Master Thesis

The influence of train stations' environment on travelers' origin station choice behavior: a TOD approach

Colophon

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Preface

This research represents my graduation thesis as a partial fulfillment of the requirements for the degree of Master of Science in Construction Management and Engineering, provided by Eindhoven University of Technology. "Behavior" and "sustainability" are two powerful words today. Worldwide there are discussions about how people have to CHANGE their way of thinking, approach to the environment, transport, consumption and lifestyle to create a better world not only for us, but for the generations to come. To be able to CHANGE there is a need to understand the mechanism behind the actual behavior. I believe that the present study contributes to this trend. It has been an exciting journey to investigate the subject of this research. And this journey wouldn't have been possible if it weren't for some people. There is a saying: "There will always be a reason why you meet people. Either you need them to change your life or you are the one that will change theirs".

First, I would like to thank my parents, Eugen and Violeta Tudorica, for believing in me, investing in my education and for their never ending love. To my younger brother, Ionut, for having his unique way to show how much he cares about me. To my boyfriend, Bobo, for understanding my passions and for never leaving my side. Of course, I was blessed with a big and lovely family and I would like to thank to each and every one of them for their unconditional support.

I want to show my appreciation to all my professors who contributed to the person I am today, but most of all to those without whom this research would not have been the same. Many thanks to prof. Peter van der Waerden for his great mentorship, to prof. Wim Schaefer for his inspiring talks and to prof. Brano Glumac for his comments. Moreover, I am grateful for the opportunity I had to complete my research in collaboration with NS. Special thanks to my two supervisors, Jildou van der Sluis, for considering me a valuable addition to the team, and Willem van Heijningen, for involving me in all the activities with the experts from this domain, and to all my colleagues who helped me when I was struggling along the way. In addition, I want to say "Thank you" to Mr. George Barbulescu for his advices, help and good will.

My international experience wouldn't have been so nice if it weren't for my Dutch friends (thank you- The Kerstens, especially- for making me part of your families), international buddies (we support one another, so thank you for being there for me in the most difficult moments) and Romanian friends (prietenia exista si la distanta, dar se leaga si in afara tarii)! I feel lucky to have you all in my life.

I would like to thank an important person, who left too early from this world, but who encouraged me all the time to pursue to this road and become a better person. This is for you, Taicule!

Last, but not least, I would like to thank the respondents who filled in the questionnaires. Without their input, there would have been no end for this research.

I am looking forward to greet new challenges and start a bright career!

Alexandra Violeta Tudorica
Eindhoven, July 2014

P.S. Thank you, Guido, for helping me with the design of the cover for this research!

Management summary

Transport infrastructure and urban development have always had a strong and complex connection and in the Netherlands, great interest has been shown in defining this relationship. Dutch urban planners sensed the benefits of a compact development around transport infrastructure since 1980s, but nowadays another planning method captured their attention, namely Transit-Oriented Development (TOD). TOD theory emphasizes how public transport and urban planning can favor each other, providing the means, the directions in which the environment around a station *can* (as opposed to *must*) be organized. By focusing on the implementation of TOD, sustainability (a modern topic on political and administrative agendas worldwide) is enhanced.

The focus of the present research is on train, as a transport mode, since railway transport represents a considerable proportion of daily travel mode chosen by Dutch travellers (Debrezion, et al., 2009). NS (Nederlandse Spoorwegen) is the Dutch Railway Company, the main train service provider and the owner of several station buildings and parts of area surrounding the stations. Nowadays, NS is confronting with congestion-related issues at the main station level (e.g. Utrecht Central, Amsterdam Central etc.), while the stations offering less opportunities in terms of shops, cafes, train frequency, connecting public transport etc, are not very well used. An increased demand for a particular station is affecting not only the station itself (high crowding level on the platforms, access-way, in-vehicle, etc.), but also the surrounding area of the station: crowded buses, taxis, no available spaces for parking the bikes,and cars. This situation is affecting travelers' experience of the station in a negative way, which might lead to a decrease in the number of people using the train and a decrease in the turnover of the company. One solution to prevent travelers to move to alternative transport modes (e.g. car) is to redirect the flow towards other less crowded stations. In analyzing this possibility, NS is interested in exteding its focus, from station only to the surrounding environment of the station as well, since it might play a role in the travelers' satisfaction. In order to determine which characteristics describing the surrounding environment of a train station, are attracting the travelers, it is important to understand how travelers choose their train station. Being one of the first attempts to determine in detail the role of the surrounding environment in the station choice decision-making process of the travelers, the focus is on the origin station of the travelers' trip with the train. On the short-run, the choice for an origin train station stays the same and the station (and the area around) is well known by the traveler.

A research approach is developed to answer the central research question: **"What attributes of train stations' environment are influencing travelers' origin station choice behavior?"**.
A literature review is providing information about the two pillars of this research thesis: railway station choice behavior and TOD. Revealed Preference (RP) is the main research approach to determine the attributes of a surrounding area of a train station which are attracting travelers to use the train station for their train trip. A case study is set up to reveal the station choice behavior of travelers when several options are available (choice set, consisting in 8 stations located in Amsterdam) and in a paper-based questionnaire, respondents were asked to indicate their actual travel experience, the way in which the selected attributes describing the surrounding environment of the station are affecting their choice and give some personal details. The collected data is analyzed by using a discrete choice method, Multinominal Logit Model (MNL) respectively.

The literature review emphasized the limited attention paid to the role of the surrounding environment of the station, but to station itself characteristics in travelers' train station choice behavior. The area surrounding the station is analyzed from the perspective of TOD. TOD can be best characterized in terms of 5Ds: Density, Diversity, Design, Destination accessibility and Distance. However, it can be said that there are various attempts to define the 5Ds, but no general conclusion could be formulated out of them. In the attempt to study the 5Ds, some other characteristics affecting the station choice were discovered, namely travelers, station and trip-related characteristics. The station itself characteristics were not part of the questionnaire.

The analysis of the collected research data shows that the research sample was a common one for the Amsterdam case. The findings related to the influence of the surrounding area on Dutch travelers' origin station choice behavior revealed that all the attributes included under the 5Ds categories have a positive effect, rather than negative. "Distance" and "Destination accessibility" can be considered as key triggers. Among the sub-attributes, "Sidewalks", "Bike-friendly design", "Pedestrian amenities", "Public transport" and "Bike shelters" are the triggers affecting travelers' choice behavior, while "Presence of a variety of shops" and "Car-friendly design" sub-attributes have a negative influence.

The second part of the analysis, the station choice model (MNL) was built on the 4 pillars determined in the literature review part and identified several attributes affecting the choice for an origin station. The coefficients of these attributes have the expected sign and they are: an alternative-specific constant for Amsterdam Rai, one comprehensive variable describing the station (travelers' general opinion of the station), 4 variables from the surrounding environment category (distance, proximity, intensity, and presence of P+R), one traveler-related variable (age), and one trip-related variable (frequency of use). Except from age and distance, all the attributes affect in a positive way the travelers' train station choice behavior. To illustrate the working of the model, the model was applied for a choice situation of two train stations: Amsterdam Central and Amsterdam Amstel. The redistribution of travelers from the Amsterdam Central to Amsterdam Amstel was studied under 5 scenarios. The results showed that the probability of choosing Amsterdam Amstel decreases with distance (the closest the station, the higher the probability to be chosen). Moreover, the presence of a P+R facility in the station has a high effect on the travelers' origin station choice. The distance has one of the highest effects on the choice. A decrease in the distance with only 1 minute has an almost equivalent effect of an increase with 19% of the intensity around the station and an increase with 3% in the proximity.

Some recommendations are formulated based on the findings of this research. One of the most important variable affecting travelers' station choice behavior is distance, therefore, in order to increase the use of (smaller) train stations, NS should collaborate with the other stakeholders (e.g. bus companies) to strengthen the accessibility of the station; since more travelers are arriving at the station by public transport, the public transport connectivity of the station should be a first priority. Distance (measured in meters) should be directly included in the travel demand forecasting models.

Finally, advices are given regarding the deepening of the research into TOD implementation and redistribution of travelers towards other stations.

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1. Introduction

This chapter is introducing the context of the research containing the topic of this study and the problem definition. Expected findings and the relevance of the research project for science and practice will follow. A reading guide will be provided at the end of this chapter.

1.1. Problem statement

Transport infrastructure and urban development have always had a strong and complex connection. Urban transportation is providing access to multiple regions, affecting the land-use through stimulation of employment, commerce, residential developments. It is demonstrated that the promotion of car-oriented development strategies leads to urban sprawl, suburbanization, more disperse activities pattern (e.g. Kuby, et al., 2004; Lin & Gau, 2006; Ratner & Goetz, 2013). The decentralization of activities, located not only on the Central Business District (CBD), but also in low-density suburban areas had as outcomes longer trips distances and, surprisingly, a reduced accessibility with car or highways, a price that cities have to pay (e.g. Handy, et al., 2005; Mavoa, et al., 2012; Ratner & Goetz, 2013). Another part of the cost is related to environmental and health issues, or better said degradations, such as increased greenhouse gas emissions, air pollution, traffic noise, physical inactivity, and obesity (e.g. Bertolini, et al., 2005; Mavoa, et al., 2012; Sung & Oh, 2011; Tiwari, et al., 2011).

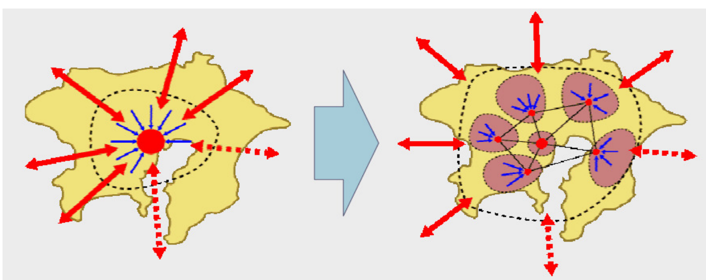
Figure 1. Core city development, decentralization of centers (source: Mori, 2011)

Next to all the reasons stated above, the higher prices of gasoline, car ownership and use, demographic changes (more single-person households, young professionals, empty-nesters), high interest for "sustainable urbanism", but also governmental support have forced a shift from the dependence on automobile to public transport system and a return to traditional land-use patterns (e.g. Ratner & Goetz, 2013; Sung & Oh, 2011; Tiwari, et al., 2011). A pressure of developing better transit policies came as a result of the advantages that public transport system is offering, namely the distinctive ability to cope with high volumes of travel demand concentrated in space and time, reduced energy consumption costs and a lower level of pollutant emissions per passenger when compared with a private car (Delmelle, et al., 2012). Traditional land-use patterns involved increased density of the area, mixed-use neighborhoods, pedestrian-friendly urban design, particularly around public transport stops (e.g. Neutens, et al., 2012; Ratner & Goetz, 2013). Within the available planning methods, Transit-Oriented Development (TOD) seems to be suitable to be employed for creating the desired developments described above.

The focus of TOD is on walkable areas around transit stations, increased density and accessibility and more opportunities (residential, recreational, shopping, etc.) for the people living or visiting the area. Moreover, within the literature, there are proofs that TOD is bringing socio-economic benefits (increase value of land and transit ridership, less car driving, decreased level of pollution), no matter if referring to the area surrounding a bus, metro or a train station (e.g. Cervero & Kang, 2011; Dorsey & Mulder, 2013; Estupiñán & Rodríguez, 2008; Gutiérrez, et al., 2011). Therefore, TOD theory emphasizes how public transport and urban planning can benefits from each other, providing the means, the directions in which the environment around a station *can* (as opposed to *must*) be organized.

In the Netherlands, great interest has been shown in defining the relationship between urban planning and public transport. Since 1980s, compact development around transit infrastructure has been the goal of Dutch planning system (van der Vliet, et al., 2012). In this country, railway transport represents a considerable proportion of daily travel mode chosen by Dutch travellers (Debrezion, et al., 2009). The train, as a transport mode, is the focus of this research project.

Nederlandse Spoorwegen (NS) is the Dutch national Railway Company which operates in public transport sector, providing trains and busses, in the Netherlands. NS Stations is part of NS and it is focused on the activities in and around the station, on the development and exploitation of buildings and surrounding environment. The aim is to develop the station in such a way that will facilitate the achievement of a balance between the station's function as a transit node (by offering transportation-related services) and as an activity place (by offering opportunities to work, shop, meet or recreate). Nowadays, NS is experiencing congested (main) stations (e.g Amsterdam Central, Utrecht Central) where many facilities are offered, while the ones with lower level of opportunities are not (very) well used. The high crowding level is affecting the station itself -access way, platform, in-vehicle, as well as the surrounding environment of the train station. Increased demand for one station lead to an overcrowded public system operating in the area adjacent to that train station (busses, taxis, bike shelters etc.).

Figure 2. Platform and stairway crowding level in Utrecht Central (source: Voskamp, 2012)

The high level of crowding can be exemplified for Amsterdam Central Station or Amsterdam Amstel, where the residents willing to park their bikes at these stations are facing problems in locating a suitable and safe place; the bikes end up being parked next to trees or bridge railings due to the shortage in racks number. "The situation around Central Station is so out of control that the area is now worse than the average disorganized messy public space. If we do not intervene, the way bicycles are parked will cause serious accessibility problems" (Municipality of Amsterdam, 2012). All the issues stated above related to the station and its surrounding environment are affecting the overall travelers' experience or satisfaction. Unsatisfied travelers can reorient towards other modes of transport (car is a one of the main competitors) on the long term which is causing a decrease in the number of travelers and therefore, affecting the travelers' turnover. The attractiveness of a station goes beyond travel-time reliability and frequency, which are known to be very important for travelers, to better door-to-door experience of traveling. Therefore, NS is extending the power from the station only, towards the surrounding area of the station as well. The focus of NS on improving/developing the surrounding area of the stations (for example by providing parking opportunities for cars, bikes, connection with other public transport modes –bus, tram, metro, at station) is summarized under hub development ("Knooppuntontwikkeling") portfolio, where the concept of TOD can be traced[1].

Figure 3. Bicycle parking lot **(source: upload.wikimedia.org)**

The preference of travelers for the well-developed stations is supported by the literature in which is demonstrated that the spatial developments within the surrounding area of the station (e.g. accessibility, aesthetics of the area) are affecting passenger's travel behavior or in other words, travelers' station choice behavior (Debrezion, et al., 2009; Cascetta, 2013). One solution to this issue (redirecting the flow of people towards other stations which are less intensively used) is to rearrange the area of the station according to travelers most preferred characteristics.

However, even though attention has been paid to the proximity of the land-use around a public transport stop, and train stations in particular, no clear guidelines on the development of spatial planning, with an immediately successful implementation in any context, has been given so far. This is also the case of the Netherlands. Likewise, no guidelines on how to organize the area around train stations in accordance with Dutch travelers' preferences are available. Important features for the Dutch travelers need to be identified due to the fact that successful implementation of TOD has to be community-oriented and to integrate the value/culture of the place. Basically, there is no "fit-all" recipe for TOD implementation.

1.2. Research aim

The objective of this research is to determine the influence of the characteristics of train stations' surrounding environments (architecture, aesthetics, spatial developments etc.) on travelers' choice of origin station for their trip with the train. Being one of the firsts research attempts to determine the way in which a train station's environment should be organized based on travelers' preferences, the target group is travelers who are using a train station as an origin station for their trip. The assumption is that this group of travelers knows better than the ones who are using the same station as a transfer station for their trip, since they are living or developing some activities in the surrounding area of their origin station. Moreover, the focal group can provide better quality data since they know the alternative

[1] www.ns.nl

stations available in the region and can make better tradeoffs among the variables for the choice, when multiple alternatives are available. In addition, the choice of the departure station is an important decision element for the households or individuals. For the short term, the choice can be unchanged, but (additional) changes at the station level can determine a different departure station choice on the long term perspective (Debrezion, et al., 2007).

The present research is a Dutch context - adapted study, aiming at bridging the link between the developments proposed by TOD planning method and what travelers value, as part of their culture.

Due to the available resources (time, money), it is not possible to analyze all kinds of developments or characteristics related to TOD literature up to the smallest level of detail. These characteristics will be selected during the research process. Concentrating on (most) relevant/common characteristics available in the literature can probably provide a better view of the preferences of travelers and later on into the (re)organization of the area surrounding the train station. For clarity reasons, before introducing the research questions of the present study, the concepts of “station” and “station area” (or surrounding environment) are presented.

The term “station” refers to the station building or station complex consisting of rails, platforms and amenities – tickets and service, shops, toilets, etc. Stations are seen as gates or access points to the train service.

The “station area” can be defined as “All built and open spaces together with activities they host, contained within the perimeter designed by a ‘walkable radius’ centered on the railway station building, as amended to take account of case specific physical-psychological, functional-historical and development features” (Bertolini & Spit , 1998). In the present study the station area is referred to as station’s surrounding environment and consists of all the layers or developments located outside the station’s building walls, therefore excluding the station complex (station itself), as it can be seen in Figure 4.

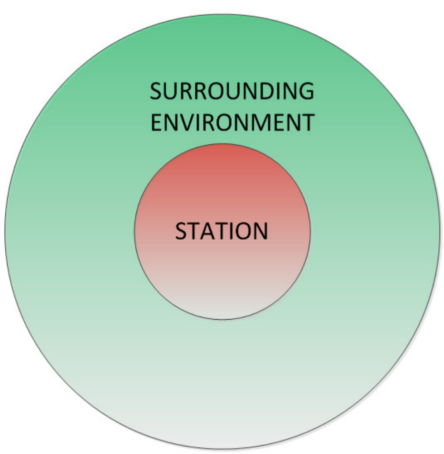

Figure 4. Station” versus “station environment”

Once the two concepts have been clarified, in order to address the issues stated above, the main research question can be formulated as follows:

“What attributes of train stations’ environment are influencing travelers’ origin station choice behavior?”

In order to answer this central question, some sub-questions need to be addressed as well:

1. How can train stations and their surrounding area be characterized in the context of travel behavior related aspects?

2. What influence do these features have on Dutch passengers' choice of origin station to enter a train?

1.3. Relevance

The relevance of this study is divided in theory and practice. The theory aspects will explain the relevance of this study for science, while the practical aspects will show the suitability of this study in the field.

Theory

The relation between urban form and travel behavior is not amply addressed (e.g. Estupiñán & Rodríguez, 2008). As far as the author knows, limited literature is available on station choice behavior in connection with built environment/urban form.

This study aims to determine characteristics from the available literature regarding urban form and transportation and build a measure instrument to determine their influence on travelers' station choice behavior. Moreover, the present study makes a contribution to the body of knowledge focusing on stimulating people to use the public transport by determining what attracts them to use a (train) station. The study addresses indirectly how the behavior of travelers can be changed towards a more sustainable lifestyle, encouraging the use of public transport.

Practice

Since TOD occurs in an already established urban context, it involves multiple stakeholders and the challenge to deal with fixed land use, history and zoning (Dorsey & Mulder, 2013). The area surrounding the train station can be seen as a competing space for all the stakeholders involved (NS, municipality, etc.). By having an insight in the organization of the area in accordance with travelers' preferences, the collaboration among them can be enhanced (heading towards the same goal). Moreover, priorities can be assigned to future developments (P+R, residential locations, etc.) based on the outcome of the present study.

In accordance with NS's strategy which places the customer as a central element of their business (The traveler on 1, 2, and 3; "De reiziger op 1, 2, en 3"), this study aims at identifying the most important attributes that have to be in the stations' environment so as to attract more (or keep, not lose the existing) travelers towards the train stations and increase transit operator's travelers' turnover. In addition, this research project emphasizes how travelers can be redistributed to other stations if new services or improvements are introduced. By redistributing travelers among the stations, the usage of stations is leveled, leading to more benefits: decrease congestion at the big stations, increase the usage of smaller stations, and achieve regional success as opposed to node or station success for the service operator (here, NS).

Moreover, this study can give a better view if the travelers know/are interested in the function of the station as a stay-in place, rather than just a transport node.

Last, but not least, knowing the sensitivity of the travelers towards the feature characterizing the train stations' surrounding environment can improve the travel demand forecasting models used by NS through the integration of the most relevant characteristics in the present models. At the time when this research thesis is written, NS is using models sensitive to changes in the timetable and access or egress facilities or fares and travel time sensitive models to forecast the travel demand.

1.4. Reading guide

The structure of this thesis consists in five chapters. This first chapter, the introduction, presented the problem statement, research aim and relevance of this research.

The second chapter, related work, describes the literature study about station choice behavior and TOD planning method. The concept of TOD is described, followed by the determination of its most important attributes and TOD outcomes. Out of them, sustainability in the TOD context is further elaborated. Finally, TOD particularities in the Netherlands are introduced.

The research approach is following in the third chapter. Firstly, the research framework will be presented, including the research questions. A description of the methods and techniques will follow. The section "data collection" will give an insight into the process of obtaining the data for the analysis.

The fourth chapter, analysis, starts with the description of the research sample, followed by descriptive statistics concerning the trip and the use of train stations included. An inventory of station aspects on choice influence is presented further. The section "Model analysis" introduces the measure instrument built to determine the weight of statistically significant variables on travelers' station choice behavior.

The final chapter introduces the general conclusion of this research, the answers to the research questions. Recommendations are related to further research, how the data can be further refined and how NS can arrange or organize the station environment in order to attract more travelers.

1.5. Demarcation

In the section "Demarcation", the focus on train stations and the stand point from which the problem is analyzed are explained.

Like in other countries such as Japan, UK or Germany, in the Netherlands the expectations are that the use of public transport will grow in the future. The nowadays trends among the youngsters are favoring the unlikelihood of owing a car and the likelihood of a combined "package" of transport modes such as bikes, public transport and car sharing (Maak plaats, 2013). By increasing the attractiveness of the station, throughout a good/optimal combination of amenities, and multimodal access, more travelers are expected to use the public transport.

The trend in the Netherlands is that all the possible public transport modes have to be brought together and the developments are located more or less around the train stations. This was encouraged by the changes in the policies promoted by government, which were stimulating the use of public transport, especially the train. Additional housing, offices and/or leisure activities, multi-modal transportation were developed around the railway stations. Moreover, in 2008, statistics from Central Bureau of Statistics (CBS) published that the railway system of the Netherlands is one of the busiest in Europe, especially for passenger's transport. It is also one of the most intense used railway networks in Europe. In 2006, the Dutch share of passenger train kilometers (km) in the total number of train km (freight and passengers) was 92%, higher than European Union's average of 79% (CBS, 2009). The remaining 8% is accounted for freight transport, less than European Union's average of 21%. The intensive use of Dutch rail system by travelers is also reflected in considerable amount of passenger transport per kilometer (km) of track: 5 million passenger-kilometers, in comparison with 1.8 million, the EU average (CBS, 2011). According to CBS (2011), two in every three people lived within 5 km away from the nearest railway station, in 2008, in the Netherlands. This increased accessibility of railway stations can be correlated with the large number of Dutch travelers using this transit mode.

Train stations have the biggest catchment areas among the other available modes of public transport (bus, tram, metro, taxi), since train is a high-capacity public transport system. "High-capacity public transit plays a critical role, as it allows for highly efficient and equitable urban mobility, and supports dense and compact development patterns. Transit also comes in various forms to support the entire spectrum of urban transport needs, including low- and high-capacity vehicles, taxis and motorized rickshaws, bi-articulated buses and trains" (Institute for Transportation & Development Policy, 2014). Therefore, the above mentioned reasons lead to the focus on train stations as the main focus of this thesis.

Train station areas represent the arena for several actors like municipalities or provincies, ProRail, NS, developers, travelers etc., as it will be discussed in the section "Involved actors", part of this thesis. In the course of this research the problem analysis is made from NS' standpoint.

NS is the Dutch national Railway Company, operating in the public transport, providing trains and buses; it serves as a transport mode for more than 1 million passengers per day. NS group consists of 4 companies (see Figure 5[2]).

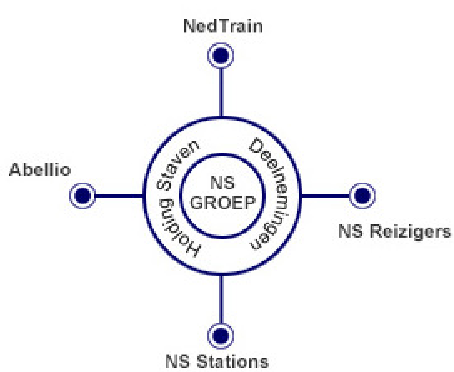

Figure 5. NS Group (source: NS, 2014)

NS Stations is part of the NS Group and it is the station company. It is the company focused on the development and exploitation of buildings and surrounding areas. It operates 404 railway stations and it has three main departments, as it can be seen in Figure 6[3].

Real Estate & Development department ("***Vastgoed & Ontwikkeling***") is responsible for the development of existing and new station locations, Retail & Transfer ("***Retail & Transfer***") focuses on the retail facilities at the station level for the travelers/visitors, while Station Operation ("***Stationsoperatie***") is concerned with the operational management of stations and real estate. Moreover, the focus of NS Stations is

[2] https://werkenbijns.nl/over-ons/ns-organisatie/
[3] www.nsstations.nl

on door-to-door travel (DTD); therefore, the development of the area surrounding the station is also of interest. The reason behind it is the thought that passengers are not traveling form station to station, but from their residential place to another place where some activities need to be done (work, recreational, etc).

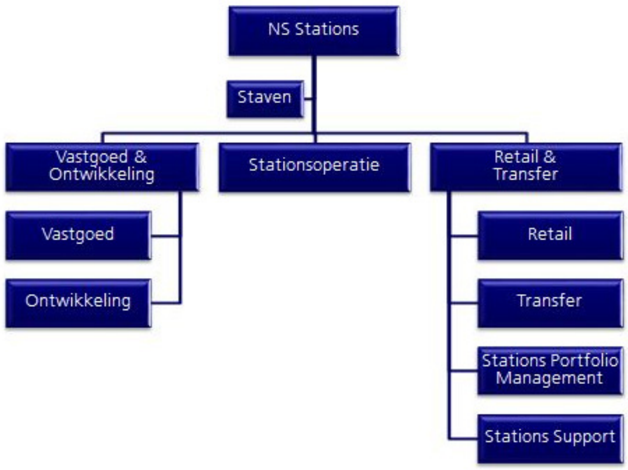

Figure 6. NS Stations organizational chart (source: NS Stations, 2014)

When referring to the area surrounding the stations, TOD is a focal point for NS, integrated under the "*Knooppuntontwikkeling*" portfolio of activities. NS Stations is the owner of land plots (out of which 4,8 million m^2 are available for (re)development) and buildings in the immediate vicinity of the station; by stimulating TOD implementation a synergy can be achieved between the urban development and the core of NS's business (transport and station exploitation) (NS Stations, 2014).

What is more, improving the station area can widen the station's catchment area. This fact was demonstrated by Cascetta (2013), in his analysis of the influence of the high architectural area around a metro station, in comparison with a traditional one (see Figure 7).

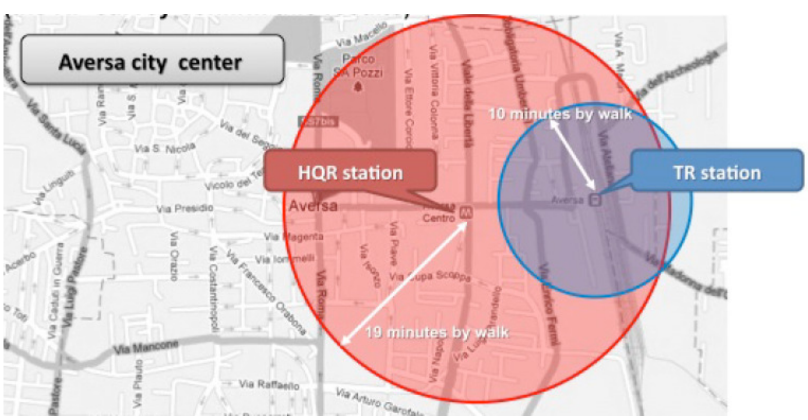

Figure 7. Widening of station catchment areas (source: Cascetta, 2013)

Two methods were developed to test the walking routes from the station on safety, quality, human dimension and vibrancy (Fixing the Link method throughout which scores are assigned to the criteria mentioned for every selected case aiming at assessing or improving the walkability) and the bicycle routes to the station on safety, directness, comfort and attractiveness (Recycle City method which recommends a good design to support biking in the city) (NS Stations, 2014).

Regarding the number of travelers forecasting and station choice, NS is employing timetable sensitivity models.

2. Related work

This chapter presents a review of the relevant literature about the topic of this thesis. The structure of this chapter is supported by two pillars: station choice behavior (as a particularity of the travel behavior topics) and TOD. First, a brief literature review about the railway station choice behavior is presented. Next, the concept of TOD, as a mean to organize the environment of a station is presented. The characteristics defining the relationship between the travel behavior and urban form are introduced. In the next section the benefits of TOD are further elaborated. The sustainability as an outcome of TOD planning method is introduced in the paragraph "Sustainability in TOD context". Furthermore, the particularities of TOD on international level and in the Netherlands are going to be presented together with the involved actors.

2.1. Railway station choice behavior

In this paragraph, a brief literature review about railway station choice behavior, with a focus on the Netherlands case, is presented.

Once the choice is made for the train as a transport mode to travel from A to B, the next issue to decide upon is which station to use; train stations are the access points to train service. Nevertheless, even if it is the next logical step, the choice of the origin station did not receive a great attention from researchers.

One of the firsts to address the issue of rail transit station choice was Kastrenakes (Kastrenakes, 1988). The author developed a model as a preparatory step in rail ridership forecasting for New Jersey transit agency (NJ TRANSIT). The data obtained from a survey conducted on origin-destination riders, he built a departure train station choice model based on whether the station is located in the passenger's residential area, the access time to reach the station, the frequency of service at the departure station and the generalized cost of the rail trip from the departure station. These variables were selected from the output of a regression analysis. The results of the choice model indicated that the location of the station in the residential area of the travelers and the frequency of service had a positive effect, while the other two variables had a negative one on the choice of a particular departure train station.

Chakour & Eluru (2013) contribute to the literature on train users' access mode and station choice behavior. Their research is conducted in Montreal, Canada, and distinguishes itself from the other due to the fact that employs latent segmentation approach that "simultaneously considers two segments of station and access mode choice behavior: Segment 1 - station first and access mode second and Segment 2 – access mode first and station second" (Chakour & Eluru, 2013). This approach determined the probability of allocating an individual to one of the two segments as a function of socio-demographic variables (age, gender, and vehicle ownership), level of service parameters (travel time by different modes, average travel times to alternative stations, and travel time to nearest and chosen stations), trip characteristics (egress mode and departure time), station level characteristics (parking and fare information) and land-use and built environment factors. The latter two were extracted from a dataset and divided into demand and supply-sides variables. "For the demand-based category, three orthogonal factors were derived: (1) zones with high median income and high proportion of newer vehicles, (2) zones with high vehicle ownership and high proportion of larger vehicles, and (3) zones with large proportion of older vehicles. The supply-based variables provided three orthogonal factors: (1) zones with high density, high walkability, and transit oriented developments (TOD), (2) zones with commercial land-use, and (3) zones with government & institutional land-use" (Chakour & Eluru, 2013). The results of the station choice model indicate that travel time by selected mode has a negative effect on station choice; on the other hand, the presence of parking spots and frequency have a positive effect.

