutes

Walking distance:

- 20m
- 100m
- 200m

Crowding in the station:

- Low level
- Medium level
- High level

Presence of toilet/information desk/kiosk/heated waiting area:

- Yes
- No

Level of the bus:

- Basic
- Comfort

3.3.2. Questionnaire design

In order to conduct the survey, a questionnaire was designed in Dutch, since most of the students who travel between Leeuwarden and Zernike campus are coming from the Netherlands. International students also study in Rijksuniversiteit Groningen (RUG), however, it is assumed that most of them live in the area or city of Groningen. Therefore they are not part of the current research group. As a result, the questionnaire was only provided in Dutch.

The survey contains three main parts; each of them has a purpose of collecting data regarding different aspects. More specifically, the first part includes questions regarding the travel behavior of the respondents in order to get information about the preferences and habits of the travelers as well as their familiarity with the research context. The second part contains the stated choice experiment, where the respondents make their choices for the presented sets. The final part consists of personal related questions in order to get information about socio-demographic characteristics of the respondents. The total questionnaire is depicted in Appendix 4.

The *first part* includes trip-related questions, in which the respondents are asked to give information about their common travel behavior. All the questions are presented below, while a clear idea about the setting of questions, with the levels of possible answers, is given in Appendix 5.

1. *How often do you travel by train?*

2. *Which transport mode do you mostly use from home to the train station (pre-transport)?*

3. *Which transport mode do you mostly use from the train station to your school/work(after transport)?*

4. *When do you travel by public transport to school/work?*

5. In this question it is asked how often the respondent makes use of the following railway stations:

6. *Do you ever travel by bus to Zernike campus?*

   If the answer in the previous question differs from ”Never”, then the next question is:

7. *Through which station do you mostly travel to Zernike campus?*

8. *How often do you use the following facilities in a train station?*

9. *When you have to change from train to bus in a train station, how important are the following aspects for you?*

The *second part* of the questionnaire included the choice experiment. This is the part where the respondents are invited to evaluate five choice situations. The respondents have to choose one of the two alternatives that are presented. In order to ensure that everything is clear to them, a short and concise explanation of the experiment is included in the first page of this second part along with a picture, where the respondents can see a visual of the two alternatives and will not be confused with too many details. It was made certain that the text and description of the case are sufficiently succinct in order to avoid any possible misunderstandings, while at the same time the text needed to be short to ward off respondents’ fatigue.

In the next page of the questionnaire, after letting the respondents have an initial idea of the experiment, the attributes and attribute levels were presented to them. Once again, it was tried to give a brief and concise explanation, avoiding in such a way to make the respondents tired. Next, one example of a choice situation followed in an effort to make the respondents familiar with the different alternatives and give them a first estimation of the experiment. The answer of the example is not included in the final responses since it plays the role of a first trial. The real answers that were included in the data come from the five choice situations that follow this initial trial.

The *third and last part* of the questionnaire reflects the personal status of the respondents. It is asked from them to give answers about their personal attributes in order to get an overview of the characteristics of our research group. The reason of asking these questions at the end of the survey is due to the fact that the respondents are less focused towards the end of the questionnaire and they can easily respond this kind of questions. It is important to note that their anonymity is clearly pointed out in this part. The included questions are mentioned below, while a thorough explanation is provided in Appendix 6.

1. *What is your age?*
2. *What is your gender?*
3. *Which is the level of achieved education?*
4. *How is your household composition?*
5. *Which is your postcode?*
6. *Can you sometimes travel for free by public transport?*

3.4. Data collection

The data was obtained at the area of Zernike campus and mainly in the bus connecting Zernike campus with Zuidhorn station. In such a way, it was more likely that respondents accustomed to the researched situation could be found. Because the case that is investigated refers to the area of the campus, the main target group of respondents is students who are traveling between these areas. That was the reason that this specific group of passengers had to be found, acquainted with the choice possibilities and with a situation where a transfer from train to bus had to be made while traveling to school or work.

Data collection took place in 4 consecutive days between May 17th and May 20th 2016. The respondents were approached by distributing a small flyer, which can be found in Appendix 7, and explaining what the research was about. The flyer also included information about the survey as well as the link that the respondents had to use in order to fill in the questionnaire. In addition, a QR (Quick Response) code was generated and was printed along with the rest of information in the flyer in order to give the possibility to the potential respondents, who had installed the QR reader application in their mobile phone, to scan the code and fill in the survey immediately. This turned out to be very successful, since most of the approached individuals were students who were technologically updated, and combined with the fact that the biggest percentage of them were found in the bus, where they were inert and had the time to fill it in, resulted in a fulfillment rate of about 35% (around 420 flyers were distributed and 148 individuals finally responded).

Because the desired size of the sample was at least 150, as already mentioned in section 3.3, in order to get reliable results, it was decided to distribute the survey to more people, who also fall in a similar category of travelers. In this way, the stated choice experiment could be responded from more people that could easily take part in it and respond to these hypothetical situations without necessarily being frequent travelers of this specific case. Therefore, the questionnaire was slightly altered by modifying a few questions that were mentioning the case of the Zernike campus. These questions were adjusted in order to be understandable for individuals that work or study at other universities, where similar situations regarding the public transport route choices exist. The universities that were added to the questionnaire were:

- The Universities of Applied Sciences of Breda, AVANS Hogeschool and NHTV;
- The Universities of Tilburg, AVANS Hogeschool Tilburg and Tilburg University;
- The Universities of Nijmegen, Radboud University and Hogeschool of Nijmegen;
- The University of Applied Sciences of Arnhem, Hogeschool of Arnhem;
- The Universities of Eindhoven, FONTYS and Technical University of Eindhoven.

Due to lack of time and flexibility, the procedure of data collection could not be repeated in the same level, by visiting these places and approaching the travelers in person. Therefore, the respondents were found by uploading the online questionnaire on social media pages of these universities and asking the members of these groups to fill in the survey in case they belonged to the category of travelers who commute to the university from another place or city. This second part of data collection commenced on 1st of June 2016 and finished on 5th of June 2016 and eventually 57 more respondents participated resulting in a total number of 205 respondents.

The target group of respondents therefore lies in the area of Groningen, however, having added the respondents from the rest of the aforementioned cities, the results obtained from this research can provide us with a valuable insight into similar situations of the Netherlands and elsewhere, where the universities are often gathered in the suburbs of the cities, not allowing the students to travel seamlessly.

3.5. Binary logistic regression model

The data was obtained by distributing the developed questionnaire and consequently they were analyzed by using a Binary Logistic Regression Model, which is a random utility model. In the current experiment only two alternatives are included in the choice sets. The binary logit model is used when only two categories are examined and is a form of the multinomial logit model (MNL) which is used for more than two alternatives. Hensher and Green (2003) state that MNL is the most used one for discrete choice modelling and support that "regardless of what is said about advanced discrete choice models, the MNL model should always be the starting point for empirical investigation", claiming that it pertains to the most important input in the modeling process that yields reasonable results in cases of models that do not contain too complex relationships.

In order to generate a MNL, it is necessary to understand the theoretical base for generating the discrete choice models, which pertains to random utility theory. Ortuzar and Willumsen (2001) mention the main pillars of this theory:

1. People who belong to an existing homogenous population *Q*, make their choices rationally by selecting the options that maximize their net personal utility.

2. A given person q is characterized by a set of attributes $\mathbf{x} \in \mathbf{X}$ and receive a choice set $\mathbf{A}$ (q) $\in$ $\mathbf{A}$,

where **A** is a set of available alternatives and **X** is a set of vectors of measured attributes of these individuals and their alternatives.

3. Every option within this choice set **A** has an associated utility U_q for every individual q. Since the researcher is not able to receive precise information about which elements are specifically considered by each individual in order to make the choice, it needs to be assumed that this utility U_q corresponds to two components and is therefore described by the following equation:

$$U_q = V_q + \varepsilon_q$$

where the first measurable and representative component V_q is a function of the measured attributes while the second random component ε_q refers to the particular tastes of each individual, including any errors made by the modeler.

According to Hensher et al. (2005) the functional relationship between the utility associated with an alternative and the variables and sociodemographic characteristics is outlined in the following equation:

$$V_q = \beta_{0i}\beta_{1i}f(X_{1i}) + \beta_{2i}f(X_{2i}) + \beta_{3i}f(X_{3i}) + \cdots. + \beta_{Ki}f(X_{ki})$$

where β_{1i} represents the parameter related to the attribute X_1 and alternative i
and β_{0i} is the alternative-specific constant, which is related to the unobserved sources of utility and thus does not represent any of the measured attributes.

As already mentioned above, a binary logistic model, which is a special form of the MNL model, will be used. The probability that an alternative is chosen is represented by the following equation (Domencich and McFadden, 1975 retrieved from Ortuzar and Willumsen, 2001):

$$P_i = \frac{\exp(\beta V_i)}{\sum_{A \in A(q)} \exp(\beta V_q)}$$

The log-likelihood function that emerges is the following one:

$$LL(\beta) = \sum_{q=1}^{Q} \sum y_{qi} ln(P_{qi})$$

where y_{qi} is equal to 0 if an individual q is not choosing the alternative *i* and equal to 1 in a different occasion,
P_{qi} is the probability that an individual q is choosing the alternative *i*, and
ln is the natural algorithm.

4. Analysis

This chapter presents the results that are emerged from the statistical analysis of the data. An explanation of the obtained data is provided and the sample is described by exhibiting the sociodemographic characteristics of the respondents as well as their travel related experience. Finally, the outcome of the binary logistic analyses is demonstrated, first by model performance tests and second by showing the final results regarding the characteristics that are influential on the route choice decision making.

4.1. Data cleaning

The first two questions of the survey were related to the frequency of traveling with public transport; the first one in general and the second one more specifically on the way to school or work. If a respondent replied "*never*" in one of the two questions, then the questionnaire was terminated. Among the total amount of respondents, 29 fell into this category and therefore they were excluded from further, since they did not provide any other characteristic of themselves. As a consequence, out of the 204 respondents, the total number of analyzed questionnaires was finally 175. The amount of respondents that did not reach the part of the survey which included the choice experiment was 5. So, ultimately 170 respondents took part in the stated choice experiment. In addition, 5 of the respondents abandoned the last part of the questionnaire, which included the questions related to personal information. Therefore, the description of the sample refers to the 165 respondents who fully completed the questionnaire. An overview of the filled in questionnaires and missing responses is provided in Table 1.

Table 1. Overview of respondents

	Final	Missing
Total respondents	204	
Main questionnaire*	175	29 *(out of 204)*
Choice experiment	170	5 *(out of 175)*
Sociodemographic characteristics	165	10 *(out of 175)*

*respondents who did not answer "never" in the public transport travel frequency

4.2. Sample description

4.2.1. General

In the third and last part of the questionnaire, questions regarding personal characteristics of the respondents were included, which help to provide a general description of the data sample. The questions that were included in this part required information about *age*, *gender*, *level of education*, *household type*, *postal code* of the home address as well as in which university the respondent works or studies. This latter one was included, in order to know in which area of interest they are involved in.

Analysis of data using the statistical software package SPSS 23 provided an overview of the sample and some frequencies of the aforementioned characteristics. The results are shown below in Table 2.

Table 2. The sociodemographic characteristics of the sample

Attribute	Level	Frequency	Percentage
Gender	Male	78	47,3%
	Female	87	52,7%
Age	16-19 years	53	32,1%
	20-24 years	79	47,9%
	25-29 years	27	16,4%
	30-60 years	6	3,6%
Achieved level of education	Secondary	79	47,9%
	Middle-level	26	15,8%
	Higher professional	31	18,8%
	Scientific	29	17,6%
Household type	Single (including living with roommates)	47	28,5%
	Living with parents	92	55,8%
	Living with partner without child(ren)	19	11,5%
	Living with partner and child(ren)	3	1,8%
Total		165	100%

As expected, the vast majority of the sample belongs to a category of young aged persons, since 8 of 10 respondents have an age of 25 years or younger. This should be kept in mind in the subsequent interpretation of data analyses. So, the results of the experiment come from young participants. However, the research is focused on the routes that exist to university locations and as a result this disproportion is neither problematic nor undesired. The two genders were rather equally spread with a slight bigger representation of women. This is in accordance with the separation of the overall Dutch population, which was estimated to be 49.5% in 2015 (CBS, 2015). Requesting the highest achieved education had an incentive of finding out what are the differences of the respondents with respect to the various education types that are offered in a campus. Almost half of the respondents had finished the secondary education, but at the same time it means that they probably study in a higher education level. Only 17.6% of them had achieved a scientific degree. All in all, the sample belongs to an “educated” category. Finally, more than half of participants responded that they live with their parents, which is expected since the biggest portion of the sample travels to the university from another city.

4.2.2. Current behavior

In this part of the chapter, the current travel behavior of the respondents is presented in order to have a clear idea regarding their travel experience. After processing the data of the questionnaire's first part, awareness is acquired regarding the travelers' knowledge of the investigated case and routes. Therefore, it is necessary to know whether the respondents participating in the survey have any related experience with route choice decisions, and more specifically with the routes between Leeuwarden and the Zernike campus. Due to the collection of data from an additional and more generalized questionnaire, information is also gathered about travel experience of the rest of respondents, so the entire sample's travel knowledge is clarified.

Table 3 and 4 provide an overview of the universities that the respondents work or study in, giving an estimation of which were the study areas that equipped us with data.

Table 3. Overview of universities in the case of the Zernike campus

Universities in Zernike campus	Frequency	Percentage
Rijks University Groningen (RUG)	35	20,6%
Hanze Hogeschool Groningen (HBO)	67	39,4%
None of the two	17	10%
Total respondents in Groningen	119	70%
Total	170	100%

Table 4.. Overview of the rest of universities

Rest of universities	Frequency	Percentage
Breda	7	4,1%
Nijmegen	26	15,3%
Arnhem	5	2,9%
Eindhoven	13	7,7%
Total of the rest of universities	51	30%
Total	170	100%

It is apparent that the majority of respondents studies/works in the area of Zernike campus (60% of the people who filled in the choice experiments) and therefore they have experience on the main investigated case in Groningen. It should be noted that there was a 10% percentage of respondents that were approached in the area of the Zernike campus, summing up the experienced-with-the-case sample proportion to 70%, but stated that they do not study or work in one of the two universities of the campus. A considerable amount of respondents (around 15%) travel to universities of Nijmegen, while the rest work or study in the universities of Eindhoven, Breda and Arnhem.

Table 5 shows the distribution of respondents depending on the train station that they use as departure point during their trip to school/work. Passengers coming from the Zernike case are thoroughly explained, but the rest of them are summed up for the sake of more concentrated results.