Even though it is not focused on train, but metro station and it is closer to the idea of TOD, the study of Cascetta (2013), analyzed the value of beauty/design, travel and access time, service frequency and monetary costs in Naples. The analysis was carried out for two metro lines, out of which one was characterized by a high architectural area, while the other by a traditional one. The findings suggested that the choice is influenced by the aesthetics of the station/area (see Figure 8), total waiting time and ticket fare. Access, egress and tranfer time, as well as total in-vehicle time parameters proved not to be statistically significant.

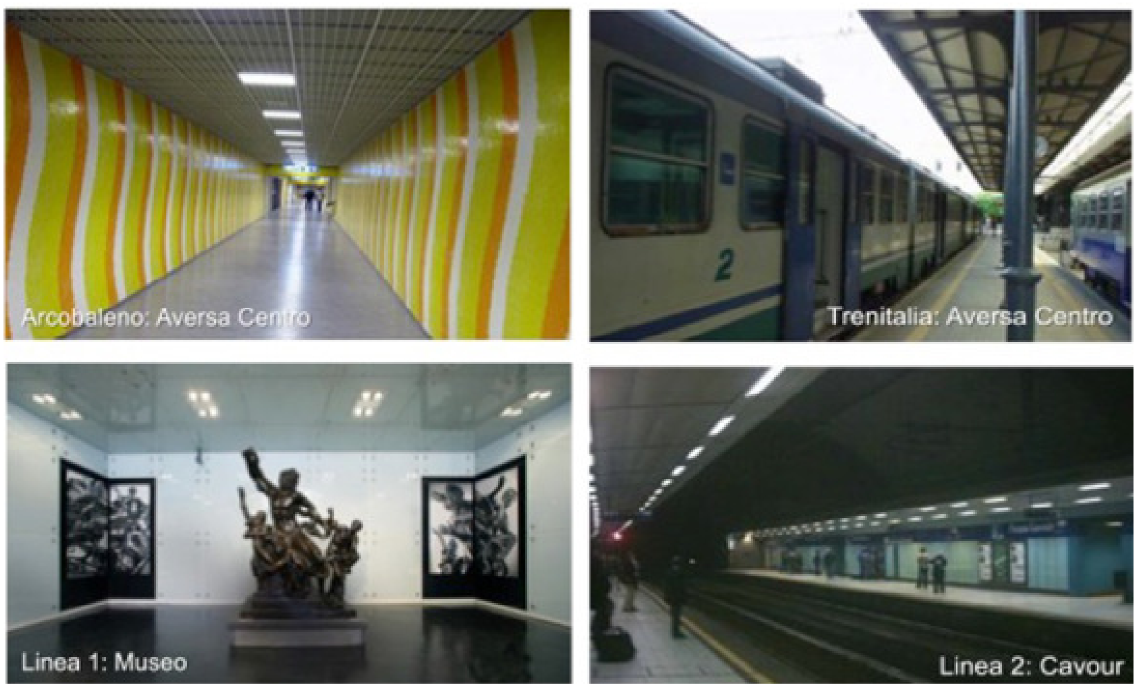

Figure 8. High Quality Rail (left) vs. Traditional Rail (right) beauty (source: Cascetta, 2013)

In the Netherlands, studying the choice of a departure railway station, Debrezion, et al. (2007) mentioned the relevance of their research "This is relevant since about 50% of Dutch railway passengers do not travel via the nearest railway station." - Phrase that adds up on the relevance of the present research thesis. The authors applied in their research a multinominal logit model. The choices of households were aggregated at the postcode level and three model specifications were applied to the utility function of a station (linear additive, linear additive with the cross product of distance and frequency of service and the transcendental logarithmic). In total, the analysis was made for 3498 postcode areas and 360 railway stations and the findings revealed that distance calculated as a Euclidean measure between the centroid of the post-code center and the station in the choice set, frequency of service, intercity status of the station and the presence of park and ride facilities have a significant effect on the choice of departure station. The intercity status of the station has the biggest effect on the choice of the departure station. "The intercity status of a station has on average an equivalent effect of a decrease of 2 km in distance or an increase in frequency of 300 trains per day" (Debrezion, et al., 2007), followed by the presence of a park and ride facility in the station, representing around 35% of the effect of the intercity status. The probability of choosing a specific station diminishes with the distance, while it increases as the service frequency increases. However, the effect of the latter is small in comparison with distance's effect: "A frequency of service increase by a hundred trains per day is equivalent to being 600 m closer to the station" (Debrezion, et al., 2007).

One of the latest researches on railway station choice is provided by Givoni & Rietveld (2014). The main focus of the paper was to determine the number of stations to provide in a multi-station region and its implications for an optimal transport network (for both, supply and demand side). To meet this aim, the first step was to understand the travelers' process of choosing a departure station when (many) alternatives are available. Amsterdam region was used as a case study (there are 11 stations available), data from NS customer satisfaction survey and a discrete choice model was employed. Their findings reinforced the idea that not many Dutch passengers are choosing the nearest departure station. To estimate the choice of a departure station, a nested logit model was applied. The model was formulated based on two factors: railway service (number of destinations served directly, the service frequency at each station level and travelers' direction) and the accessibility of the departure station. The residential locations were aggregated at 6-digits postcode level and the focus of the model was on the accessibility of the station. The results suggested the importance of accessibility of the station, "the disutility from travel time by public transport to the rail station (access journey) is greater than that from rail travel time (-0.117 vs. -0.090). The results also suggests that as distance to the departure station increases the disutility from accessing the station by certain modes rises most when choosing walking, followed by bicycle, taxi and car" (Givoni & Rietveld, 2014). Regarding the quality of the rail station facilities in relation to the access modes, the coefficient for the quality of the bicycle parking was found "positive, relatively very high and significant" (Givoni & Rietveld, 2014). Based on the outcome of the choice model, the effect of closing a station was examined. The conclusion was that it is not beneficial to reduce the number of stations in Amsterdam region.

As a general conclusion, one of the features defining the literature on train station choice is scarcity, as Debrezion, et al. (2007) noted in their article. The above brief literature review highlights some shortcomings the present research thesis is trying to address and indicates in which way this research differs from previous efforts to address the choice of a departure station. First, the focus in the past research was on station's features (facilities and level of service) and out of the 5Ds introduced in the next section of this thesis, mainly on accessibility. In addition the latter, was examined in relation to mode choice decision. The other TOD characteristics were included as variables in a model, but in a different manner that the present study does, and on international level, not for the Netherlands case. However, Givoni & Rietveld (2014) mentioned in their article, that in the analysis of station choice process did not integrated "other characteristics of the access journey, like built environment features, which will be important especially for walking", emphasizing the importance of considering them in the development of (future) models.

In the present research thesis, the analysis of the organization of the surrounding environment of the station is made from TOD perspective. A literature review about the concept of TOD is presented in the next section.

2.2. Transit-Oriented Development (TOD)

2.2.1. Introduction

According to California Department of Transportation (2005), TOD can be defined as "moderate to higher-density development, located within an easy walk of a major transit stop, generally with a mix of residential, employment and shopping opportunities designed for pedestrians without excluding the auto. TOD can be new construction or redevelopment of one or more buildings whose design and orientation facilitate transit use." Ratner & Goetz (2013) mentioned this definition in their paper as being a comprehensive one and identified a series of common features among the available definitions of this concept. On short, TOD is focusing on a walkable area to a transit station, increased density, developments and livability (better accommodations, less traffic congestions in the zone) which will lead to better transit ridership.

In their highly acclaimed paper, Cervero & Kockelman (1997) grouped the TOD planning strategies in relation to transportation objectives into 3 dimensions (3 Ds): increased *density* to stimulate the transit ridership, enhancing *diversity* of land use for a better coverage of public transport and pedestrian-oriented *design* to increase the number of non-motorized trips. Later on, Cervero & Murakami (2008) added two more dimensions (4th D and 5th D): *distance to transit* and *destination accessibility,* referring to the extent to which public transport is connecting in an efficient manner the station area and the activities within it. Regarding distance to travel, Cervero & Landis (1993) found that more people are using public transport instead of their own autos if the public transport stop is close to their home/work. By overlapping all this 5 Ds, sustainability and high quality of environments can be achieved (Cervero & Murakami, 2008).

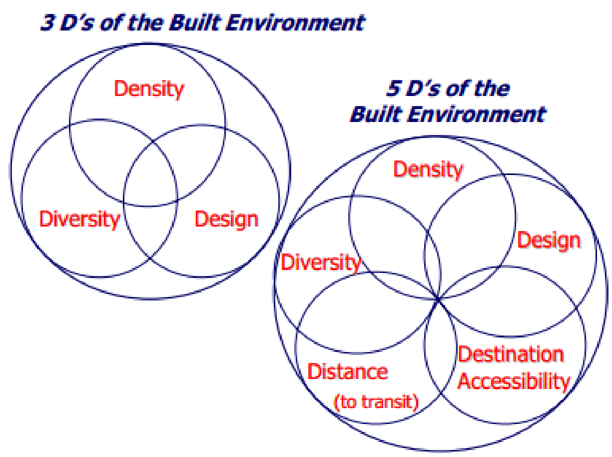

Figure 9. The 3 and 5 Ds of Built Environments: Density, Diversity, Design, Destination Accessibility, and Distance to Transit
(source: Cervero & Murakami, 2008)

The 5Ds, characterizing the built environment in TOD context, are presented in more detail below.

2.2.2. The 5 Ds of built environment

In order to define the 5 Ds characterizing the built environment in relation to transportation objectives and in particular affecting travel behavior, a literature search was realized. The reason for focusing on the general view of travel behavior and not only station choice behavior is the scarcity of the literature available for the latter purpose mentioned. The literature review was made by using an online database, Science Direct, based on keywords such as station context, station characteristics, TOD, travel behavior, (railway) station characteristics, route mode choice, and transit ridership. The identified built environment characteristics can give an insight in how the station's environment can be characterized in the context of travel behavior aspects, as well. Moreover, the review of the available literature revealed the fact that travel behavior is not affected only by the built environment, but by station itself characteristics, personal characteristics of the traveler and trip attributes, as well.

The rest of the sub-chapter is organized as follows: the literature regarding the relationship between urban form and travel behavior will be presented first and the characterization of the 5Ds is next; characteristics of the stations, characteristics of the trip and travelers will be introduced afterwards.

Literature review regarding travel behavior – urban form relationship

Appendix 1. Literature review matrix contains the characteristics selected from the available articles. It can be seen that even if not amply addressed, there are various attempts to examine the relationship between urban form and travel behavior. This is why an extensive literature review was needed. Moreover, there are not many articles addressing the relation between railway stations' (built) environment and travel behavior (or railway station choice behavior), so BRT/light rail/train/metro stations were included in the literature review matrix (e.g. Atkinson-Palombo & Kuby, 2011; Cardozo, et al., 2012; Eboli & Mazzulla, 2011; Jiang et al., 2012; Kuby, et al., 2004; Rodríguez, et al., 2009; Sohn & Shim, 2010; Zhao, et al., 2013).These components of transport systems are implemented and have a significant level of success all over the world.

Figure 10. Travel behavior and urban form
(source: http://www.thinksiliconvalley.com/)

As stated earlier, even though it is not an amply addressed topic, analyzing the relationship between urban form and travel behavior is a complex task and several different approaches have been used (Estupian & Rodríguez, 2008; Handy, 1996). According to Handy (1996) there are five basic research methodologies: simulation studies, aggregate analysis, disaggregate analysis, choice models and activity-based models. Most of the studies, however, can be categorized under the first three approaches. The differences among these methodologies appear from the complexity of representing urban form and socio-economic factors (as independent variables) and travel characteristics (as dependent variables), but also from the analysis techniques used (varying from tests of correlations, regression analysis, multivariate analysis to theoretically-based behavioral models). In addition to the studies mentioned above, there are the direct models wide spread within the literature (e.g. Gutiérrez, et al., 2011; Kuby et al., 2004; Loo, et al., 2010; Zhao, et al., 2013). These direct models are fond on multiple regression analysis and are used to estimate transit ridership as a function of station environments and transit service characteristics (e.g. Cervero, 2006; Kuby, et al., 2004).

A closer look at the matrix included in Appendix 1 will reveal that the main feature defining the analysis related to the relationship between urban form and built environment is diversity. The purposes of the papers reviewed are dispersed. Apart from the articles which are belonging to one of methodologies briefly described above, some characteristics were selected form already made literature reviews (e.g. Litman, 2012) and policy recommendations (e.g. Kamruzzaman, et al., 2014). The variability can also be seen among the statistically significant variables, shown in light grey color in Appendix 1. They are not only diverse in terms of numbers, but their statistically significance differs from model to model or from paper to paper. For example, "distance" proved to be significant in the models employed in some papers (Brons, et al., 2009; Cervero & Murakami, 2008; Debrezion, et al., 2009; Duncan & Christensen, 2013; Jiang, et al., 2012 Loo et al., 2010), but not statistically significant in others (Yang et al., 2013; Sohn & Shim, 2010; Zhao et al., 2013; Litman, 2012; Loo et al., 2010). The same situation can be seen for the respondents' characteristics. However, it must be underlined that the characteristics selected from literature review papers and policy recommendations were included under the non-significant category. In addition, there is no general agreement in describing the 5 Ds. For example, Litman (2012) and Yang, et al. (2013) are defining the destination accessibility (one of the 5 Ds) from the perspective of walking, focusing on sidewalk/path quality, street crossing aids, etc., while the same variables are used by Rodríguez, et al. (2009) or Cervero & Kockelman (1997) to characterize the design dimension of built environment.

5Ds of the built environment in the TOD context

The built environment dimensions are characterized under the 5Ds (core dimensions): density, diversity, design, destination accessibility and distance to transit based on the findings presented in the papers of Cervero & Kockelman (1997) and Cervero & Murakami (2008) since these are reference papers in the TOD literature. This division of built environment features adopted in this thesis was widely used within the literature (e.g. Aditjandra, et al., 2013; Cervero, 2002; Gutiérrez, et al., 2011; Handy, et al., 2005; Kuby, et al., 2004; Rodríguez, et al., 2009; Sung & Oh, 2011; Zhao, et al., 2013).

In their paper, Jiang, et al. (2012) were stressing the importance of the station environment in influencing the distance (access or egress) travelers will be willing to walk to access the station. This decision is affected by both, actual distance and times (influenced by directness of routes, crossing aids, for example) and the perceived/subjective times and distances. The latter are believed to influence more the overall walking experience; by extrapolating this finding, it is not difficult to say that the perception of the traveler on the built environment dimensions can affect the overall station experience.

DENSITY

Density can be defined as "having enough residents, workers, and shoppers within a reasonable walking distance of transit stations to generate high ridership" (Cervero & Murakami, 2008). Density reflects the intensity of land use developments for housing, employment or other purposes (Cervero, 2002). In other words, the static density (e.g. number of shops, number of houses) can be connected with the dynamic density (e.g. number of workers, number of residents). An outcome of higher densities is the lower level of solo-commuting, especially at the trip destination and for work trips (Cervero, 2002).

Figure 11. Density (source: Adapted from TOD Standard of Institute for Transportation & Development Policy, 2014)

Building a table which contains variables describing each dimension, Cervero & Kockelman (1997) suggested that population (population per developed acre), employment (employment per developed acre) and accessibility of jobs should fall under the umbrella of density. Sung & Oh (2011) integrated under the density category commercial density as well.

Density, next to diversity of land uses (which will be next presented) can contribute to an increase sense of public safety (California Department of Transportation, 2005).

DIVERSITY

Diversity is referring to "a mixture of land uses, housing types, building vernaculars, and ways of circulating within neighborhoods" (Cervero & Murakami, 2008). Enhancing diversity of land use around the stations has as purposes the achievement of a better coverage of public transport; induce transit and the decrease of car usage. Diversity can contribute to a better distribution of public transport demand in time (lowers the unbalanced number of travelers during the peak and off-peak hours) and in space (refers to the direction of flow) (Zhao, et al., 2013).

Cervero & Kockelman (1997) include under the density class: dissimilarity index ("proportion of dissimilar land uses among hectare grid cells within a tract"), entropy ("mean entropy for land-use categories among hectare grid cells within half mile radius of each hectare grid cell within a tract"), vertical mixture (proportion of commercial/retail parcels with more than one land-use category on the site), per developed acre intensities of land uses classified as residential, commercial, office, industrial, institutional, parks and recreation, activity center mixture, commercial intensities (per developed acre rates of convenience stores, retail services, supermarkets, eateries, entertainment and recreational uses, auto-oriented services, mixed parcels), proximities to commercial-retail uses.

In their study, Mavoa, et al. (2012) categorized the land-use destinations into education (schools, universities, etc.), financial (banks, ATMs, post offices), health (pharmacies, hospitals), shopping (convenience stores, supermarkets) and social and recreational (cinemas, cafes and restaurants, parks). Among the articles, several diversity indices were taken into account (e.g. Cardozo, et al., 2012; Cervero, 2002; Sung & Oh, 2011; Loo, et al., 2010).

Figure 12. Diversity (source: Adapted from TOD Standard by Institute for Transportation & Development Policy and NS, 2014)

Most common one was the so-called "land-use mix" or "land-use diversity index", defined by Cardozo, et al. (2012) as "reciprocal of the variation coefficient of the area covered by different land uses within the 800 m catchment area (higher values indicate higher diversity of use)". Rodríguez, et al. (2009) defines the "land-use mix" as "degree of pedestrian-friendly land use mix "assigning "0" for industrial or vacant;"1 or 2" for low, high respectively density residential; "3" for commercial and "4" for mix residential/commercial. The "residential/commercial mix" index or "total commercial/residential floor area" is also present in the study of Sung & Oh (2011) and Loo, et al. (2010). In other studies, distinction between residential floor area ("total floor area of residential buildings within walking distance"), business floor area ("total floor area of office buildings within walking distance"), commercial floor area ("total floor area of commercial buildings within walking distance") or other area (Sohn & Shim, 2010; Zhao, et al., 2013). However, including residential, business and commercial floor area can lead to correlation with the intensities, grouped under first dimension, of density. Including ways of circulating may lead to correlation with the design dimension.

DESIGN

In numerous travel-behavior related studies, the design represents the quality of walking environment and physical configuration of the street networks (e.g. Cervero, 2002; Litman, 2012; Rodríguez, et al., 2000; Sung & Oh, 2011).

Design "embodies physical features, site layouts, aesthetics, and amenities that encourage walking, biking, and transit riding as well as social engagement" (Cervero & Murakami, 2008). An important accent should be on aesthetics and amenities, "on livability through high quality and coordinated urban designs, ample landscaping and greenery, display of the arts, and preservation of natural features; aesthetics become all the more important in TODs so as to soften peoples' perceptions of surrounding densities" (Cervero & Murakami, 2008). The idea of focusing on the aesthetics of the environment of the station was also promoted in the study of Cascetta (2013). Analyzing the case of the Regional Metro System (RMS) of Naples, Cascetta (2013) pointed out that the beauty/aestetics of the area will influence people's choice of a specific stations when two options are available between the same departure and destination points. For commuting between Aversa center and Napoli historical center, travelers have two options: use a high quality station or a standard quality station. The findings suggested that the choice is influenced by the beauty of the area. Moreover, in their study, Loo, et al. (2010) found that years of operation variable (in characterizing a station) is statistically significant in forecasting transit ridership in one of the models emplyed by in the study. They associeted the large number of travelers using an old(er) station also with citizens' preference to live, work or shop in the "old urban area or city center" (Loo, et al., 2010). This conclusion suggests that the building architecture, the aethetics of the building itself, the history of the place can attract travelers toward this particular station in comparison with a new, modern one. Moreover, Cervero & Murakami (2008) stressed the importance of a design where people can feel comfortable; comfort was defined as "a human-scale setting whereby people are not overwhelmed by the height of buildings, robbed of daylight by the cast of shadows, or excessively subjected to such elements as wind eddies. Comfort is particularly important for rail station areas where real estate markets exert pressure to maximize profits by increasing densities at and near station entrances".

Figure 13. Pedestrian amenities
(source: http://www.dailytonic.com/)

Cervero & Kockelman (1997) characterized the design attribute via: streets (predominant pattern: regular/curvilinear grid; proportion of intersections that are 4 or 3 ways etc.), pedestrian and cycling provisions (proportions of block with sidewalks, plating strips, street trees, etc.) and site design.

Figure 14. Kowloon Mass Rapid Transit Station in Hong-Kong
(source: http://en.wikipedia.org)

Even though Cervero & Kockelman (1997) underlined that "micro-design elements are too 'micro' to exert any fundamental influences on travel behavior; more macro-factors, like density and the comparative cost of transit vs automobile travel, are the principal determinants of commuting choices", Rodríguez et al. (2009) found evidence that not only the aggregated neighborhood variables, but also micro-scale, segment specific characteristics can explain observed pedestrian counts. Micro-scale elements include the presence of sidewalks and their quality (width, continuity, maintenance), street traffic, block size, presence of traffic control devices to help pedestrian in street crossing (crosswalks, signals, stop signs) and presence of amenities (benches, trash bins) (Rodríguez, et al., 2009).

Ewing & Cervero (2001) suggested that a pedestrian-friendly environment is not necessarily equal with a transit-friendly environment. Therefore, next to pedestrian-friendly design, the satisfaction in relation to bike or car routes should not be undermined.

DESTINATION ACCESSIBILITY

Destination accessibility refers to the extent to which public transport is connecting in an efficient manner the station area and the activities within it (Cervero & Murakami, 2008). "Accessibility has been recognized as one of the most important factors affecting transit use", was noted in the paper of Gutiérrez, et al. (2011). Therefore, this issue is addressed in many papers (e.g. Brons, et al., 2009; Cervero, 2002; Debrezion, et al., 2009; Gutiérrez, et al., 2011; Handy, et al., 2005; Litman, 2012; Marshall, 2013; Mavoa, et al., 2012; Redman, et al., 2013; Sung & Oh, 2011; Yang, et al., 2013). The reason why it received so much attention is the fact that "improvements to the accessibility of stations might be cheaper and overall more cost effective than improvements to the actual train journey" (Givoni & Rietveld, 2007). It can be stated that improving the accessibility of the railway station by public transport and non-motorized modes, railway use is enhanced, and in addition social exclusion is lowered, and car usage and environmental impacts are decreased (Givoni & Rietveld, 2007).

Figure 15. Connecting public transport, Arnhem Central Station, The Netherlands (source: http://www.treesteps.nl/)

A railway journey is predominantly a segment of a trip chain that involves a journey to and later on, from the railway station using different modes of transport. Providing easy access to stations can contribute to the achievement of a better doo-to-door travel and increase attractiveness of railway. "Such integration depends very much on the extent to which the interchange between transport modes and services is seamless" (Givoni & Rietveld, 2007).

In the Netherlands, cycling (33% of railway passengers are biking to the station), public transport (bus/tram/metro, 22% of the railway users) and walking (30%) are the main modes used to go to and to return from the railway station (Bertolini, et al., 2005; Givoni & Rietveld, 2007). Therefore, providing bike shelters, good public transport connections and walking ways are most likely to increase the attractiveness of the railway station. Only 10% of the travelers are using the car to access the train station (Bertolini, et al., 2005). However, the importance of Park and Ride provision should not be underestimated. In their article, Duncan & Christensen (2013), noted: "P&R has proved an extremely effective means of attracting riders to rail". Moreover, in order to be consistent with the modes that travelers are using to access the station, people arriving with the car as passengers require the provision of drop-on/drop-off points to be assessed (the presence of drop-on/drop off points can increase the attractiveness to use the train station).

Accessibility is also improved by design factors like the presence of intersection of sidewalk density, sidewalk quality (Cervero & Kockelman, 1997; Moniruzzaman & Páez, 2012).

DISTANCE TO TRANSIT

Regarding distance to travel, Cervero & Landis (1993) found that more people are using public transport instead of their own cars if the public transport stop is close to their home/work. As the walking distance between final destination/origin of the trip and station increases, less likely it is that people will use the transit.

Nevertheless, by addressing the problem departure station choice, Debrezion, et al. (2009), revelead that in approximatly 47% of the cases, passengers were selecting to use a station which was not the nearest to their places of residence. This finding suggested that distance to the railway station is not the strongest characteristic that people are taking into consideration when choosing to use a particular station. Station and surroundings oriented factors should be taken into account when analyzing the choice of a station.

2.2.3. Station characteristics

In this part the research thesis way in which NS is seeing the station and the station characteristics found in the literature are introduced.

According to NS, the station lay-out consists in four layers. They can be divided two by two in relation to approaching the station as a transportation node (so "moving process") and as a place (the "staying process"). These two processes can be further decomposed into 4 functions (as in Figure 16):

- Transfer, which is the core of the station;
- Service, supporting the travel activity by providing information;
- Commerce and social , by providing shops and meeting facilities (catering);
- Spatial development, the transition for the urban fabric, providing living, working and shopping facilities

The first 2 layers are referring to the "hard" elements that a station has to possess (infrastructure, travel information etc.), while the last 2 are the "soft" elements and can be assessed among the travelers in order to improve the perception about the station (in terms of comfort via seats, shops, pubs, restaurants, lockers, elevators, escalators or a pleasant experience itself via the design, art, smell, sounds, cleanliness) and therefore to contribute to an increased use of the railway station. In the pyramid of Customer Needs comfort and experience is at the top of it (as it can be seen in Figure 17).

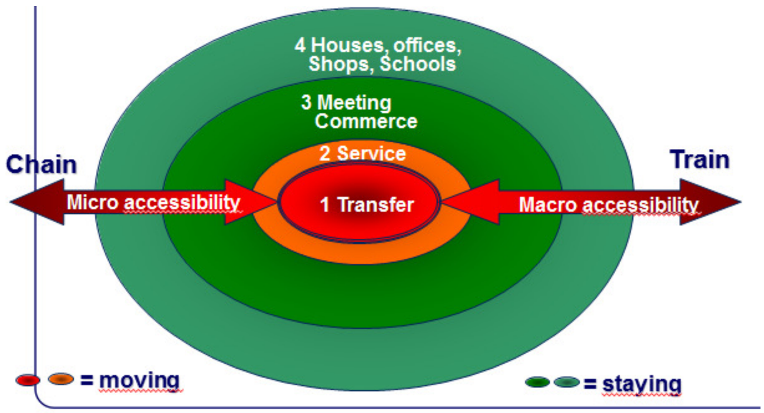

Figure 16. Station lay-out in 4 layers (source: van Hagen, 2013)

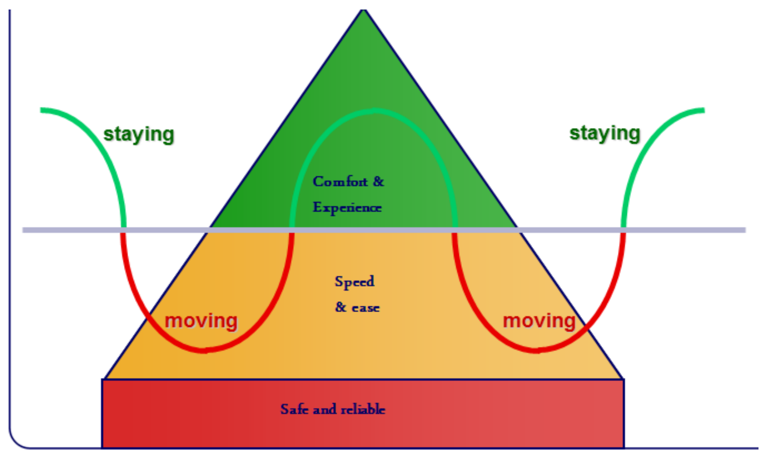

Figure 17. Pyramid of customers' wishes balanced between node and place functions of a station (source: van Hagen, 2013)

Within the literature, there is evidence that characteristics of the stations are affecting transit ridership or in other words, the station choice behavior. Many articles are paying attention to factors of influence such as relative location of the station, level of service or station function (e.g. Atkinson-Palombo & Kuby, 2011; Brons, et al., 2009; Duncan & Christensen, 2013; Eboli & Mazzulla, 2011; Gutiérrez, et al., 2011; Jiang, et al., 2012; Li & Hensher, 2011; Loo, et al., 2010; Zhao, et al., 2013). A brief overview of the most important findings from the literature will be further given.

Station function and level of service

Level of service (the middle of the pyramid of customers' needs, including ease and speed) has a positive relationship with the use of station, meaning that higher levels of service bring more people to the station. The importance of the level of service is emphasized in the section "Railway station choice behavior", in which the models employed in the presented articles included several service-related characteristics of the station (e.g. intercity status of the station, frequency of service, level of information, ticket price, waiting time etc.).

The most important attribute which falls under the category of level of service is travel-time reliability, increasing the likelihood of using the railway as a transport mode (Brons, et al., 2009; van Loon, et al., 2011).

Brons, et al., (2009) analyzed the characteristics of service as dimensions of travelers' satisfaction (see Appendix 1). Significant weights were found for travel comfort (riding and sitting, heating and ventilation, cleanliness inside the train), travel time reliability, station organization and information (station overview, signage, cleanliness, protection against wind, rain and cold, travel information at the station), service schedule dynamic information, price-quality ratio, accessibility, ticket service, personal safety. However, the findings suggested that the Dutch passengers (the study was carried out in the Netherlands) are most satisfied with “station information and organization”, with “soft elements” (comfort, safety), while the dimensions related to “hard elements” (accessibility, service schedule, travel time reliability) brought a lower level of satisfaction. Moreover, frequency of public transport seems to have a positive association with transit ridership/ attractiveness to use railway network (Debrezion, et al., 2009).

In the Netherlands, NS Stations is assessing customer satisfaction (surveys in the train) and station experience (surveys at the platform). For the latter, there are three basic surveys for station under construction “SBO(V)”, large stations “SBM Large” and small stations “SBM Small”. These surveys are held once every season (4 times for the big stations vs. 1 time for small ones). Via these questionnaires the travelers are asked to express their general opinion about the station, as well as to rate the atmosphere, invitingness, functionality (orientation and transfer), cleanliness, safety.