Table 3. Overview of the departure stations

Station	Frequency	Percentage
Leeuwarden CS	30	17,1%
Leeuwarden Camminghaburen	7	4,0%
Hurdegaryp	6	3,4%
Feanwalden	14	8,0%
Buitenpost	20	11,4%
Grijpskerk	6	3,4%
Zuidhorn	36	20,6%
Other	51	29,1%
Living in the same city with the university	5	2,9%
Total	175	100%

Observing the numbers presented in Table 5 leads to the realization that 2 of 3 respondents depart from one of the stations of the Leeuwarden-Groningen connection. The additional data come from travelers who depart from other areas as can be seen in Table 5, with only a minor part of them (2.9%) who stated that they live in the same city where their university is situated. This means that the majority is acquainted with transferring to the campus from another city. However, attention is necessitated here because 1 of 5 respondents uses Zuidhorn station as their departure point. This means that these travelers, who were approached in the bus no. 11, do not represent a group that faces two route choices in reality, but choosing this route is their exclusive alternative. Therefore, this part of the sample does not exactly have the researched route choice experience.

Information regarding the frequency of traveling by public transport (generally and to university) as well as the mode of transport before and after the main train trip is provided in Table 6.

Table 4. Overview of the travel frequency and the modes of pre-transport and post-transport

Attribute	Level	Frequency	Percentage	Frequency	Percentage
		Generally		***To university***	
Travel frequency	Never	0	0%	9	5,1%
	1 time per month or less	13	7,4%	12	6,9%
	2-4 times per month	33	18,9%	24	13,7%
	2-4 times per week	66	37,7%	69	39,4%
	5 times per week or more	63	36,0%	61	34,9%
		PRE-transport		***POST-transport***	
Transport	On foot	24	13,7%	40	22,9%
	Bike	86	49,1%	19	10,9%
	Bus	45	25,7%	114	65,1%
	Car	17	9,7%	2	1,1%
	Other	3	1,7%	0	0%

Table 6 reveals that the participants have experience with public transport traveling since the majority travels on a weekly basis (almost 2 of 3 respondents travel *2-4 times per week* or *5 times per week or more*). In addition, information is obtained about the modes of transport that they use before and after their train trip. The analysis shows that the bike is used by half of respondents as the means of transport to arrive at the railway station. The bus is also a frequently chosen transport option, as it is the mode of *pre-transport* for 1 of 4 participants. Use of bus is overwhelmingly chosen as mode of *post-transport* since 2 of 3 participants mainly take the bus after alighting from the train in order to reach their final destination. This shows a certain familiarity with the current case.

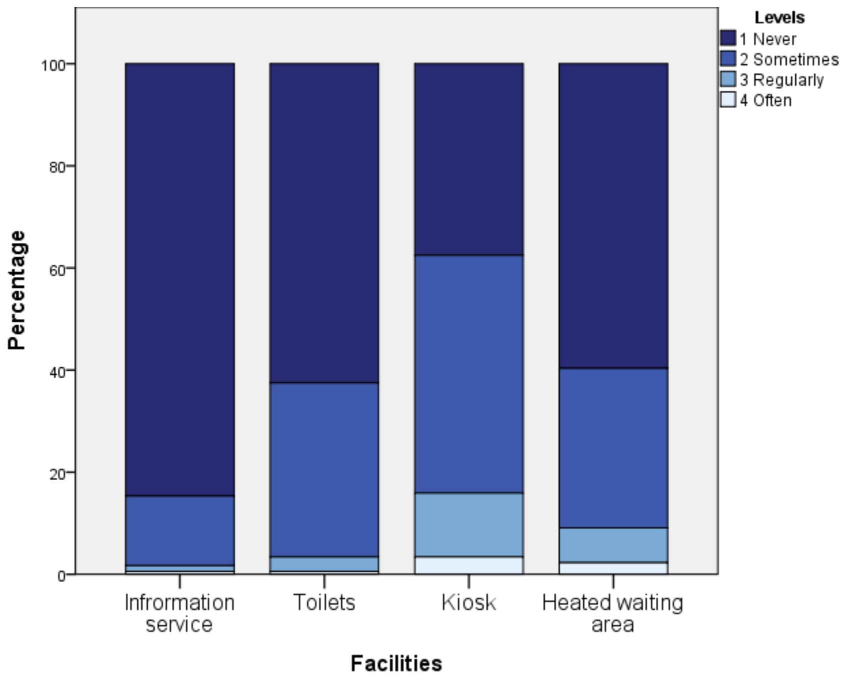
4.2.3. Use of various facilities at a railway station

The survey also included a question related to use of certain facilities at a railway station. These were later included as separated attributes in the choice alternatives. Specifically, respondents were asked *how often they make use of the following facilities*:

1. Information service (a desk where an employee provides information and answers questions);
2. Toilets;
3. Kiosk;
4. Heated waiting area.

The participants could express their use by choosing "*never*", "*sometimes*", "*regularly*" and "*often*". As can be seen in figure 18, they rarely make use of these services. Specifically, information service is the least used facility, since 84.6% replied that they *never* make use of it. Toilets and a heated waiting area are used more frequently (more than 30% of them mentioned that they *sometimes* use it) and presence of a kiosk appeared to be the most necessary facility, since 46.9% and 12.6% of the respondents replied that they use it *sometimes* and *regularly* respectively. Hence, these results create the expectation of a higher influence of the "*existence of a kiosk*" attribute and probably an insignificant effect of the "*information service*" attribute. The total results for the facility usage can be found in Appendix 8.

Figure 18. Use of the investigated facilities in a railway station



4.2.4. Importance of various aspects during transfers

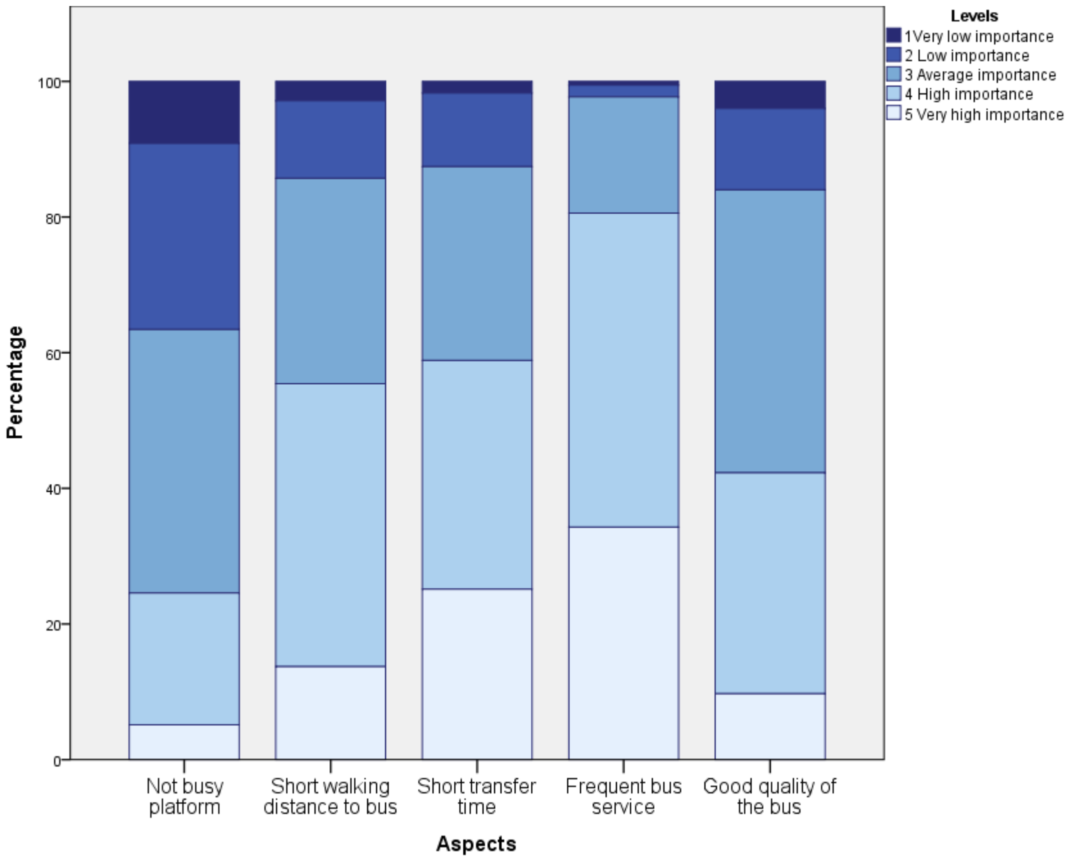
Respondents were also asked to express the importance of various aspects when they have to make a transfer from train to bus at a railway station. Five aspects were presented to them, which they were asked to rate by choosing *"very low importance", "low importance", "moderate importance", "high importance" or "very high importance".* The aspects were the following ones:

1. That the platform is not very busy;
2. That there is short walking distance from the platform to the bus;
3. That there is short transfer time between the arrival of the train and the departure of the bus;
4. That there is frequent bus service;
5. That the quality of the bus is good.

The results of passengers' evaluation regarding the significance of the aforementioned aspects are presented cumulatively in Figure 19, where it can easily be traced which of the aspects the respondents attach their higher importance to. For instance, it is noticed that when they have to make a transfer from train to bus, the frequent bus service holds the highest importance, with 80.6% of the respondents stated that it is *important* or *very important.* On the other hand, a not so busy platform accumulates 24.5% of answers related to *importance/high importance,* revealing that this aspect seems not highly meaningful for the respondents while they make their transfer. A short walking distance to the bus is more essential to them (more than 1 out of 2 rated it as *important/very important*) and a short transfer time is also more necessary (58.8% rated it as *important/very important*) while they have to switch to bus. Good quality of the bus shows an average significance, since 42.3% of the respondents claimed that they find this aspect noteworthy. These results create anticipation for the significance of the related attributes of the real experiment. So, a higher influence of the "headway of the bus" variable and a lower influence of the "crowding in the platform" variable will probably be noticed after the analyses of the model.

It should be underlined here that requesting the respondents to evaluate these features, laid the foundation for the stated choice experiment which followed afterwards, where these aspects were incorporated in the choice sets as attributes of the alternatives. More detailed information about the final importance percentages of these aspects can be found in Appendix 8.

Figure 19. Importance of various aspects while making a transfer



4.3. Model analysis

The step that follows pertains to the estimation of the model parameters and the interpretation of the outcome of the model estimation. Binary logistic regression models were built in order to draw the aimed conclusions. What need to be described in this part are the model performance and the characteristics of the parameters. Respectively, the overall fit of the model is explained by the likelihood ratio statistic (LRS) and the R-square, while an explanation of the parameters will be provided through significance level, effect, and importance(range).

Testing the values of LRS and R-square enables us to realize how well the model fits the data in order to conclude whether the observed data can be predicted satisfactorily by the model. For that purpose, the optimal and the constant only model were compared. Constant only model is the one that does not include any predictor but only the values of the outcome are known, while optimal model is the one that emerges when all the predictor variables are included.

4.3.1. Likelihood ratio

In order to realize whether the estimated model is overall significant then the log likelihood (LL) of the estimated model needs to be examined. Specifically, since the LL itself cannot provide an estimation about the significance of the model, it needs to be compared with the LL functions of two other models, i.e. the null model, which does not include any information of the data, and the constant model which includes only the constant parameters, which represent the unobserved factors that influence the choice decisions (Hensher et al., 2005).

Therefore, if the LL function of the estimated model is not improved, this means that the parameters added to the estimated model did not add to its predictive power. The way to make the comparison of the LL functions with respect to that is provided by the likelihood ratio statistic (LRS) test, the formula of which is the following one:

$$-2(LL_{base\ model} - LL_{estimated\ model}) \sim \chi^2_{(number\ of\ new\ parameters\ estimated\ in\ the\ estimated\ model)}$$

Analysis of the data with binary logistic regression results in the following log likelihoods:

$-2LL_{base\ model}$= 1140.549

and $-2LL_{estimated\ model}$= 999.655

so the LRS = 140.884

Furthermore, the critical value of the chi-square distribution is compared with the LRS. The number of degrees-of-freedom in the chi-square has to be equal to the number of restrictions implied by the null hypothesis, i.e. the difference in number between the two compared models. Therefore, the estimated model is preferred over the constant model when the LRS is greater than the critical value and the null hypothesis is rejected. In the opposite case, the model with parameters included does not fit the data better than the model without any parameters.

The difference in degrees-of-freedom between the constant only and the optimal model is equal to 15, so the critical value based on the chi-square table is equal to 25.00 (at 95% confidence level). Therefore, since 140.884>25.00, the estimated model performs significantly better than the constant only model. All the aforementioned results are summarized in Table 7, along with a comparison between the constant only and the null model, which is estimated as if the market shares are equal across the two alternatives.

Table 5. Comparison between the likelihood ratio statistic (LRS) and the chi-square

Model	-2Log Likelihood	LRS	Critical value	df	Sig.
Null	*1157.556*			*0*	
Constant	*1140.549*	*17.007*	*3.841*	*1*	*0.000*
Optimal	*999.655*	*140.884*	*25.0*	*15*	*0.000*

4.3.2. R-square

In addition, in order to determine the fit of the model, the pseudo-R^2 statistic has to be estimated by the following equation:

$$R^2 = 1 - \frac{LL_{estimated\ model}}{LL_{base\ model}}$$

In order to understand the two extremes of the function, it should be noted here that when the parameters of the estimated model do not result in a better performing model (compared to a model with no parameters) then $LL_{estimated\ model} = LL_{base\ model}$ and therefore R^2 = 0.

On the other hand, when the model performs ideally, i.e. the model is able to perfectly predict the sample's choices, then the likelihood function would be equal to 1, the log likelihood function would be equal to 0 and consequently R^2= 1. There are various opinions about which is the best likelihood ratio index, but generally a model which gives values of R^2 between 0,2 and 0,4 is supposed to satisfactorily fit the data (e.g. Maitra et al., 2013, Louviere et al.,2000, Hensher et al., 2005), while models with an R-square below 0.1 can be considered weak

The analysis shows a R^2= 1-(999.655/1157.556)= 0,136, which is accepted for the current research.

4.3.3. Model analysis

The models were estimated using SPSS Statistics 23, where the utility of each alternative had to be estimated. The second alternative (fast train) was kept stable throughout all choice sets with predefined attribute levels and the part-worth utilities of the attribute levels of the first alternative (stop train) were calculated using the dummy coding as showed in Table 8.

Table 6. Dummy coding of the investigated variables.

Attributes	Labels	Levels	Codes	
Transfer time	*3 minutes*	0	1	0
	6 minutes	1	0	1
	9 minutes	2	0	0
Time in the bus	*12 minutes*	0	1	0
	14 minutes	1	0	1
	16 minutes	2	0	0
Crowding in the station	*Low*	0	1	0
	Medium	1	0	1
	High	2	0	0
Existence of toilets	*No*	0	1	
	Yes	1	0	
Existence of information service	*No*	0	1	
	Yes	1	0	
Existence of kiosk	*No*	0	1	
	Yes	1	0	
Existence of heated waiting area	*No*	0	1	
	Yes	1	0	
Walking distance	*20m*	0	1	0
	100m	1	0	1
	200m	2	0	0
Frequency of the bus	*Every 10 minutes*	0	1	0
	Every 20 minutes	1	0	1
	Every 30 minutes	2	0	0
Level of the bus	*Basic*	0	1	
	Comfort	1	0	

Table 9 is used as a compass in order to derive the part-worth utilities for the separate levels of the attributes. Hence, parameter β can be estimated by multiplying each coefficient with the respective coded value. An example with 3 levels can be seen in table X.

Table 7. Calculation of the part-worth utilities of each level

Attribute level	Codes		Utility
1st level	1	0	$\beta_1*1+\beta_2*0$
2nd level	0	1	$\beta_1*0+\beta_2*1$
3rd level	0	0	$\beta_1*0+\beta_2*0$

Table 10 displays all the coefficients of the estimated model and their significance in order to understand how the final utilities arise and which of them actually play a significant role in the calculation of utility. The ones that are non-significant in the confidence range of 90% (α < 0.10) are marked with red. It is realized from Table 10 that none of the facility attributes managed to be significant nor the level of the bus, while the rest of them showed a significant effect in the confidence level of 95% (α < 0.05) or 99% (α < 0.01).

Table 8. The coefficient values of every attribute level and their significance

	Attributes	Attribute level	Part-worth utility	Significance
significant attributes	**Transfer time**	*3 minutes*	1.165	0.000
		6 minutes	0.599	0.002
		9 minutes	0	
	Time in the bus	*12 minutes*	0.733	0.000
		14 minutes	0.591	0.002
		16 minutes	0	
	Crowding in the station	*High*	-1.144	0.000
		Medium	-0.472	0.011
		Low	0	
	Frequency of the bus	*Every 10*	1.343	0.000
		Every 20	0.679	0.001
		Every 30	0	
	Walking distance	*20m*	0.587	0.020
		100m	0.445	0.019
		200m	0	
non-significant attributes	**Information Service**	*No*	0.221	0.178
		Yes	0	
	Toilets	*No*	-0.028	0.865
		Yes	0	
	Kiosk	*No*	-0.261	0.110
		Yes	0	
	Heated waiting area	*No*	0.066	0.686
		Yes	0	
	Level of the bus	*Basic*	-0.125	0.432
		Comfort	0	
	Constant		-1.770	0.000

As mentioned above, the β-parameters are the coefficients of the attribute levels and they represent the part-worth utility of each attribute, as shown in Table 10. A higher β indicates a higher contribution of the level to the preference. The confidence level that is used is 95%, therefore the level of significance which is supposed necessary for the current research has a value of 0.05 or less. As a result, the variables that are presented in the table have a significance value lower than 0.05 in order to show only these ones that finally influenced the route choice decision.

4.3.4. Effect

The Figures 20 to 24 depict the effect of each attribute based on significant parameters. The attributes related to the walking circumstances in the train station of the transfer, showed an important effect. More specifically, Figure **20** indicates that the *walking distance* can have an influence in the choice of the stop train alternative when the levels are relatively low. Setting the walking distance of the second alternative to 200m, only the first levels of 20 and 60m seemed to increase the utility of the stop train alternative. Increasing it to 90m caused a drop in the part-worth utility of this attribute, indicating that only very short walking distances from train to bus can make a stop train alternative attractive regarding this characteristic.

Crowding at the station, as can be seen in Figure **21** demonstrated a strong effect. The values of the coefficients show that the more crowded the conditions in the train station the more disturbance the passengers perceive. This is an indicator that whereas the main railway stations can be quite crowded and busy, the necessary measures must be taken in the smaller stations, so that the flow of passengers is more unhindered and consequently more people can be triggered to choose this option.

Transfer time and *time in the bus* also demonstrated a significant effect on passengers' decision. The coefficients of *the time in the bus* attribute are positive for the levels of 12 and 14 minutes, but the fast train alternative possessed a fixed level of 16 minutes for this characteristic. Therefore, Figure **22** illustrates that when the time in the bus is 16 minutes in both cases, there is a noteworthy drop in the utility of the stop train alternative. As a result, it is perceived that in order to make the slow train more attractive, a reduction in the time spent in the bus has to be pursued.

It should be reminded that the level of the *transfer time* attribute for the fixed alternative of the fast train was set to 7 minutes. This means that even if the coefficients had a positive value for the first two levels of this attribute, these levels were preferred over a bigger transfer time that was offered in the other alternative. Figure **23** illustrates that when the level is reduced to 9 minutes, the part-worth utility falls considerably.

Figure **24** shows that there is a drop in the part-worth utility when the frequency of the bus is reduced from "every 10 minutes" to "every 20 minutes". However, what should be noted here is that the decline is much bigger when the level is reduced from "every 20 minutes" to "every 30 minutes". Taking into account the fixed level of this attribute for the "fast train" alternative, which was "every 10 minutes", it is denoted here that when the bus that the passengers need to take after departing from the stop train has this low level, then they perceive a significant disutility compared to the more frequent bus service that is provided if they choose the fast train.

Figure 20. Visualization of the attribute "walking distance"

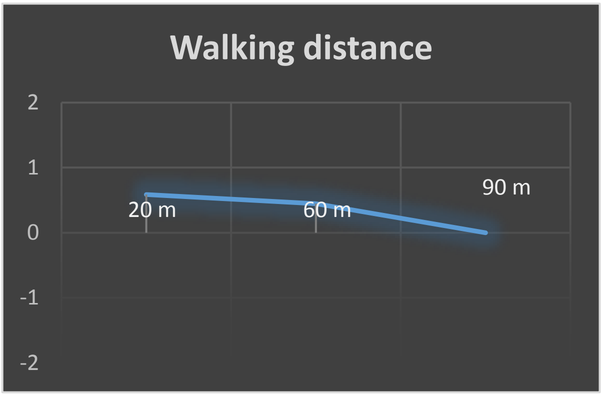


Figure 21. Visualization of the attribute "crowding at the station"

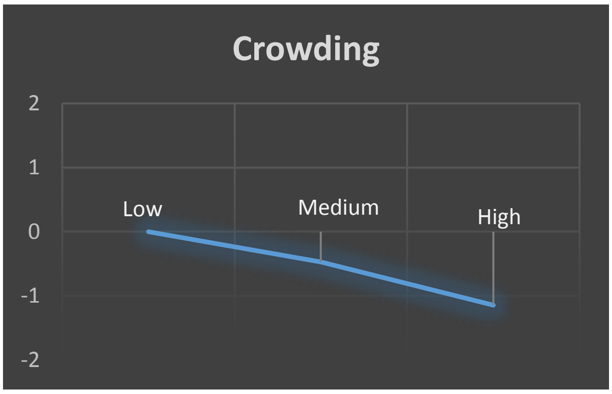


Figure 24. Visualization of the attribute "time in the bus".

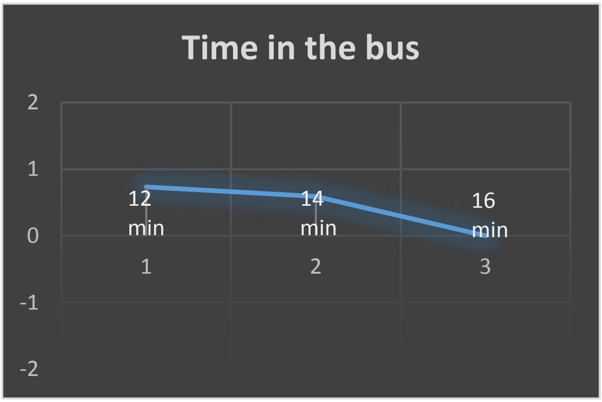


Figure 23. Visualization of the attribute "transfer time"

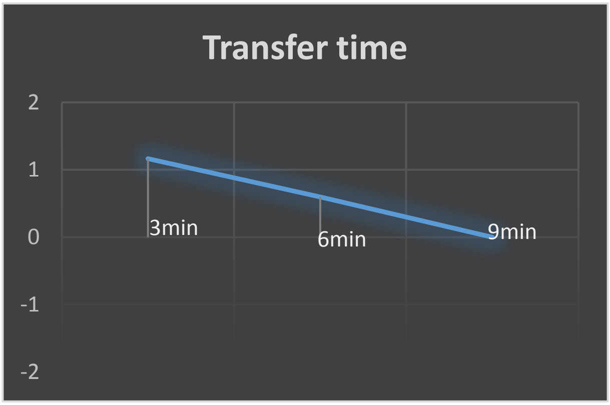
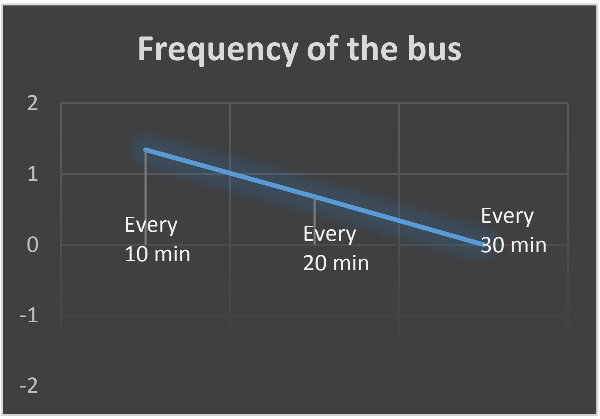


Figure 22. Visualization of the attribute "frequency of the bus"



4.3.5. Relative importance of the attributes (range)

After discussing the effect that each of the significant attributes has, based on their part-worth utilities, their relative importance is examined in order to know which of them are the most influential. This was proved to be the *frequency of the bus*. The way to arrive to this conclusion is to calculate the absolute differences between the values of the highest and lowest level of each attribute. Therefore, each relative importance can be found by dividing this range with the sum of all the ranges. For instance, the range of the transfer time attribute is calculated by summing the coefficient of the 3 minutes level with the absolute value of the coefficient of the 9 minutes level, i.e. 1.165+1.764= 2.929. The sum of all the ranges is equal to 12.770, so the relative importance of this specific attribute is calculated by dividing 2.929 by 12.770, which is equal to 22.9%. All the calculations are shown in Table 11 and the results are presented in Figure 25.

Table 9. Range calculation of the significant attributes

Ranges		Total
Transfer time	2,929	0,229
Time in the bus	2,097	0,164
Crowding	2,76	0,216
Walking distance	1,619	0,127
Frequency of the bus	3,365	0,264
Sum	12,77	1

Figure 25. Relative importance of the most influential attributes

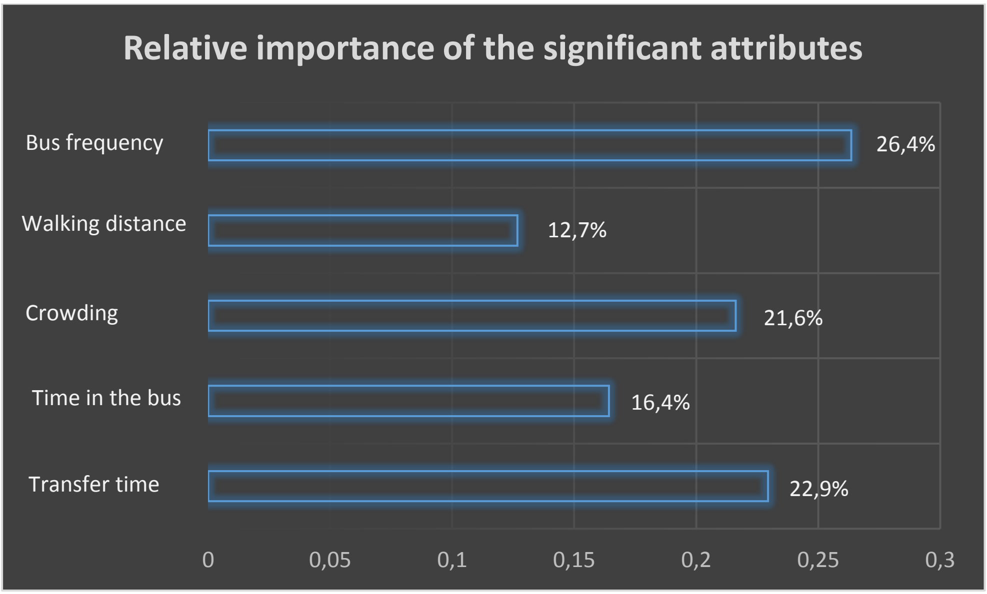


Figure 25 enables us to understand that the most influential characteristic in passengers' route choice decision in a case like the one examined is the frequency of the bus that the passengers need to take after alighting from the train. Hence, the passengers need frequent bus services as they try to avoid long waiting times in case of missing an infrequent bus. The next two attributes that showed an important effect pertain to transfer time and crowding at the station. The time in the bus appeared to have a slightly smaller effect and the last attribute that showed significant influence was the walking distance from train to bus. The most important attributes of this research are therefore time related since one could guess that even the desired short walking distances and the low occupancy rates in the station have also a relation with the effort of minimizing the time spent during the chosen route.

It should be reminded at this point that the final results about the relative importance encapsulate an anticipated and an unanticipated outcome. Specifically, the "bus frequency" was rated as the most important for the respondents among the rest of the aspects that they were asked to evaluate, which is in accordance with the final relative importance of this attribute. On the other hand, it is reminded that "crowding in the station", which finally proved to be the third most influential characteristic, achieved the lowest rating in comparison to the other aspects. This is quite noteworthy, since it reveals that while the sample thought that this attribute is not important, it was finally proved to have an essential significance.

In addition, the answers that the respondents provided regarding the use of the facilities in a railway station conform to the final outcome, as none of the included facility attributes demonstrated a significant effect. This could be anticipated due to the fact that a very minor amount of respondents replied that they make use of these facilities. It should also be stressed that presence of a kiosk, the only facility that appeared to be used more frequently by the respondents, was the one that could almost be included in the influential attributes of the current route choice experiment. However, its value of significance was slightly bigger than 10%, so it did not have a significant effect in the confidence level of 90%, but it can be interpreted that the existence of this facility is more necessary than the rest of the investigated ones.

4.3.6. Additional models for separate groups

Some additional models were estimated in order to draw conclusions for separate groups and realize the possible differences regarding the influential factors of these groups' behaviour. Although the socio-economic characteristics were not included in the modelling approach, they let us classify the sample into separate groups of travellers and draw conclusions for each different cohort. Specifically, the groups that were chosen to investigate further are the following:

- Difference between *males* and *females (*to realize if there are noteworthy differences between the 2 genders*);*
- Difference between *frequent* and *non-frequent* travelers (to see if the frequency of public transport use affects the importance of the researched attributes);
- Difference between travelers that *travel to the Zernike* campus and the *rest* (because the former were approached in person, while the latter through social media);
- Difference between travelers who *start their journey in Zuidhorn* and the *rest* (because the former are possibly not familiar with use of the train).

The Tables 12-15 contain information only about the attributes that were found to have a significant influence on the decision making of the above pairs, in order to make a direct comparison. In case a variable was significant only for the one of two compared groups, it was included in the table to show the difference between them. Complete information about the total amount of coefficients and log likelihoods of every model is provided in Appendix 9.

Table 12 shows the outcome of the estimated models about male and female participants of the experiment. The most notable finding is that the presence of a kiosk is influential in women's decision making process, while for male participants none of the facilities was found significant. This means that female respondents care more for the presence of a kiosk in the station's environment. The results of the rest of attributes do not show important differences between the two genders. It can be mentioned that the most important attribute for males appears to be the transfer time, while for females is the frequency of the bus.