In addition to the study of Cascetta (2013), who emphasized the importance of the value of beauty of a station and its surrounding area, in their study, Loo, et al. (2010) found that years of operation variable (in characterizing a station) is statistically significant in forecasting transit ridership, for Hong Kong case. They associeted the large number of travelers using an old(er) station also with citizens’ preference to live, work or shop in the “old urban area or city center” (Loo, et al., 2010). This conclusion suggests that the building architecture, the aesthetics of the building itself, the history of the place can attract travelers toward this particular station in comparison with a new, modern one.

Comfort, station organization, as well as the aesthetics of the station can contribute to a pleasant atmosphere and invitingness at the station level (therefore, it can provide some understanding for the atmosphere and invitingness assessments at station level, which NS is concerned about). On the other hand, a vital element that can break this circle is crowding (see Figure 18). In the literature there is evidence that the density gradient (or crowding level) has a significant importance in choosing to access a station (Jiang, et al., 2012). It is an important factor to be assessed in order to identify if the density gradient is a major problem at the station level (no matter if it is the access to platform, so the walk inside the station, or at a platform level). “Crowding can be a potential threat both to the health of the public transport industry (e.g. delays and low efficiency) and passengers (e.g. safety and stress issues)” (Li & Hensher, 2011). Assessing and solving the crowding problem is also an important factor in improving the attractiveness of a railway station. Moreover, crowding can affect the perception of safety level.

Within the literature, there is another division when referring to station function. As it can be seen from the articles included in Appendix 1, in terms of station function (or characteristics) a distinction is made among: airport (the presence of a station at an airport), university (station serves an university), terminal (a station at the end of a line), major interchange station, intermodal, intermediate or transfer (e.g. Atkinson-Palombo & Kuby, 2011; Duncan & Christensen, 2013; Gutiérrez, et al., 2011; Jiang, et al., 2012; Kuby, et al., 2004; Loo, et al., 2010; Zhao, et al., 2013). The number of riders and therefore, the attractiveness of the station, are related to the type of the station (Gutiérrez, et al., 2011). Terminal and intermodal stations are attracting more riders, the former due to a larger catchment area and the latter because of the connection with other transport modes,

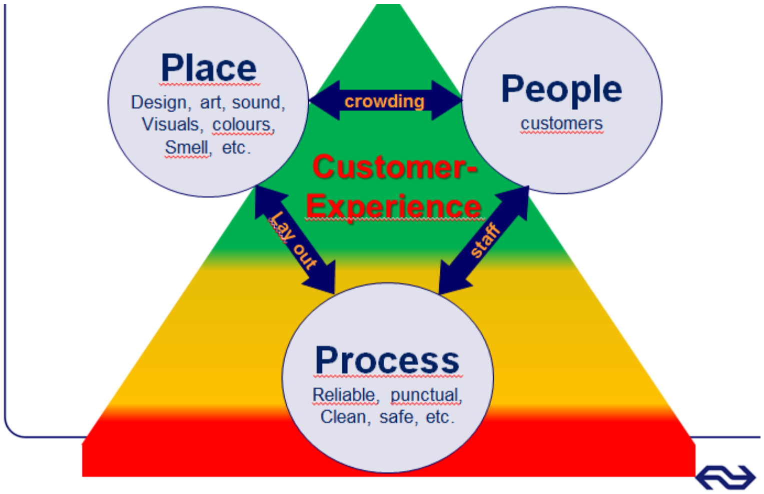

Figure 18. Three management dimensions for customer satisfaction (source: van Hagen, 2013)

bringing more riders to the station (e.g. Gutiérrez, et al., 2011; Kuby, et al., 2004). (Major) interchange stations are more attractive for passengers than intermediate stations (Gutiérrez, et al., 2011). Moreover, when compared with the terminal station, transfer station seems to be more significantly associated with station boardings, transfer stations being preferred over single-line stations (the attractiveness of the station increases with the number of lines) (e.g. Cardozo, et al., 2012; Gutiérrez, et al., 2011; Kuby, et al., 2004; Sohn & Shim, 2010).

Station location

Another characteristic that was taken into account in the literature is the location of the station, (far/close/in) CBD, suburbs or down-town, in attracting travelers (e.g. Duncan & Christensen, 2013; Jiang, et al., 2012; Kuby, et al., 2004; Zhao, et al., 2013). The centrality of the station within the network (or the distance between CBD and the station) has a significant weight in the decision-making process of the travelers on which station to use, "since people tend to use public transport more frequently in central areas than in peripheral ones" (Gutiérrez, et al., 2011).

2.2.4. Travelers-related characteristics

The importance of socio-demographics (the other term used in the literature to refer to trip-maker's attributes) as explanatory factors of mobility and travel behavior is confirmed in the literature (e.g. Cervero, 2002; Curtis & Perkins, 2006; Gutiérrez, et al., 2011; Handy, 1996, Jiang, et al., 2012; Moniruzzaman & Páez, 2012). In the literature review regarding the methodologies employed to explore the link between urban form and travel behavior, Handy (1996) conclude that for most dimensions of travel, socio-economic attributes can capture more variation then the spatial factors. Therefore, it is important to consider both types of factors (travelers' characteristic and urban form ones) in assessing different aspects of travel behavior.

By addressing the effect of socio-demographic variables and travel behavior, a number of papers discovered significant relationships between travel behavior and attributes such as gender, age, income, car ownership, employment, education, driver's license (e.g Brons, et al., 2009; Jiang, et al., 2012; Kuby, et al., 2004; Loo, et al., 2010; see Appendix 1).

In their highly acclaimed paper, Cervero and Kockelman (1997) presented a list with standard demographics and household variables associated with travel demand. Socio-demographics of trip makers include age, gender, employment, ethnicity, possession of driving license, while household of trip-maker can be characterized in terms of size (number of members, number of individuals under 5 years old (pre-school child dependency), number of individuals 5 years old and over (active household members)), vehicle ownership, income and housing tenure.

For the focus of the present paper, to determine the effect of stations' environment on travelers' train station choice behavior, the following socio-economic characteristics were included: age, gender, employment status, education, car ownership and household composition since these features are believed to explain the variation in travelers' decision-making. These attributes are detailed further.

Age

Analyzing the distance people will walk to access the transit system, Jiang, et al. (2012) included in their paper a review of factors influencing transit walk access distance. Statistically significant evidence of the effect of age on walking distance was found among the reviewed articles. However, the results of the model employed by Jiang, et al. (2012) to assess the distance people will walk to the transit stop, did not show a clear effect of age. Sub-levels of age were: <20; 20-40; 40-60; >60 (years old) and the findings suggested that people aged 40-60 walk less than the rest of the groups, but on the other hand over 60 and under 20 to 40 groups seemed to walk the same distances. The interpretation given by authors was "This result should be interpreted with some caution. For example, older adults may have a lower value of time, seat privileges on the system, and enjoy benefits of a free ticket policy which give them an incentive to walk more" (Jiang, et al., 2012).

Cao & Jordan (2009) found a negative association between age and choice of park and ride.

Gender

Variation in travel behavior explained by gender was a significant factor among several papers (Jiang, et al., 2012). Curtis & Perkins (2006) discovered in their literature review that "women made fewer journeys to work by car and more journeys for maintenance activities such as shopping and child-care".

Employment status

Evidence that employment (status) has a significant effect on travel behavior is available within the literature (e.g. Cardozo, et al., 2012; Curtis & Perkins, 2006; Kuby, et al., 2004). This feature is important due to trip duration flexibility/inflexibility. For example, being an employee or a student in comparison with unemployed or a pensioner involves less flexibility in the duration of the trip.

Education

Rodríguez, et al. (2009) found that educational attainment (years of schooling 0-17) is statistically significant in explaining the pedestrian activity around BRT stations. This is an important result for the purpose of this present study, since TOD is focusing on walkable-areas around transit stops in which a mix of activities and land-use destinations take place.

Household composition
According to Cervero and Kockelman (1997) and Curtis & Perkins (2006), household composition influences travel behavior. Household composition can be characterized in terms of: number of household members, number of children (under 5 years old (pre-school child dependency) and 5 years old and over (active household members)) (Cervero & Kockelman, 1997).

Car ownership
The presence of a car within the household was a variable present in a significant number of articles (Cervero, 2002; Cardozo, et al., 2012; Debrezion, et al., 2009; Gutiérrez, et al., 2012; Jiang, et al., 2012); car ownership is statistically associated with mode choice.

2.2.5. Trip-level characteristics
In the section "trip-level characteristics", the characteristics identified in the literature review are discussed in relation to travel behavior or station choice behavior and urban environment.

Purpose of the trip
Jiang, et al. (2012) divided the trip purposes into: work, school, shopping and recreational, but their findings suggested that purpose is not significantly affecting walk access distance. However, due to duration flexibility for the last two purposes, factors such as design, diversity, opportunities offered around train station can play a significant role in choosing a specific railway station. For work and education purposes, accessibility or distance to transit can weight more.

Station use frequency
Another important characteristic that can be taken into account to explain station choice behavior is the journey frequency from/to a specific station. Travelers who often access a specific station know it better than the ones who do not use it regularly. Nevertheless, both opinions are important: for the first in order to improve it and so to keep them as active users and for the latter to develop it in such a way that will increase the attractiveness. Brons, et al. (2009) assessed the overall passengers' satisfaction with the rail journey and in particular, how much access-to-the-station counts as part of the rail journey, for both frequent (using the station more than 4 days/week) and infrequent travelers. They discovered important differences between the two groups (such as the fact that for infrequent travelers the accessibility variable is more important than for the frequent travelers).

Access mode
This characteristic became important in the travel behavior context mainly due to a paradigm shift: from mobility-oriented planning (transport system performance of physical movement of people and goods) to accessibility-based planning (which takes into consideration broader possible solutions to transportation problems) (e.g. Curtis & Scheurer, 2010; Litman, 2012; Ratner & Goetz, 2013). Alternative modes are considered and their implications or effects in relation to the accessibility of a station (train station, in the present research): wider catchment area, different speeds according to the used mode (walking-the

slowest, to auto or public transport – higher speed). As specified earlier, in the Netherlands, the most used access mode is cycling, followed by public transport and walking.

2.3. Sustainability in TOD context

TOD-based planning was applied in many cities within Europe and United States bringing a lot of benefits (Knowles, 2012; Ratner & Goetz, 2013). By supporting the modal shift from car to transit, the physical activity is improved (Morency, et al., 2011). Cervero (1996) demonstrated that density and mixed land-uses contribute to less car ownership, shorter commutes and commutes distances and so lower average of vehicle-miles-traveled per person. In the same article, Cervero integrated also evidence from his previous research. He found that 3% increase in the share of transit and ride-sharing commutes corresponds to every 10% increase in floor space allocated for retail commercial purpose. This results also into decreasing CO2 emissions and less energy consumption. Moreover, Cervero & Kang (2011) discovered that land-use intensification and improved access increase the real-estate value, particularly the residential, finding resulting from the analysis of BRT in Seoul, Korea: "Land price premiums of up to 10% were estimated for residences within 300 m (meters) of Bus Rapid Transit (BRT) stops and more than 25% for retail and other non-residential uses over a smaller impact zone of 150 m".

In addition, Dorsey & Mulder (2013) stated that livability, efficiency, flexibility /choice possibilities are other possible benefits. Livability is in connection with providing open spaces, access to service, clean air, better mobility; efficiency is achieved throughout mixed-use, pedestrian friendly land-uses not only on a local, but regional level; flexibility and choice opportunities are in close connection with the diversity dimension of TOD: more choices in terms of housing, shopping, and mobility than the suburban model of development. Moreover, by providing more options in terms of housing (apartments, studios etc.), the affordability can be increased. Table 1 summarizes the benefits of TOD.

Table 1. The benefits of TOD **(source: Adapted from Dorsey & Mulder, 2013)**

Economic benefits	Social benefits	Environmental benefits
Housing affordability	Improved physical activity	Less CO2 emissions
Increased real-estate value	Community identity	Less energy consumption
Increased demand for retail commercial space	Shorter commutes and commutes distances	Improved air quality
Decrease household transportation spending	Mobility, housing, and community choices	Decrease the congestion level
Reduced costs with the infrastructure spending	Urban revitalization	Brownfield redevelopment
Increased transit ridership	Attention towards preserving the open spaces	Livability
	Enhance public safety	Sustainability

From the available benefits, sustainability is going to be introduced in the next paragraphs since it is a modern topic, a goal the nowadays society is aiming at.

Urban transportation planning requires to combine the transportation network and travel solutions with the land-use planning, due to the focus on accessibility and public transport.

This integration can be the framework towards more sustainable and compact cities, as well as more sustainable transportation (e.g. Bertolini, et al., 2005; Curtis & Scheurer, 2010). Jeon, et al. (2013) stated in their paper that “here is emerging consensus that the issues of transportation system sustainability should be incorporated at the transportation planning level, to have any policy effect on decision making”.

There is a general agreement within the literature that sustainability has a variety of definitions (Jeon, et al., 2013; Marshall, 2013; Reusser, et al., 2008). However, more definitions are depicting the preservation need of natural resources for the welfare of present and future generations (Reusser, et al., 2008). In relation to a sustainable transportation system, there are four essential attributes that define it, as it can be seen in Figure 19 (Jeon, et al., 2013). However, Marshall (2013) identified only three pillars which are defining the sustainability: environmental, social, and economic sustainability. Therefore, system effectiveness is the attribute that distinguishes the two approaches in relation to sustainability.

Sustainability in spatial development patterns and infrastructure involves urban forms which favor fewer and/or shorter trips, modes alternative to cars (Reusser, et al., 2008). As mentioned before, TOD is promoting these outcomes by encouraging the developments (facilities, houses, etc.) near public transport infrastructure, in this way providing also accessibility. Moreover, a comparison between Table 2 (The benefits of TOD) and Figure 19 (The four essential factors of transportation system sustainability) convey the close relation between TOD outcomes and sustainability principles.

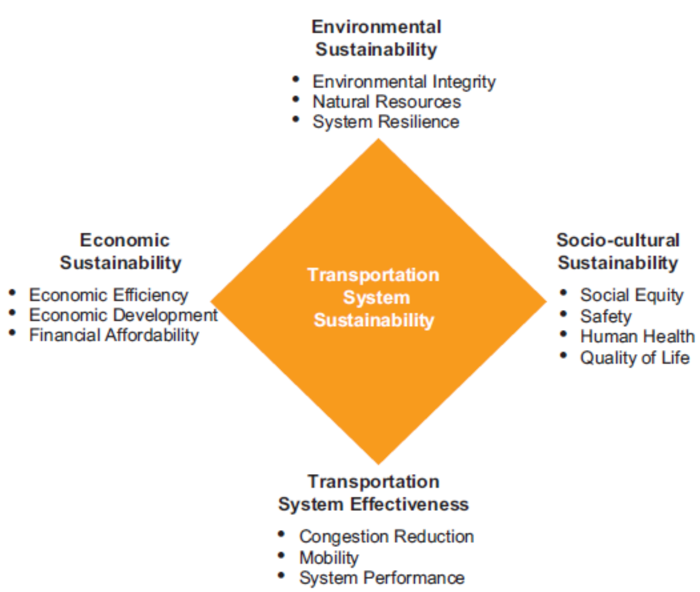

Figure 19. The four essential factors of transportation system sustainability (source: Jeon, et al., 2013)

Next to TOD and accessibility (discussed before in this report), another concept focusing on sustainability is livability. The main difference of the latter in comparison with the first ones is the local component, livability being a *community-level* strategy for economic development, improved transportation choices, accessibility, pollution exposure, public health, and social equity (National Association of Regional Councils' Livability Literature Review 18: A Synthesis of Current Practices, 2012). A brief explanation of livability concept is given below.

Livability is a concept linked to sustainable transportation and with TOD as well. It can be seen as an outcome/method to measure the (regional) performance of TOD (Marshall, 2013). In the attempt of understanding this concept, there are many definitions available in the literature. However, the Sustainable Communities Partnership (created by U.S. Department of Transportation: U.S. DOT, the U.S. Environmental Protection Agency: U.S. EPA and the U.S. Department of Housing and Urban Development: U.S. HUD, in 2009) is defining the six principles that can consist in a framework to define the concept of livability: Provide more transportation choices, Expand equitable, affordable housing choices, Enhance economic competitiveness, Support existing communities, Coordinate and leverage federal policies and investment, Value communities and neighborhoods. Unlike TOD and sustainability, the concept of livability has a sound local component, being focused more on the "community experience in a specific place". In contrast, sustainability strategy is a high-level one, focusing on "how to sustain human society without harming the natural environment" (National Association of Regional Councils' Livability Literature Review 18: A Synthesis of Current Practices, 2012). The local component arises from the particular mix of attributes which defines the communities. These characteristics can vary over time and from place to place and they are emerging from local politics, trends in perceived quality of life, and preferences of people living in a specific context (Miller, et al., 2013). The built environment should reflect the group's shared expectations since it is developed to be more permanent, convenient and pleasing (Niraarta Samadhi, 2001). This is the reason why in implementing successful TOD, the culture of the country/community should be taken into consideration.

Livability of public spaces, neighborhoods, cities, or regions can be improved by promoting the public involvement of citizens in the planning, transformation, and beautify of the surrounding environment. Stressing the importance of community involvement is a feature promoted by the concept of place-making, as well. Place-making focuses on providing affordable housing, economic development and transportation choices (National Association of Regional Councils' Livability Literature Review 18: A Synthesis of Current Practices, 2012). It is a multi-disciplinary approach of public spaces, helping the planners, designers, engineers to take into consideration a community-driven development (Projects for Public Spaces, 2013). The purpose of place-making is to achieve a balance among built, ecological, cultural and social, even spiritual qualities of a place to maximize shared value. Next to these, planning and place-making are greatly influenced by transportation, shaping the form of the places. For example, the dominance of a TOD infrastructure results in higher densities and mix-use, more people-oriented places with public transit accessibility (Dorsey & Mulder, 2013).

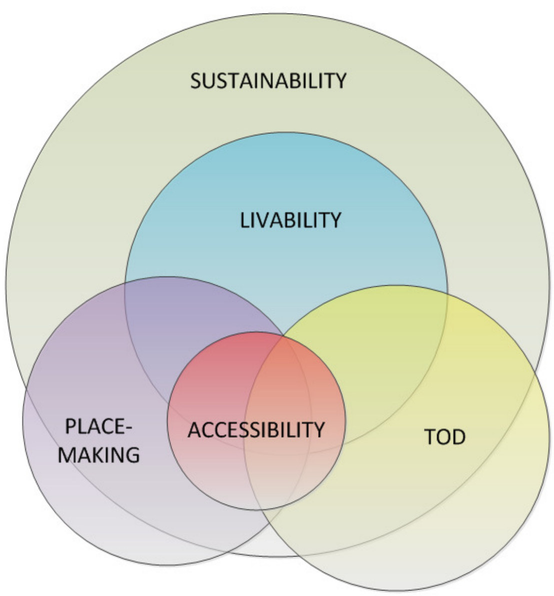

Figure 20. The relationship among sustainability-livability-place-making-TOD-accessibility concepts

Dorsey & Mulder (2013) demonstrated thorough a case study of Ogden, Utah, that the role and importance of community activism should be taken into account when selecting transit and defining places. By promoting a community-driven TOD, the redevelopment and investment will be directed towards making a place in which community needs are headlines. The connection among all the concepts presented above is synthetized in Figure 20.

2.4. Transit-Oriented Development in international context

Atkinson-Palombo & Kuby, (2011) noted that "TOD can take a variety of forms and individual station areas can serve different but complementary functions within a system". What makes the international context interesting is the fact that TOD is focused on the stations serving all high-capacity public transport services – BRT, train, metro, tram or bus. Due to this several stations (classified here by modes of transport), the database is massive. Some successful worldwide examples were chosen for exemplification (see Appendix 2. TOD in pictures, as well). A summary of the selected examples is given in the table below.

Table 2. International cases of TOD

Continents	Cities, Countries	Description
Europe	Copenhagen, Denmark	One of the earliest planned TOD (after World War 2) occurred here, when the Danish Town Planning Institute created the Finger Plan ("Egnsplan") in 1947. Ørestad is the best developed part of Copenhagen, built around stations located on a metro line (Knowles, 2012).
	Stockholm, Sweden	"Planetary Cluster Plan" was promoting developments along defined growth axes in a similar way to Copenhagen's Finger Plan (Cervero, 2006).
	Malmo, Sweden	TOD focused on railway stations
	Vauban district, Freiburg, Germany	TOD can be traced in the tramway network, linking the peripheral sites with the center of the city
USA	Oregon, Portland	The TOD planning strategy public transport networks (tram, bus and trains) have to link all the new developments
	Denver, Colorado	Train relared TOD
	San Francisco, California	TOD can be traced in Bay Area Rapid Transit (BART)
Canada	Vancouver	New developments were created around Skytrain lines
	Calgary	Developments are located along the subway line
	Toronto	Very successful TOD community called The Bridges, located in the community of Bridgeland
Latin America	Bogota	Transmilenio, its BRT system started to be operated in 1990 and it is a good example of TOD
	Curitiba, Brazil	BRT system developed according to TOD concept
Asia	Hong Kong	It is an illustrative for metro Mass Rapid Transit (MRT)
	Singapore	This city-state has applied Scandinavian planning principles in its structure plan – "Constellation Plan", promoting the developments of new towns around a central core, with interspersed with greenbelts (Cervero, 2006).

2.5. Transit-Oriented Development in Dutch context

In the section "Transit-Oriented Development in Dutch context", the particularities of TOD in the Netherlands are discussed. Two main features are very representative: the increased role of the bikes and the fact that TOD is focusing on train stations.

2.5.1. Introduction

Infrastructure and hub development have never played a leading role in the spatial planning's tradition of the Netherlands. The main principle was that the spatial development is decided and then the infrastructure will follow. In the twenties, although attention was paid to the road network ("*Rijkswegenplannen*") by the Government, the infrastructure was still seen as subservient to other matters, for example the housing program. Little interest was shown in the development of the cities in connection with their position in the (railways) road network (Maak plaats, 2013).

Since 1980s, compact development around transit infrastructure has been the goal of Dutch planning system (van der Vliet, et al., 2012). With the introduction of the Fourth Report on Physical Planning ("V*ierde Nota Ruimtelijke Ordening*"), in 1988, the focus shifted towards the compact cities. In this report the ABC policy played an important role. The policy aims to promote a spatial strategy based on the analysis of the relation between transport demand (mobility profile) and accessibility of different business locations (accessibility profile), reduce the car usage and reinforce the urban vitality. The central element of this policy is the classification of types of locations and types of companies, namely their division into A, B or C-locations. "A" stood for central station locations, with a very good accessibility of public transport; "B"-location were reasonably accessible via car o public transport, while "C"-locations were industrial districts that were hardly accessible by public transport (Maak plaats, 2013; Martens & Griethuysen, 1999).

In 2006, the "National Spatial Strategy - Creating Space for Development" ("*Nota Ruimte*") was formulated and the Spatial Planning was decentralized. Housing, mobility and spatial planning are issues belonging to provinces and regions ("*regio's*"). Responsibilities of the government were taken over by the provinces in their own planning policy. In the field of public transport this led to the introduction of new forms of high quality public transport on a regional scale, for example in the Stadsregio Arnhem Nijmegen, Randstadrail in the South Wing and in North Holland, the high quality bus Zuidtangent (Maak plaats, 2013). Increased attention was given to the integration of urban planning with public transport, as well as to the involvement of the government in area in the form of public-private partnerships (Maak plaats, 2013).

In 2013, the National Spatial Strategy was replaced by Structural Vision on Infrastructure and Space ("*Structuurvisie Infrastructuur en Ruimte*"(SVIR)), in which the government is sketching the vision on the Netherlands up to 2040. One of the main purposes in SVIR is improving accessibility by strengthening chain mobility and multimodal connections of transports hubs. Together with other parties, which are going to be discussed under "Involved actors" paragraph, the government wants to make better use of the existing P+R, bike shelters located at the station level, or create new ones. This is part of the Better Utilisation program ("*het programma Beter Benutten*") throughout which the government is promoting the efficient utilization of existing infrastructure. Moreover, in SVIR the concept of Sustainable Urbanization ("*Ladder voor Duurzame Verstedelijking*") is introduced. The aim of this program is a careful use of scarce space and prevention over-programming (Maak plaats, 2013).

In a great part of the Netherlands, the mix of functions in the urban environment has developed to accommodate peoples' needs to work, learn and live in an efficient manner. However, there is space for future developments and this stays true for the infrastructure as well. It can be improved in such a way that it can function more efficient (e.g. different transport modes can be connected to offer travelers more alternatives, improve facilities) (Maak plaats, 2013).

The government allocated a budget of 4.4 billion euros for the High Frequency Rail Transport Program ("*Het Programma Hoogfrequent Spoorvervoer*" (PHS). On the busiest routes in the Randstad timetable-free travel will be enter in order to accommodate the high number of passengers (Maak plaats, 2013). The frequency of trains on the PHS routes goes up to six intercity trains and up to six sprinters per hour (meaning that in every 10 minutes a train will be at each station)[4]. OV-Bureau Randstad, acting as a platform for cooperation and strengthening the relationships between the parties involved in developing qualitative public transport, by integrating different modes such as rail (intercity and Sprinter), (high) metro, tram and bus. The projects which OV-Randstad agency is focusing on are Implementation R-net, Supply chain integration, Chain and node development and Local involvement in the rail[5].

However, the economic crisis limited the means to invest in large-scale spatial development and infrastructure projects, as well as the demand for new housing and office locations. Therefore, a strategy to combine the different aspects coming from the urban development and infrastructure sides is needed. The policy to develop the area around transit stops seemed to be a suitable one: it is focused on intensive use of the already existing infrastructure, on activities and destinations of people in the existing urban environment. A TOD approach is a subject of much interest for Dutch experts and a significant attention is given to push the concept from theoretical level to real world implementation.

Debrezion, et al. (2009) mentioned in their article related to station choice behaviour in the Netherlands that approximatly 47% of the cases, passengers were selecting to use as a departure station one which was not the nearest to their places of residence. This finding suggested that distance to the railway station is not the strongest characteristic that people are taking into consideration when choosing to access a station. Knowing that areas providing a rich mix of functions to accommodate needs like living, working, recreation etc is part of the Dutch urban planning and a way of everyday life of the Dutch people, the high interest in developing transit areas in the same way can be explained.

"We need TOD" is the sentence which opens the article "Legitimatie en realisatie van het TOD concept" ("Legitimation and realistion of TOD concept") written by professor Luca Bertolini (University of Amsterdam), for S+RO (Stedenbouw en Ruimtelijke Ordening – Urban and regional planning) magazine, in 2013. In this article, he is addressing the issues faced in implementing TOD in the Netherlands, namely insufficient understanding of the opportunities offered by both nodes quality and transport quality - especially their synergy and insufficient understanding of the incentives that involved parties may use to actually achieve the opportunities.

[4] http://www.rijksoverheid.nl/
[5] http://ov-bureaurandstad.nl/

In addition, the impediments of implementing TOD in the Netherlands are coming from the focus of the government to achieve 'node' developments, but not thinking in regional terms, from the on-going projects which do not have public transport as a backbone, as well as the municipalities which are still bonded by the Vinex contracts and their current land exploitations (Bertolini, 2012).

The barriers can also arise from the fact that even if the TOD concept can fit in the tradition of spatial panning in the Netherlands, it works differently than in the case of compact cities, which was the main development strategy promoted along the time. The focus was on the development of the location itself, while the TOD is starting from the networks and it focuses on development of the regions. "The idea of TOD means a whole different way of developing the regions. All nodes have a role, even the small ones" (Bertolini, 2012).

According to Bertolini (2012), in the Netherlands there are only two regions which can be considered to be developed in the same way as TOD concept and those are the South Holland via Stedebaan and the city region Arnhem –Nijmegen. "The concept of OV network can be seen as being the backbone of these plans for urban and regional development" (Bertolini, 2012).

In the North wing (Amsterdam metropolitan region) the TOD thinking is not implemented as a total concept, only the part of it focusing on nodes (e.g. Zuidas). Still, the public transport is not the backbone for development of the regions.

Great part of the efforts to materialize TOD is dedicated to the north wing, which is part of the Randstad. This is the largest conurbanation in Europe, consisting of cities of Amsterdam, Rotterdam, The Hague and Utrecht and their surrounding areas. This area in characterized by a large infrastructure system including many motorways, wide railway network, trams and subways; it benefits also from the presence of port of Rotterdam and Schiphol airport, international ways. The reason why it is a central focus is the nowadays context itself, when the requirements to use existing infrastructure in an efficient way. Deltametropool is the current term that the Dutch planners are using for Randstad, dividing it into two main areas: the North Wing ("*Noordvleugel*") and the Southwing ("*Zuidvleug*el"). Moreover, the public transport share is twice as high in the Randstad than in the rest of the Netherlands: 65-70% of all rail journeys have a destination in the Randstad[6].

However, there are a lot of initiatives dedicated to understand the TOD concept implementation potential in the Netherlands and overcome the implementation issue. There are projects throughout which the researchers are brought together with the field experts. One example is NICIS Institute' s KEI project (Knooppuntontwikkeling: Economische betekenis en Institutionele prikkels - Node Development: Economic significance and institutional incentives) developed between 2009-2013, which brought together practice experts from Amsterdam, Stadsregio Amsterdam, Stadsregio Arnhem-Nijmegen, provincie Gelderland, NS Poort and Movares and researchers from University of Amsterdam and Vrije University , Amsterdam[7]. VerDus (an abbreviation of the Dutch term Verbinden van

[6] http://ov-bureaurandstad.nl/files/Rapport%20Kiezen%20voor%20kwaliteit%20-%2012%20maart%202013.pdf
[7] http://niciskei.wordpress.com/about/

Duurzame Steden – Connecting Sustainable Cities) is another project tackling issues such as urbanization, mobility, transport or environment. It is an initiative aiming at combining the views of professionals and researchers developed by NOW (Netherlands Organisation for Scientific Research), Nicis Institute (known at the moment as Platform 31) and different Dutch ministries. VerDus is concerned with sustainable mobility in relation to spatial developments, energy transition and climate change. In relation to TOD, VerDus has as on-going projects: Sustainable accessibility of the Randstat (DBR – the abbreviation of Dutch term Duurzame Bereikbaarheid van de Randstad), Strategy towards sustainable and reliable multi-modal transport in the Randstad (SMRT), Implementing TOD (iTOD)[8].

For both wings, if it were to refer to the 5Ds of the built environment it can be said that destination accessibility is the most studied one.