Table 10. The significant attributes of the estimated binary logistic regression model (MEN/WOMEN)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Men		Women	
Transfer time	*3 minutes*	1.369	<1%	1.031	<1%
	6 minutes	0.699	<1%	0.538	<10%
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.866	<1%	0.596	<5%
	14 minutes	0.987	<1%	*Not significant*	
	16 minutes	0		0	
Crowding in the station	*High*	-1.287	<1%	-1.071	<1%
	Medium	*Not significant*		-0.555	<5%
	Low	0		0	
Kiosk	*No*	*Not significant*		-0.467	<5%
	Yes			0	
Walking distance	*20m*	0.551	<10%	0.576	<5%
	100m	*Not significant*		0.592	<5%
	200m	0		0	
Frequency of the bus	*Every 10*	1.241	<1%	1.464	<1%
	Every 20	*Not significant*		0.973	<1%
	Every 30	0		0	
Constant		-1.617	<1%	-1.899	<1%
R-square		0.141		0.170	

Table 13 presents the findings of the model analysis of the frequent and non-frequent travelers. The former group includes respondents who travel either 2-4 times per week or more than 5 times per week, while the latter refers to the ones who travel 2-4 times per month or less. Observation of the table leads to realization of some interesting facts. For instance, many of the attributes were not significant for the non-frequent group. It seems that these travelers are influenced only by the transfer time, the crowding of the station, and the frequency of the bus. The latter one, specifically was the most powerful characteristic, as it is the case in most of the cases. The high value of the *frequency of the bus* coefficient shows that people who do not travel so often are mainly concerned for the frequency of the bus. It can therefore be concluded that in order to attract more passengers who do not travel so often, a more frequent bus service should be provided. The time in the bus was not found to be significant to them, possibly because of the small differences between the values of this attribute, which could not cause a noteworthy difference to people who anyway do not travel on a regular basis. On the other hand, the frequent travelers show more interest on the transfer time, which shows that this group prefers short transfers. In addition, it is important to note that the presence of a kiosk was found to be significant for this group, which means that people who travel regularly are in need of the facilities that a kiosk can offer.

Table 11. The significant attributes of the estimated binary logistic regression model (FREQUENT/NON FREQUENT)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Frequent		**Non-frequent**	
Transfer time	*3 minutes*	1.208	<1%	0.996	<5%
	6 minutes	0.552	<5%	0.833	<5%
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.846	<1%	*Not significant*	
	14 minutes	0.652	<1%	*Not significant*	
	16 minutes	0		0	
Crowding in the station	*High*	-1.119	<1%	-1.174	<1%
	Medium	*Not significant*		-0.742	<10%
	Low	0		0	
Kiosk	*No*	-0.303	<10%	*Not significant*	
	Yes	0		0	
Walking distance	*20m*	0.620	<5%	*Not significant*	
	60m	*Not significant*		0.835	<5%
	100m	0		0	
Frequency of the bus	*Every 10*	1.140	<1%	2.033	<1%
	Every 20	0.503	<5%	1.209	<1%
	Every 30	0		0	
Constant		-1.649	<1%	-2.390	<1%
R-square		0.122		0.229	

Next, a comparison was made between the respondents who were approached in the area of the Zernike campus and the rest, due to the fact that these people are more familiar with the case that is investigated. The differences that should be emphasized from Table 14 concern the transfer time, which was proved significant only for the Zernike-case travelers and the frequency of the bus, which was the most influential attribute. These results show that people who are familiar with traveling to the Zernike campus substantially care for short transfers and minimal loss of time. The presence of the kiosk is also important for them, revealing that inclusion of this facility in the station of Zuidhorn might attract more passengers who travel to the campus, since this characteristic also plays a role in their choice behavior. However, the crowding at the station appears to be more important, so it should be secured that overcrowding is avoided.

Table 12. The significant attributes of the estimated binary logistic regression model (ZERNIKE/NOT ZERIKE)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Zernike		**Non-Zernike**	
Transfer time	*3 minutes*	1.473	<1%	*Not significant*	
	6 minutes	0.751	<1%	*Not significant*	
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.740	<1%	0.871	<5%
	14 minutes	0.592	<1%	0.844	<5%
	16 minutes	0		0	
Crowding in the station	*High*	-1.241	<1%	-1.214	<1%
	Medium	-0.693	<1%	*Not significant*	
	Low	0		0	
Kiosk	*No*	-0.432	<5%	*Not significant*	
	Yes	0		0	
Walking distance	*20m*	0.504	<5%	0.829	<5%
	60m	*Not significant*		0.592	0.822
	100m	0		0	
Frequency of the bus	*Every 10*	1.498	<1%	1.272	<1%
	Every 20	0.703	<1%	0.768	<10%
	Every 30	0		0	
Constant		-1.235	<1%	*Not significant*	
R-square		0.146		0.240	

Last but not least, a separation was made between the respondents who stated that Zuidhorn station is their trip's starting point and the rest, shown in Table 15. Hence, this group refers to the people who do not actually have a transfer in Zuidhorn after traveling by train, but they probably live in Zuidhorn or in the area nearby. So, it was intended to observe whether different attributes have an effect on this group. The most influential was again found to be the frequency of the bus, showing their need of a more frequent bus service. The crowding of the station was found less influential compared to the rest of the travelers and it should be noted here that since these respondents start their journey from Zuidhorn station to the Zernike campus, then they possibly do not make use of the station at all, but directly embark to the bus, therefore they do not evaluate this attribute in the same way. Finally, it should be pointed out that presence of the kiosk had the highest coefficient for this specific group, demonstrating the likely importance of this facility for people who use the Zuidhorn station (or the nearby area) frequently.

Table 13. The significant attributes of the estimated binary logistic regression model (ZUIDHORN/NOT ZUIDHORN)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Zuidhorn		**Non-Zuidhorn**	
Transfer time	*3 minutes*	1.363	<1%	1.188	<1%
	6 minutes	*Not significant*		0.538	0.652
	9 minutes	0		0	
Time in the bus	*12 minutes*	*Not significant*		0.596	<5%
	14 minutes	*Not significant*		0.908	<1%
	16 minutes	0		0	
Crowding in the station	*High*	-0.915	<10%	-1.332	<1%
	Medium	*Not significant*		-0.555	-0.506
	Low	0		0	
Kiosk	*No*	-0.867	<5%	*Not significant*	
	Yes	0		0	
Walking distance	*20m*	1.283	<1%	0.408	<10%
	60m	*Not significant*		0.592	0.414
	100m	0		0	
Frequency of the bus	*Every 10*	1.565	<1%	1.339	<1%
	Every 20	0.813	<10%	0.725	<1%
	Every 30	0		0	
Constant		-1.818	<5%	<5%	<1%
R-square		0.191		0.146	

4.3.7. Simulation example

The results of the model analysis can help us derive the probabilities of two route choice alternatives, when the levels of the researched attributes are known. The estimated coefficients enable the calculation of the utility of the stop train alternative, while the alternative of the fast train has fixed attributes and its utility is always equal to 0.

The current situation of the sop train alternative that is in reality met in Zuidhorn station during the morning rush hours will be given in order to show how the model can be applied to predict the probabilities of available route alternatives. The attributes that were not proved to have an influence on the choice behavior are not included. The chosen attribute levels of the stop train alternative are the following:

Time in the bus	14 minutes
Transfer time	6 minutes
Crowding in the station	High
Walking distance to the bus	100 m
Frequency of the bus	Every 30 minutes

It is reminded that the fixed levels of the fast train alternative are the following:

Time in the bus	16 minutes
Transfer time	7 minutes
Crowding in the station	Medium
Walking distance to the bus	200 m
Frequency of the bus	Every 10 minutes

For this example, the utility of the slow train is calculated as follows:

$U_{(stop\ train)}$ = 0.591 + 0.599 – 1.144 + 0.445 + 0.000 - 1.770 = -1.279

and because *Exp(-1.279)=* 0.278*,* the following probabilities arise:

Alternative	Exp(Utility)	Probability
Stop train	0.278	**0.218**
Fast train	1.000	**0.782**
Σ	1.278	

It can be seen that the estimated model predicts that the stop train alternative has a probability of 21.8% to be chosen instead of the fast train alternative, which possesses a probability of 78.2%. This result reflects the current situation and shows that with the given attribute levels the stop train alternative (which includes the use of a side railway station) is almost 4 times less likely to be chosen than the fast train alternative. In order to augment the probability of the former, the attribute levels are modified into the following ones:

Time in the bus	12 minutes (instead of **14**)
Transfer time	6 minutes
Crowding in the station	Medium (instead of **high**)
Walking distance to the bus	100 m
Frequency of the bus	Every 20 minutes (instead of **30**)

For this example, the changed probabilities are shown below:

Alternative	Exp(Utility)	Probability
Stop train	1.239	**0.553**
Fast train	1.000	**0.447**
Σ	2.239	

Therefore, it can be perceived that by modifying three of the five influential attribute levels, the probability of choosing the stop train alternative increased from 21.8% to 55.3%. More examples are presented in Appendix 10, in order to realize how the model can be used to increase or decrease the probabilities by making various changes in the values of the attributes.

4.4. Conclusions

The current study was focused on route choice behavior of public transport travelers and specifically it was tried to find out which characteristics play an important role in their decision making process of a multimodal route. The data was collected mainly from passengers who were traveling from/to the Zernike campus in Groningen as well as from students of some other universities of the Netherlands, who travel to the campus from another city. The final sample size is equal to 175 respondents, while 170 of them participated in the designed experiment. However, 165 of them filled in their personal characteristics.

The sample description shows the genders were almost equally spread, which is quite representative for the Dutch population. In addition, the age of the respondents was very low, since 80% of them were below 25 years old, which was anticipated because students traveling to their universities were mainly approached. The participants' level of education was high, which was also expected due to the fact that collection of data occurred in the university area. In addition, more than half of the respondents live with their parents, showing that a big percentage of the sample travels from their hometown to the campus. It should be noted that 70% of the respondents were approached in person in the area of the Zernike campus in Groningen, while the rest 30% of them come from the universities of Breda, Nijmegen, Arnhem and Eindhoven. Only 3% of them live and study at the same city, which means that the sample was quite familiar with traveling from another city and with having to choose various routes to arrive at the destination. In addition 2 in 3 participants travel on a weekly basis, showing a sample that is familiar with use of public transport. The dominant modes of pre-transport and post-transport were the bike and the bus respectively.

The obtained data shows that the respondents rarely make use of the station facilities that were included as attributes of the choice experiment, apart from the kiosk that seems the only one that they need a bit more frequently. Moreover, they were asked to rate some aspects of the railway station while they have to make a transfer from train to bus and it seems that the frequency of the bus was the most important followed by a short transfer time. Crowding in the station was rated as the lowest one among the asked aspects.

The data was analyzed with a binary logistic regression model. The likelihood ratio statistic test showed that the estimated model proved to be statistically better than the null and the constant only model, but the pseudo-R^2 statistic was a bit lower than the usually suggested values of 0.2-0.4. This might have occurred because the number of respondents was only slightly bigger than the lowest required for this experiment number. The model was estimated to derive the part-worth utilities of each attribute and to calculate the final probabilities of each alternative. The analysis showed that half of the included variables proved to be influential, which were only the ones related to time and to walking conditions in the station. It is noteworthy that none of the facilities proved to have a strong impact on the route choice in addition to the level of the bus, which also did not affect the participants' choices. As mentioned above this was expected already from the answers of the preliminary questions of the survey.

Among the influential attributes, the level of the bus was found the characteristic with the strongest impact, also expected from the rating of the aspects that the respondents had already done. Next was the transfer time between the train and the bus, also anticipated as already mentioned above. However, crowding in the station was the next influential feature, even though it was rated as the least important aspect from the participants. Finally, time in the bus and walking distance from train to bus were the last two attributes that seem to affect the respondents' route choice behavior.

In addition, the data was separated in various groups, for which some more models were estimated, in order to realize if some attributes have a different influence for specific groups of travelers. This led to the realization that the presence of a kiosk was indeed important for some groups, such as females, frequent travelers and people who travel to Zernike campus. The rest of the attributes showed similar behavior in relation to the initial overall model, with some slight changes across the various groups. Finally, different scenarios were presented in order to calculate the probabilities of the two alternatives when the levels of the attributes are known.

5. Conclusion

Last but not least, the conclusions of this research study are drawn in this chapter. The scientific and societal relevance are explained. In addition, some recommendations for the stakeholders of the topic as well as for future researchers of related studies are given and finally, the possible weaknesses of this project are discussed.

5.1. General conclusion

This graduation project tried to shed lights on the route choice behavior of the public transport users who cannot travel seamlessly to their destination and therefore they have to choose among different routes that include transfers. The aim was to realize whether a main or a side railway station would affect their decision making process in order to take the necessary measures that could redirect the passengers from crowded railway stations to less crowded side stations. The main research question that was formulated for this reason was the following one:

Which are the influential characteristics in the public transport passengers' decision making process while choosing the route and the railway station(s) that they will use during a multimodal trip?

By conducting a stated choice experiment and after analyzing the obtained data, the results show that the answer to the research question pertains to time and crowding-related attributes. The characteristics that were found to have an impact on the route choice behavior of public transport passengers are the frequency of the bus, the transfer time, the crowding in the station, the in-vehicle time in the bus and the walking distance from train to bus. The estimated models showed that the investigated facilities of the railway stations did not prove to have a strong effect in the choice behavior. Through this finding it can be concluded that the presence of facilities in the railway stations is not a highly-influential characteristic that could increase the choice of routes that require a transfer at a main railway station, compared to the rest of the aforementioned attributes.

5.2. Societal relevance

The research that was carried out can be quite beneficial for the transportation planning authorities. The literature review showed that multimodal mobility holds a substantial part of the public transportation traveling, therefore the results of studies related to this kind of mobility can be very helpful. In addition, the literature study reveals that transportation planning is well organized in the Netherlands as the related authorities constantly seek ways to keep public transport users satisfied by offering high-quality transportation. Therefore the results of the current research project have a certain societal relevance.

The estimated models showed that not all of the included variables proved to have an impact on the route choice behavior. Four of the ten attributes that were included in the experiment were related to railway station facilities, specifically to presence of a kiosk, information service, toilets and a heated waiting area. Around 1 of the 3 railway stations in the Netherlands belong in the "stop" category (ProRail(b), 2015), which means that they do not possess these facilities. Therefore, it was intended to realize if the inclusion of these facilities could attract more passengers in the stop train option. However, none of these attributes was statistically significant in the experiment. It should be noted that some more models were estimated and the presence of a kiosk was found to have a remarkable influence to some specific groups such as females and frequent travelers. This denotes that the related authorities should keep it in mind when they would like to attract more passengers in smaller railway stations. If the budgets for these stations' development are limited, then perhaps addition of a kiosk in the station area would be one of the necessary actions.

The attributes that were found to have an effect were (from most to least important) the frequency of the bus, the transfer time, the crowding of the station, the time in the bus and the walking distance from train to bus. It is therefore interpreted that travelers mainly care about the time and the comfort in the station. It should be reminded here that cost-related attributes were out of the scope of this research, so they were not included as an attribute. The frequency of the bus was proved to have the highest effect. This means that when train passengers have to make a transfer to a bus, the frequency of the latter is really important, because in case of missing the bus, a considerable increase of the total travel time is implied. Importance of the transfer time also shows the travelers' need of minimizing the total time they spend in public transport. The crowding conditions in the stations and platforms also seem to be of great importance. The results showed that the public transport users prefer fewer disturbances in the area of the station instead of presence of facilities. This shows the willingness to avoid crowded situations and therefore, station planners should keep this in mind when designing the railway stations. Since walking distance was also part of the influential characteristics, this shows the importance of short walking distances from trains to buses. Related stakeholders should therefore try to connect the bus areas as effectively as possible with the main area of the railway station. In a nutshell, a good collaboration between railway and bus authorities is necessary in order to result in satisfied passengers, when a transfer is needed from the former to the latter. The general pieces of advice are: short transfer times that connect the bus fast after departing from the train, frequent buses in order to minimize the stress and the time loss in case of a missing vehicle, station designs that enable short connection between the two modes and the unobstructed flow of station users, and design of bus routes as fast as possible. In order to stimulate more people in a route that involves a transfer at a side railway station, these attributes should certainly be more attractive than the ones available at a main railway station.

5.3. Scientific relevance

This study also contributes to the body of route choice knowledge from a scientific point of view. The literature review provided important information about the factors that are influential in the travel behavior. However, when the route choice concept was approached in the past, it was mainly focused on drivers and not so much evidence is available about the public transport route choices. This research project adds knowledge about the public transport users specifically.

It is realized that in this context, the station facilities possess a less important status relative to the time-related attributes. It was given attention for the first time on the role of main and side railway stations in an effort to realize how the side railway stations can attract more passengers. It was found that a main railway station is more likely to be chosen when the attribute levels are the same in both cases, which shows the lower utility that is received from the side railway stations.

In addition, the influence of the station facilities has not been studied before by separating every facility and including it as a distinct attribute. The investigated facilities were not proved to be significant for the route choice behavior. However, sociodemographic characteristics and travel experience were found to have an influence on the outcome, since the presence of the kiosk was found to be significant for women, for frequent travelers and for individuals who use a railway station without using the train. The crowding of the station was proved quite important, something that was not clearly stated by previous studies. The traditionally significant time-related attributes dominated in this study as well, showing the high importance of time for every kind of traveler. The found relationships can be considered reliable because the collection of data happened by approaching passengers who are familiar with the research problem.

5.4. Recommendations

Through this study some recommendations can emerge for the involved stakeholders who are directly related to the topic as well as recommendations for future research, based on the pitfalls of this research. First, in order to get more accurate and reliable results, a bigger sample should be obtained. The limited amount of time that was available for the collection of data did not allow for a large sample size. The outcome is still considered valid and reliable, but if the policy makers want to take related decisions and determine new policies, then a more extensive collection of data should be employed, and it should take place in various regions in order to detect the differences and the common needs.

In addition, the involved stakeholders in the area of railway stations should examine the importance of various facilities separately than other attributes. It is repeatedly proved that time-related features are the ones that influence the travel choice decisions the most, so the station planners have to ensure these aspects first by coordinating all the involved means of transport in the area of a train station. In order to compete with the main railway stations, the importance of frequent connections and short transfer times must not be neglected. But after these characteristics are ensured, more aspects should be given attention, such as comfortable station environment that permits unhindered flows and a satisfactory station design that does not force the users to walk long distances to re-embark in other vehicles. But since it was proved that station facilities possess a lower status among the determinants of the route choice behavior, it is recommended that the importance of facilities should be investigated separately, which will shed lights on which of the facilities are indeed important in these occasions. The results show that when some separate groups of the total sample are checked, the outcome is different and the presence of the kiosk has an influence on some cohorts' decision making process. It is therefore recommended that more data should be collected, different groups should be observed in more detail and facilities should be examined separately to realize which ones are the most crucial. In that way, the smaller stations can become optimal and attractive, influencing people to change their choice behavior.

Recommendations for further research are related to the choice experiment. Constructing choice experiments has a certain difficulty and creating a good design demands time and careful consideration of the included attributes and attribute levels. As mentioned above, it is recommended to future researchers that the attributes that are found in the past to have a lower importance should not be examined together with the traditionally strong attributes. The visuals that are included in the experiment should also be carefully designed. In the current case, the visuals were somehow biased since the two alternatives were depicted with a difference in the used vehicle (stop train-fast train) and a difference in the railway station of transfer (side station-main station). It should be carefully thought what is the exact information that the researcher wants the participant to know.

The levels of the attributes have to be expressed clearly as well and be presented as logical options to the participants. Crowding at the station was found to be one of the influential attributes. It is recommended that this attribute should be further examined because the attribute levels that were assigned were *high level*, *medium level*, and *low level.* However, this labeling does not provide clear instructions about how the situation in the station should be as each individual might interpret every level in a different way. A satisfactory labeling of this attribute could not be found in the literature review, so the levels were roughly presented in this way. Therefore, it is proposed that more research should be carried out regarding this feature.

The collection of data in this research project was further facilitated by creating a Quick Response (QR) code that the respondents could use to participate immediately on the spot simply by scanning the QR code with their mobile phone. Future researchers that will need to collect new data are advised to adopt the current trends of mobile use and technologies during the collection because it can considerably enhance the results, especially when young individuals need to be approached.

6. Discussion

Finally, some limitations and weaknesses of this research are discussed and possible improvements are mentioned. One of the limitations was that the Dutch public transport network was only taken into account and examples from train stations and combinations of routes in the Netherlands were presented. The main center of attention was on the case of route choices from the city of Leeuwarden to the Zernike campus in the city of Groningen and some more routes, existing in the Netherlands and similar to the case of the campus in Groningen, were examined in order to support the results. Lack of time and financial resources did not let the collection of data from more cases but different results could be revealed in case other cities or other countries would have been examined.

Another limitation of this study is that only the ten aforementioned attributes were included in the experiment, so the results of the analysis are only related to these attributes. This causes a limitation in the results, since a different outcome would emerge if different attributes were assigned to the alternatives. Also, adding more attributes in the experiment would make it more complex and possibly not easy to handle by the respondents. In addition, the main focus was put on a case of multimodal transport between train and bus. Therefore, there is no insight into what would be the outcome in other cases, such as transferring from train to train. In addition, it is reminded that the vast majority of the respondents were young adults, which means that the sample is not completely representative of the Dutch population and different results could possibly arise if participants of a bigger age variety were approached. The outcome is still considered valid for the cases that have been studied, because they refer to traveling to university campuses where the majority of visitors are students. If a more universal approach is demanded then older individuals should be invited to participate as well.

Previous researches have shown that the cost is one of the most significant attributes in travel behavior, but this was not included in the current research. This decision was taken due to the fact that the investigated case is related to students who have free transportation in the Netherlands and therefore, it was assumed that cost would not have an important effect in their decision. Indeed, data collection shows that 80% of the respondents possess a card for free public transportation in the Netherlands. However, this creates a limitation, because no conclusions can be made based on the impact of the cost, which has been proved to play a major role in the decision making process of the travelers. Another limitation of this research is that a rather young sample was obtained. 80% of the respondents were 24 years old or younger, which means that the results pertain to a specific age and the conclusions cannot be universal.

Furthermore, the choice sets were composed of only two alternatives representing a stop train and a fast train choice, which means that the respondents were invited to select one of the two labeled alternatives. First, some different results might emerge in case the choice sets were unlabeled, because in the current structure of the experiment the respondents could already have an inclination on the fast or the stop train. It is likely that the label attached can somewhat act as an attribute for that alternative (Hensher et al., 2005), therefore it would be interesting to investigate what would be the outcome in case a different setting was selected. In addition, the attribute levels of the fast train alternative were kept stable throughout the entire experiment. This decision was based on the fact that this alternative, which represented the situation of a main railway station, does not have so much flexibility to be readjusted, since the planning of such a station is somewhat more defined. This allowed for more attributes to be included in the experiment because the attribute levels were only changing in the stop train alternative. However, constructing the experiment in this way does not give the opportunity to check the probabilities by making changes in the alternative of the fast train.

In a nutshell, some suggestions for future research would be that different regions or cases could be studied in order to compare the results. In addition, a wider spectrum of ages should be included to check if this demographic characteristic plays a role in the route-choice behavior. A different set of attributes would also be interesting to investigate, to realize if there are different factors that influence the studied decision making process and cost should be included. Finally, it is of interest to test if unlabeled choice sets would lead to a different result and it would certainly be more valuable to permit various levels to all the alternatives included.

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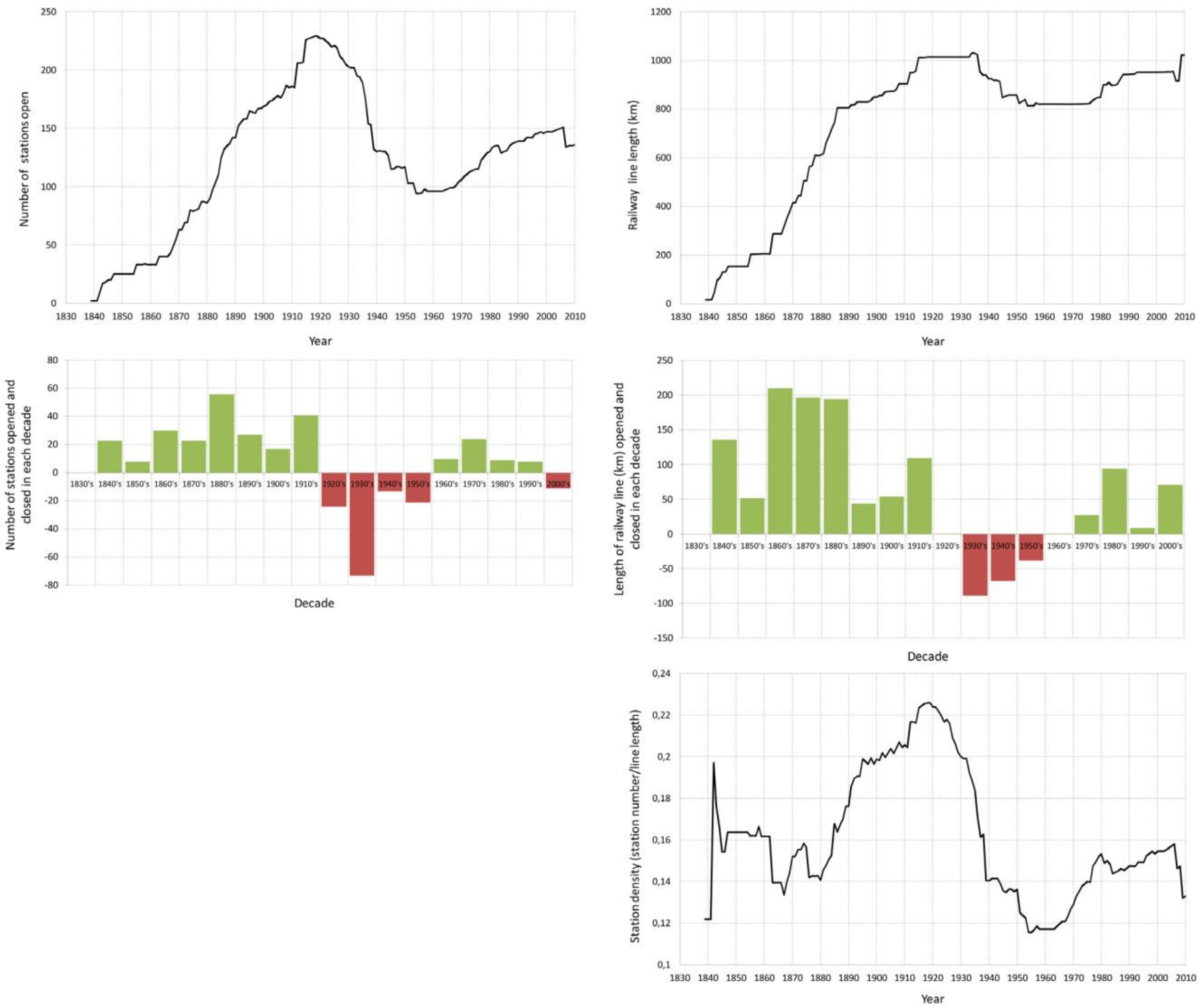
Appendices

Appendix 1. The most prominent features of the Dutch railway development

The first phase refers to the period before 1850 when transportation was achieved by barges and the first railways were constructed along the canals, competing flat-bottomed boats, until the moment the former dominated in the end of 19^{th} century. In that remote time, not only were the railways constructed for the connection between the cities, but the government policies aimed in connection between seaports and industrial areas as well as connection between the country and its neighbors. Later on, the railway boom occurred between 1850-1910, when the already existing lines improved and developed into an integrated railway network, initially connecting the main population areas, but further on, the demand increased even in less populated regions, where the network was expanded. These improvements influenced the urban population growth and the suburbanization. Conditions changed to a greater extent by moving to the third phase, i.e. 1910-1940, when in the first two decades economy was flourishing, leading to industry growth, people's movement to cities and therefore an integrated railway network which facilitated the commute from houses in the countryside to the jobs in the city. However, the interwar era caused a decline in railway network due to huge financial losses and many stations and kilometers of railways had to cease, also because of the improvement of roads and bus services. The fourth period refers to the years between 1940-1980 that brought new conditions with a demographic explosion and a rapid economic growth. The cities expanded and the road network was extensively improved, causing a huge demand of private modes that exceeded the use of public transport and therefore the railway network was increasingly shrunk until 1960. This situation resulted in a more active involvement of the Dutch Railways in planning and an overall development in the existing railway network and in urban rail transit networks was observed, mainly in the area of Randstad. The following era between 1980 and 2010 brought some new conditions, where the growth of railway network was relatively slow in the 80s and the decentralization was supported along with carpooling and public transport use from the new (re)developed locations, which caused a concentration of housing, industries and employment around the public transport points. The advent of the new century was characterized by the transit-oriented development that promotes highly frequent public transport services and therefore urban growth around the public transport nodes and along the public transport corridors (Kasraian et al., 2016). These conditions can be observed in Figure 4, where the railway boom in the end of the 19^{th} century is visible, followed by the big decline of the interwar and second world war era, to be increased again in the upcoming period.

Figure 26. a) Number of stations open, b) number of stations opened and closed in each decade, c) railway line length (kilometres), d) length of railway line (kilometres) opened and closed in each decade, e) station density (station number/line length). Source: (Kasraian et al., 2016)



Appendix 2. Observations of the main investigated routes of the case study

Leeuwarden-Zernike through Zuidhorn

Figure 27. Stop train Leeuwarden- Groningen CS at 07:30 (before Buitenpost)

The stop train from Leeuwarden to Groningen normally starts with a medium occupancy in the beginning, with passengers having the possibility to easily find a seat, but it gradually approaches full capacity as the vehicle stops in the stations that follow, enforcing the passengers to stand still, especially after Buitenpost.