One of the research programs focusing on improving the accessibility of the Randstad is Strategy towards sustainable and reliable multi-modal transport in the Randstat (SMRT), a program dedicated to breed comprehensive strategies for the Randstad relying on integrated scientific methods regarding land-use, location choices, multimodal transport network design, travel behavior and transport policy. The program helps in achieving sustainable mobility and improved accessibility, by estimating the trend of traveling by (a mix of) environment friendly transport modes such as walking, cycling, bus, tram etc. as a dependent variable of accessibility, quality of transport service, attractiveness, cost and purpose of the travel[9]. The models will give an insight in the consequences of higher density of housing, business, education, public services around public transport stops and railway station; increased speed, frequency, reliability and comfort of bus, tram and railway services; developments of transport infrastructure and capacity management on transport demand, network traffic flow, capacity utilization and environment[10].

Another program aiming at improving the accessibility of the Randstad for a long term perspective is the Sustainable accessibility of the Randstad. Of special interest are the projects concerning TOD (iTOD) and bicycle use, parts of the DBR research program. Implementing TOD (iTOD) is a project dedicated to overcome the barrier of sustainable integration of the spatial developments and transport nodes in the Amsterdam metropolitan region. It consists in 3 projects aiming at: analyzing the transport, land-use policies, financial and legal aspects in relation to TOD principles, on both international and local level and the potential of knowledge transfer or improvement of planning concepts in Amsterdam metropolitan region[11].

In the South wing of Randstad another project is aiming at the same purpose, developing and implementing effective TOD strategies, throughout a program named Stedebaan (Stedebaan Plus, 2011). As iTOD, it has three subprojects concerning improving station accessibility (as an alternative to the urban densification around railway stations due to the short-term decreasing demand for housing and offices location), users willingness to adjust

8 http://www.verdus.nl/pagina.asp?id=1372
9 http://dbr.verdus.nl/pagina.asp?id=717
10 http://www.utwente.nl/ctw/vvr/projects/projects/Robust%20multi-objective%20multimodal%20network%20design/
11 http://dbr.verdus.nl/pagina.asp?id=1313

their residential and business locations choices as well as their travel behavior in the TOD context; the third focus is on social costs and benefits of TOD, the policy transfer from successful projects in Europe and the USA to the Stedebaan case[12].

Bike as a transport mode is the very best feature describing the Dutch transport system. In comparison with the car use on international level, in the Netherlands car use is lower. Therefore, an increased attention is given to "keep satisfied" the people using the bikes, while not neglecting the auto users. The Meerjarenplan Fiets (Long-term Bicycle Plan) is targeting Amsterdam and it is operational since 2012 until 2016, and a budget of € 120 million will be invested in this program until 2020. Long-term Bicycle Plan is meant to overcome the problem arose at Amsterdam Central Station or Amsterdam Amstel mentioned in the "Problem statement" section of this research thesis, where the occupancy rates of the bike shelters is a real problem. This shortcoming can affect the overall train station experience of the travelers and received a great attention.

Under DBR, there are two projects dedicated to bike users as well: Understanding social and spatial dynamics in bicycle use in the Randstad and its policy implication and The role of the bicycle as an egress and access mode for multi-modal nodes, since the bike is increasingly used as an access and egress mode at the multimodal transport hubs level, mainly as a part of the train or car trips[13].

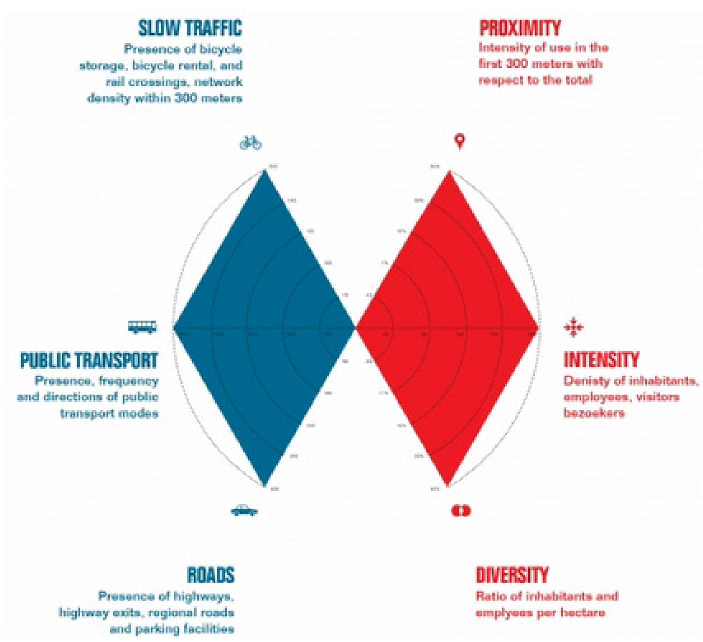

Figure 21. The butterfly diagram (source: Maak plaats, 2013)

A TOD-related recent study, focusing on the developments of the surrounding areas of the train stations and their potential to be integrated with the node function of these stations is "Maak plaats" (a joint effort of APPM, "Deltametropool" association and the Province of North Holland). This study is focusing on identifying the opportunities to develop the nodes and corridors in North Holland, through the analysis of the present situation and the chances/directions to be develop. These opportunities are extracted from the "butterfly diagram", which can be seen in Figure 21; one "wing" is representing the transport node (characterized in terms of slow traffic, public transport and roads) and the other is representing the place (characterized by proximity, density and mixing). Therefore, the aim of developing symmetrical wings for the butterfly diagram is to achieve a balance between

[12] http://dbr.verdus.nl/pagina.asp?id=1535
[13] http://dbr.verdus.nl/pagina.asp?id=1467; http://dbr.verdus.nl/pagina.asp?id=1650

node and place at the station level. “Slow traffic” can be defined as presence of bicycle storage, bike rental, rail crossings and network density within 300m radius, “public transport” – presence, frequency and directions of public transport modes, while “roads” is defined throughout presence of highways, highways exits, regional roads and parking facilities. On the other hand, “proximity” means the usage intensity in the first 300 meters in respect to the total; “mixing” means the proportion of residents and workers per ha; “intensity” is defined as density of inhabitants, employees, visitors.

In addition, ten principles were formulated to “express the opportunities for an integral policy for housing, working, amenities and recreation in combination with good accessibility” for the (surrounding areas of) train stations in North-Holland (Maak plaats, 2013). These principles are:

1. **“Frequency increase and spatial development are mutually reinforcing**. An increase of the train frequency is only viable when there are sufficient activities around the stations to generate passengers.
2. **Realize at least 50% of the newly-built homes within the catchment areas of stations.** A better alignment with the qualitative demand allows at least half of the housing program in the province of North-Holland to be realized within the catchment areas of stations.
3. **Prioritize existing land use plans within the urban growth boundary (BBG-contour) around stations.** Existing plans within the urban growth boundary can contribute to a stronger relationship between frequency increase and spatial development, and also comply 50% of the qualitative market demand for new housing around public transport nodes.
4. **Align the urban growth boundary (BBG-contour) with the transit-oriented development strategy.** Basically new urban developments may only be built within the urban growth boundary. If there is no capacity available within the urban growth boundary to satisfy the regional demand, priority must be given to locations that are multimodal or may be in the short term.
5. **Reduce the number of vacant offices in areas that are not multimodal accessible.** Station areas with a good car accessibility are attractive office locations. A transit-oriented development strategy must therefore not focus on directing new offices to station areas. Rather it should focus on reducing (transforming) vacant offices in areas that are not multimodal accessible.
6. **Focus on the quality of working environments in the most accessible locations.** New offices should only be realized at the most promising places; locations that enjoy excellent accessibility from the Randstad by car and public transport with at the same time a high-quality mixed environment.
7. **Locate regional facilities in multimodal, accessible locations.** Multimodal accessible nodes can become mixed, vibrant environments that serve the region. Regional facilities can contribute to the development of that liveliness and can at the same time generate railway passengers in off peak hours and initiate counter peak traffic flows.
8. **A smoother transfer between modes of transport.** Accessibility and chain mobility will improve with smart links between public transport, car, pedestrian and bicycle networks and its related services.
9. **Develop nodes as ‘gateways’ to the countryside.** Some stations can function as a hub to the countryside, thus integrating recreational, cultural historical, living environments and transportation modes.

10. Make space! Create attractive public spaces around stations where people would like to stay and create clear routes with high spatial continuity and spatial coherence." (Maak plaats, 2013)

It can be said that "Maak plaats" study is the most comprehensive one in relation to the 5Ds characterizing the built environment around the train station, "touching" density, destination accessibility, distance.

Another interesting project which is on-going is Knowledge for strong cities (KKS – the abbreviation of the Dutch term Kennis voor Krachtige Steden). This project is dedicated to urban setting, the economic and social dynamics in the cities and urban regions. Under this research program, since 2007 there are about 50 projects related to themes as Education and Labor, Safety, Security and Innovation, as well as Housing. In relation to TOD the housing theme might be of interest, because it can furnish information about the ways of meeting the changes in housing demand, the way people want to live in their neighborhoods. This data can be used as input data for arranging the areas around stations and increase the number of people who are living there and so, the number of station users[14].

In what concerns distance to transit, according to CBS (2011), two in every three people lived within 5 km away from the nearest railway station, in 2008, in the Netherlands. However, as mentioned earlier, this dimension of built environment does not seem to be highly appreciated by the Dutch travelers.

The design dimension for the Dutch context is the focus of one iTOD Project. During one of the workshops (21th of February, held in TU Delft) that the author had taken part in, design qualities of TOD projects in the Netherlands (Arnhem, Delft and Zaandam), design qualities of TOD projects in other countries (Copenhagen, Malmo, London, Portland, Perth, Singapore , Stockholm, Tokyo, Vancouver) as well as the design qualities of hypothetical TOD models in the Netherlands / Envision a Dutch TOD prototype were evaluated. The criteria used for the evaluation were: scale, diversity, continuity, imaginability, enclosure and transparency (the order is presented according to the scores given by the experts present at this workshop in the evaluation on the design in the Dutch context). For more examples of the TOD in the Netherlands see Appendix 3. TOD in the Netherlands in pictures.

[14] http://kks.verdus.nl/projectpaginalijst.asp?id=1538

2.5.2. Involved actors

"In the Netherlands, TOD involves a complex interplay between public and private actors dealing with land use change, transportation network development and economic growth" (van der Vliet et al., 2012). A multitude of public, semi-public and private actors are involved in the development of the area around stations, "transforming" it into a competing public space for all of them. These stakeholders are further presented.

Public and semi-public actors

Governmental structures

In relation to transportation and infrastructure developments (TOD, in particular), the public structures have several responsibilities.

As a member state of European Union, the Netherlands is adapting its growth/development strategy to the ones proposed at European level. One interesting issues present on the EU Territorial Agenda is "Encouraging integrated development in cities, rural and specific regions to foster synergies and better exploits local territorial assets" (Böhme et al., 2011). This priority is particular important in TOD context because it promotes the better use of existing developments within the cities, creating a favorable context for the implementation of TOD.

The national government in the Netherlands is responsible for developing policies on the national level and allocates tasks to provinces, regions and municipalities. The national railways (NS, semi-public company), national railway infrastructure (ProRail, also a semi-public company) and general visions on land use ("structuurvisies" – elaborated in collaboration with city regions) are the national government's responsibilities (van der Vliet et al., 2012). Regarding the TOD context, the national government is a powerful player since the land use plans and development of infrastructure projects are starting to be elaborated at its level. The developments around train stations can be affected (encouraged/delayed/stopped) by the presence of these land use plans.

On the regional level, TOD is promoted by regional and provincial governments, structures managing the public transport services at the supra-regional and regional level. Since the public transport services are tendered to private transportation companies, this group of actors has more limited power, because they are depending on the other actors to achieve the TOD implantation (van der Vliet et al., 2012). On the other hand, their power is increased by the fact that they possess land in the area around train stations.

On the local scale, municipalities are responsible for elaborating further the land use plans into zoning plans. In relation to TOD concept, the municipalities are also a powerful actor, because they are owners of (some parts of) the public space around train stations.

NS (responsible for trains, in general) and ProRail (responsible for tracks, in general) are the two semi-public companies involved in the TOD context. They are not only targeting the railway transport sector (train stations and railway infrastructure), but they are also land owners in the surrounding area of a train station.

Private actors
Private actors can be divided into land owners, developers, transport companies, research groups, housing associations, "retail chains, or large companies and institutions (schools, hospitals) looking for an accessible location" (van der Vliet et al., 2012).

The land owners and the developers are driven by the economic feasibility of the investment. By adapting their visions to the one promoted by TOD all the involved parties can benefit from each other.

The transport companies (e.g. Veolia, Connexion, etc.) are not only responsible for efficiency of their transit system, but they are actively involved in implementing TOD as well. As it can be seen in Figure 22, they are interested in being located nearby a train station. In this way, the transport company, the travelers and the train company are sharing the benefits of improved accessibility.

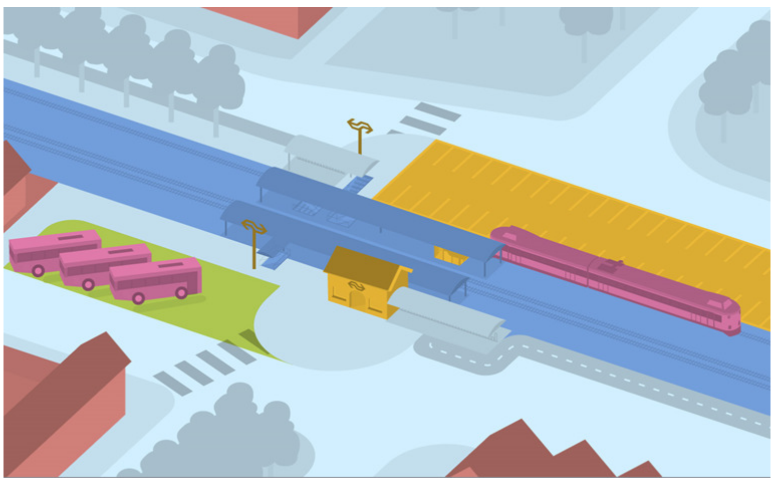

Figure 22. Involved actors in (the surrounding area of) a train station
(source: van Heijningen & van Noord, 2014)

Legend: Yellow: NS Stations; Blue: ProRail; Pink: Transport service companies (NS, Connexxion, Arriva etc); Green: Provincie; Light blue: Municipality; Red: residents and other property owners

Housing associations, retail chains and companies are an important stakeholder in TOD context. On one hand, their presence around train station enhances the number of travelers and the public realm around train stations, a TOD desirability. On the other hand, due to the fact that in the Netherlands it is a high rate of vacancies, the presence of train station can stimulate the attractiveness of the housing, offices, retail location.

Last, but not least, the travelers are one of the major actors, since as in all the development project, market demand is the driver. Their wishes and needs have to be satisfied in order to attract them to use a train station and make all the investments worthy. By focusing the improvement or growing strategy of train service operator (NS) on the characteristics which makes a train station attractive for the travelers, the turnover of the company can be increased.

2.6. Conclusions

In this chapter a brief literature review about the (train) station choice behavior is presented. As a general conclusion it can be said that characteristics describing station (level of service) were mostly taken into account, while from the factors describing the surrounding environment of the station characteristics accessibility-related were the subject of much research. Moreover, the number of articles addressing the station choice behavior issue is very limited, no matter if referring to train stations or other types of stations (metro/bus, etc.). The concept of TOD, as a particular mean to organize the station's environment was introduced. TOD targets a high quality built environment designs to support mainly walking, cycling and public transport as modes of transport. It can be characterized in terms of 5Ds (Density, Diversity, Design, Destination accessibility and Distance). However, in defining the 5Ds it can be said that there are various attempts, but no general conclusion could be formulated out of them. In the attempt to study the 5Ds, some other characteristics describing the relationship between urban form and travel behavior were discovered, namely travelers, station and trip-related characteristics.

By overlaying the5Ds, sustainable developments can be created around stations areas (e.g. decrease levels of CO_2 due to low car usage). TOD as a planning method was applied in many countries and it is a subject of interest for the Netherlands as well. In the literature there were attempts to study the weight of built environment dimensions, but in neither of them these dimensions were all defined in the way that the present study is doing.   In order to answer the main research question further analysis is needed.

3. Research approach

This chapter presents the research questions and methods employed to give an answer to them. In the first paragraph, the research questions and conceptual framework are introduced. The methods and techniques are described further. The paragraph "Data collection" describes the process of obtaining the answers from the respondents. A questionnaire was used for this purpose.

3.1. Conceptual framework

The main research question can be formulated as follows: **"What attributes of train stations' environment are influencing travelers' origin station choice behavior?"**

In order to answer this central question, some sub-questions need to be addressed as well:

1. How can train stations and their surrounding area be characterized in the context of travel behavior related aspects?

2. What influence do these features have on Dutch passengers' choice of origin train station to enter a train?

A conceptual framework was developed to define the way in which the answers to the questions will be sought. The review of the literature represents the starting point of this research project. This phase gave an insight into the theory of TOD and station choice behavior; besides, it helped in the identification of the built environment dimensions, station aspects, travel makers and trip characteristics and their definition in relation to travel behavior. Therefore, the conceptual framework proposed here assumes that there is a relationship between the station choice and the attributes divided into the presented four categories. The conceptual framework underlying this study can be seen in Figure 23.

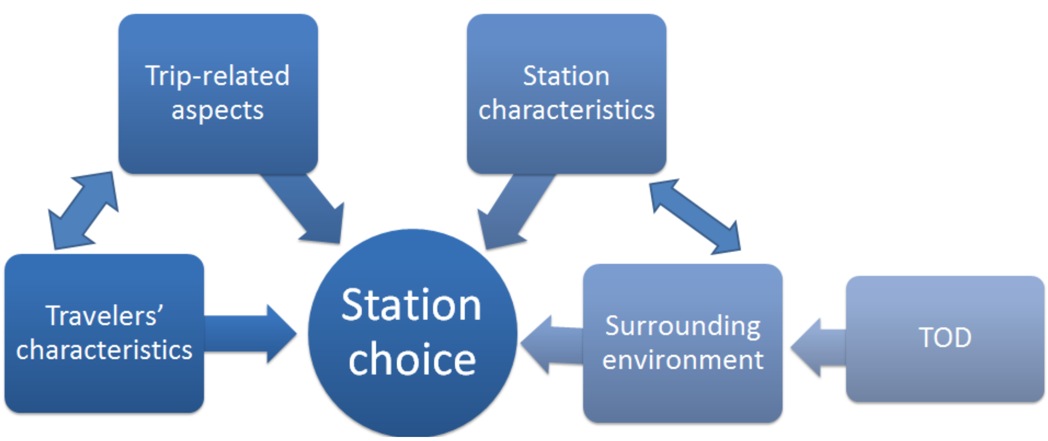

Figure 23. Conceptual framework

These four elements represent the pillars on which the research methods and the developed model to answer the sub-questions are built. It must be underlined that the station characteristics were not part of the questionnaire. The reason is two-fold: firstly, there is significant amount of data available about the stations' characteristics gathered and analyzed by the research department of NS; the other reason is related to the limits of the questionnaire size; priorities were assigned to the 4 pillars mentioned above leading to the exclusion of the characteristics of the stations, based on the first mentioned reason.

3.2. Revealed preference approach

This study represents an effort to determine the attributes of a surrounding area of a train station which are attracting travelers to use the train station for their train trip. In order to determine them, travelers' preferences were collected by employing revealed preference approach. The collected data is analyzed by using a discrete choice method, Multinominal Logit Model (MNL) respectively.

In market research, consumer's choice behavior has been analyzed by employing discrete choice models. A general framework of consumer decision process is represented in Figure 24, where the ovals symbolize unobservable/latent variables and the rectangular shapes - observable variables. In order to capture the latent psychological variables, researchers have relied upon different indicators of attitudes, perceptions, and preferences. These factors are characterizing the relation between the existent features of alternatives and consumer's behavior. The attitudes constitute consumer's individual/personal relevance of the attributes describing the available alternatives. Perceptions are influenced by consumer's socioeconomic characteristics and can be defined as "consumer's perceived values of attributes of alternatives" (Morikawa, et al., 2002). Both, attitudes and perceptions, are captured by indicators revealing the level of satisfaction with the attributes, measured on a semantic differential scale. Preference is the third latent factor and expresses the selection of one alternative over another/others and is articulated by utility functions. There are two types of data collected to represent consumer's choices: revealed preference (RP) and stated preferences (SP) data. The latter are delivering the choice responses in hypothetical scenarios, while RP data are gathered from choices under real market conditions (Hensher, et al., 2005; Morikawa, et al., 2002).

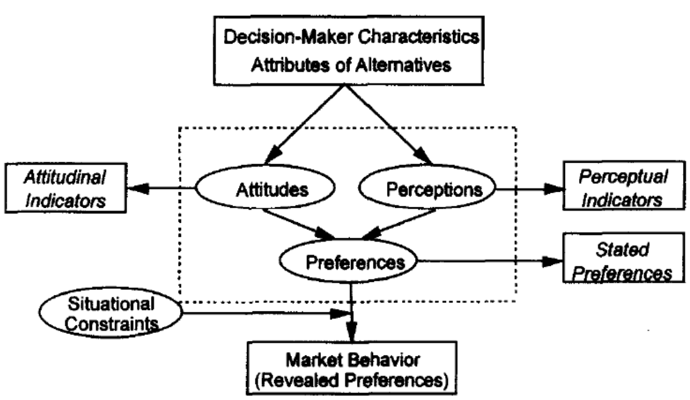

Figure 24. Framework for Analysis of Consumer Behavior (source: Morikawa, et al., 2002)

Revealed preference method have been used in transportation research field in order to analyze travel demand or various aspect of travel behavior (e.g. route or mode choice)(Caldas, 1997). One of the most important advantages of this approach is that the collected data are expressing individual's actual market behavior, the choices made among the existing alternatives (Caldas, 1997; Hensher, et al., 2005). In contrast, there are some disadvantages of this method as well, such as "the interpretation and the choice made against the actual set of trade-offs depends exclusively upon the respondents' market perception" (Caldas, 1997). This can affect the parameters estimates due to the fact that "pre-specified boundaries for the error term related to respondents' perceptions on the set of variables cannot be incorporated in the questionnaire design" (Caldas, 1997). Moreover, RP data embodies constraints affecting choices made by individuals in real market (Hensher, et al., 2005). It must be noted that RP cannot give any information about not chosen alternatives.

In order to be a real-world representation, the outcome of the collected data on real life choices, the sample of the population must be representative.

Another disadvantage worth to be discussed is the correlation/multicolinearity among/between the attributes (represents a barrier toward independent estimation of an attribute or it might be the case that the correlation between attributes to happen only in the given context, affecting the generalization), which impacts the model estimation (Hensher, et al.,2005). Therefore, a correlation test is needed.

When building a discrete choice model, some steps must be followed and these steps are captured in Figure 25.

The first step involved by the design of the model involves the formulation of the problem. This was clarified in Chapter 1. The choice set determination will be tackled in the "Case study" paragraph. Data collection is made via a questionnaire. Last, but not least, the development of the model is discussed.

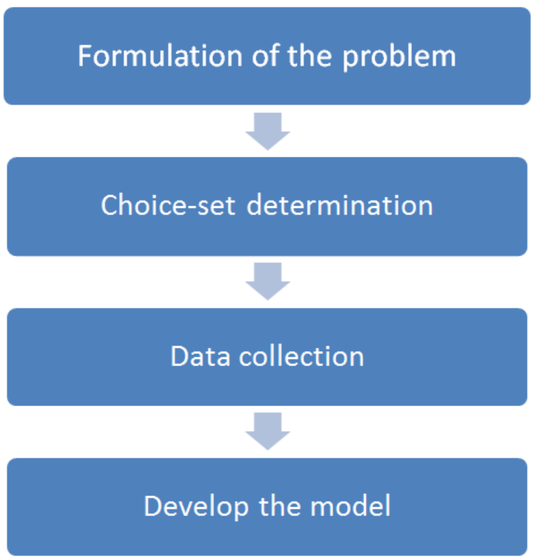

Figure 25. Design process for MNL model
(source: Adapted from Ortuzar & Willumsen, 2011)

3.3. Case study

A case study was set up for revealing the choice behavior of travelers in a context with many opportunities to be selected from (a choice set). The real world collected information was employed further in the model. Choice set determination is analogous with identifying the alternatives that the decision maker has to choose from. In this research study, the choice set is composed out of 8 train stations located in Amsterdam.

A great part of the efforts are going towards finding the best way to implement TOD in the North wing of Randstad as shown in the previous chapter. Amsterdam was chosen as the location for the case study since it is the most important public transport destination, as well as trip origin, and it knows the densest concentration of travelers in the City Region ("*Stadsregio*"). 84% of the public transport trips heading towards the City region have a destination in Amsterdam, while 70% of them have the origin in Amsterdam. This concentration of public transport trips is explained also by the fact that Amsterdam has the lowest car ownership and parking rates in the region[15].

8 train stations in Amsterdam were included in the case study: Amsterdam Central, Amsterdam Amstel, Amsterdam Rai, Amsterdam Zuid, Amsterdam Sloterdijk, Amsterdam Muiderpoort, Amsterdam Lelylaan and Amsterdam Sciencepark. The reason why they were chosen is their presence in a special network, forming a ring for Amsterdam (the Ring of Amsterdam), a multi-station region, offering travelers many alternatives to choose from (see Figure 26. The Amsterdam Ring train stations (including Amsterdam Sciencepark)). Not only provides the number of stations presented an opportunity for the visitors/workers/residents in the area, but also the spatial developments around this ring. Almost 15% of the offices in the region of North-Holland are developed around the stations of Amsterdam ring. In addition, it is this area where the most important touristic attractions can be found. Residential locations can be found around stations like Amsterdam Lelylaan, Amsterdam Amstel, Amsterdam Muiderpoort (the station with the highest concentration of residents in the North-Holland) and Amsterdan Central (Maak plaats, 2013). Due to high number of residents around station Amsterdam Muiderpoort and its direct connection with Amsterdam Sciencepark, the latter was also included in the case study. On the other hand, even if Duivendrecht station is located on the ring, it serves more as a transfer station, being less accessible.

As it can be seen in Figure 26, there is no train connection between Amsterdam Sloterdijk and Amsterdam Rai. Therefore, for the train as a transport mode, this ring is not really functional as a ring, but it compensates with the metro. The metro system is very important for the ring, and there are plans to open in 2017 a new line (North-South line) which will directly connect Amsterdam Central Station with Amsterdam Zuid.

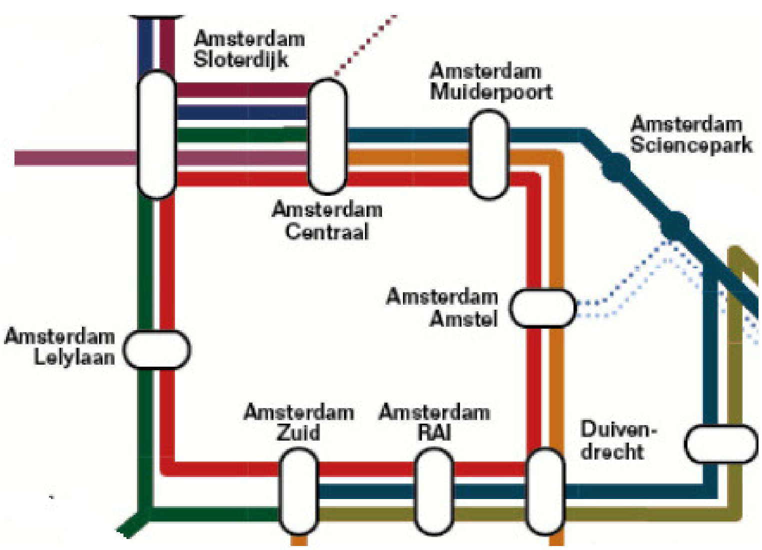

Figure 26. The Amsterdam Ring and Amsterdam Sciencepark train stations **(source: Adapted from Maak plaats, 2013)**

The Ring of Amsterdam stations are the subject of much research. In 2012, The Municipality of Amsterdam, together with Schiphol Group, Stadsregio Amsterdam and Strategy Development Partners co-financed by I & M Ministry released a report aiming at improving the public transport for Amsterdam region ("*Beter OV voor de Stadsregio Amsterdam*" – BBROVA, 2012), by improving the activity of the transport node and without massive investments in

[15] http://www.stadsregioamsterdam.nl/beleidsterreinen/openbaar-vervoer/beter-ov-stadsregio/

infrastructure projects. In this study it has been noted that the existing public transport system brings a too large proportion of commuters with a detour via Amsterdam Central Station to their workplace. In order to cope with the high amount of travelers in this area, based on the accessibility of the stations in the rail corridor and fast transfer to the metro connection, this study identified 5 public transport gates of Amsterdam towards which the crowds can be (re)distributed: Amsterdam Zuid, Amsterdam Central Station, Amsterdam Amstel, Amsterdam Bijlmer Arena and Amsterdam Sloterdijk. In addition, the stations located on the ring have been regarded by the researchers as "competing" stations for passengers (Givoni & Rietveld, 2014). The overlapping of the catchment areas is seen in Figure 27. It can be seen that the figure is supporting the findings from the literature, that travelers are not always using the station which is closest to their residential location.