There is a massive flow of passengers who get off the train in Zuidhorn in order to get the bus no. 11. Due to the small size of the platform, which leads to the exit of the station, there is a passengers' "bottleneck" that is additionally encumbered by the existence of only two check-out machines in the platform. These two machines, necessary for checking-out during the trip when somebody holds a seasonal card, a situation that is the most common in the Netherlands, are next to each other, which lead to more overcrowding around them, as people have to make a queue in order to check-out. Time can be lost there and there is a general discomfort due to overcrowding. As a result, the scheduled walking time/waiting time proportion of 1min/4min is changed according to the situation mentioned above.

Figure 28. Passengers getting off the bus no. 11 from Zernike campus head to train station in Zuidhorn

Afterwards, the passengers, mainly students, need to board in the bus, which is overcrowded and reaches its fullest capacity in the rush hour. Travelers are "squeezed" in the vehicle and the doors can barely close. There is an additional burden in this situation which relates to the traffic jams that are usually created in Friesestraatweg, the local street that leads to Zernike campus. Consequently, the conditions in the bus become even more disturbing and finally even 10 minutes of delay can be observed in this route. The situation described is mostly met around 08:00-08:30 hours. Later, in the time slots after 09:00 hours, these problems start to mitigate and a smoother transition takes place between Zuidhorn and Zernike campus.

Leeuwarden-Zernike through Groningen CS

Figure 29. Groningen central station at 08:20- passengers disembarking from the train Leeuwarden-Groningen

The second choice, which refers to the transition from Leeuwarden to Zernike campus through Groningen CS, was also examined and observations show milder results. As already mentioned, passengers who use the fast train board only at the stations of Leeuwarden and Buitenpost. Hence, the travelers who use the intermediate stops do not have the possibility to take the fast train to Groningen. As a result, the size of the ridership is not so big and there is enough comfort even during the rush hours, although the train is quite full and there are almost no free seats. The main problem lies in the main station. There is some overcrowding when people alight from the train, also due to passengers from other trains that walk in the station, and the situation described above about the check-out machines cause more burden.

Figure 30. Passengers have to walk around 200-300m from Groningen CS to Groningen bus station

Passengers have to walk a distance of about 200-300 meters depending on the wagon of the train that they were sitting or the platform that their train stops. Bus no. 15 leaves from the bus station, next to Groningen CS, and needs 17 minutes to arrive in Zernike campus. The annoying situation that was observed in the first route is not the same in this case. Probably due to the fact that the bus no. 15 runs every 5 minutes in the rush hour, not a big problem is met in the bus station of Groningen. The seats are almost fully occupied, but only a few passengers are standing still and therefore there is not much annoyance for the ridership. When arriving at the campus, bus no. 15 as well as bus no.11 from Zuidhorn station, stop in 4 different stops, facilitating many locations that passengers may want to visit.

Appendix 3. Reasoning behind the selection of attribute levels

Transfer time:

- 3 minutes
- 6 minutes
- 9 minutes

The real transfer times between the arrival and the train and the departure of the bus are as follows. In Zuidhorn it is *3 minutes* during morning rush hour and *5 minutes* after 09:30 hours, while in Groningen CS there is a transfer time of *7 minutes*. These transfer times are tailored to the distance that needs to be covered in the stations. This distance is shorter in Zuidhorn station; therefore the transfer time is shorter as well. The transfer time for the second alternative (i.e. the Groningen CS) is set at 7 minutes in the experiment, maintaining the representation of the real time situation. The levels that are mentioned above are only applied in the first alternative (Zuidhorn case) in order to realize whether passengers prefer really short transfer times (3 minutes), less tight transfer times (6 minutes) or a bigger amount of transfer time (9 minutes), perhaps due to their need to use some of the station facilities. These relationships need to be examined.

Time in the bus:

- 12 minutes
- 14 minutes
- 16 minutes

The real in-vehicle times in the two buses (no. 11 from Zuidhorn and no. 15 from Groningen CS) are 14 minutes and 15 minutes respectively. For the first alternative, the real in-vehicle bus time is presented as the middle level and the other two levels are created by adding/deducting 2 minutes in the real time. By reducing the time from 14 to 12 minutes, it is desired to check if a faster bus service can attract more passengers, this simply done probably by providing a direct bus connection instead of one with intermediate stops. In order to compare that with the second alternative, the fixed value that is given to this attribute is set to 16 minutes (1 minute more than the real time between Groningen CS and Zernike campus).

Headway of the bus:

- Every 10 minutes
- Every 20 minutes
- Every 30 minutes

The real frequency of the bus no.11, leaving from Zuidhorn to Zernike campus, is every 30 minutes, which is adjusted to the arrival times of the stoptrains that arrive in Zuidhorn. The situation is different in Groningen CS, where the frequency of the bus no. 15 is every 5 minutes during the rush hours, probably making it a more attractive choice, since missing the bus does not mean long waiting time for the next one. For this reason, the real situation that is met in Zuidhorn is related to the third attribute level and two more levels are introduced, presenting two better options that might look more appealing to the travelers. It should be noted here that the unique level that has been given to this attribute of the second (fast train) alternative is every 10 minutes instead of 5 minutes, in order to have at least one case where the two alternatives are comparable in respect to this attribute. It would be quite likely that in case the level is maintained at 5 minutes, the respondents would be substantially more prone to always choose this alternative, and this would also possibly mean that this attribute would dominate, not letting receiving conclusions regarding other attributes.

Walking distance:

- 20m
- 100m
- 200m

This also depends on the railway carriage where the passenger is seated, but the approximate distance is 30-100 meters in Zuidhorn and 100-300 meters in Groningen CS. The aforementioned levels are presented only for the first alternative, in an effort to realize whether a very short distance of 20 meters, possibly by connecting the platform directly to the bus, will attract more passengers to this alternative. Next, an average level of 100 meters is introduced and the last level is related to a distance bigger than what is met in Zuidhorn station. For the second alternative the fixed level that is included is set to 200 meters, which pertains to the medium distance that needs to walked in Groningen CS.

Crowding in the station:

- Low level
- Medium level
- High level

Versluis (2010) mentions that individuals tend to seek more comfortable conditions when their personal space is "invaded" by another person, therefore if the users of a public space feel irritated by the existence of many individuals in this space, they tend to change this situation by finding more comfortable solutions. However, it is quite difficult to define the magnitude or size of this space. Four areas of personal space have been defined from Hall (1966) (retrieved from (Versluis, 2010), but they are related to standing rather than moving conditions. It should be kept in mind that personal limits might change as conditions change, such as by changing from a standing to a moving position, especially when it comes to a disembarking situation. Daamen and Hoogendoorn (2003) did some experiments about pedestrian walking behavior by applying microscopic and macroscopic pedestrian flow models and on the situation of narrow bottlenecks and mention that:

- inside the bottleneck densities and flows are *high* with speeds around 1m/s; and
- in the congested region upstream of the bottleneck densities are *high* and flows are *low* with speeds around 0.3m/s

The situation with the checking-out machines in the Dutch railway stations can be related. It is quite challenging to use a specific parameter that can depict the level of discomfort for each individual in circumstances like these, but walking speed or density might be one of them. Similarly, the most appropriate attribute levels for this variable are difficult to be captured for each individual. A simple classification of both densities and walking speeds could be *high-medium-low*, since indicating people per square meter (for density) or meters per second (for walking speed) might not be interpreted appropriately by the respondents.

Presence of toilet/information desk/kiosk/heated waiting area:

- Yes
- No

Giving two levels in these four facility-related attributes enables a simple and direct investigation of the importance or not of their existence in the railway station. As already mentioned before, these facilities are not provided in the station of Zuidhorn. Since, Groningen CS offers plenty of facilities to the passengers, there is a strong advantage there. Hence, it needs to be specified whether one of these facilities adds value to the chosen route. It should also be noted that the provided information can have various types (e.g. a counter with an employee giving face-to-face information, a screen indicating the departure times or an automated machine that the passengers can call for receiving information or making questions). However, one type of information facility had to be chosen. As Ben-Akiva and Bierlaire (1999) state, the information provided about the conditions of the network can significantly affect the route choice decision making process and it can be modeled by binary variables that identify what type of this information this is.

Level of the bus:

- Basic
- Comfort

This attribute is divided into 2 levels, which appear in the case of the first alternative, while the second alternative is only presented with the “basic” level. The lower level (“basic”) corresponds to a standard bus, while the higher level (“comfort”) represents a more comfortable bus with modern seats, Wi-Fi and air-conditioning. What is aspired to achieve in this way is to find out whether, by providing only a basic level of bus in combination with the fast train, more passengers can be enticed into using the stop train alternative. Therefore, in the latter case, both levels can appear in the choice sets.

Appendix 4. The online Questionnaire

Routekeuze in het openbaar vervoer

Welkom!

Geachte heer/mevrouw,

Mijn naam is Sofia Tzouli en ik studeer 'Construction Management and Engineering' aan de Technische Universiteit Eindhoven. Graag wil ik u uitnodigen om deel te nemen aan mijn afstudeeronderzoek.

Als u met het openbaar vervoer reist, zijn er soms meerdere routes beschikbaar. Het kan daarbij voorkomen dat u op een treinstation moet overstappen naar een andere trein of op een bus/tram. In mijn onderzoek ga ik op zoek naar de belangrijkste factoren die uw keuze voor een bepaalde route in het openbaar vervoer beïnvloeden. Het doel van mijn onderzoek is om meer inzicht te krijgen in routekeuzegedrag in het openbaar vervoer.

Uw deelname helpt mij om dit afstudeeronderzoek tot een succes te maken. Ik wil u bij voorbaat bedanken voor het invullen van de vragenlijst.

Het invullen van de vragenlijst duurt ongeveer 10 minuten. Uw informatie blijft geheel anoniem en wordt enkel voor dit onderzoek gebruikt.

Met vriendelijke groet,
Sofia Tzouli

Begin

Routekeuze in het openbaar vervoer

Deel A : Huidig verplaatsingsgedrag

In dit deel van de enquête wordt u gevraagd om een aantal vragen over uw recente reisgedrag van de laatste paar maanden te beantwoorden.

Vorige Volgende

Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv specialisten in verkeer

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Hoe vaak reist u met de trein in het algemeen?

- Nooit
- 1 keer per maand of minder
- 2-4 keren per maand
- 2-4 keren per week
- 5 keren per week of meer

De volgende vragen gaan over uw reis van huis naar school / werk.

Vorige | Volgende

Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv specialisten in verkeer

Routekeuze in het openbaar vervoer

Hoe vaak reist u met de trein naar uw school/werk lokatie?

- Nooit
- 1 keer per maand of minder
- 2-4 keren per maand
- 2-4 keren per week
- 5 keren per week of meer

Previous | Next

Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv
specialisten in verkeer

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Welk vervoermiddel gebruikt u meestal als u van thuis naar het treinstation reist (voortransport)?

- ○ Te voet
- ○ Fiets
- ○ Bus
- ○ Auto
- ○ Anders

Namelijk: __________

Welk vervoermiddel gebruikt u meestal als u van het treinstation naar uw school/werk lokatie reist (natransport)?

- ○ Te voet
- ○ Fiets
- ○ Bus
- ○ Auto
- ○ Anders

Namelijk: __________

Vorige | Volgende

TU/e

Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv specialisten in verkeer

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Welk van de onderstaande stations gebruikt u het vaakst als *vertrekstation* voor uw reis van huis naar school/werk?

- ○ Leeuwarden CS
- ○ Leeuwarden Camminghaburen
- ○ Hurdegaryp
- ○ Feanwalden
- ○ Buitenpost
- ○ Grijpskerk
- ○ Zuidhorn
- ○ Geen van de hierboven genoemde stations

Welk van de onderstaande stations gebruikt u wel eens als *aankomststation* voor uw reis van huis naar school/werk?

Geef hieronder uw antwoorden (ieder station één antwoord).

Station	Nooit	Soms	Regelmatig	Vaak
Leeuwarden Camminghaburen	◉	○	○	○
Hurdegaryp	◉	○	○	○
Feanwalden	◉	○	○	○
De Westereen	◉	○	○	○
Buitenpost	◉	○	○	○
Grijpskerk	◉	○	○	○
Zuidhorn	◉	○	○	○
Groningen CS	◉	○	○	○

Vorige Volgende

Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv specialisten in verkeer

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Wanneer maakt u het meest gebruik van het openbaar vervoer als u naar school/werk gaat?

- ○ Tijdens ochtendspits
- ○ Tijdens daluren
- ○ Tijdens avondspits
- ○ Wisselend

Vorige Volgende

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Reist u wel eens met de bus van/naar de Zernike campus in Groningen?

- Nooit
- Soms
- Regelmatig
- Vaak

Vorige Volgende

Routekeuze in het openbaar vervoer

Deel A: Huidig verplaatsingsgedrag

Via welke treinstations reist u naar de Zernike Campus?
(U kunt meer dan één antwoord te geven.)

- Via station Groningen Centraal
- Via station Zuidhorn
- Via station Groningen Noord
- Anders, namelijk:

Vorige Volgende

Routekeuze in het openbaar vervoer
Deel A: Huidig verplaatsingsgedrag

Hoe vaak maakt u, bij een bezoek aan een treinstation, gebruik van de volgende faciliteiten?

Geef hieronder uw antwoorden (voor iedere faciliteit één antwoord).

Faciliteit	Nooit	Soms	Regelmatig	Vaak
Informatieservice*				
Toiletten				
Kiosk				
Verwarmde wachtruimte				

* Een informatiebalie waar een medewerker van het openbaar vervoer informatie verstrekt en/of vragen beantwoordt.

Vorige Volgende

Routekeuze in het openbaar vervoer
Deel A: Huidig verplaatsingsgedrag

Als u op een treinstation moet overstappen van een trein naar een bus, hoeveel waarde hecht u dan aan de volgende omstandigheden?

Geef hieronder voor elke omstandigheid één antwoord.

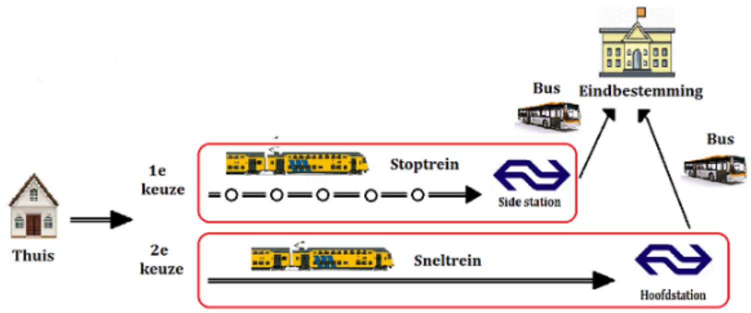
Omstandigheid	Zeer weinig	Weinig	Gemiddeld	Veel	Zeer veel
Niet te druk op perron / in station					
Korte loopafstand van perron naar de bus					
Korte overstaptijd tussen aankomst trein en vertrek bus					
Frequente busverbinding					
Goede kwaliteit van de bus					

Vorige Volgende

Routekeuze in het openbaar vervoer

Deel B: Keuzesituaties

In dit gedeelte van de vragenlijst vraag ik u om een keuze te maken uit 2 *denkbeeldige route-alternatieven* wanneer u met het openbaar vervoer reist van thuis naar een eindbestemming (werk-/studie-lokatie). Uw reis begint bij een treinstation en later moet u overstappen op een bus. De **reistijd in de trein** is voor beide route-alternatieven hetzelfde. De af te leggen afstand met de stoptrein is **korter** dan de afstand met de sneltrein. Hieronder ziet u een afbeelding met de 2 route-alternatieven.



Hierna worden meerdere keuzesituaties gepresenteerd waarbij u een keuze moet maken tussen 2 route-alternatieven. Elk alternatief wordt gekenmerkt door enkele variabelen. Deze worden op de volgende pagina uitgelegd.

Vorige | Volgende

Routekeuze in het openbaar vervoer
Deel B: Keuzesituaties

Uitleg variabelen

De gekozen kenmerken worden hieronder uitgelegd. Per kenmerk zijn er 2 of 3 waarden mogelijk. Deze waarden zijn toepasbaar in elk route-alternatief.

1. **Toiletten**: *Toiletten aanwezig / niet aanwezig (--)*
2. **Informatieservice**: *Informatieservice aanwezig / niet aanwezig (--)*
3. **Kiosk**: *Kiosk aanwezig / niet aanwezig (--)*
4. **Verwarmde wachtruimte**: *Verwarmde wachtruimte aanwezig / niet aanwezig (--)*

5. **Drukte op het station:** Het kenmerk geeft aan of het perron waar u moet overstappen druk is of niet.
• *Rustig*: u heeft veel ruimte op het station en u kunt zich vrij bewegen

• *Gemiddeld*: de drukte is normaal, maar u moet zich aanpassen aan andere lopende passagiers

• *Druk*: het station is erg druk, u kunt zich niet vrij bewegen omdat het te druk is

6. **Overstaptijd:** De tijd tussen de aankomst van de trein en het vertrek van de bus.
• *3 minuten* • *6 minuten* • *9 minuten*

7. **Loopafstand:** De afstand die u moet lopen van de trein naar de bus.
• *20m* • *100m* • *200m*

8. **Frequentie van de bus:** Hoe vaak vertrekt de bus.
• *Elke 10 minuten* • *Elke 20 minuten* • *Elke 30 minuten*

9. **Kwaliteit van de bus:** De kwaliteit en het comfort van de bus.

• *Basis (standaardbus)* • *Comfort (comfortabele bus met moderne zittingen, WIFI en airconditioning)*

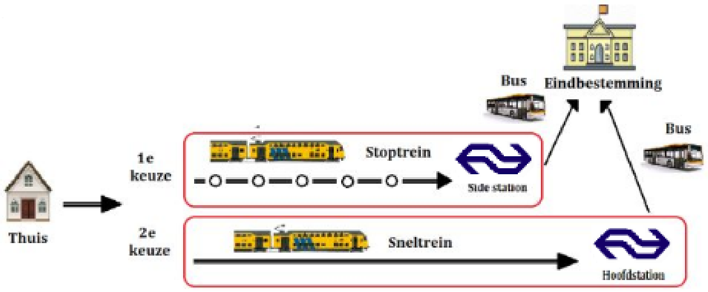
10. **Tijd in de bus:** De totale reistijd in de bus.
• *12 minuten* • *14 minuten* • *16 minuten*

Vorige Volgende

Routekeuze in het openbaar vervoer
Deel B: Keuzesituaties

In de onderstaande tabel ziet u een voorbeeld van een keuzesituatie waarin 2 routes worden getoond. *Let op: de route met de 'Sneltrein' is in elke keuzesituatie hetzelfde.*

Tot nu toe is er enkel gekeken naar de tijden van elke route. Naast tijd zijn er nog andere kenmerken die uw keuze kunnen beïnvloeden. Bekijk en vergelijk deze kenmerken goed zodat u een onderbouwde keuze kunt maken. Onder aan de tabel kunt u de route die uw voorkeur heeft aanvinken.



Voorbeeldtabel

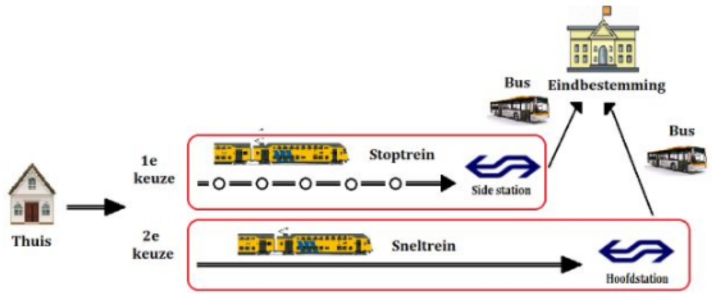
Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	5 minuten	7 minuten
Tijd in de bus	13 minuten	16 minuten
Totale reistijd	53 minuten	58 minuten
Drukte	Druk	Gemiddeld
Toiletten	Toiletten	Toiletten
Informatieservice	–	Informatieservice
Kiosk	–	Kiosk
Verwarmde wachtruimte	–	Verwarmde wachtruimte
Loopafstand	20 meter	200 meter
Frequentie van de bus	Elke 20 minuten	Elke 10 minuten
Kwaliteit van de bus	Comfort	Basis
Uw voorkeur	○	○

Nu volgen nog 5 gelijksoortige keuzesituaties. Succes!

Vorige Volgende

Routekeuzes in het openbaar vervoer

Deel B: Keuzesituaties



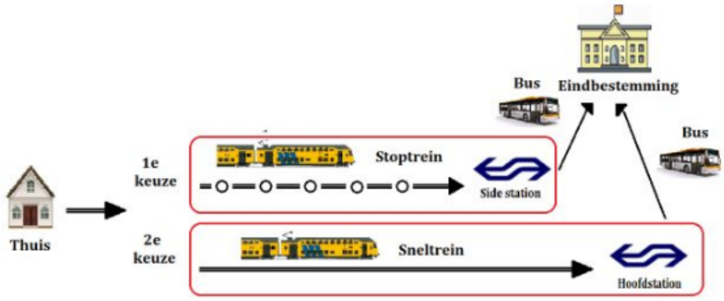
Welk route alternatief heeft uw voorkeur als u van thuis naar werk/studie-lokatie reist?

Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	9 minuten	7 minuten
Tijd in de bus	12 minuten	16 minuten
Totale reistijd	**56 minuten**	**58 minuten**
Drukte	Druk	Gemiddeld
Toiletten	--	Toiletten
Informatieservice	--	Informatieservice
Kiosk	--	Kiosk
Verwarmde wachtruimte	Verwarmde wachtruimte	Verwarmde wachtruimte
Loopafstand	200 meter	200 meter
Frequentie van de bus	Elke 30 minuten	Elke 10 minuten
Kwaliteit van de bus	Basis	Basis
Uw voorkeur	○	○

Vorige Volgende

Routekeuzes in het openbaar vervoer

Deel B: Keuzesituaties

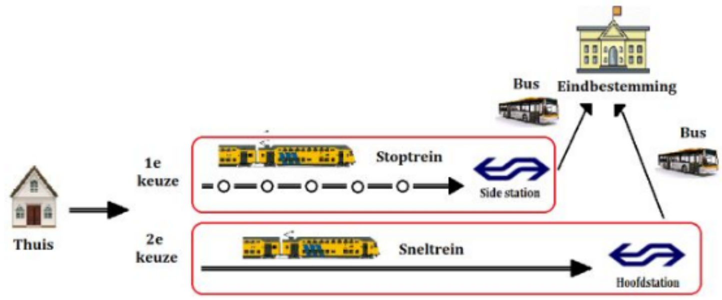


Welk route alternatief heeft uw voorkeur als u van thuis naar werk/studie-lokatie reist?

Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	6 minuten	7 minuten
Tijd in de bus	14 minuten	16 minuten
Totale reistijd	**55 minuten**	**58 minuten**
Drukte	Gemiddelde	Gemiddeld
Toiletten	--	Toiletten
Informatieservice	Informatieservice	Informatieservice
Kiosk	--	Kiosk
Verwarmde wachtruimte	--	Verwarmde wachtruimte
Loopafstand	20 meter	200 meter
Frequentie van de bus	Elke 20 minuten	Elke 10 minuten
Kwaliteit van de bus	Basis	Basis
Uw voorkeur	○	○

Vorige Volgende

Routekeuzes in het openbaar vervoer
Deel B: Keuzesituaties



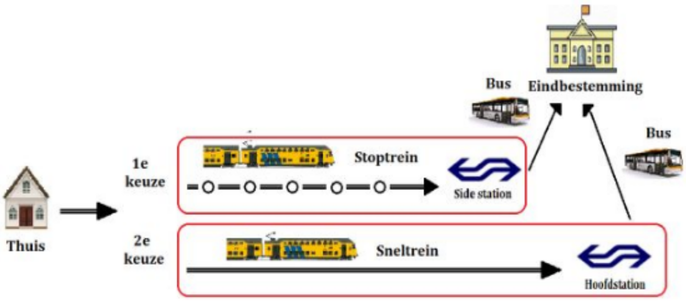
Welk route alternatief heeft uw voorkeur als u van thuis naar werk/studie-lokatie reist?

Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	6 minuten	7 minuten
Tijd in de bus	12 minuten	16 minuten
Totale reistijd	**53 minuten**	**58 minuten**
Drukte	Rustig	Gemiddeld
Toiletten	Toiletten	Toiletten
Informatieservice	Informatieservice	Informatieservice
Kiosk	--	Kiosk
Verwarmde wachtruimte	--	Verwarmde wachtruimte
Loopafstand	20 meter	200 meter
Frequentie van de bus	Elke 30 minuten	Elke 10 minuten
Kwaliteit van de bus	Comfort	Basis
Uw voorkeur	○	○

Vorige Volgende

Routekeuzes in het openbaar vervoer

Deel B: Keuzesituaties



Welk route alternatief heeft uw voorkeur als u van thuis naar werk/studie-lokatie reist?

Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	9 minuten	7 minuten
Tijd in de bus	14 minuten	16 minuten
Totale reistijd	**58 minuten**	**58 minuten**
Drukte	Gemiddelde	Gemiddeld
Toiletten	--	Toiletten
Informatieservice	--	Informatieservice
Kiosk	Kiosk	Kiosk
Verwarmde wachtruimte	--	Verwarmde wachtruimte
Loopafstand	20 meter	200 meter
Frequentie van de bus	Elke 10 minuten	Elke 10 minuten
Kwaliteit van de bus	Comfort	Basis
Uw voorkeur	○	○

Vorige Volgende

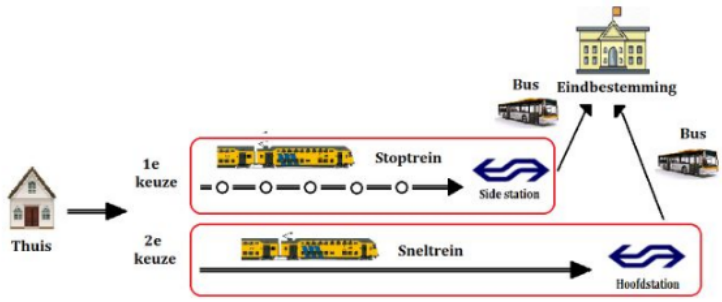
Technische Universiteit Eindhoven University of Technology

ov bureau groningen drenthe

BonoTraffics bv specialisten in verkeer

Routekeuzes in het openbaar vervoer

Deel B: Keuzesituaties



Welk route alternatief heeft uw voorkeur als u van thuis naar werk/studie-lokatie reist?

Kenmerken	Stoptrein	Sneltrein
Tijd in de trein	35 minuten	35 minuten
Overstaptijd	6 minuten	7 minuten
Tijd in de bus	16 minuten	16 minuten
Totale reistijd	**57 minuten**	**58 minuten**
Drukte	Rustig	Gemiddeld
Toiletten	--	Toiletten
Informatieservice	--	Informatieservice
Kiosk	Kiosk	Kiosk
Verwarmde wachtruimte	Verwarmde wachtruimte	Verwarmde wachtruimte
Loopafstand	100 meter	200 meter
Frequentie van de bus	Elke 30 minuten	Elke 10 minuten
Kwaliteit van de bus	Comfort	Basis
Uw voorkeur	○	○

Vorige Volgende

Technische Universiteit Eindhoven University of Technology

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BonoTraffics bv specialisten in verkeer

Routekeuze in het openbaar vervoer

Deel C: Persoonlijke Informatie

U bent aangekomen bij het laatste deel van deze enquête!

Tot slot worden u nog enkele vragen over uw persoonlijke situatie voorgelegd zodat de enquête in een goede context geplaatst kan worden.

Deze gegevens worden uiteraard volledig anoniem verwerkt en zullen niet kunnen worden herleid naar een persoon of adres.

Vorige Volgende

Routekeuze in het openbaar vervoer
Deel C: Persoonlijke Situatie

Wat is uw leeftijd?

Wat is uw geslacht?

- Man
- Vrouw

Wat is het hoogste opleidingsniveau dat u heeft afgerond?

- Lager- of basisonderwijs
- Voorgezet onderwijs
- MBO
- HBO
- WO
- PhD
- Anders,

Namelijk:

Hoe is uw gezin samengesteld?

- Thuiswonend bij ouders
- Alleenstaand (inclusief samenwonend met huisgenoten)
- Met partner zonder thuiswonend(e) kind(eren)
- Met partner en thuiswonend(e) kind(eren)
- Alleenstaand met thuiswonend(e) kind(eren)
- Anders

Wat zijn de vier cijfers van de postcode van uw woonlocatie?

Kunt u gratis reizen met het openbaar vervoer?

- Altijd
- Op doordeweekse dagen
- In het weekend
- Nooit

Waar studeert of werkt u?

- Rijksuniversiteit Groningen (RUG)
- Hanzehogeschool Groningen (HBO)
- Geen van de hierboven genoemde instellingen

Vorige | Volgende

Routekeuze in het openbaar vervoer

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Welke niet genoemde faciliteiten op een station zouden u stimuleren om een bepaald station als op-/overstappunt te gebruiken?

Heeft u nog aanvullingen op dit onderzoek of de enquête?

U kunt uw antwoorden nu indienen.

Vorige   Versturen

Routekeuze in het openbaar vervoer

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Dank u wel!

Appendix 5. The questions of the first part of the questionnaire

1. *How often do you travel by train?*

The levels that are presented in this question are:

- Never
- 1 time per month or less
- 2-4 times per month
- 2-4 times per week
- 5 times per week or more

2. *Which transport mode do you mostly use from home to the train station (pre-transport)?*

The levels that are presented in this question are:

- On foot
- Bike
- Bus
- Tram
- Metro
- Car
- Other

3. *Which transport mode do you mostly use from the train station to your school/work(after transport)?*

The levels that are presented in this question are the same as in the previous question.