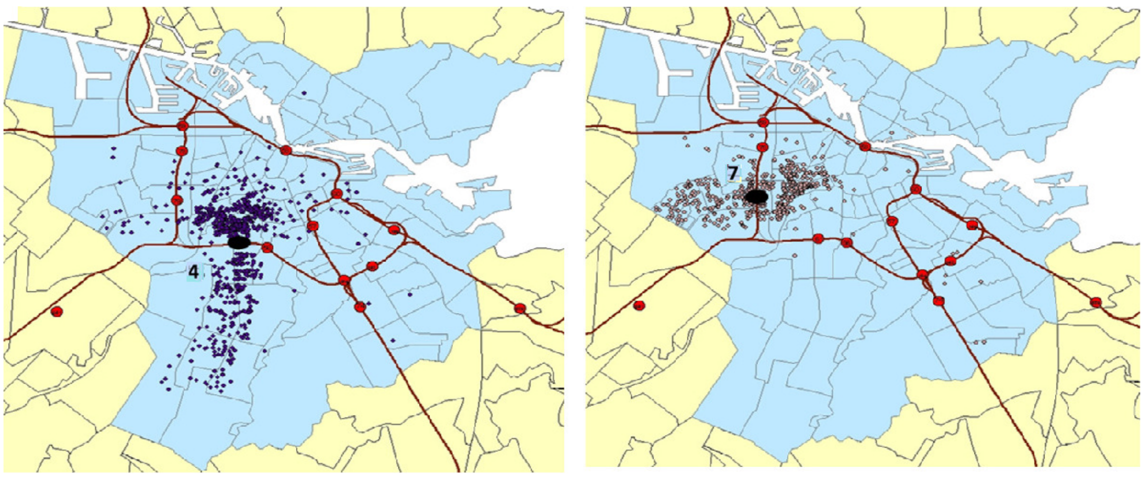

Figure 27. The catchment areas of Amsterdam Zuid (left) and Amsterdam Lelylaan (right) stations (source: Adapted from Givoni & Rietveld, 2014)

Nevertheless, even if there are so many options, travelers choose to use Amsterdam Central Station, the biggest and offering the most opportunities in comparison with the other stations. Amsterdam Central it is the only station ranked as type 1 out of the 6 available in the Netherlands' division of stations. The criteria for this categorization are the type of trains operating at the station level and the location of the train station. Figure 28. Typology of the railway stations in the Netherlands indicated the division of this 6 types pf stations (Rond, 2011). Type 1 of stations are very large stations, located in the center of a large city, which international/intercity/sprinter trains are operating (e.g. Amsterdam Central Station). Types 2 and 3 of stations have intercity and sprinter trains stops, but the difference is given by the location: in the center of a medium sized city vs. peripheral location. Types 4, 5 and 6 are defined small stations and only the sprinter trains are stopping there. Within this group, type 4 covers the biggest stations, located in the center of small city/village, while type 5 stations are in the suburbs and type 6 – the smallest,

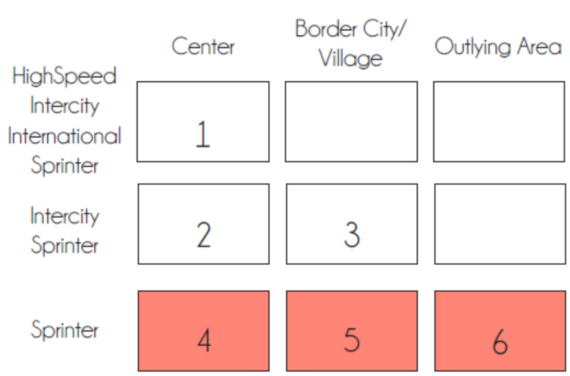

Figure 28. Typology of the railway stations in the Netherlands (source: Rond, 2011)

located in an outlying area of a small city/village (Rond, 2011). Another type of station is considered to be the event stations, operating only for special occasions (e.g. football matches).

The catchment area of residents using Amsterdam Central station as their origin station for the trip with the train is shown in Figure 29. Only by comparing it with the ones of Amsterdam Zuid and Amsterdam Lelylaan it can be seen that Amsterdam Central is one of the most preferred station of the region. This is affecting the good functionality of the (public) transport system. For example, one finding reported in the BBROVA study (2012) was that in May and November 2011, the occupation rate of bike shelter was more than 120%. Bikes had to be regularly removed by the municipality and the comfort of the travelers was negatively affected. In order to redistribute the high amount of travelers from Amsterdam Central station towards the other ones, it is important to understand what affects the choice made by the travelers for a station over another, in such a complex network. Moreover, it is important to know the triggers because there is room for improvements around all of the 8 stations included in the case study, as suggested in the study "Maak plaats" (2013): "Adding jobs, facilities and homes, transforming some of the vacant office supply and simultaneously improving the link between the entire public transport chain and the care and the bicycle, the station areas on the ring can become vibrant and mixed urban destinations that are able to effectively capture and spread large passenger flows to and from the city").

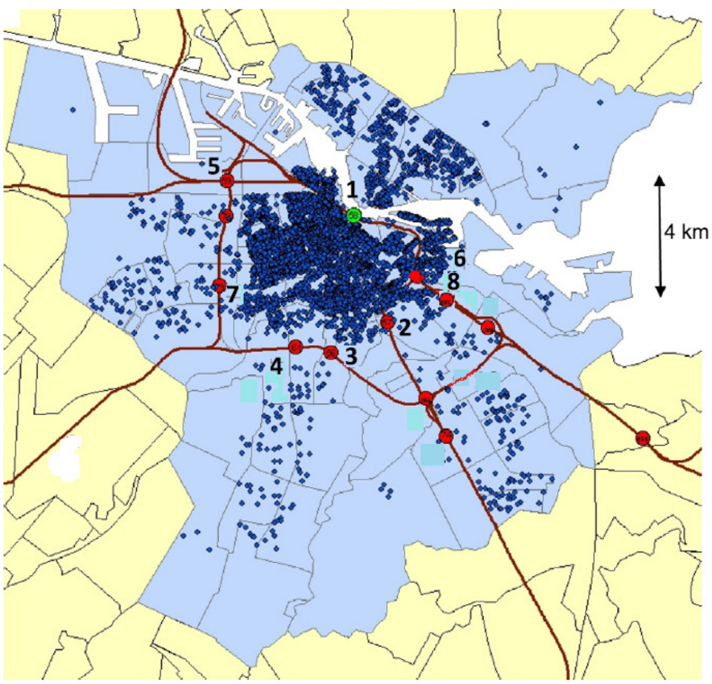

Figure 29. Residences of Amsterdam Central station users
(source: Adapted from Givoni & Rietveld, 2014)

Legend: 1 – Amsterdam Centaal; 2 – Amsterdam Amstel; 3 – Amsterdam Rai; 4 – Amsterdam Zuid; 5 – Amsterdam Sloterdijk; 6 – Amsterdam Muiderpoort; 7 – Amsterdam Lelylaan; 8 – Amsterdam Sciencepark (Note: Stations are numbered according to their rank in the questionnaire)

3.4. Questionnaire design

The estimation of the model is dependent on the integrity of the data collected from respondents, who may face time constraints in filling it in , as well as when processing the information. The questions included have clear and straightforward instructions. The time constraint is coming from the fact that it is a paper-based questionnaire which is distributed in the stations presented in the previous paragraph. Therefore, based on NS experience as well, the questionnaire is fitted in two sides of an A4 page format.

Selection of attributes and sub-attributes

The purpose of the literature review was to determine the characteristics of built environment and station, travelers and trip-related characteristics as well, which are affecting the travel behavior in order to assess their weight for the travelers' station choice decision. Due to the wide variety identified in the literature and the fact that a questionnaire is going to be employed in order to reveal the influence of these characteristics on travelers 'station choice behavior, a selection of them was needed. The selected attributes and sub-attributes can be seen in Appendix 4. Attributes selection.

The main principles used for the selection are:

- The built environment dimensions are categorized under the 5 Ds (core dimensions): density, diversity, design, destination accessibility and distance to transit and the papers of Cervero & Kockelman (2007) and Cervero & Murakami (2008) are of reference for this study due to their recognition as being referencing papers in defining TOD;
- The built environment dimensions can be spatially correlated, introducing the problem of multicolinearity in the model, affecting model estimation. The selection of the attributes under the 5D categories will take the issue of multicolinearity into consideration (this principle is going to be explained below);
- The characteristics of respondents and of the trip were selected based on the assumption that they can explain station choice behavior;
- Discussions with experts during the TOD-related aspects workshops that the author had taken part in, presented in "TOD in the Dutch context" paragraph.

Each out of the five dimensions is characterized by not a single one, but several variables to fully describe it. Therefore, these characteristics of built environment can be spatially correlated (e.g. neighborhoods with higher density tend to have more land-use destinations and more pedestrian-friendly amenities) (Cervero & Kockelman, 1997; Rodríguez et al., 2009). In order to reduce the correlation in the data and to group the variables into factors/sets of variables describing the dimensions of built environment, the literature revealed that multivariate technique or factor analysis was employed (Cervero & Kockelman, 1997; Handy et al., 2005; Rodríguez, et al., 2009). Factor analysis helps to create elements representing associations among multiple interrelated variables, preventing the multicolinearity to bias the analysis. For example, applying factor analysis, Cervero & Kockelman (1997) were able to group under the dimension of "pedestrian-oriented design" many variables, such as average sidewalk width, incidence of signalized crossings and intensity of planting strips and street trees, instead of analyzing the contribution of every individual variable for the travel demand. The variables were grouped under each built environment dimension according to the findings from the literature and to avoid (as much as possible) the multicolinearity.

The **Density** dimension was assessed in terms of the travelers' perception on the amount of people (with no discrimination among residents, workers or travelers) when choosing their origin station.

Stating from the definition of land-use mix proposed by Litman (2012) as "various types of land uses (residential, commercial, institutional, recreational etc.) located close together" and the theory of activity-based models, which are allocating first priorities to the trips satisfying basic needs (groceries, shopping: retail, convenience stores), the hypothesis is that stations with many opportunities in terms of shopping (commercial and supermarkets) are attracting more travelers. The other types of land-uses (recreational, leisure, educational) are not present around every station therefore they can be considered as triggers only at individual stations level. However, due to the function of the station as meeting place (as opposed to transit node), the presence of restaurants, cafes, fast-food restaurants are important to be assessed; the assumption is that stations with (more) variety in terms of meeting facilities are attracting more travelers. As noted before, residential and employment can fall under density and diversity category, leading to multicolinearity. Moreover, the residential and employment characteristics were analyzed in more detail in the study "Maak plaats", presented in the previous chapter.

The **Diversity's sub-attributes** are:

- Presence of supermarkets (satisfying daily needs);
- Presence of a variety of stores (retail services, clothes, technology-oriented stores etc.);
- Presence of restaurants, cafes, fast-food restaurants.

A statement must be made regarding the variables describing the design dimension. Due to multicolinearity reasons, presence of sidewalks, sidewalks quality, width, presence of crossing aids and presence of pedestrian-friendly amenities –benches, trash bins, could have been included under the "Pedestrian-friendly design" variable. However, include them jointly makes it difficult for the respondents to be assessed. What if a respondent finds the infrastructure (sidewalks) good, but the amenities very bad? Another statement has to be made regarding the aesthetics of the surrounding area of the station. During a discussion of the experts present at the iTOD workshop regarding TOD design for the Netherlands (21^{st} of February 2014, Delft) it appeared that it is important to assess individually the aesthetics of the building and open/green spaces, and not jointly.

The **Design**'s sub-attributes are sub-divided in:

- Aesthetics of the buildings in the station's environment (art/architecture/building height);
- Attractiveness of the open/green spaces;
- Presence of sidewalks, sidewalks quality, width, and presence of crossing aids;
- Presence of pedestrian-friendly amenities – benches, trash bins;
- Bike-friendly design (presence of bike lines, quality and width of them, presence of crossing aids);
- Car-friendly design (presence of roads, their quality, traffic speed, traffic lights provision etc).

The **Destination accessibility**'s sub-attributes are:

- Provision of bike shelters;
- Public transport connectivity;
- P + R provision;
- Kiss and Ride provision.

Regarding the respondents' characteristics, the following hypotheses lead to their inclusion in the questionnaire:

a. Age: Older travelers are less willing to have longer walking distance to access the train station (e.g. Jiang, et al., 2012). No age groups were pre-defined.

b. Gender: female travelers will choose for stations providing more opportunities in terms of public transport and/or shops/shopping facilities (e.g. Curtis & Perkins, 2006).

Levels of this attribute are:
- Female;
- Male.

c. Employment: Due to time inflexibility, in choosing a train station, distance between final/origin destination and the station (so access/egress time) can be a determinant factor, as well as the connectivity (public transport) or accessibility of the station, while other urban form characteristics account less in the decision-making process. On the other hand, due to duration flexibility, other urban form aspects such as design, land-use mix or opportunities can have a bigger weight in selecting a specific railway station.

The levels of employment status are divided according to Eboli & Mazzulla (2011):
- Employed;
- Un-employed;
- Student;
- Pensioner.

However, the employed status is further decomposed into full-time and part-time employment, the reason behind being time flexibility, which leads to a different demographic profile, as well.

d. Education: better-educated people will not only think in terms of cost – benefit (e.g. money, environmental concern) analysis when selecting the mode of transport (car vs. public transit), but they will be (more) aware of the benefits offered by a public transport access to different locations/facilities/shops/etc. Therefore, they will be more likely to select to travel from/to a train station providing more opportunities to be reached.

According to the Netherlands education system[16], the education segments can be divided as follows:
- Elementary school ("*Basisschool*")
- Middle-level applied education (*"voorbereidend middelbaar beroepsonderwijs: vmbo*")
- Higher general continued education ("*hoger algemeen voortgezet onderwijs: havo*")
- Preparatory scholarly education ("*voorbereidend wetenschappelijk onderwijs: vwo*")
- Vocational education ("*middelbaar beroepsonderwijs: mbo*" and ("*hogerberoeponderwijs: hbo*")
- Higher education ("*wetenschappelijk onderwijs: wo*", universiteit, gepromoveerd).

e. Household composition: a significant importance is the presence of children going to school, for example, since the choice of the station can be based on the proximity of school rather than on other urban form-related aspects (e.g. Cervero & Kockelman, 1997). Moreover, another assumption can be the fact that different household sizes will tend to choose stations around which all members' needs/wishes can be satisfied, leading to different choice and underlying decision-making criteria.

[16] http://taalunieversum.org

Therefore, the household composition will be breakdown as follows:

- Number of adults;
- Number of under 4 years old children (proxy to school dependency);
- Number of 4-12 years old children;
- Number of 12-28 years old children.

f. **Car ownership**: it can explain longer distances to access the train station, for example, or a higher value put on parking spaces availability at the station level or in its surroundings, leading to a choice of a station over another.

The levels of this attribute are:

- Yes;
- No.

As for travel related characteristics, the ones suggested in chapter 2 of this research thesis are the one included in the questionnaire, based on the following hypothesis:

g. **Purpose of the trip**: Travelers with work/business/education have less time flexibility; therefore they are less likely to appreciate design or diversity.

In the survey that NS is presenting to travelers couple of times per year (in the station) under the section of station characteristics, the purpose of the journey is divided into:

- From/to work;
- Business trip;
- From/to school/college/university/training course;
- Visit to family/fiends/hospital;
- Shopping;
- Holiday/trip/day out;
- Sport/hobby;
- Other.

This division is adopted in the questionnaire presented to the travelers for the purpose of this research thesis.

h. **Station use frequency**: The more frequent the travelers are using the station, the better they know about the opportunities offered and the better they can explain their station choice behavior.

In their paper, Givoni & Rietveld (2007) distinguished among the following journey **frequencies**:

- 4 or more times/week;
- 1-2 days/week;
- 1-3 days/month;
- Less than 12 days/year.

In the questionnaire taken in the stations, NS is distinguishing among the following trip frequencies:

- More than 4 days/week;
- 1-3 days/week;
- 1-3 days/month;
- Less than 2 days/month;
- Less than 2 days/year.

The division used by NS is adopted in the questionnaire employed to collect data for the present research thesis.

i. **Access mode**: Travelers arriving at the station with one of the available modes can value more the level of accessibility of the station in relation to that specific mode.

The levels of the access mode are:

- Walking;
- Bike;
- Car;
- Public transport (bus/metro/tram);
- Other.

Moreover, in the questionnaire filled in in stations, a clear distinction is made between transport mode car as a driver and car as a passenger, taxi and train. In this paper, the distinction between car as a passenger and car as a driver will be made. Train and taxi are included under "other "category. Therefore, car as a mode of transport will be further divided:

- Car as a driver;
- Car as a passenger.

Therefore, the questionnaire (which can be seen in Appendix 5) has three parts aiming to collect data about the travel experience - actual origin station choice and reason to choose it (part I), the composition on choice set (question 2) and reasons why it is chosen (part II) and data on personal travelers' characteristics (part III).

The influence of built environment dimension on travelers' choice station behavior is assessed via a five-points rating scale (very negative, negative, neutral, positive, and very positive).

3.5. Data collection

As the survey is focused on the train stations used as an origin for the train trip the target group is people using these train stations, living/working inside and outside the ring of Amsterdam. People arriving at the station with the train (either if it is the destination station or transfer station of their trip) are not considered in this research. The questionnaire was distributed by the fieldwork company Almere Marktonderzoek Advies B.V., in the specified stations, on 3rd and 7th of April 2014 (working days). According to Hensher, et al. (2005), the choice-based sampling (CBS) is suitable for the collection of RP choice data and the rule of thumb suggests that at least 50 decision makers must be sampled for each alternative. Therefore, in each station, 50 respondents were asked to fill in the questionnaire. Moreover, it must be underlined that it will be a one-time (cross-sectional) survey and one of the directions given to the field-workers was to distribute the questionnaire only to the targeted travelers.

3.6. Model form

In building up the model that will reveal travelers' preferences for the alternatives some aspects need to be taken into account, such as the structure of the model (MNL, probit, etc.), the identification of dependent and independent variables, the form of utility functions (linear or non-linear) and the recognition of individual's choice set (Ortuzar & Willumsen, 2011). This paragraph is presenting the theoretical framework behind the discrete choice models, MNL specifically.

The most common theoretical based of discrete choice models is the random utility theory (Ortuzar & Willumsen, 2011). The assumption of this theory is that an individual will choose from an available set of alternatives based on utility maximization. For each individual, the modeler is associating the utility of the alternative via two components:

$$U_i = V_i + \varepsilon_i \quad (3.1.)$$

Where: U_i is the utility offered by alternative i;
V_i is the representative component of utility, which is a function of the measured attributes;
ε_i is the random/error component of utility due to unobserved influences.

The probability that an alternative will be chosen is given by the relations:

$$Prob_i = Prob\ (U_i \geq U_j),\ \forall\ j \in j = 1,..\ ,\ J\ ;\ i \neq j \quad (3.2.)$$

$$Prob_i = \frac{\exp(\beta j * Vi)}{\sum_{k=0}^{j}(\beta j * x_{ki}\ )} \quad (3.3.)$$

Where: i = observation number or individual;
k, j = choices;

$$V_i = \beta_{0i} + \beta_{1i} * f(X_{1i}) + \beta_{2i} * f(X_{2i}) + \cdots + \beta_{ki} * f(X_{ki}) \quad (3.4.)$$

Where: V_i is the representative component of utility;
β_{1i} is the weight associated with attribute X_1 and alternative i, which establishes the relative contribution of the attribute to the observed sources of relative utility;
β_{0i} is the alternative-specific constant, which represents on average the role of all the unobserved sources of utility.

The above utility functions are the base for the "simplest and most popular practical discrete choice model", which is the Multinominal Logit Model (MNL) (Ortuzar & Willumsen, 2011). These models allow the modeler to estimate the choice by integrating data for all the alternatives. More specific, in the present study the dependent variable is station choice and this will be predicted by integrating all alternatives available and their characteristics .This is in contrast with a regression model since the latter cannot allow the modeler to take into account all the alternatives available at once, but predict the likelihood of choice of one single station, based on its individual characteristics.

The underlying assumption for the MNL model is that any individual's decision to choose an origin station is based on utility maximization when selecting from a set of feasible alternatives defined by different features. The expected results consist in the weight of the characteristics describing the 4 categories included in the conceptual framework in the travelers' station choice decision making. Moreover, based on the identified characteristics and some scenarios, the way of redirecting the flow of travelers from Amsterdam Central station to other station, in order to decrease the congestion level at the first mentioned station, is analyzed.

3.7. Conclusions

In this chapter the research approach is presented. First, the research questions, conceptual framework and research methods are explained, followed by the structure of the research: criteria selection for the attributes included in a questionnaire and data collection.

Central question of this research: "What attributes of train stations' environment are influencing travelers' origin station choice behavior?". To answer the main question, sub-questions concerning the way of characterizing the train station in the context of travel behavior and the weight of these characteristics in their decision regarding travelers' origin train station choice. The research approaches are selected to answer the sub- and later on the main questions.

In order to answer the first sub-question, regarding the way of characterizing the train stations in context of travel behavior, a literature study was made as a first step. Based on the findings from the literature review, some characteristics defining trip-related aspects, travelers' and stations' surrounding environment were selected to be used as attributes in a paper-based questionnaire. Station itself characteristic were not part of the questionnaire due to the widespread analysis of them in the literature and within NS. In order to collect the data in a relevant context (a multi-station city from which the travelers can consider feasible alternatives) a case study was set up. 8 stations from Amsterdam Metropolitan area were selected to enter the choice set and the targeted respondents were travelers using one of these 8 train stations as an origin station for their trip with the train. Next to the findings from the literature review and the outcome of the questionnaire, the first sub-question can be answered.

The background information is further used in a MNL model aiming at determining the attractiveness of the train stations' characteristics for the travelers. This is the answer for the second sub-question, the weight of the characteristics in Dutch travelers' origin train station choice decision-making.

4. Analysis

This chapter describes the analysis phase of the present research project. In the first paragraph the number of filled-in questionnaire and stations choice frequency is introduced, followed by "Data cleaning", which the search for inconsistencies within the answers is presented in. The next three paragraphs, the research sample, actual travel experience and choice influence are described. The chapter ends with model analysis and conclusions.

4.1. Number of filled-in questionnaires and stations choice frequency

The table below summarizes the number of distributed questionnaires at each station level. It can be seen that a minimum number 50 questionnaires (the threshold suggested in the literature) were completed for all the stations, except for Amsterdam Sciencepark (the station was most of the time empty during the day in which the questionnaires were distributed).

Table 3. Number of filled-in questionnaires

Origin station	Number of filled-in questionnaires
Amsterdam Central	50
Amsterdam Amstel	57
Amsterdam Rai	58
Amsterdam Zuid	51
Amsterdam Sloterdijk	50
Amsterdam Muiderpoort	50
Amsterdam Lelylaan	60
Amsterdam Sciencepark	6
Total:	382

A total of 382 respondents were approached. However, not all the respondents mentioned the station which they were using at that moment as being the most often used one as an origin station for their trips. The results are integrated in the "Frequency of choice as origin station" column, in Table 4. Only three stations were chosen as origin stations more than 50 times (Amsterdam Central, Amsterdam Amstel and Amsterdam Muiderpoort), out of which Amsterdam Central is by far the most used one (25,4%). This finding it is not surprising, but reflecting the real case and supporting the problem statement of this research paper: high crowding level at the stations offering more opportunities, while the stations with fewer opportunities are not among travelers' preferences.

Table 4. The frequencies of stations choice as an origin station

Origin station	Frequency	Valid percentage
Amsterdam Central	97	25,4
Amsterdam Amstel	54	14,1
Amsterdam Rai	33	8,6
Amsterdam Zuid	48	12,6
Amsterdam Sloterdijk	47	12,3
Amsterdam Muiderpoort	57	14,9
Amsterdam Lelylaan	42	11
Amsterdam Sciencepark	4	1
Total:	382	100

4.2. Data cleaning

There were two cases in which the respondents did not mention any alternative station, but filled in a suitable manner the rest of the questionnaire; their answers were taken into account for sample description and travel experience. However, for building the choice model, these two respondents were removed from the analysis.

Another check for inconsistencies in the database reveled that in 6 cases, the respondents chose as alternative station the same one mentioned as the origin station, even though in the questionnaire in was mentioned that they need to be different. As in the previous case, when no alternative station was mentioned, for sample description and travel experience their answers were taken into account, but not for the choice model.

Table 5. Origin and alternative stations

		2. Alternatief treinstation									
		Amsterdam Centraal	Amsterdam Amstel	Amsterdam Rai	Amsterdam Zuid	Amsterdam Sloterdijk	Amsterdam Muiderpoort	Amsterdam Lelylaan	Amsterdam Science Park	Geen	Total
1.1. Treinstation van herkomst	Amsterdam Centraal	5	23	3	7	19	6	4	1	29	97
	Amsterdam Amstel	32	0	4	5	0	3	0	1	9	54
	Amsterdam Rai	7	5	0	12	2	0	1	0	5	32
	Amsterdam Zuid	11	12	7	1	1	0	4	0	11	47
	Amsterdam Sloterdijk	20	2	1	0	0	0	9	0	15	47
	Amsterdam Muiderpoort	28	18	1	0	0	0	0	3	7	57
	Amsterdam Lelylaan	10	0	0	5	18	0	0	0	9	42
	Amsterdam Science Park	0	0	0	0	0	2	0	0	2	4
Total		113	60	16	30	40	11	18	5	87	380

Further, another consistency check focusing on travelers who arrived with car as a driver at the station, but do not possessed a car (mode=car as a driver and car possession=no), revealed one such case. After checking the questionnaire proved to be a wrong insertion of the mode access (car as a driver instead of walking), done by the fieldwork company.

Regarding working situation, there were 24 respondents who mentioned 2 responses even if it was a single response question. The fieldwork company inserted these two answers under “Others” field. The data was cleaned as follows: “student” was replaced if the working situation was part-time and student/ student and part-time, full-time and student/student and full-time; “pensioner” in the case of part-time and pensioner. The age was also an important factor in proceeding with data cleaning in this way: the respondents mentioning the student status in combination with part/full-time jobs were between 16 and 27 years old, while the respondent mentioning pensioner and part-time job was aged 57. In addition, 13 respondents mentioned their actual occupation (e.g. freelancer, self-employed, working abroad). These responses were assimilated to full-time employment.

Regarding the access mode, there were 3 respondents mentioning 2 modes instead of 11 and another one which was not included in the predefined list of answers. According to the order in which the combined modes were mentioned, the last one was chosen: public transport (the percentage of public transport increased with 0,5 percent). Only one different access mode remained: pont, but since it is a form of public transport it was assimilated to this category.

Some combined purposes of the trip were mentioned. The correction was made according to the following rules: firstly, all the cases in which the purpose was other than the predefined answers and the work situation was other than the predefined answers; (this is necessary due to the correction made for the double answers (e.g. Student and part-time) for consistency reasons; next, all the cases in which the work situation was student (in the case when no previous corrections were made) and the purpose was other than the predefined answers; this was necessary to keep the consistency with already made corrections for the work status; the rest of the cases: the first purpose mentioned (in the order they are standing in the predefined answers list) stands as the most important.

The question regarding household composition was left out of the analysis because of inconsistency reasons; as it a box was ticked but the number of people was not filled in, since this was different than 0; at a closer look at the answers showed that there was also 0 inserted.

To sum up, the number of respondents included in sample description, travel experience and choice influence is 382, while for the model construction only 374 respondents were suitable. With all the corrections made, the database provided by the fieldwork company can be trusted.

4.3. Research sample description

From the 382 respondents, 2 did not indicate their age, 2 – their gender, 31- their postcode of residential location, 6 – their last completed education, 5 – their work situation, and 35 did not indicate if they own a car or not. Table 6 presents an overview of the respondents' characteristics.

Table 6. Research sample

Attribute	Level	Frequency	Percentage (%)
Gender (N=380)	Women	173	45,5
	Men	207	54,5
Age (N=380)	16-19	66	17,4
	20-24	112	29,4
	25-44	121	31,9
	45-64	64	16,8
	65+	17	4,5
Education (N=376)	Middle-educated	105	28,1
	Higher- educated	271	71,9
Postcode of residence (N=351)	Amsterdam and surroundings	277	78,9
	South Holland	17	4,4
	Utrecht and surroundings	27	8,2
	Breda and surroundings	5	1,4
	Eindhoven and surroundings	4	1,1
	Gelderland	7	2
	Over Ijssel	9	2,6
	Groningen	4	1,1
	Friesland	1	0,3
Car owners (N=347)	Yes	134	38,6
	No	213	61,4
Time flexibility in work (N=377)	Low	122	32,4
	Medium	229	60,8
	High	26	6,9

It can be said that the research sample includes a bigger percentage of people younger than 45 years old (the 25-44 years old group being the most representative with 31,9%) in comparison with the older population (over 45 years old), part of the sample. Regarding the gender distribution, there is a difference of 9% between the women and man ratios, the sample being characterized by the presence of more women as respondents. In general, it can be stated that from the point of view of age and gender distribution, this sample is a common one if it were to be compared with the one that NS is using.

Concerning the residential postcodes, the majority of the respondets are living in Amsterdam and its surrounding area (almost 80%), a situation which is favourable since the purpose of this study is to determine the origin station choice behavior for Amsterdam case. Moreover, more than 61% of respondents do not own a car.

Questions about education, working status and household composition are not usually reported in the station analysis performed by NS, this is why the sample cannot be described as being a particular or a common one.

The sample is characterized by the presence of higher educated travelers (almost 72%) and more flexible (almost 61% and including part-time employees and students).

4.4. Information about current travel experience

As mentioned before, Amsterdam Central is the most frequently used station (25,4%), followed by Amsterdam Muiderpoort, Amsterdam Amstel, Amsterdam Zuid, Amsterdam Sloterdijk and Amsterdam Lelylaan (with more than 10% each). Amsterdam Sciencepark is the least used, with only 1%, while Amsterdam Rai has a value below 10% (8,6%). Table 7 gives an overview about the trip-related aspects of the research sample.

Table 7. Current travel experience

Attribute	Level	Frequency	Percentage (%)
Travel time to the station (N=377)	Less than 8 minutes	118	31,3
	9 to 12 minutes	120	31,8
	More than 13 minutes	139	36,9
Frequency of use (N=382)	More than 4 days/week	162	42,4
	1-3 days/week	118	30,9
	1-3 days/month	45	11,8
	Less than 2 days/month	36	9,4
	Less than 2 days/year	21	5,5
Purpose of use (N=382)	Work/business	160	41,9
	Social/recreational	76	19,9
	School/study	146	38,2
Access mode (N=382)	Walking	100	26,2
	Bike	109	28,5
	Car as a driver	5	1,3
	Car as a passenger	7	1,8
	Public transport	161	42,1

In this section of the questionnaire there were less missing values, only 5 for the duration to arrive at the station. One reason can be the fact that it was the first part of the questionnaire. Regarding the duration, the missing values were replaced with the average of all durations mentioned (15,12 minutes); it can be said that there is an almost even distribution (around 31%) of respondents among the durations of less than 8 minutes and 9-12 minutes groups. However, the majority of respondents are traveling for more than 13 minutes to arrive at the station. In addition, the majority of respondents are frequent travelers, more than 70% traveling between 1 to more than 4 days/week.

More travelers included in the sample are using the station for work/business (almost 42%) and school/study (38,2%) purposes and the most used mode of transport to arrive at the station is the public transport (42,1%), followed by bike (28,5%) and walking (26,2). Car (as a driver and passenger combined) represents less than 4%. The lowest percent of car as a mode is not surprising, giving the fact that Amsterdam has the lowest rate of car ownership and parking spaces in the region (BBROVA, 2012). The large amount of travelers reaching the station by public transport can be associated with the fact that it is not the nearest station that is often used as an origin station for the trip with the train. In general, it can be stated that from the point of view of purpose and access modes distribution, this sample is up to a certain extent a particular one if it were to be compared with the one that NS is using. Data available from NS shows that the most common mode of transport is the bike and car has even a lower percentage, while the most common purpose is work/business. Thus, in comparison with the national scale, the Amsterdam case is a particular one. This is not a surprising fact, since Givoni & Rietveld (2014) had the same outcome in their analysis: "Thus in Amsterdam the share of public transport is much higher, whereas the share of the bicycle is lower".

4.5. Inventory of station aspects on choice influence

This paragraph describes the findings related to the influence of the surrounding area on travelers' origin station choice behavior. First, the results for the main 5Ds are introduced, succeeded by the sub-attributes of diversity, design and destination accessibility.

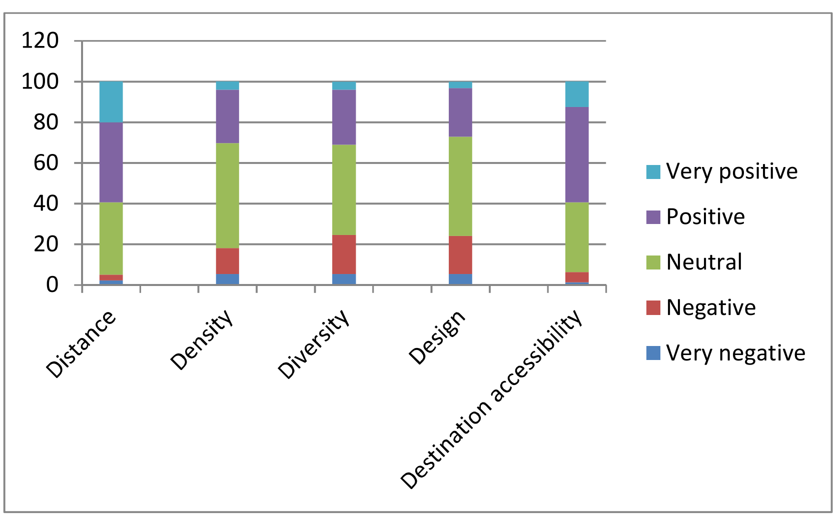

Figure 30. Influence of the 5Ds on travelers' origin station choice behavior

The missing values were replaced with 3 (neutral); this change did not affect in a great way the average (mean) for each attribute. For all the attributes, the average is positive.

All the attributes are affecting the choice in a positive way, rather than negative as it can be seen in the Figure 30. Distance and

Destination accessibility are the attributes with the highest scores for the positive side (59,5%, summing up positive and very positive scores) and the least for the negative (5%, 6,3% respectively). Therefore, Distance and Destination accessibility can be considered as triggers. Diversity and Design have the highest negative scores, followed by Density. However, these three attributes have more than 44% neutral answers, with density the highest: 51,6%.

Concerning the Diversity sub-attributes, the sum of all the missing values was 33. After replacing all of them with 3 (neutral) as in the previous case, the average did not increase with more than 0,01. Nevertheless, one particularity of these sub-attributes is the negative mean of "Presence of a variety of shops".

The same finding is showed in Figure 31, "Presence of a variety of shops" having the highest score for the negative effect, almost 30%. "Presence of supermarkets" and "Presence of eateries" have a positive effect, with their means positioned around neutral value and these two attributes are contributing to the positive influence of Diversity attribute. Their extent of influence is not as high as Distance and Destination accessibility.

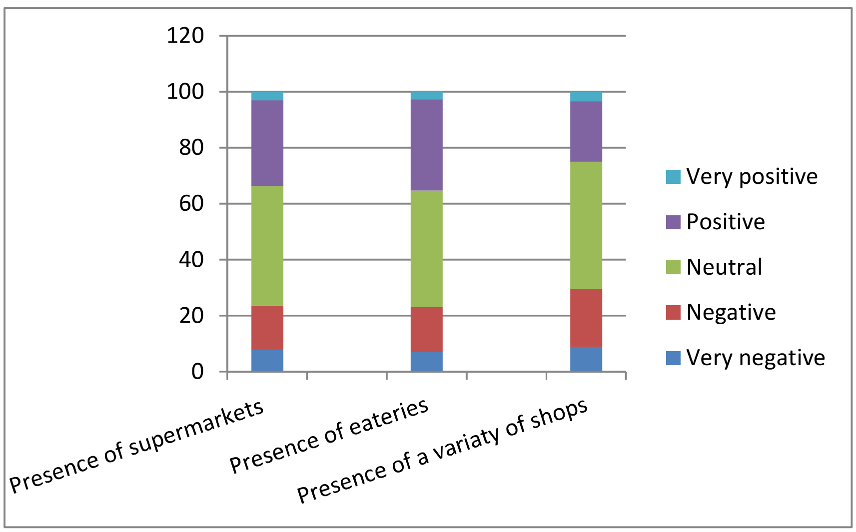

Figure 31. Influence of the Diversity sub-attributes on travelers' origin station choice behavior

Among the Design sub-attributes, "Sidewalks", "Bike-friendly design" and "Pedestrian amenities" are the triggers affecting travelers' choice behavior, with an average higher than 3.16. "Buildings" and "open Space" have a more neutral influence, while "Car-friendly design" has a negative influence, lower than "Presence of a variety of shops". The highest scores for the pedestrian-friendly and bike-friendly designs can be explained by the large amount of travelers arriving by walking or by bike, in comparison with the ones using the car, as mentioned before when referring to the access modes.

"Car-friendly design" has the highest neutral score, 56,5% and the lowest positive and very positive influence in comparison with the rest of Design sub-attributes, as it can be seen in Figure 32.

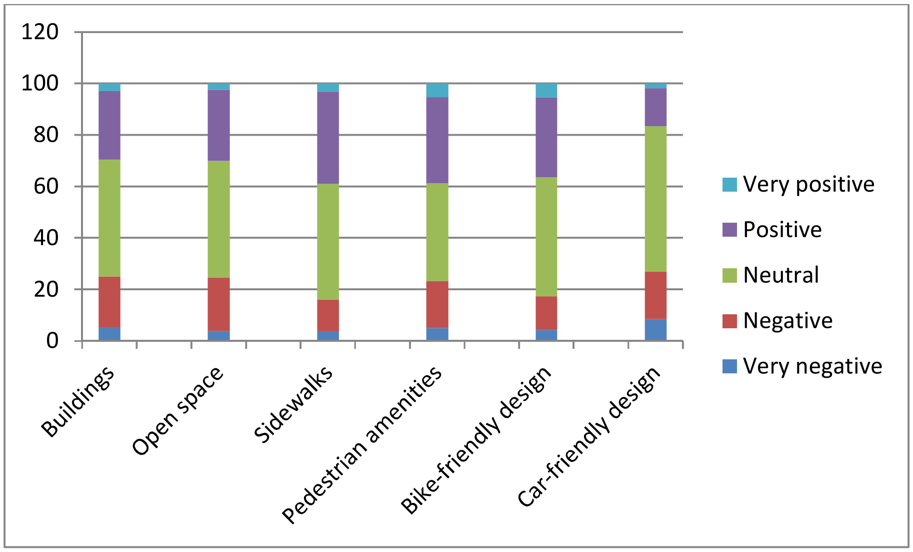

Figure 32. Influence of the Design sub-attributes on travelers' origin station choice behavior

In the group of Destination accessibility, "Public transport" has the highest positive influence, with an average of almost 4%. "Bike shelters" has the second most positive influence (3,27%), while "P+R" and "K+R" have more neutral influence on travelers' station choice behavior.

Destination accessibility sub-attributes have the highest rate of neutral answers in comparison with the other groups (e.g. for K+R the neutral answers represent 67,5%, while for P+R is 62% as seen in Figure 33. The highest positive influence of "Public transport" and "Bike shelters" can be explained by the fact that Public transport and bikes have a big share in the access modes used by travelers to arrive at the station.

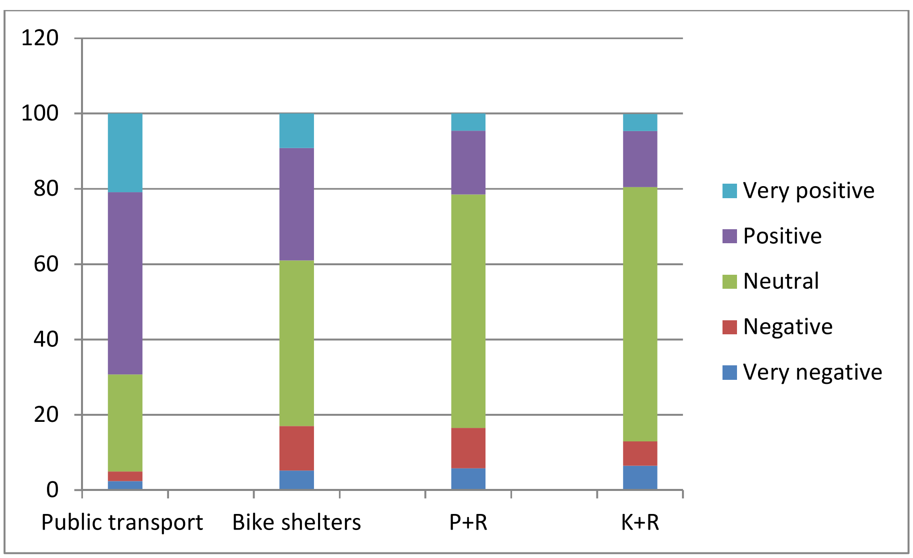

Figure 33. Influence of the Destination accessibility sub-attributes on travelers' origin station choice behavior

4.6. Model analysis

In the section "Model analysis", the model estimation and an application are presented.

4.6.1. Model estimation

To analyze to what extent station, built environment, travel and personal characteristics influence the probability that a station is chosen, multinomial logit models were estimated. For building up the model, aiming at revealing structural information regarding the station choice for all the respondents, some steps were followed and they are introduced in this section. The selected model is presented in the end of the "Model specification" part.

Step 1. Stations characterization in the context of station choice behavior

The variables included in the characterization of the station in the context of station choice behavior can be seen in Table 8. This table is divided into two main parts: variables describing the station itself (mainly level of service) and variables describing the surrounding environment of the stations. These variables were selected based on the following principles:

- Outcome of the literature review
- Outcome of the questionnaire
- Availability of the data.

The variables marked with "*" have as source the study "Maak plaats" (2013) mentioned before in this research study; their meaning is also discussed in Chapter2 of this study. Crowding level was determined based on realistic assumptions (size of the station related to the average number of travelers during a working day). Due to the fact that this research paper is one way or another a pioneer in integrating the surrounding area of stations in travelers' choice behavior, some information were not available. Besides, due to the time frame of this research, the figures were not too much detailed, but estimated based on the information provided by Google Maps for characteristics like: eateries/cafes/hotels, shops, supermarkets, leisure/touristic attractions, parks. The other variables have as a source, O.P.S. Type 4,5,6, 2013 and NS, 2012. The levels of variables are not detailed in this report due to confidentiality reasons.

Step 2. Characterization of the alternative stations by coding the characteristics' levels

As it can be seen in the Table 8, some of the variables included in the data set are discrete, requiring that words are used as descriptors for their levels (e.g crowding level is "high", "medium" or "low"). These variables need to be numerically coded. The reason for not using a discrete data is the fact that qualitative or discrete structure of coding implies a linear relationship among the effects of the levels of the attribute (Hensher, et al., 2005). Effect coding was used to represent these discrete variables. By employing this coding system, a two level variable is represented by one parameter, while a three level variable is represented by two levels. For example, the presence of parks (named "Parks" in table x) has two values -1 (level one for "No") and +1 (level 2 for "Yes"), while crowding level has three levels coded as: "low"=1 (level 1: -1 -1), "medium"=2 (level 2: 0 +1) and "high"=3 (level 3: +1 0). The coding of the levels of variables can be seen in table 8, as well.

Table 8. Coding

Characteristics		Type of variable	Levels					
			Level1	K1	K2	Level 2	K1	K2
Station	Station type	Continous	Number					
	Types of trains*	Discrete	Sprinter*	1	0	Sprinter+Intercity*	0	1
	Number of trains/hour	Continous	Number					
	Crowding level	Discrete	High*	1	0	Average*	0	1
	Transfer station	Discrete	Yes*	1		No*	-1	
	Monument building	Discrete	Yes*	1		No*	-1	
	General opinion	Continous	Number					
	Atmosphere	Continous	Number					
	Functionality	Continous	Number					
	Safety	Continous	Number					
	Number of passenger (average on a working day)*	Continous	Number					
Surrounding environment	Distance (average in minutes)	Continous	Number					
	Proximity*	Continous	Number					
	Intensity*	Continous	Number					
	Offices (nr of people working)*	Continous	Number					
	Residential location*	Continous	Number					
	Eateries/cafes/hotels	Discrete	Many*	1	0	Average*	0	1
	Shops	Discrete	Many*	1	0	Average*	0	1
	Supermarkets	Discrete	Yes*	1		No*	0	
	Leisure/touristic attractions	Discrete	Many*	1	0	Average*	0	1
	Parks	Discrete	Yes*	1		No*	-1	
	Public transport connectivity*	Continous	Number					
	Bike shelters	Continous	Number					
	P+R	Continous	Number					
	K+R	Continous	Number					

* effect coding

Step 3. Preparing the analysis data file

For preparing the analysis data file, 2 cases were removed from the database containing the respondents' answers (no alternative was specified); 6 others were removed because the station of origin was chosen as alternative as well. Only the respondents who chose a viable alternative were selected (287 cases). The rest mentioned no alternative. After cleaning, the resulting data file contained all 287 respondents with their individual origin station, alternative station, age and frequency of use for their origin station and the variables included in Table 8. Moreover, some data needed to be standardized: to have a value between "0" and "1", in order to equalize the data variability in the model.

These file was the input for MNL. In order to determine the influence of the station, built environment, travel and personal characteristics on station choice behavior, the program NLOGIT 5 was used to estimate the MNL models. NLOGIT is a large model estimation and analysis package for regression, discrete choice, counts etc., an extension of an integrated econometrics package (LIMDEP) (Hensher, et al., 2005). To estimate the discrete choice model, NLOGIT uses the method of maximum likelihood estimation (MLE), "an estimator that calculates parameters for which the observed sample is most *likely* to have occurred"(Hensher, et al., 2005). MLE is employed when several parameters have to be simultaneously estimated. "Indeed, MLE has become a popular method of model estimation because of its robustness and ability to deal with complex data" (Hensher, et al., 2005). In the output release by NLOGIT model estimation log likelihood is an approximation of the overall model significance. Another measurement of how good the model describes the set of observation (goodness to fit of choice models) is Rho square method and it is estimated by the next formula:

$$P^2=1-\frac{\log likelihood\ for\ alternative\ model}{\log liklihood\ for\ nul\ model} \qquad (4.1.)$$

According to the literature, a ρ^2 value around 0.2 to 0.4 is believed to be good model fit (Maitra, et al., 2013). Rho square measures the improvement of the estimated model when compared with a model which assumes all the parameters equal with zero.

Step 4. Checking for correlation
Since RP was the method employed to collect the necessary data, a check for correlation among the variables was needed. The results of the test can be seen in Appendix 6. Correlation matrix.

Once the model estimation process started, it could be seen that not all the variables characterizing the station choice behavior could be integrated in one model, not only because the variables will not be statistically significant, but due to the fixed parameters problem as well. Multiple alternative models were estimated by paying attention the correlation matrix (exclude from one model the variables highly correlated: the coefficient of correlation had to be higher than 0.6).

The most optimal model was chosen based on the following criteria:
- High log likelihood value;
- Should include at least one alternative-specific constant due to its importance (especially for MNL model). Besides the role of capturing the unobserved effect associated with a particular alternative, the constant terms represent, on average, the sample choice shares of the alternatives (Hensher, et al., 2005).
- The mix of variables must include more variables describing the built environment dimension (in accordance with the purpose of this study).

Therefore, the chosen model as being the most optimal is shown in Figure 34. The model uses a utility function which includes an alternative-specific constant (ISP 3), one comprehensive variable describing the station (general opinion) and 4 variables from the surrounding environment category. The parameters (β coefficients for the variables) have the expected directions. The alternative-specific constant is referring to Amsterdam Rai station and has a positive sign because it needs a correction, an increase to reach the average of selected stations (it has been chosen 33 times by the respondents, in comparison with Amsterdam Central 97 times). The other positive coefficients of the variables mean that the higher the variable's value, the more chances the station has to be chosen. On the other hand, the negative values of the coefficients for the rest of the variables suggest that a decrease in the value of the variables leads to a decrease in the chances that a station it is chosen (e.g. distance: the longer the distance, the lower the chance of a station to be chosen).

From the observation of multiple models estimation, it can be stated that the log likelihood value of the null model is -198.93324. Therefore the value of ρ^2 is 0,1948 (value between 0 and 1), in the range of 0.2 (a good model fit).

```
--------------------------------------------------------------------------
Discrete choice (multinomial logit) model
Dependent variable              Choice
Log likelihood function      -160.18971
Estimation based on N =    287, K =   8
Inf.Cr.AIC  =    336.4 AIC/N =    1.172
Model estimated: May 21, 2014, 11:33:21
R2=1-LogL/LogL* Log-L fncn R-sqrd R2Adj

 Response data are given as ind. choices
 Number of obs.=   287, skipped    0 obs
--------+-----------------------------------------------------------------
        |               Standard          Prob.      95% Confidence
    ICHO|  Coefficient      Error      z    |z|>Z*        Interval
--------+-----------------------------------------------------------------
ISP3|    6.04686***     1.74690     3.46  .0005     2.62300   9.47073
KN6_1|    13.7204**      6.52628     2.10  .0355      .9291   26.5117
KN11_1|   -75.8923***    16.87149    -4.50  .0000   -108.9598  -42.8247
KN12_1|    12.3546***     4.23243     2.92  .0035     4.0592   20.6500
KN13_1|    27.1067***     8.45803     3.20  .0014     10.5293   43.6841
KN24_1|    4.92334***     1.54646     3.18  .0015     1.89233   7.95435
1_IAG1|    -.60868***      .14709    -4.14  .0000    -.89697   -.32039
1_IFR1|     .73773***      .14901     4.95  .0000     .44567   1.02979
--------+-----------------------------------------------------------------
Note: ***, **, * ==>  Significance at 1%, 5%, 10% level.
--------------------------------------------------------------------------
```

Figure 34. The chosen model

Legend: ISP3 – Alternative specific constant
KN6_1 – General opinion
Kn11_1 – Distance
KN12_1 – Proximity
KN13_1 – Intensity
KN24_1 – P+R
1_IAG1 – Age
1_IFR1 – Frequency of use

In order to prepare the data for the next stage, which is model application, the utilities (by applying formula 3.4.) and the probabilities of utilities (by applying formula 3.3.) associated with two alternative stations were calculated. The calculations can be seen in Table 9. The selected alternatives were Amsterdam Central and Amsterdam Amstel stations. Both of them are station with high(er) scores for the variables; however, what makes it very interesting is the fact that even if the general opinion about Amsterdam Amstel is higher than the one for Amsterdam Central, more travelers are using the latter.

After calculating the probabilities of choosing the station revealed that the model is not predicting that Amsterdam Central is still the station with the highest chance to be chosen, but Amsterdam Amstel (0.42 probability of choosing Amsterdam Central, in comparison with 0.58 for Amsterdam Amstel). Some explanations for this outcome are being discussed. Firstly, in the file used as a input for the MNL model containing the origin and alternative stations for all the respondents, Amsterdam Central is more often not chosen than chosen

(108 times not chosen versus 63 times chosen). Secondly, in the research sample, the proportion of travelers choosing Amsterdam Central vs Amsterdam Amstel is 1.89, while in the reality this value is 6.76. These two reasons lead to the conclusion that the research sample used in this study is not entirely reflecting the reality, fact leading to this uncommon prediction.

Table 9. The choice details of Amsterdam Central and Amsterdam Amstel

Xi	Coefficient value	Amsterdam Central station	Amsterdam Amstel
Alternative specific constant (X3=1)	6,04686	0	0
General opinion	13,7204	0,1368	0,1408
Distance	-75,8923	0,1601	0,1413
Proximity	12,3546	0,03	0,31
Intensity	27,1067	0,29	0,12
P+R	4,92334	0	0
Vi		-2,04182551	-1,70901967
		0,129791559	0,181043188
P(Vi)		0,417558076	0,582441924
100 travelers		41,75580761	58,24419239

4.6.2. Model application

The application of the model for the two alternative stations selected consists in scenario analysis. More specific, it is about the analysis of "what if" scenarios to answer the question how will the probability of choosing the stations will increase/decrease if the value of the variables is changed. Based on the probabilities, a prediction of the distribution of 100 travelers between the two stations will be made.

Moreover, a division among two group age groups of travelers (younger than 30 years old and older than 30 years old) and frequency groups (more than 4 days/week and others) was supposed to be made. The personal characteristics (age and frequency) could not be integrated for the selected case (Amsterdam Amstel). The parameters for age and frequency represent a correction of the alternative specific constant which is included in the model, therefore only Amsterdam Rai (alternative station 3) could be corrected for groups.

Table 10 represents a summary of the scenarios and their outcomes. It can be seen that under all of the scenarios the probability of choosing Amsterdam Amstel (since one of the goals of the project was to determine how the flow of travelers could be redirected from Amsterdam Central to other station, or Amsterdam Amstel in this case) is increased at least with 1.27% (on the current level of variables the probability of choosing Amsterdam Amstel is 58.24%, while the smallest increase in the probability to choose it is in case of an increase to 65% of the general opinion: 59.51%). Two of the best improvements that can be developed at Amsterdam Amstel station level in order to determine more travelers to use it are: increase the number of available parking spaces (50 parking spaces determine 76/100 travelers to use Amsterdam Amstel as opposed to 24/100 – Amsterdam Central) and increase the intensity around the station (a 250 level of residents, workers or visitors around

Amsterdam Amstel are attracting 81/100 travelers to use this station, in contrast with 19/100 in Amsterdam Central).

Table 10. Forecasting the use of stations analysis under 5 scenarios

Scenario	Number of travelers using Amsterdam Centraal	Number of travelers using Amsterdam Amstel	Total number of travelres
Increase to 65% the general opinion about Amsterdam Amstel Station	40,49	59,51	100
Increase with 50 the number of available parking spaces at Amsterdam Amstel Station	24,23	75,77	100
Descrease with 1 minute the travel time to Amsterdam Amstel Station	29,62	70,38	100
Increase to 22% the proximity at Amsterdam Amstel Station	27,72	72,28	100
Increase to 250 the intensity around Amsterdam Amstel Station	18,67	81,33	100

4.7. Conclusions

The analysis of the research data consists of research sample description, information about current travel experience, inventory of station aspects on choice influence and MNL model analysis is presented in this chapter.

In what concerns the research sample, it can be stated that there was a large proportion of younger than 45 years old travelers filling in the questionnaire than old travelers and more women. The present research sample is not a particular sample in comparison with the NS's sample. The majority of the respondents are living in Amsterdam and surrounding areas of Amsterdam (almost 80%), do not own a car (more than 61%) and are higher-educated.

Regarding the current travel experience information, the data collected via the questionnaire revealed that Amsterdam Central station (25,4%) is the most used train station in the Amsterdam Metropolitan area. To arrive at the station, the highest number of travelers have a time duration of more than 13 minutes and are using as transport modes public transport (42,1%), followed by bike (28,5%) and walking (26,2). Public transport as being the most used transport mode to access the station is not a surprising finding for the Amsterdam case. In addition more than 70% are frequent travelers, using the train between 1 to more than 4 days/week.

The findings related to the influence of the surrounding area on Dutch travelers' origin station choice behavior reveled that all the attributes included under the 5Ds category have a positive effect, rather than negative. Distance and Destination accessibility can be considered as triggers, while Diversity and Design have the highest negative scores, followed by Density. Concerning the Diversity sub-attributes, one particularity is the negative mean of "Presence of a variety of shops". Among the Design sub-attributes, "Sidewalks", "Bike-friendly design" and "Pedestrian amenities" are the triggers affecting travelers' choice behavior, "Buildings" and "Open Space" have a more neutral influence and finally, "Car-friendly design" has a negative influence. In the group of Destination accessibility, "Public transport" has the highest positive influence, with an average of almost 4%. "Bike shelters" has the second most positive influence (3,27%), while “P+R” and “K+R” have more neutral influence on travelers’ station choice behavior.

The outcome of the questionnaire and the findings from the literature review were combined in a characterization of the train stations in station-choice behavior context. This file, together with respondents’ age, frequency of use, main origin train station and their alternative were the input of the MNL model. Some steps were taken before the modeling process (effect coding, correlation checks). Due to high correlation among the variables (a drawback of the data collection approach –RP), several alternative choice models were estimated. Based on some relevant criteria, an optimal model was selected to further analysis. The statistically significant variables which entered the utility function underlying the model are: an alternative-specific constant (ISP 3), one comprehensive variable describing the station (general opinion) and 4 variables from the surrounding environment category (distance, proximity, intensity and P+R), one trip-related variable (frequency of use) and one travelers’ characteristic (age). The utilities of two stations (Amsterdam Central and Amsterdam Amstel) and their probability of being chosen were calculated. The results did not match entirely the expected findings since the model predicts the higher likelihood of Amsterdam Amstel to be chosen by the travelers instead of Amsterdam Central.

The chapter ends with the distribution of travelers flow from one station to another according to 5 scenarios.

5. Conclusions and recommendations

This chapter presents the results of this graduation project. First, the results are summarized, followed by conclusions. Last, but not least, this chapter ends with limitations of this research and recommendations included in the section “Discussion and recommendations”. Advices are given for improvement of the research for theory and practice.

5.1. Conclusions

Summary

The current demands of CO_2 emissions reduction imposed worldwide for a more sustainable urban life redirected the attention on public transport. In the attempt to stimulate the use of public transport, in particular the train as a mode of transport, not enough attention was paid to the travelers’ decision making process of choosing an origin station. The aim of this research was to determine the influence of the surrounding environment of train stations on travelers’ choice of train stations as origin station. One planning method focusing on the organization of the station’s environment and on maximizing the benefits of public transport is TOD. Generally, it can be characterized in terms of 5Ds (Density, Diversity, Design, Destination accessibility and Distance). However, in the literature there is no general agreement about the sub-attributes of the 5Ds. In seeking for a suitable way to define the 5Ds, some other characteristics characterizing the relationship between urban form and travel behavior (station choice behavior) were discovered.

How can train stations and their surrounding area be characterized in the context of travel behavior related aspects?

The answer for this sub-question is composed by two parts. First, the literature review revealed that the train stations and their surrounding area can be described in terms of four characteristics categories, namely travelers (socio-demographic characteristics), trip-related (frequency of use, access mode, etc.), station (level of service, type of station, etc.) and surrounding environment (the 5Ds). These four categories were the pillars on which the model was built. Moreover, the outcome of the questionnaire suggested some important variables/characteristics which need to be taken into account, since they were important for the travelers.

What influence do these features have on Dutch passengers’ choice of origin train station to enter a train?

The answer to the second research question is divided in two parts, according to the analysis performed in the present research project.

First, the analysis of the data collected using a questionnaire distributed in the 8 stations which were included in the case study showed that the 5Ds defining the surrounding area of the station have a positive effect on Dutch travelers’ origin station choice behavior. “Distance” and “Destination accessibility” can be considered as triggers, while Diversity and Design have the highest negative scores, followed by Density. Among the sub-attributes, “Sidewalks”, “Bike-friendly design”, “Pedestrian amenities”, “Public transport” and “Bike shelters” are the triggers affecting travelers’ choice behavior, while “Presence of a variety of shops” and “Car-friendly design” sub-attributes have a negative influence.

The second part of the analysis, the station choice model (MNL), identified several attributes affecting the choice for a departure station. The coefficients of these attributes have the expected sign and they are: an alternative-specific constant for Amsterdam Rai, one comprehensive variable describing the station (travelers’ general opinion) , 4 variables from the surrounding environment category (distance, proximity, intensity and P+R), one trip-related variable (frequency) and one personal variable (age) . Except from age and distance, all the rest of the attributes affect in a positive way the travelers’ train station choice behavior.

What attributes of train stations’ environment are influencing travelers’ origin station choice behavior?

Based on the answers found for the two sub-questions, the main research question’s answer can be formulated. It can be stated that Distance and Destination accessibility (2 out of 5Ds) have the highest influence on the origin station choice. The other 3 Ds (Diversity, Design, and Density) have less influence, but they still affect the choice in a positive way. The positive influence of proximity and intensity (density) is supported by the model results as well. On the other hand, the Distance attribute has a negative influence on the choice. One special sub-attribute is “P+R” because the outcome of the questionnaire is that it has a neutral influence on the station choice behavior, while the model showed that it has a positive effect. “Sidewalks”, “Bike-friendly design”, “Pedestrian amenities”, “Public transport” and “Bike shelters” are attracting travelers, while “Presence of a variety of shops” and “Car-friendly design” sub-attributes have a negative influence. The findings are not surprising if compared with the results shown in the available literature Dutch context-related. In their article, Debrezion, et al. (2007) found that distance and the presence of P+R facility have a significant effect on the choice of departure station, next to frequency of service and the intercity status of the station. The findings of the model employed by Givoni & Rietveld (2014) were that distance and accessibility of the station are increasing the disutility from using a station, while the quality of bicycle parking was increasing the likelihood of choosing a station.

General conclusions

This research thesis addresses a study of travelers’ choice of a train station as an origin station in the Netherlands. To collect data about station choice behavior, a case study was set up. The Amsterdam region was selected since it is one of the busiest regions in the Netherlands, with 70% of the public transport trips having the origin in Amsterdam. 8 stations formed the choice set and travelers were asked to fill in a questionnaire in these stations. Revealed preference was the research approach to collect the data and MNL models were built to describe the travelers’ train station choice behavior. The models rely on 4 pillars: travelers’ characteristics, trip-related characteristics, station and surrounding environment characteristics, important aspects reveled by the literature review and questionnaire outcome. The explanation for building up more models is the fact that the variables characterizing the stations were highly correlated. Based on some criteria mentioned before, the most optimal model was chosen. One alternative-specific constant, one station feature (general opinion), 4 variables describing the surrounding environment of the train station (distance, proximity, intensity and P+R), one travelers' characteristic variable (age) and one trip-related variable (frequency of use) entered the utility function, having significant effect on the choice of origin train station. To illustrate the working of the model, the model was applied for a choice situation of two train stations: Amsterdam Central and Amsterdam Amstel. The calculation of the probabilities of these 2 stations to be chosen revealed that the model was not predicting the reality – Amsterdam Central being most likely to be chosen, but vice-versa. One issue leading to the higher chances of another station to be chosen instead of Amsterdam Central is that the research sample was not reflecting the reality (10 times more travelers are using Amsterdam Central in comparison with the other station, while in the present research sample they were only 2 times higher). However, the redistribution of the flow of travelers from Amsterdam Central to Amsterdam Amstel was still studied under 5 scenarios. The results showed that the probability of choosing Amsterdam Amstel decreases with distance (the closest the station, the higher the probability to be chosen). Moreover, the presence of a P+R facility in the station has a high effect on the travelers' origin station choice. The distance has one of the highest effects on the choice. A decrease in the distance with only 1 minute has an almost equivalent effect of an increase with 19% of the intensity around the station and an increase with 3% in the proximity.