4. *When do you travel by public transport to school/work?*

The levels that are presented in this question are:

- During rush hours
- Not during rush hours
- Both

5. In this question it is asked how often the respondent makes use of the following railway stations:

- Leeuwarden CS
- Leeuwarden Camminghaburen
- Hurdegaryp
- Feanwalden
- De Westereen
- Buitenpost
- Grijpskerk
- Zuidhorn
- Groningen CS

These railway stations are the ones who connect Leeuwarden with Groningen and it is therefore desired to see If the respondents are familiar and to which extent with them.

6. *Do you ever travel by bus to Zernike campus?*

The levels that are presented in this question are:

- Never
- Sometimes
- Regularly
- Often

If the answer in the previous question differs from ”Never”, then the next question is:

7. *Through which station do you mostly travel to Zernike campus?*

The levels that are presented in this question are:

- Through Groningen CS
- Through Zuidhorn
- Through Groningen North station
- Other

8. *How often do you use the following facilities in a train station?*

The facilities that are presented in this question are:

- Information point
- Toilets
- Coffee place
- Escalators

The levels that are presented in this question are:

- Never
- Sometimes
- Regularly
- Often

9. *When you have to change from train to bus in a train station, how important are the following aspects for you?*

The aspects that are presented in this question are:

- Not busy at the platform/station
- Short walking distance from train to bus
- Short transfer time between arrival of train and departure of bus
- Frequent bus service
- Comfortable bus

The levels that are presented in this question are:

- Very low
- Low
- Medium
- High
- Very high

Appendix 6. The questions of the third part of the questionnaire

1. *Age*

Age is frequently reported in the literature as an indicative factor of the transportation choices. For instance, RSG, Inc et al. (2015) initiated their research about the dynamic travel markets by explaining some clear differences between age and gender groups, taking part in the same choice sets. Hence, age and gender are two characteristics that are asked in the questionnaire. There were no age levels predefined.

2. *Gender*

The levels that are presented in this question are:

- Male
- Female

3. *Education*

Well-educated people are expected to treat some situations on a different way than others. For instance, it is underlined in the study of Axhausen et al. (2006) that a specific group of well-educated people showed more willingness and consideration about the improvement of the transportation system.
The levels that are presented in this question are:

- Primary education
- Secondary education
- Middle-level applied education
- Higher professional education
- Scientific education (university)
- Doctorate Degree (PhD)
- Other, namely:

4. *Household composition*

The levels that are presented in this question are:

- Single (including living with roommates)
- Living with parents
- Living alone with child(ren)
- Living with partner without child(ren)
- Living with partner and child(ren)
- Other

5. *Postcode*

There are no levels for this attribute, simply because each respondent was asked to fill in the four digits of their postal code. In such a way the neighborhood of the respondents' residence could be identified in order to have some insights into where the sample is situated and how close the respondents live compared to the study area.

6. *Possibility to travel for free (indirect question about possession of a free-transport card)*

The levels that are presented in this question are:

- Always

- During the weekdays
- During the weekend
- Never

As already mentioned in section 2.5.1, the selection of these levels stems from the fact that the Dutch students are offered free transportation within the entire country (until a specific year of their studies) and they normally have to choose between having this possibility during the weekend or during the weekdays.

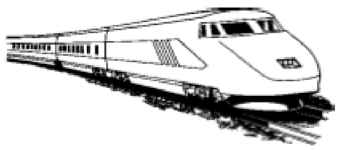
It can also be the case that some travelers possess a card that provides free transportation throughout the entire week (because they have paid by themselves or their employer has done so). The purpose of this question is to assess if the respondents have a freedom to choose their routes regardless of the price. Evidently, when they have the opportunity to travel for free, they will consequently be freer to choose also the most preferred routes

Appendix 7. The distributed flyer

Heb je ooit aarzelen over welke route te kiezen?

Bepaal de toekomst van het transport systeem rond Zernikecampus!

Ook uw mening telt dus!



Uw deelname zal me helpen met mijn afstudeerproject.

Vul de Internet enquête in.

Webpagina:
https://vragen1.ddss.nl/q/RoutekeuzeOV

Technische Universiteit Eindhoven
Sofia Tzouli, Faculteit Bouwkunde
Email: s.tzouli@student.tue.nl

Appendix 8. Used facilities and importance of station aspects

Table 14. Frequency of facilities' usage according to respondents

	Information Service	Toilets	Kiosk	Heated waiting area
Never	84,6%	62,3%	37,1%	59,4%
Sometimes	13,7%	34,3%	46,9%	31,4%
Regularly	1,1%	2,9%	12,6%	6,9%
Often	0,6%	0,6%	3,4%	2,3%

Table 15. Importance of various aspects during a transfer according to respondents

Aspect / *Importance*	Not busy platform	Short walking distance to bus	Short transfer time	Frequent bus service	Good quality of the bus
Very low importance	9,1%	2,9%	1,7%	0,6%	4,0%
Low importance	27,4%	11,4%	10,9%	1,7%	12,0%
Average importance	38,9%	30,3%	28,6%	17,1%	41,7%
High importance	19,4%	41,7%	33,7%	46,3%	32,6%
Very high importance	5,1%	13,7%	25,1%	34,3%	9,7%

Appendix 9. Results of various models' analysis

Table 16. The coefficient values of every attribute level and their significance (MEN/WOMEN)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Men		Women	
Transfer time	*3 minutes*	1.369	<1%	1.031	<1%
	6 minutes	0.699	<1%	0.538	<10%
	9 minutes	0		0	
Time in the bus	*12*	0.866	<1%	0.596	<5%
	14	0.987	<1%		>10%
	16	0		0	
Crowding in the station	*High*	-1.287	<1%	-1.071	<1%
	Medium	-0.398	>10%	-0.555	<5%
	Low	0		0	
Toilets	*No*	-0.066	>10%	0.055	>10%
	Yes	0		0	
Information service	*No*	0.225	>10%	0.194	>10%
	Yes	0		0	
Kiosk	No	-0.065	>10%	-0.467	<5%
	Yes	0		0	
Heated waiting area	*No*	0.071		0.015	>10%
	Yes	0		0	
Walking distance	*20m*	0.551	<10%	0.576	<5%
	60m	0.219	>10%	0.592	<5%
	100m	0		0	
Frequency of the bus	*Every 10*	1.241	<1%	1.464	<1%
	Every 20	0.382	>10%	0.973	<1%
	Every 30	0		0	
Level of the bus	*Basic*	-0.176	>10%	-0.041	>10%
	Comfort	0		0	
Constant		-1.617	<1%	-1.899	<1%
R-square		0.141		0.170	

Table 17. The coefficient values of every attribute level and their significance (FREQUENT/NON FREQUENT)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Frequent		**Non-frequent**	
Transfer time	*3 minutes*	1.208	<1%	0.996	<5%
	6 minutes	0.552	<1%	0.833	<5%
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.846	<1%	0.437	>10%
	14 minutes	0.652	<1%	0.486	>10%
	16 minutes	0		0	
Crowding in the station	*High*	-1.119	<1%	-1.174	<1%
	Medium	-0.383	>10%	-0.742	<10%
	Low	0		0	
Toilets	*No*	-0.025	>10%	-0.018	>10%
	Yes	0		0	
Information service	*No*	0.219	>10%	0.184	>10%
	Yes	0		0	
Kiosk	No	-0.303	>10%	-0.011	>10%
	Yes	0		0	
Heated waiting area	*No*	0.135	>10%	-0.051	>10%
	Yes	0		0	
Walking distance	*20m*	0.620	<10%	0.406	>10%
	60m	0.340	>10%	0.835	<5%
	100m	0		0	
Frequency of the bus	*Every 10*	1.140	<1%	2.033	<1%
	Every 20	0.503	>10%	1.209	<1%
	Every 30	0		0	
Level of the bus	*Basic*	-0.085	>10%	-0.269	>10%
	Comfort	0		0	
Constant		-1.649	<1%	-2.390	<1%
R-square		0.122		0.229	

Table 18. The coefficient values of every attribute level and their significance (ZERNIKE/MON ZERNIKE)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Zernike		Non-Zernike	
Transfer time	*3 minutes*	1.473	<1%	0.554	>10%
	6 minutes	0.751	<1%	0.128	>10%
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.740	<1%	0.871	<5%
	14 minutes	0.592	<1%	0.844	<5%
	16 minutes	0		0	
Crowding in the station	*High*	-1.241	<1%	-1.214	<1%
	Medium	-0.693	<1%	-0.147	>10%
	Low	0		0	
Toilets	*No*	-0.182	>10%	0.254	>10%
	Yes	0		0	
Information service	*No*	0.232	>10%	0.137	>10%
	Yes	0		0	
Kiosk	No	-0.432	<5%	0.143	>10%
	Yes	0		0	
Heated waiting area	*No*	-0.147	>10%	0.602	<10%
	Yes	0		0	
Walking distance	*20m*	0.504	<5%	0.829	<5%
	60m	0.308	>10%	0.822	<5%
	100m	0		0	
Frequency of the bus	*Every 10*	1.498	<1%	1.272	<1%
	Every 20	0.703	<1%	0.768	<10%
	Every 30	0		0	
Level of the bus	*Basic*	-0.084	>10%	-0.153	>10%
	Comfort	0		0	
Constant		-1.235	<1%	-1.235	<1%
R-square		0.146		0.240	

Table 19. The coefficient values of every attribute level and their significance (ZUIDHORN/NON ZUIDHORN)

Attributes	Attribute level	Part-worth utility	Significance	Part-worth utility	Significance
		Zuidhorn		**Non-Zuidhorn**	
Transfer time	*3 minutes*	1.363	<1%	1.188	<1%
	6 minutes	0.515	>10%	0.652	<1%
	9 minutes	0		0	
Time in the bus	*12 minutes*	0.558	>10%	0.908	<1%
	14 minutes	0.490	>10%	0.711	<1%
	16 minutes	0		0	
Crowding in the station	*High*	-0.915	<10%	-1.332	<1%
	Medium	-0.514	>10%	-0.506	<5%
	Low	0		0	
Toilets	*No*	0.415	>10%	-0.117	>10%
	Yes	0		0	
Information service	*No*	0.634	>10%	0.167	>10%
	Yes	0		0	
Kiosk	No	-0.867	<5%	-0.119	>10%
	Yes	0		0	
Heated waiting area	*No*	-0.395	>10%	0.149	>10%
	Yes	0		0	
Walking distance	*20m*	1.283	<1%	0.408	<10%
	60m	0.436	>10%	0.414	<10%
	100m	0		0	
Frequency of the bus	*Every 10*	1.565	<1%	1.339	<1%
	Every 20	0.813	<10%	0.725	<1%
	Every 30	0		0	
Level of the bus	*Basic*	0.244	>10%	-0.249	>10%
	Comfort	0		0	
Constant		-1.818	<5%	-1.844	<5%
R-square		0.191		0.146	

Table 20. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for MALES)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*561.449*			*0*		
Constant	*561.328*	*0.121*	*3.841*	*1*	*0.000*	
Optimal	*482.252*	*79.076*	*25.0*	*15*	*0.000*	*0.141*

Table 21. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for FEMALES)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*596.107*			*0*		
Constant	*566.595*	*29.512*	*3.841*	*1*	*0.000*	
Optimal	*494.607*	*71.988*	*25.0*	*15*	*0.000*	*0.170*

Table 22. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for FREQUENT TRAVELERS)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*856.730*			*0*		
Constant	*852.680*	*4.05*	*3.841*	*1*	*0.000*	
Optimal	*752.042*	*100.638*	*25.0*	*15*	*0.000*	*0.122*

Table 23. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for NON-FREQUENT TRAVELERS)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*300.826*			*0*		
Constant	*278.5*	*22.326*	*3.841*	*1*	*0.000*	
Optimal	*231.997*	*46.503*	*25.0*	*15*	*0.000*	*0.229*

Table 24. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for ZERNIKE CAMPUS USERS)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*829.004*			*0*		
Constant	*828.041*	*0.963*	*3.841*	*1*	*0.000*	
Optimal	*707.695*	*120.346*	*25.0*	*15*	*0.000*	*0.146*

Table 25. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for NON-ZERNIKE CAMPUS USERS)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*328.552*			*0*		
Constant	*289.380*	*39.172*	*3.841*	*1*	*0.000*	
Optimal	*249.618*	*39.762*	*25.0*	*15*	*0.000*	*0.240*

Table 26. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for travellers who start their trip in ZUIDHORN)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*242.602*			*0*		
Constant	*242.459*	*0.143*	*3.841*	*1*	*0.000*	
Optimal	*196.347*	*46.112*	*25.0*	*15*	*0.000*	*0.191*

Table 27. Comparison between the likelihood ratio statistic (LRS) and the chi-square (Model for travellers who DON'T start their trip in ZUIDHORN)

Model	-2Log Likelihood	LRS	Critical value	df	Sig.	R-square
Null	*914.954*			*0*		
Constant	*895.164*	*0.963*	*3.841*	*1*	*0.000*	
Optimal	*781.366*	*120.346*	*25.0*	*15*	*0.000*	*0.146*

Appendix 10. **Simulation Examples**

Time in the bus: ***TIB***; Transfer time**:** ***TT***; Crowding: ***C*** ; Walking Distance**:** ***WD***; Frequency of the bus: ***FB***

Worst case scenario

*(TIB **16 min**/ TT **9 min**/ C **high**/ WD **200m**/FB **every 30min**)*

Alternative	Utility	Exponent	Probability
Stop train	-2,914	0,054	0,051
Fast train	0,000	1,000	0,949
Σ		1,054	

Best case scenario

*(TIB **12 min**/ TT **3 min**/ C **low**/ WD **20m**/FB **every 10min**)*

Alternative	Utility	Exponent	Probability
Stop train	2,058	7,830	0,887
Fast train	0,000	1,000	0,113
Σ		8,830	

Scenarios with similar probabilities

1. *(TIB **16 min**/ TT **6 min**/ C **medium**/ WD **200m**/FB **every 10min**) (same attribute levels for both)*

Alternative	Utility	Exponent	Probability
Stop train	-0,300	0,741	0,426
Fast train	0,000	1,000	0,574
Σ		1,741	

2. *(TIB **14 min**/ TT **3 min**/ C **medium**/ WD **100m**/FB **every 30min**)*

Alternative	Utility	Exponent	Probability
Stop train	-0,041	0,960	0,490
Fast train	0,000	1,000	0,510
Σ		1,960	

Scenarios which increase the stop train probability

1. *(TIB **12 min**/ TT **6 min**/ C **low**/ WD **100m**/FB **every 20min**)*

Alternative	Utility	Exponent	Probability
Stop train	0,686	1,986	0,665
Fast train	0,000	1,000	0,335
		2,986	

2. *(TIB **14 min**/ TT **3 min**/ C **medium**/ WD **100m**/FB **every 10min**)*

Alternative	Utility	Exponent	Probability
Stop train	1,302	3,677	0,786
Fast train	0,000	1,000	0,214
Σ		4,677	