To sum up, it can be stated that the expected findings were not totally met due to the model prediction, but this research thesis is still providing valuable insights about origin train station choice behavior of the travelers.

5.2. Recommendations and Discussion

Recommendations

The present research gives a general overview about the role played by the surrounding environment of a train station in travelers' station choice. Nevertheless, the model presented in this research project is suffering from some limitations. First of all, the focus of this research was on explaining travelers' origin train station choice behavior, therefore the data collected is not allowing the study of the destinations of the trips. This is important because one important trip-related aspect can be included in the analysis, namely the direct connection between the origin and destination stations. It might be the case that direct connection can make the other variables (e.g. describing the surrounding environment) weighting less in the travelers' decision to choose an origin train station.

Secondly, there is a need of additional collection of the data to make the sample representative since the questionnaire is a good tool to gather information about the influence of variables on station choice behavior. However, if it were to follow the first advice given above (to include the destination station as well), instead of choosing the relevant characteristics of the alternative station, the respondents can be asked to do the same, but for the destination station and assess the direction connection between origin and destination stations next to all the other attributes. In addition, since Amsterdam has a high number of expats, it would be interesting to take English speaking travelers into account as well for the next study focused on Amsterdam region. This recommendation leads to the translation of the questionnaire in English, next to Dutch language.

Next, the characteristics affecting travelers' behavior were selected from the literature. The lack of "standardized" descriptions for the 5Ds forced to develop selection rules during the process of elaborating this research paper. Interviews with experts to discuss about the characteristics took place, but in an informal way. Qualitative research –e.g. interviews with specialists but in a formal, structured way, could deliver another set of characteristics than the ones included in this research thesis. Moreover, it will be interesting to compare the findings of this thesis with the outcome of one of iTOD workshops, in which the design dimension around train stations was analyzed by Dutch experts. Besides, due to time constraint, the levels of some selected variables to characterize the stations were estimated according to Google Maps or common sense. For a future research, these levels could be determined using GIS. Besides, a new research approach can be used, Stated Preference (SP). In this way the correlation issue (which affected the model estimation in the present research) can be overcome, since SP allows the researcher to control for it before the actual data collection.

What is more, in the model presented in this research, age, gender and frequency of use were taken into account, out of which gender proved to be statistically insignificant. In the same way as this study is presenting the modeling part, some other models for sub-groups (e.g. by purpose of use, distance etc.) can be estimated. In this way, some other variables can prove to be statistically significant.

Further, since this research thesis found out that the 5Ds are affecting in a positive way the station choice behavior; it gives an indication about travelers' awareness about developments around the train stations when choosing a train station as an origin for their trip with the train. Since one of the most important variables affecting travelers' station choice behavior is distance, some recommendation can be made for NS in order to increase the use of (smaller) train stations. The collaboration with the other stakeholders (e.g. bus companies) should be enhanced to strengthen the accessibility of the station; moreover, in collaboration with the municipalities, NS should keep the access routes to the stations as free of obstacles as possible. Direct routes should also be taken into consideration, with fewer detours. Besides, as it is shown in the present research, more travelers are arriving at the station by public transport. The public transport connectivity of the station should be a first priority. Some investment should be made in the way that more parking spaces are available as well. Regarding the models that are currently used by NS to forecast number of travelers (time table, access or egress facilities, fares and travel time sensitive models), one suggestion to improve them is to add distance (measured in meters, in the same way as Debrezion, et al. (2007) as the variable to be changed for forecasting travel demand.

Last, but not least, this study represents one of the first attempts to study the origin station choice behavior of the travelers based on the influence of the surrounding environment of the station. Therefore, the approach is general, assuming that there is a relationship between the surrounding area's characteristics and the station choice. For further research, the approach should be moved towards a particular way: the area surrounding the station should be analyzed from travelers' perspective and the activities that travelers are doing in the surrounding area of a station. In other words, instead of assuming the existence of the relationship, the focus should shift towards determining the relationship from the travelers' point of view. By studying their behavior in between their origin point of their trip and origin station (or the last segment of the trip – from the destination station to the final point of the trip) improved insights could be gain on how the area around a station should be organized to attract more travelers towards a particular station.

Discussion

This final part of the present research is divided according to two main questions: "Should NS keep researching about TOD implementation?" and "Can the flow of travelers be redirected towards (smaller) other stations?"

"Replication" and "policy transfer" are words that fit in the context of nowadays efforts to support urban developments. One trend promoted in Europe is regarding a process through which good or successful examples already implemented are selected, analyzed and understood in order to be implemented in another context – city, region or even country (e.g. Greater Manchester, Low Carbon Hub, Eurbanlab). However, the local culture (values, laws, planning systems, etc.) should not be neglected. The maximum outcome of replicating a successful example can be achieved only by understanding the mechanism of the focal project and adapt it to local context.

This is the case of TOD as well. There are several international cases (e.g. Hong-Kong, Denver, and Copenhagen) in which it is proved to be a suitable planning method to be used for achieving sustainable developments. In the Netherlands, several attempts were and are dedicated to the implementation of TOD and they should not be abandoned nor should the role of interdisciplinary "teams" involving experts with different professional or educational background be undermined. Research parties (universities, organizations) are dedicating a great part of their research to understand how TOD should work and be translated in the Dutch context (e.g. iTOD workshops) and it is only by good collaboration with the market entities (NS, municipalities, etc.) and build on each other's knowledge that a feasible direction can be agreed on. More research and meetings should be dedicated to elaborate on a common vision about how the area around a train station should be organized in more structured or programmed way in order to increase the number of travelers who use a certain train station. These ideas are not totally new for any of the parties, including NS. One of the outcomes of an iTOD workshop, bringing together experts and researchers and which the author attended, was the necessity of moving the relationships among stakeholders from an informal or "LinkedIn" level to a more formal level, on which the parties can be bind to the vision. Otherwise, the outcome of the discussion stays at the discussion level. Based on the reasons stated before, NS should not interrupt the focus on TOD implementation around their train stations. Each stakeholder involved in this implementation process has a crucial role and NS is the party which has the most information about travelers and it is able to achieve even more knowledge about their preferences. NS is the facilitator of a "bottom-up" approach: starting with the travelers' perspectives.

Regarding the stimulation of the travelers to use other train stations, NS can be able to redirect the flow of people from one station to another, but this should be the subject of more research.

The present project is giving an insight on how the variables characterizing the surrounding environment of a station are affecting the choice of a train station, but not in a detailed way. To exemplify, there is a negative way in which the presence of shops are affecting the station choice. But how this finding can be interpreted? Is it because there are too many shops or too few? Or is it because the travelers themselves are not using the shops at all? As mentioned earlier, the behavior of travelers in the surrounding area of a station is of high interest to be investigated. The focus should be on connecting the activities develop on the route between the origin point of the trip and origin station or station and final destination, the facilities (e.g. there are bike shelters provided, but are they used?) with the station choice. Moreover, the level of detail should extend towards their evaluation of the current situation regarding the stations' surrounding environment and understanding their wishes or needs.

Another insight offered by the current project is the awareness of the travelers regarding the role of the surrounding area of the train station in their station choice decision-making. However, there is need to increase the awareness, to "educate" or to give the travelers a TOD mind-set when choosing for a station. Public participation is a good information channel to be used to disseminate what a train station can be and mean to the travelers. In this way, the travelers can be determined to choose differently and the issue of redirecting the flow of travelers from the overcrowded stations to the less crowded stations can be solved. By bringing the public (travelers) in the same room with the experts, a common "story" can be built starting with travelers' wishes and the common vision proposed by the experts. From this perspective, TOD planning method can be seen as a product development: there is a need of early adopters (travelers) who will share the story further, convincing more people to start using it (in this case, think about choosing the train station based on the opportunities offered by the station and its surrounding area) and finally achieving a breakthrough. However, this is expected to be a slow process since it is know that people are resistant to change; behavior adaptation is done in steps, but the sooner it starts, the sooner a solid base can be achieved to serve as an example for the future generations.

Last, but not least, it is interesting to mention that this research is focusing on public transport, a topic which does not receive too much attention in the last period of time. Even if public transport is a feasible way to help in the reduction of CO2 emissions and ways to make it more efficient can still be sought, more talks are dedicated to electric cars and their infrastructure (how to organize it, implement it etc.), car sharing and carpooling. If it were to refer to the last two mentioned, aren't they also a form of public transport? Moreover, optimizing the public transport is a cheaper option, since it already benefits from an existing infrastructure. Therefore, NS should seek to constantly improve the service and develop the area around the stations according to travelers' wishes.

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Appendices

Appendix 1. Literature review matrix

	Attribute	Definition/Levels	Sources
Socio-economic and demographic characteristics	Car/ vehicle ownership	e.g. number of cars per household; yes/no; zero car household: 0=No, 1=Yes; one-car household: 0=No, 1= Yes	Brons et al., 2009; Cervero, 2002; Loo et al., 2010
	Car/ vehicle ownership	e.g. number of automobiles, trucks, vans and motorcycles per household; possession of car; number of family members owning a car	Cao & Jordan, 2009; Cardozo et al., 2012; Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Eboli & Mazzulla, 2011; Jiang et al., 2012
	Driver's license	0=No, 1= Yes; number of family members with driving license	Cao & Jordan, 2009; Cervero, 2002; Cervero & Kockelman, 2007; Eboli & Mazzulla, 2011
	Population size/ density	e.g. the total number of people living within the catchment area of the station; number of population within Dissemination Area (DA)/ DA in sq. km	Brons et al., 2009; Loo et al., 2010; Moniruzzaman & Páez, 2012;
	Population size per residential floor area	Density of population per square meter of residential land use;	Loo et al., 2010
	Employment over population	Employment size over the population size around the station;	Loo et al., 2010
	Employment status	e.g. employed, full-time or part-time status, unemployed, student, housewife, pensioner	Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Eboli & Mazzulla, 2011;Litman, 2012
	Full time employed	0=No, 1= Yes	Cervero, 2002;
	Unemployment	Unemployment proportion in the area surrounding the station	Rodriguez et al., 2009

Table continued

	Attribute	Definition/Levels	Sources
Socio-economic and demographic characteristics	Gender	e.g. male or female; male status	Cao & Jordan, 2009; Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Jiang et al., 2012; Litman, 2012
	Age	e.g. <20; 20-40; 40-60; >60; or 0-20; 21-40; 41-56 years old	Cao & Jordan, 2009; Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Eboli & Mazzulla, 2011; Jiang et al., 2012; Litman, 2012
	Population share over 65	Number of people over 65 years old	Brons et al., 2009
	Race and ethnicity	Racial-ethnic category; Caucasian status	Cervero & Kockelman, 2007; Curtis & Perkins, 2006
	Income	Average income per inhabitant	Brons et al., 2009
	Income	e.g. different levels of incomes according to the country; household/family income	Cao & Jordan, 2009; Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Eboli & Mazzulla, 2011; Jiang et al., 2012; Litman, 2012
	Occupation	Professional, blue collar, service/self-employed;	Jiang et al., 2012
	Renters	Percent renters within walking distance	Kuby et al., 2004;
	Housing tenure	Own or rent	Cervero & Kockelman, 2007
	Household size/ composition of the trip-maker	e.g. number of members; number of people under 5 years of age (proxy for ore-school child dependency); number of people 5 years of age and over (proxy for active household members)	Cao & Jordan, 2009; Cervero & Kockelman, 2007; Curtis & Perkins, 2006; Eboli & Mazzulla, 2011

Table continued

	Attribute	Definition/Levels	Sources
Socio-economic and demographic characteristics	Place of living	Urban area or small village	Eboli & Mazzulla, 2011
	Homelessness	Presence of homeless on segment (1 = yes)	Rodriguez et al., 2009
	Stratum	Socio-economic stratum of neighborhood (1–6)	Rodriguez et al., 2009
	UBN	Proportion of population with unsatisfied basic needs (0–1)	Rodriguez et al., 2009
	Education	Average years of schooling (0–17)	Rodriguez et al., 2009
	Education	Educational level	Curtis & Perkins, 2006
	Violent deaths	Violent deaths/100 000 inhabitants	Rodriguez et al., 2009
	Vehicle accidents	Vehicle crashes/1000 inhabitants	Rodriguez et al., 2009
	Thefts	Thefts/1000 inhabitants	Rodriguez et al., 2009
Trip characteristics	Access mode/ mode split	e.g. walking, cycling, automobile driver, automobile passenger, transit passenger	Cao & Jordan, 2009; Eboli & Mazzulla, 2011; Litman, 2012
	Type of ticket	one-way ticket; one-day travel card; monthly travel card	Eboli & Mazzulla, 2011
	Trip purpose	Recreational/Social; Shopping; Commuting/schooling; personal errands/business;	Jiang et al., 2012; Litman, 2012;
	No alternative mode available		Jiang et al., 2012
	Trip time	e.g. weekend; day of the week; hour; season	Jiang et al., 2012; Litman, 2012
	In group	yes/no	Jiang et al., 2012
	Frequency of use	e.g. frequent/infrequent travelers; 4 or more times/week; 1-2 days/week; 1-3 days/month; less than 12 days/year	Brons et al., 2009; Givoni & Rietveld, 2007; Yang et al., 2013;

Table continued

	Attribute	Definition/Levels	Sources
Station characteristics	Crowding	waiting (three levels of crowding in the platform); walking (three levels of crowding in the access-way/entrance)	Li & Hensher,2011
	Density gradient	e.g. categorical (flat/hill/valley)	Jiang et al., 2012
	Years of operation		Loo et al., 2010
	Station location	e.g. distance to Midtown; distance to city center; suburbs, down-town, CBD, average distance; CBD distance	Brons et al.,2009; Duncan & Christensen, 2013; Jiang et al., 2012; Loo et al., 2010
	Directness	station's relative "detour" factor	Jiang et al., 2012
	Station function (level of service)	Major interchange station; transfer; CBD; transit type; route frequency; terminal; categorical (typical/transfer/terminal); airport; university; travel comfort (riding and seating, heating and ventilation inside the train, cleanliness of train interior), travel time reliability, station organization and information (station overview, signage, travel information at the station, cleanliness at the station, protection against wind, rain and cold, connections with other trains), service schedule, dynamic information, price-quality ratio, accessibility (unguarded bicycle parking, guarded bicycle parking, connection with public transport, car parking capacity), ticket service, personal safety, public transport travel time, public transport service frequency, intercity status of the station, total waiting time, ticket fare	Brons et al.,2009; Cascetta, 2013; Debrezion et al, 2007; Duncan & Christensen, 2013; Givoni & Rietveld, 2007; Jiang et al., 2012; Loo et al., 2010; Zhao et al., 2013
	Station function (level of service)	personnel, bicycle parking (unguarded), transfer, frequency of trains per day, destination reached without a transfer, transfer time, total in-vehicle time	Cascetta, 2013; Duncan & Christensen, 2013; Givoni & Rietveld, 2007

Table continued

	Attribute	Definition/Levels	Sources
Station characteristics	Ease to access the station	rail journey time (min), car distance, quality of parking space on car driver, quality of parking space on car passenger, public transport travel time (min), taxi distance, bicycle distance, walking distance, other distance, access, egress	Cascetta, 2013; Givoni & Rietveld, 2014
	Number of lines	appreciation of the service level	Cardozo et al., 2012
Built environment (5Ds of TOD)	Distance	e.g. average distance; CBD distance; distance to the most-frequently chosen station;	Brons et al., 2009; Cervero & Murakami, 2008; Duncan & Christensen, 2013; Debrezion et al., 2009; Jiang et al., 2012; Loo et al., 2010
	Distance	distance to centers; distance to city center; distance access rail station; distance to Midtown; distance: from origin to destination, and from origin to access each mode, such as walking distance to transit stations	Litman, 2012; Loo et al., 2010; Sohn & Shim, 2010; Yang et al., 2013; Zhao et al., 2013
	Density	Road density: linear km. in buffer	Rodriguez et al., 2009
		Street density: length of streets in km within DA/DA area in sq. km	Moniruzzaman & Páez, 2012
		Sidewalk density: length of sidewalks in km within DA/DA area in sq.km	Moniruzzaman & Páez, 2012
		Net population density: the ratio of population to unit residential floor area	Sohn & Shim, 2010
		Density (people per hectare)	Rodriguez et al., 2009
		Residential; Dwelling density: number of dwellings within DA/Da area in sq. km	Moniruzzaman & Páez, 2012; Sung & Oh, 2011
		Employment: total number of jobs within the 800 m catchment area	Cardozo et al., 2012
		Gross density, destination TAZ: (population +employment)/gross square miles, in 1000s	Cervero, 2002

Table continued

	Attribute	Definition/Levels	Sources
Built environment (5Ds of TOD)	Density	e.g. population density: population (number of people) per developed acre; total population within the 800 m catchment area	Cardozo et al., 2012; Cervero & Kockelman, 2007; Litman, 2012
		e.g. employment density: employment (number of jobs) per developed acre; number of jobs (in thousands)within ¼ mile of a station; business density	Cervero & Kockelman, 2007; Duncan & Christensen, 2013; Litman, 2012; Sung & Oh, 2011
		Commercial density	Sung & Oh, 2011
		Accessibility to jobs	Cervero & Kockelman, 2007
		Street density within the 800 m catchment area (ratio between street length and catchment area)	Cardozo et al., 2012
		Housing density: number of housing units (in thousands) with ¼ mile of a station	Duncan & Christensen, 2013
		Gross density, origin Traffic Analysis Zones (TAZ): (population +employment)/gross square miles, in 1000s	Cervero, 2002
	Diversity	Total commercial/residential floor area (m^2)	Loo et al., 2010
		Total commercial floor area (m^2)	Loo et al., 2010; Sohn & Shim, 2010
		Total garage floor area	Loo et al., 2010
		Mixed land use; land-use mix index	Loo et al., 2010; Sung & Oh, 2011
		Building area: square footage of building within DA divided by plot area DA area within DA	Moniruzzaman & Páez, 2012
		Land-use mix: by using the reciprocal of the variation coefficient of the area covered by different land uses within the station service area (higher values indicate higher diversity of use); degree of ped-friendly land use mix (0= industrial or vacant; 1= low density residential; 2= high density residential; 3= commercial; 4= mix residential/commercial)	Gutiérrez et al., 2011; Rodriguez et al., 2009

Table continued

	Attribute	Definition/Levels	Sources
Built environment (5Ds of TOD)	Diversity	Office floor area: total floor area of office buildings within walking distance	Sohn & Shim, 2010
		Residential floor area: total floor area of residential buildings (m2)	Zhao et al., 2013
		Land-use diversity, origin TAZ: retail employment and population relative to countrywide ratio	Cervero, 2002
		Land-use diversity, destination TAZ	Cervero, 2002
	Diversity	e.g. **land-use mix**: provide and integrate a mix of uses to create a greater variety of services catering for the diverse needs of a vibrant community; provide timely and convenient access to services and facilities required to support people's daily needs, including an appropriate mix of commercial and retail services, jobs, community infrastructure and open space relevant to the context of the surrounding area; various types of land use (residential, commercial, institutional, recreational, etc.) located close together; Reciprocal of the variation coefficient of the area covered by different land uses within the 800 m catchment area (higher values indicate higher diversity of use)	Cardozo et al., 2012; Md. Kamruzzaman et al., 2014; Litman, 2012; Moniruzzaman & Páez, 2012; Sohn & Shim, 2010
		Dissimilarity index: proportion of dissimilar land uses among hectare grid cells within a tract	Cervero & Kockelman, 2007
		Entropy: mean entropy for land-use categories among hectare grids cells within a half mile radius of each hectare grid cell within a tract	Cervero & Kockelman, 2007
		Per developed acre intensities of land uses classified as: residential, commercial, office, industrial, institutional, parks and recreation	Cervero & Kockelman, 2007
		Activity center mixture and commercial intensities (per developed acre rates of: convenience stores, retail services, supermarkets, eateries, entertainment and recreational use, auto-oriented services, mixed parcels)	Cervero & Kockelman, 2007
		Proximities to commercial-retail uses	Cervero & Kockelman, 2007

Table continued

	Attribute	Definition/Levels	Sources
Built environment (5Ds of TOD)	Diversity	Total off-street parking floor area (m^2)	Loo et al., 2010
		Commercial/business mix index	Sung & Oh, 2011
		e.g. vertical clustering: people and activities locating together, including vertical clutering e.g. multi-story buildings; proportion of commercial/retail parcels with more than one land-use category on the site	Cervero & Kockelman, 2007; Litman, 2012
		Residential floor area: total floor area of residential buildings within walking distance	Sohn & Shim, 2010
		Business floor area: total floor area of business/office buildings (m2)	Zhao et al., 2013
	Design	Percentage of driveway	Sung & Oh, 2011
		Four-way intersection density (involves pedestrian friendly, narrow, grid-type street network system); (statistically significant on both modes and transfer transit ridership)	Sung & Oh, 2011
		Sidewalk width	Rodriguez et al., 2009
		Sidewalk quality (0 = absent, 1 = poor, 2 = medium, 3 = good)	Rodriguez et al., 2009
		Presence of benches (1=yes)	Rodriguez et al., 2009
		Presence of trash bins (1=yes)	Rodriguez et al., 2009
		Crossing aids (# of control devices: traffic signal, pedestrian signal, stop sign, crosswalk, overpass)	Rodriguez et al., 2009
		Aesthetics of the station/area	Cascetta, 2013
	Design	e.g. streets: (1) predominant pattern (regular grid, curvilinear grid); (2) proportion of intersections that are four-way; (3) per developed acre of: number of freeways, number of blocks, number of dead ends and cul-de-sac; (4) averages of: arterial speed limits, street width; total road length	Cervero & Kockelman, 2007; Sung & Oh, 2011
		Pedestrian and cycling provisions: (1) proportion of blocks with: sidewalks, plant trees, overhead street lights, bicycle lanes; (2) proportion of intersections with signalized control; (3) averages of block length, sidewalk width, slope, pedestrian green lights; (4) bicycle lanes per developed acre	Cervero & Kockelman, 2007

Table continued

	Attribute	Definition/Levels	Sources
Built environment (5Ds of TOD)	Design	Site design: proportion of commercial-retail and service parcels with off-street parking, on-street front or side parking, on-site drive-in or drive-through	Cervero & Kockelman, 2007
		Built form: Ensure development features high-quality subtropical design that maximizes amenity, street activity and pedestrian connectivity	Md. Kamruzzaman et al., 2014
		Physical activity options: bike routes, sidewalks parks and green spaces, good public transit service	Handy et al., 2005
		Attractiveness: attractive appearance of the neighborhood, veriety in housing styles, big street trees	Handy et al., 2005
		Sidewalk buffer: buffer width between sidewalk and road (0 = no buffer, 1 62 m; 2=2 m or more)	Rodriguez et al., 2009
		Sidewalk continuity: inverse of number of sidewalk obstructions (automobiles, trees, lighting poles, bollards, trash bins, or other)	Rodriguez et al., 2009
		Signage: Presence of way finding and signs (1 = yes)	Rodriguez et al., 2009
		Vehicle obstruction: presence of vehicles blocking walkway (1 = yes)	Rodriguez et al., 2009
	Destination accessibility	Walking: (1) protection: security against traffic safety risk and against crime; (2) comfort: ease of walking (fewer obstacles), including sidewalk quality and street cleanliness; (3) enjoyment: aesthetic and utilitarian aspects related to the presence of activities and relief from the elements (e.g., shade from sun)	Jiang et al., 2012
		Unguarded bicycle parking	Brons et al., 2009
		Connections with public; bus connection	Brons et al., 2009; Givoni & Rietveld, 2007; Kuby et al., 2004

Table continued

	Attribute	Definition/Levels	Sources
Built environment (5Ds of TOD)	Destination accessibility	Car parking capacity; park and ride	Brons et al., 2009; Debrezion et al., 2009; Kuby et al., 2004; Zhao et al., 2013
		Bicycle parking (guarded)	Givoni & Rietveld, 2007
		Bicycle stand	Debrezion et al., 2009
	Destination accessibility	Universal design (degree to which transport facilities and services accommodate people with disabilities and other special needs)	Litman, 2012
		Walking: sidewalk/path quality, street crossing conditions, land use conditions, security, prestige; road congestion level; woods shading rates, sidewalk obstacles, roadside architectural style, roadside landscape, streetlight conditions	Litman, 2012; Yang et al., 2013
		Cycling: path quality, street riding conditions, parking conditions, security	Litman, 2012
		Easy access to a regional shopping mall; easy access to downtown; other amenities such as a community center available nearby; shopping areas within walking distance; east access to the freeway; good public transit service (bus or rail)	Handy et al., 2005
		Connectivity: connectivity (grid network, hierarchical road network, cul-de-sac)	Litman, 2012
		Roadway design and management: how road design and management practices affect vehicle traffic, mobility and accessibility	Litman, 2012
		Guarded bicycle parking	Brons et al., 2009
		Train taxi	Brons et al., 2009
		Bicycle parking (unguarded)	Givoni & Rietveld, 2007

Appendix 2. TOD in pictures

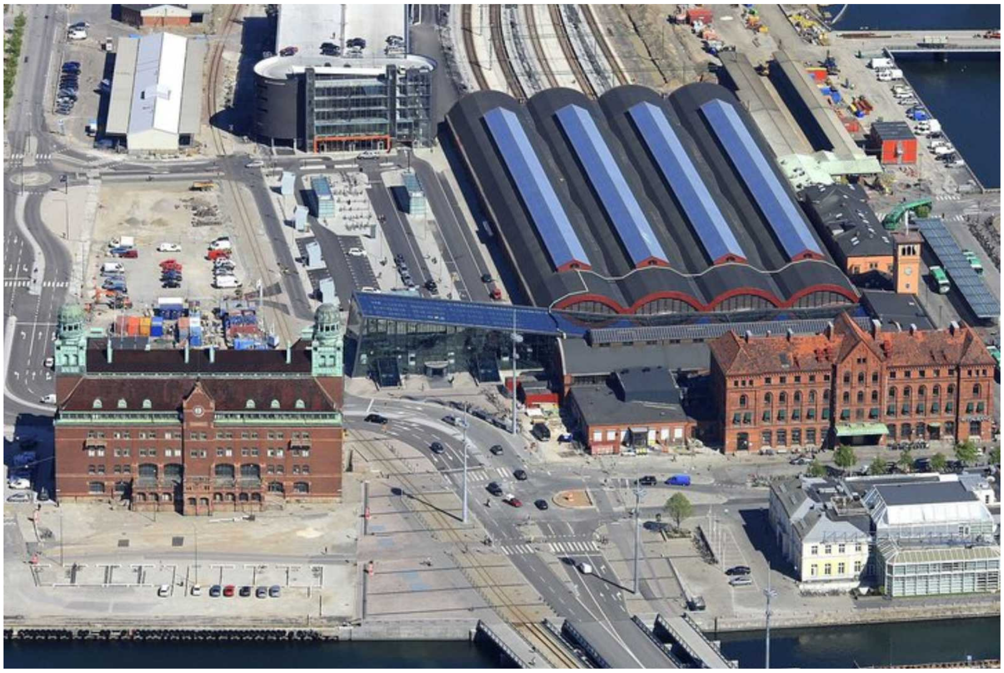
Europe

Picture 1. Ørestad Station, Denmark
Source: http://en.wikipedia.org/wiki/File:%C3%98restad_station.jpg) <Accessed 6-5-2014>

Picture 2. Metro station in Copenhagen, Denmark
Source: http://commons.wikimedia.org/wiki/File:Metro_station_(Copenhagen).jpg <Accessed 6-5-2014>

Picture 3. Vauban in Freiburg, Germany
Source: http://www.railconferences.com/rail-news-and-resources1/planning-transport-for-active-and-healthy-regional-communities <Accessed 6-5-2014>

Picture 4. Station Triangeln in Malmo, Sweden
Source: http://www.dn.se/kultur-noje/cykeldack-och-appelmunk-inspirerade-prisad-station/ <Accessed 6-5-2014>

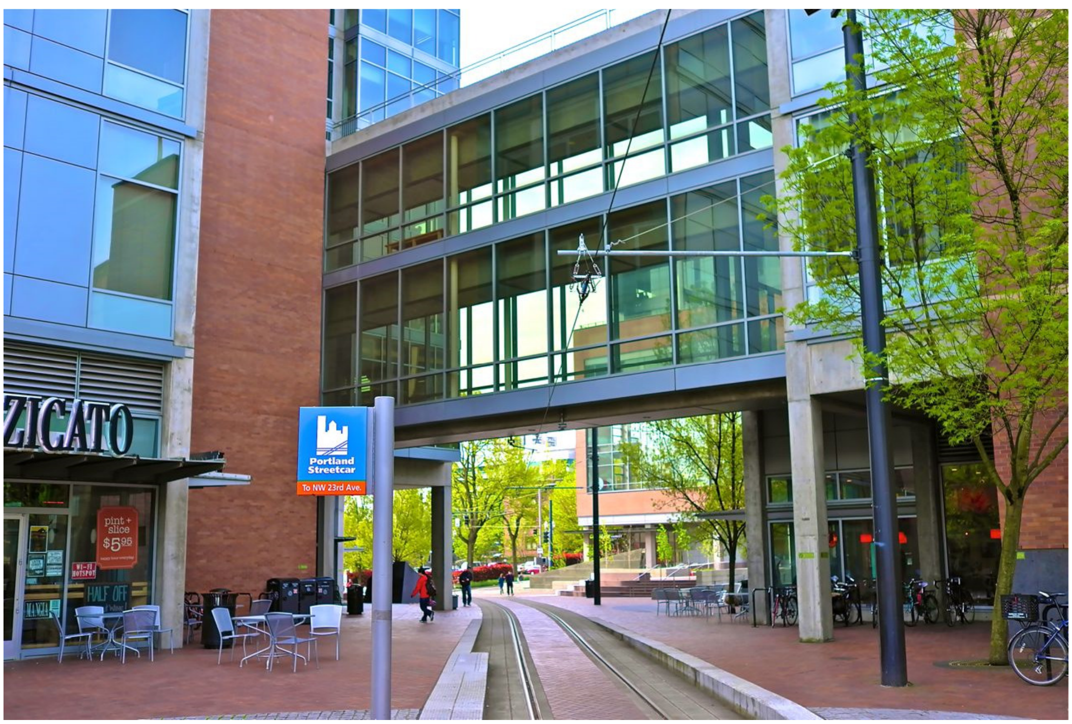


Picture 5. TOD in Malmo, Sweden
Source: http://aasarchitecture.com/2013/02/malmo-central-station-by-metro-arkitekter.html <Accessed 6-5-2014>

United States

Picture 6. Transit – oriented development in Oregon, Portland, United States
source: http://www.flickr.com/photos/jamesbondsv/4587858297/ <Accessed 6-5-2014>

Picture 7. TOD in, Oregon, Portland United States
source: http://www.myurbanist.com/wp-content/uploads/2011/05/PortlandLivability_ChuckWolfe2.jpg <Accessed 6-5-2014>



Picture 8. TOD in Oregon, Portland, United States
source: http://www.myurbanist.com/wp-content/uploads/2011/05/PortlandLivability_ChuckWolfe6.jpg <Accessed 6-5-2014>

Picture 9. TOD in Oregon, Portland, United States
source: http://www.myurbanist.com/wp-content/uploads/2011/05/PortlandLivability_ChuckWolfe1.jpg <Accessed 6-5-2014>

Picture 10. TOD in Portland, United States
Source:
http://www.wired.com/images_blogs/autopia/2009/11/portland_trimet_mass_transit_02.jpg <Accessed 6-5-2014>

Picture 11. BRT HealthLine, Cleveland, United States
Source: http://usa.streetsblog.org/2013/09/26/itdp-study-a-coming-out-for-bus-based-transit-oriented-development/ <Accessed 6-5-2014>

Picture 12. Contra Costa Centre Bay Area Rapid Transit (BART) Station, Walnut Creek , California, United States Source: http://blog.2030palette.org/swatch-profile-transit-oriented-development/ <Accessed 6-5-2014>

Picture 13. TOD in New Jersey, US
Source: http://www.njfuture.org/issues/development/redevelopment/ <Accessed 6-5-2014>

Picture 14. Union Station, Denver, Colorado, US
Source: http://www.thetransportpolitic.com/2010/01/07/a-grand-gateway-for-denvers-transit-users/ <Accessed 6-5-2014>

Latin America

Picture 15. Curitiba, Brazil, Latin America
Source: http://cincinnatitransforum.org/2010/08/at-the-heart-of-the-streetcar-is-transit-oriented-development/ <Accessed 6-5-2014>

Picture 16. BRT in Bogota, Latin America
Source:
http://81.47.175.201/livingrail/index.php?option=com_content&view=article&id=710:2013-12-10-16-13-21&catid=37:technologies&Itemid=126
<Accessed 6-5-2014>

Canada

Picture 17. Calgary, Canada
Source: http://cincinnatitransforum.org/wp-content/uploads/2010/08/calgary.jpg
<Accessed 6-5-2014>

Picture 18. Vancouver, Canada
Source: http://cincinnatitransforum.org/wp-content/uploads/2010/08/calgary.jpg
<Accessed 6-5-2014>

Picture 19. Toronto, Canada
Source: http://cincinnatitransforum.org/wp-content/uploads/2010/08/calgary.jpg <Accessed 6-5-2014>

Asia

Picture 20. Transit-oriented city - Dongtan, South Coreea source: http://en.51arch.com/2012/07/ojanen_chiou-architects-dongtan-central-business-master-plan/ <Accessed 6-5-2014>

Picture 21. Mass Rapid Station (MRT) Tanjong Pagar Center, Singapore
Source: http://www.arch2o.com/portfolio/singapore-developer-guocoland-reveals-plans-for-som-designed-tanjong-pagar-centre/ <Accessed 6-5-2014>

Picture 22. MRT, Yio Chu Kang, Singapore
Source: https://www.flickr.com/photos/digitaljourney/5522353154/ <Accessed 6-5-2014>

Picture 23. Singapore Rapid Transit
Source: http://www.devtome.com/doku.php?id=transit_oriented_development <Accessed 6-5-2014>

Picture 24. Kowloon MRT Station, Hong- Kong, China
Source: http://en.wikipedia.org/wiki/File:Kowloon_Waterfront,_Hong_Kong,_2013-08-09,_DD_03.jpg <Accessed 6-5-2014>

Picture 35. Kowloon MRT Station, Hong- Kong, China
Source: http://runstadfellows.files.wordpress.com/2011/04/kowloon-housing-towers-2.jpg
<Accessed 6-5-2014>

Picture 26. Kowloon MRT Station, Hong- Kong, China
Source: http://runstadfellows.files.wordpress.com/2011/04/kowloon-housing-towers-2.jpg
<Accessed 6-5-2014>

Picture 27. Hong -Kong, China
Source: http://cincinnatitransforum.org/2010/08/at-the-heart-of-the-streetcar-is-transit-oriented-development/ <Accessed 6-5-2014>

Appendix 3. TOD in the Netherlands in pictures

Picture 1. Utrecht Centraal Station (in the future)
Source: http://aasarchitecture.com/2014/05/stationsquare-east-utrecht-ector-hoogstad-architecten.html <Accessed 12-5-2014>

Picture 2. Utrecht Centraal Station (in the future)
Source: http://aasarchitecture.com/2014/05/stationsquare-east-utrecht-ector-hoogstad-architecten.html <Accessed 12-5-2014>

Picture 3. Arnhem Central Station
Source: http://bright.nl/designstation-arnhem-cs-krijgt-vorm <Accessed 12-5-2014>

Picture 4. Leiden Central Station
Source: http://www.omroepwest.nl/nieuws/14-10-2008/proef-voor-blinden-op-station-leiden-centraal <Accessed 12-5-2014>

Picture 5. Leiden Central Station
Source: http://www.coltinfo.nl/centraal-station-leiden.html <Accessed 12-5-2014>

Picture 6. Amsterdam Central Station
Source: http://1.bp.blogspot.com/-dmAL1LSKoAs/UUzbSwgt_BI/AAAAAAAAPoQ/WvMn2XgcfoI/s1600/14.jpg <Accessed 12-5-2014>

Picture 7. Amsterdam Central Station
Source:
http://krant.telegraaf.nl/krant/enverder/venster/reizen/reis.Nederland/reis.Noordholland/reis.001230amsterdam.cs.html <Accessed 12-5-2014>

Picture 8. Rotterdam Central Station
Source: www.google.nl <Accessed 12-5-2014>

Picture 9. Zaandam Central Station
Source: http://projets-architecte-urbanisme.fr/hotel-insolite-pays-bas-architecture-amsterdam/ <Accessed 12-5-2014>

Appendix 4. Attributes selection

	Attribute	Levels	Sources
Respondents' characteristics	Age	To be introduced by the respondents	Cao & Jordan, 2009; Cervero and Kockelman, 1997; Jiang et al., 2012
	Gender	Male	Cervero and Kockelman, 1997; Curtis & Perkins, 2006 ; Jiang et al., 2012; Litman, 2012
		Female	
	Employment status	Full-time employed	Cervero, 2002; Cervero and Kockelman, 1997; Curtis & Perkins, 2006 ; Eboli & Mazzulla, 2011; Gutiérrez et al., 2011; Litman, 2012
		Part-time employed	
		Un-employed	
		Student	
		Pensioner	
	Education	Elementary school (“*Basisschool*”)	www.taalunieversum.org; Rodriguez et al., 2009
		Middle-level applied education (*“voorbereidend middelbaar beroepsonderwijs: vmbo*”)	
		Higher general continued education (“*hoger algemeen voortgezet onderwijs: havo*”)	
		Preparatory scholarly education (*“voorbereidend wetenschappelijk onderwijs: vwo*”)	
		Vocational education (“*middelbaar beroepsonderwijs: mbo*” and (“*hogerberoeponderwijs: hbo*”)	
		Higher education (“*wetenschappelijk onderwijs: wo*”, universiteit, gepromoveerd)	
	Household composition	Number of adults	Cervero, 2002; Cervero and Kockelman, 1997
		Number of 0-4 years old children	
		Number of 4-12 years old children	
		Number of 12-18 years old children	

Table continued

	Attribute	Levels	Sources
	Car ownership	Yes/No	Cardozo et al., 2012; Cervero, 2002; Debrezion et al., 2009; Gutierrez et al., 2012; Jiang et al., 2012
Trip characteristics	Purpose of the trip	From/to work	Jiang et al., 2012; Litman, 2012; NS
		Business trip	
		From/to school/college/university/ treining course	
		Visit to family/friends/hospital	
		Shopping	
		Holiday/trip/day out	
		Sport/hobby	
	Frequency of use	More than 4 days/week	Brons et al., 2009; Givoni & Rietveld, 2007; NS
		1-3 days/week	
		1-3 days/month	
		Less than 2 days/month	
		Less than 2 days/year	
	Access mode	Walking	Givoni & Rietveld, 2007; Bertolini et al., 2005
		Bike	
		Car as a driver	
		Car as a passenger	
		Public transport	

Table continued

	Attribute	Levels	Sources
Built environment (5Ds of TOD)	Density	Number of people in the catchment area	Cervero, 2002; Cervero and Kockelman, 1997; Cervero and Murakami, 2008; Jiang et al., 2012; Sung & Oh, 2011
	Diversity	Presence of supermarkets	California Department of Transportation, 2005; Cervero, 2002; Cervero and Kockelman, 1997; Cordozo et al., 2012; Loo et al., 2010; Sung & Oh, 2011; Sohn & Shim, 2010; Zhao et al., 2013;
		Provision of a variety of shops	
		Presence of restaurants, fast-food restaurants and cafes	
		Overall (shops offer)	
	Design	Presence of sidewalks, sidewalks quality, width, and presence of crossing aids	California Department of Transportation, 2005; Cascetta, 2013; Cerver, 2002; Cervero and Kockelman, 1997; Cervero and Murakami, 2008; Jiang et al., 201; Litman, 2012; Rodriguez et al., 2009; Sung & Oh, 2011
		Presence of pedestrian friendly amenities (benches, trash bins etc.)	
		Bike-friendly design (presence of bike lines, speed, quality and width of them, presence of crossing aids)	
		Car-friendly design (presence of roads, their quality, traffic speed, safety, stoplights provision etc)	
		Aesthetics of the station’s environment (art/architecture/building height)	
		Presence of open/green spaces	
		Overall design	

Table continued

	Attribute	Levels	Sources
Built environment (5Ds of TOD)	Destination accessibility	Provision of bike shelters	Brons et al., 2009; California Department of Transportation, 2005; Cervero, 2002; Cervero and Murakami, 2008; Debrezion et al., 2009; Givoni & Rietveld, 2007; Gutierrez et al., 2011; Handy et al., 2005; Litman, 2012; Marshall, 2013; Mavoa et al., 2012; Redman et al., 2013; Sung & Oh, 2011; Yang et al., 2013
		Public transport connectivity	
		P + R provision	
		Kiss and Ride provision	
		Overall accessibility of the station	
	Distance to transit	The distance between the origin point of the trip and the origin station	Brons et al., 2009; Cervero, 1993; Cervero and Murakami, 2008

Appendix 5. Questionnaire design

Datum: ☐☐ - ☐☐ Tijd: ☐☐ - ☐☐ Perron (alleen cijfers) ☐☐ Station: ____________

NS streeft voortdurend naar verbetering van het station en de omgeving van het station. Uw mening is hierbij van groot belang. Daarom vragen wij u deze vragenlijst in te vullen. Het invullen duurt slechts 5 minuten en uw antwoorden worden anoniem verwerkt.

1.1. Welk treinstation in Amsterdam gebruikt u het vaakst als het station van vertrek? (*Slechts 1 antwoord mogelijk*)

☐ (1) Amsterdam Centraal ☐ (2) Amsterdam Amstel ☐ (3) Amsterdam Rai ☐ (4) Amsterdam Zuid
☐ (5) Amsterdam Sloterdijk ☐ (6) Amsterdam Muiderpoort ☐ (7) Amsterdam Lelylaan ☐ (8) Amsterdam Science Park

1.2. Hoe vaak gebruikt u dit treinstation? (*Slechts 1 antwoord mogelijk*)

☐ (1) Meer dan 4 dagen/week
☐ (2) 1-3 dagen/week
☐ (3) 1-3 dagen/maand
☐ (4) Minder dan 2 dagen/maand
☐ (5) Minder dan 2 dagen/jaar

1.3. Hoe gaat u meestal naar dit station? (*Slechts 1 antwoord mogelijk*)

☐ (1) Lopend
☐ (2) Fiets
☐ (3) Auto als bestuurder
☐ (4) Auto als passagier
☐ (5) Openbaar vervoer (tram/ bus/metro)
☐ (6) Anders, namelijk ________________

1.4. Hoelang duurt de reis om bij dit treinstation te komen (in minuten) gemiddeld? [______] *minuten*

1.5. Wat is meestal het belangrijkste doel van uw treinreis? (*Slechts 1 antwoord mogelijk*)

☐ (1) Van/naar werk
☐ (2) Zakenreis
☐ (3) Van/naar school/college/universiteit/training
☐ (4) Bezoek aan familie/vrienden/ziekenhuis
☐ (5) Winkelen
☐ (6) Vakantie/dagje weg
☐ (7) Sport/hobby
☐ (8) Anders, namelijk ________________

Op welke wijze hebben de volgende kenmerken van de omgeving van het treinstation een invloed op uw keuze van het station?
(*Geef een score van 1=zeer negatief tot 5=zeer positief*)

	Zeer negatief	Negatief	Neutraal	Positief	Zeer positief
1.6. De afstand tussen het startpunt van de reis en het genoemde treinstation	☐1	☐2	☐3	☐4	☐5
1.7. Drukte (hoeveelheid mensen)	☐1	☐2	☐3	☐4	☐5
1.8. Winkelaanbod (de aanwezigheid van winkels)	☐1	☐2	☐3	☐4	☐5
1.9. Aanwezigheid van supermarkten	☐1	☐2	☐3	☐4	☐5
1.10. Aanwezigheid van eetgelegenheden	☐1	☐2	☐3	☐4	☐5
1.11. Aanwezigheid van gevarieerd winkelaanbod	☐1	☐2	☐3	☐4	☐5
1.12. Aantrekkelijkheid van de omgeving in totaal (fysieke kenmerken van de omgeving van het station	☐1	☐2	☐3	☐4	☐5
1.13. Aantrekkelijkheid van gebouwen in omgeving (kunst/architectuur/hoogte van de gebouwen)	☐1	☐2	☐3	☐4	☐5
1.14. Aantrekkelijkheid van openbare ruimte	☐1	☐2	☐3	☐4	☐5
1.15. Aanwezigheid/kwaliteit/breedte/ oversteekvoorzieningen van trottoirs	☐1	☐2	☐3	☐4	☐5
1.16. Aanwezigheid van voorzieningen (bankjes/vuilnisbakken)	☐1	☐2	☐3	☐4	☐5
1.17. Fiets vriendelijkheid (kwaliteit/breedte/veiligheid/snelheid van fietspaden)	☐1	☐2	☐3	☐4	☐5
1.18. Auto vriendelijkheid (kwaliteit/aanwezigheid/verkeerslichten/snelheid)	☐1	☐2	☐3	☐4	☐5
1.19. Algemene toegankelijkheid/ gemakkelijk te bereiken	☐1	☐2	☐3	☐4	☐5
1.20. Gemakkelijk te bereiken met het openbaar vervoer	☐1	☐2	☐3	☐4	☐5
1.21. Fietsenstallingen	☐1	☐2	☐3	☐4	☐5
1.22. P+R voorzieningen	☐1	☐2	☐3	☐4	☐5
1.23. Kiss en Ride voorzieningen	☐1	☐2	☐3	☐4	☐5
1.24. Anders, namelijk ____________	☐1	☐2	☐3	☐4	☐5

2. **Welk alternatief treinstation kunt u kiezen wanneer u met hetzelfde doel een treinreis maakt?**
Kies een ander treinstation dan bij vraag 1. (Slechts 1 antwoord mogelijk)

☐ (1) Amsterdam Centraal ☐ (2) Amsterdam Amstel ☐ (3) Amsterdam Rai ☐ (4) Amsterdam Zuid
☐ (5) Amsterdam Sloterdijk ☐ (6) Amsterdam Muiderpoort ☐ (7) Amsterdam Lelylaan ☐ (8) Amsterdam Science Park
☐ (9) Geen (Ga naar vraag 3.1)

2.1. Hoe gaat u naar dit alternatieve treinstation? (*Slechts 1 antwoord mogelijk*)

☐ (1) Lopend
☐ (2) Fiets
☐ (3) Auto als bestuurder
☐ (4) Auto als passagier
☐ (5) Openbaar vervoer (tram/ bus/metro)
☐ (6) Anders, namelijk ________________

2.2. Welke van de onderstaande aspecten stimuleren u bij de keuze voor bovengenoemde alternatief treinstation?
*(Maak een keuze uit de onderstaande lijst, **meerdere antwoorden mogelijk**)*

☐ (1) De afstand tussen het startpunt van de reis en het genoemde treinstation
☐ (2) Drukte (hoeveelheid mensen)
☐ (3) Winkelaanbod (de aanwezigheid van winkels)
- ☐ (4) Aanwezigheid van supermarkten
- ☐ (5) Aanwezigheid van eetgelegenheden
- ☐ (6) Aanwezigheid van gevarieerd winkelaanbod

☐ (7) Aantrekkelijkheid van de omgeving in totaal (fysieke kenmerken van de omgeving van het station
- ☐ (8) Aantrekkelijkheid van gebouwen in omgeving (kunst/architectuur/hoogte van de gebouwen)
- ☐ (9) Aantrekkelijkheid van openbare ruimte
- ☐ (10) Aanwezigheid/kwaliteit/breedte/ oversteekvoorzieningen van trottoirs
- ☐ (11) Aanwezigheid van voorzieningen (bankjes/vuilnisbakken)
- ☐ (12) Fiets vriendelijkheid (kwaliteit/breedte/veiligheid/snelheid van fietspaden)
- ☐ (13) Auto vriendelijkheid (kwaliteit/aanwezigheid/verkeerslichten/snelheid)

☐ (14) Algemene toegankelijkheid/ gemakkelijk te bereiken
- ☐ (15) Gemakkelijk te bereiken met het openbaar vervoer
- ☐ (16) Fietsenstallingen
- ☐ (17) P+R voorzieningen
- ☐ (18) Kiss en Ride voorzieningen

☐ (19) Anders, namelijk ______________________

3. Uw gegevens

3.1. Wat is uw leeftijd? [_____]

3.2. Wat is uw geslacht? ☐ (1) Man ☐ (2) Vrouw

3.3. Wat zijn de vier cijfers van de postcode van uw woonadres [___ ___ ___ ___]

3.4. Wat is uw hoogst afgeronde opleiding?
☐ (1) Basisschool
☐ (2) Voorbereidend middelbaar beroepsonderwijs (v(m)bo, lts, lts, lbo, huishoudschool)
☐ (3) Hoger algemeen en voorbereidend wetenschappelijk onderwijs (havo, vwo, hbs)
☐ (4) Middelbaar beroepsonderwijs (mbo, mts)
☐ (5) Hoger beroepsonderwijs (hbo, pabo, hts, heao)
☐ (6) Wetenschappelijk onderwijs (wo, universiteit, gepromoveerd)
☐ (7) Anders, namelijk ________________

3.5. Wat is uw werksituatie?

☐ (1) Part-time in dienst
☐ (2) Full-time in dienst
☐ (3) Werkloos
☐ (4) Student
☐ (5) Gepensioneerd
☐ (6) Anders, namelijk ________________

3.6. Bent u in het bezit van een auto? ☐ (1) Ja ☐ (2) Nee

3.7. Wat is uw gezinssamenstelling?
☐ (1) Aantal volwassenen [_______]
☐ (2) Aantal kinderen 4-12 jaar oud [_______]
☐ (3) Aantal kinderen 0-4 jaar oud [_______]
☐ (4) Aantal kinderen 12-18 jaar oud [_______]

Hartelijk dank voor uw medewerking!
NS

Appendix 6. Correlation matrixes

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases	Missing
ISP1	.297909	.457738	0.0	1.0	574	0
ISP2	.182927	.386944	0.0	1.0	574	0
ISP3	.074913	.263480	0.0	1.0	574	0
ISP4	.111498	.315023	0.0	1.0	574	0
ISP5	.125436	.331501	0.0	1.0	574	0
ISP6	.106272	.308454	0.0	1.0	574	0
ISP7	.088850	.284776	0.0	1.0	574	0
KN3A	-.216028	.746385	-1.000000	1.0	574	0
KN3B	-.012195	.898821	-1.000000	1.0	574	0
KN4	-.648084	.762233	-1.000000	1.0	574	0
KN5	-.174216	.985566	-1.000000	1.0	574	0
KN16A	-.108014	.836872	-1.000000	1.0	574	0
KN16B	-.120209	.827859	-1.000000	1.0	574	0
KN17A	.080139	.940010	-1.000000	1.0	574	0
KN17B	-.292683	.656328	-1.000000	1.0	574	0
KN18	-.383275	.924440	-1.000000	1.0	574	0
KN19A	-.120209	.821510	-1.000000	1.0	574	0
KN19B	-.292683	.656328	-1.000000	1.0	574	0
KN20	-.153310	.989040	-1.000000	1.0	574	0
KN1_1	.099676	.049549	.035714	.178571	574	0
KN2_1	.154457	.085032	.050633	.291139	574	0
KN6_1	.127389	.025249	.053393	.151279	574	0
KN7_1	.125585	.036171	.064516	.207885	574	0
KN8_1	.136769	.027324	.071588	.170022	574	0
KN9_1	.129017	.023353	.075774	.155757	574	0
KN10_1	.222506	.226094	.003664	.564661	574	0
KN11_1	.137456	.025638	.085371	.160060	574	0
KN12_1	.134975	.107498	.016393	.311475	574	0
KN13_1	.165617	.089770	.046014	.290343	574	0
KN14_1	.160736	.062663	.025583	.237617	574	0
KN15_1	.138507	.052534	.057291	.242509	574	0
KN22_1	.205039	.179066	.008316	.478170	574	0
KN23_1	.178624	.112365	.003105	.305181	574	0
KN24_1	.113040	.227556	0.0	.655738	574	0
KN25_1	.131555	.135913	0.0	.384615	574	0

Table 1. Descriptive statistics for the variables included in the model (source: Nlogit 5)

Table 2 (continued)

Cor.Mat.	ISP1	ISP2	ISP3	ISP4	ISP5	ISP6	ISP7	KN3A
ISP1	1.00000	-.30821	-.18537	-.23075	-.24669	-.22462	-.20341	-.68480
ISP2	-.30821	1.00000	-.13465	-.16762	-.17919	-.16316	-.14776	.13707
ISP3	-.18537	-.13465	1.00000	-.10081	-.10777	-.09813	-.08886	.46403
ISP4	-.23075	-.16762	-.10081	1.00000	-.13416	-.12215	-.11062	-.37241
ISP5	-.24669	-.17919	-.10777	-.13416	1.00000	-.13059	-.11826	.10971
ISP6	-.22462	-.16316	-.09813	-.12215	-.13059	1.00000	-.10768	.56230
ISP7	-.20341	-.14776	-.08886	-.11062	-.11826	-.10768	1.00000	.09046
KN3A	-.68480	.13707	.46403	-.37241	.10971	.56230	.09046	1.00000

Cor.Mat.	ISP1	ISP2	ISP3	ISP4	ISP5	ISP6	ISP7	KN3A
KN3B	-.71651	.53331	.00386	-.38966	.42686	.00468	.35197	.60740
KN4	-.30101	-.21864	.61582	-.16369	-.17500	-.15934	.67578	.44062
KN5	-.54627	-.39680	.33933	.42242	.45160	-.28918	.37237	.17650
KN16A	-.69490	.06112	.37710	-.37790	.50186	.04455	.41381	.75886
KN16B	-.69286	.64081	.04136	-.37680	.05504	.46701	.04538	.79392
KN17A	-.74915	.46342	.27871	-.03023	.37092	-.39658	.30585	.42271
KN17B	-.70261	.21119	.12701	.69832	.16903	-.37194	.13938	.03458
KN18	-.43495	.70863	-.19001	-.23654	.56718	-.23025	-.20851	.19343

Cor.Mat.	KN3B	KN4	KN5	KN16A	KN16B	KN17A	KN17B	KN18
KN3B	1.00000	.26610	.24386	.82885	.79546	.82532	.31048	.75259
KN4	.26610	1.00000	.55102	.61234	.06716	.45258	.20625	-.30855
KN5	.24386	.55102	1.00000	.56960	-.15191	.58023	.71964	-.00829
KN16A	.82885	.61234	.56960	1.00000	.57319	.77418	.28232	.41110
KN16B	.79546	.06716	-.15191	.57319	1.00000	.49457	.08288	.57592
KN17A	.82532	.45258	.58023	.77418	.49457	1.00000	.69435	.65397
KN17B	.31048	.20625	.71964	.28232	.08288	.69435	1.00000	.29802
KN18	.75259	-.30855	-.00829	.41110	.57592	.65397	.29802	1.00000

Cor.Mat.	ISP1	ISP2	ISP3	ISP4	ISP5	ISP6	ISP7	KN3A

Table 2 (continued)

KN19A	-.69822	.64576	.04168	.05188	.05546	-.36962	.42619	.29058
KN19B	-.70261	.21119	.12701	.69832	.16903	-.37194	.13938	.03458
KN20	.76025	-.40541	-.24382	-.30352	.44200	-.29546	-.26756	-.56032
KN1_1	-.84161	.07136	.45350	.05343	.05712	.54954	.04710	.90685
KN2_1	.56271	-.43724	-.34776	-.01067	.60929	-.31865	-.28856	-.61503
KN6_1	.27221	.23946	-.10694	.21052	-.20912	.20492	-.91597	-.19337
KN7_1	.32054	.60824	-.25508	.10405	-.26436	-.44590	-.52768	-.47758
KN8_1	.36640	.30492	-.67942	.43149	-.09732	-.25816	-.41291	-.77095

Cor.Mat.	KN3B	KN4	KN5	KN16A	KN16B	KN17A	KN17B	KN18
KN19A	.77088	.39097	.37286	.56239	.53043	.90518	.68556	.58037
KN19B	.31048	.20625	.71964	.28232	.08288	.69435	1.00000	.29802
KN20	-.37707	-.39593	-.20291	-.30680	-.60443	-.44479	-.53704	-.02239
KN1_1	.47659	.39975	.38175	.64490	.68312	.44109	.35434	.10070
KN2_1	-.33777	-.49518	.02009	-.28792	-.63017	-.33533	-.24781	.07095
KN6_1	-.47666	-.72803	-.56915	-.64252	-.04234	-.47015	-.18511	.05048
KN7_1	-.20254	-.49771	-.49624	-.54587	-.09867	-.05441	.03595	.31959
KN8_1	-.37327	-.81271	-.41818	-.77150	-.32045	-.33202	.07289	.18546

Cor.Mat.	KN19A	KN19B	KN20	KN1_1	KN2_1	KN6_1	KN7_1	KN8_1
KN19A	1.00000	.68556	-.60910	.33622	-.51803	-.41928	.12623	-.12273
KN19B	.68556	1.00000	-.53704	.35434	-.24781	-.18511	.03595	.07289
KN20	-.60910	-.53704	1.00000	-.74073	.92930	.11179	.11949	.27391
KN1_1	.33622	.35434	-.74073	1.00000	-.66660	-.11246	-.46660	-.63357
KN2_1	-.51803	-.24781	.92930	-.66660	1.00000	.11134	.08134	.39658
KN6_1	-.41928	-.18511	.11179	-.11246	.11134	1.00000	.65834	.58030
KN7_1	.12623	.03595	.11949	-.46660	.08134	.65834	1.00000	.72822
KN8_1	-.12273	.07289	.27391	-.63357	.39658	.58030	.72822	1.00000

Cor.Mat.	ISP1	ISP2	ISP3	ISP4	ISP5	ISP6	ISP7	KN3A
KN9_1	.51146	-.01264	-.13596	.40597	-.45425	.08411	-.71259	-.48983
KN10_1	.98664	-.29101	-.25278	-.15641	-.14398	-.29125	-.25898	-.76451
KN11_1	.57482	.10443	.03633	.12946	.10578	-.59538	-.63495	-.67319
KN12_1	-.61976	.77756	-.31418	.20366	.27553	-.11755	-.15412	.12157
KN13_1	.90584	-.24120	-.31573	.10611	-.42565	-.08359	-.31036	-.76812
KN14_1	.79988	-.21165	-.52263	.16038	.04651	-.29166	-.33770	-.89857
KN15_1	.11009	.28907	-.29251	-.35806	-.56376	.68326	.07950	.23742
KN22_1	.99445	-.25635	-.25007	-.19604	-.22279	-.25094	-.22362	-.73709

Table 2 (continued)

Cor.Mat.	KN3B	KN4	KN5	KN16A	KN16B	KN17A	KN17B	KN18
KN9_1	-.80150	-.60997	-.51780	-.89029	-.41185	-.68936	-.20137	-.33637
KN10_1	-.70808	-.39930	-.50566	-.71966	-.73055	-.71733	-.62630	-.34688
KN11_1	-.45531	-.51357	-.24327	-.55512	-.54012	-.21247	-.05894	.16329
KN12_1	.63177	-.35794	.03871	.20845	.58481	.61248	.58523	.84853
KN13_1	-.85766	-.49289	-.59971	-.92848	-.68511	-.86290	-.54154	-.50719
KN14_1	-.64452	-.68279	-.39425	-.79040	-.71090	-.64135	-.34381	-.14382
KN15_1	.01114	-.19237	-.75693	-.23635	.46507	-.43563	-.56976	-.16234
KN22_1	-.70110	-.37519	-.56536	-.72924	-.68857	-.73811	-.66971	-.37438

Cor.Mat.	KN19A	KN19B	KN20	KN1_1	KN2_1	KN6_1	KN7_1	KN8_1
KN9_1	-.56189	-.20137	.16891	-.34268	.16016	.88380	.60684	.65010
KN10_1	-.68163	-.62630	.81674	-.89362	.66532	.30532	.36958	.46983
KN11_1	-.29745	-.05894	.60297	-.66554	.59963	.52929	.64705	.59426
KN12_1	.69041	.58523	-.38896	.22329	-.19077	.15034	.37498	.38198
KN13_1	-.71435	-.54154	.55313	-.77828	.44307	.48317	.41221	.60184
KN14_1	-.58501	-.34381	.77157	-.89399	.78705	.38816	.42088	.76173
KN15_1	-.17716	-.56976	-.27601	.09285	-.45512	.18358	-.01879	.02765
KN22_1	-.67448	-.66971	.77114	-.88211	.59470	.29669	.36577	.44939

Cor.Mat.	KN9_1	KN10_1	KN11_1	KN12_1	KN13_1	KN14_1	KN15_1	KN22_1
KN9_1	1.00000	.53005	.56036	-.14085	.76171	.57831	.15818	.52841
KN10_1	.53005	1.00000	.66205	-.52732	.90827	.87959	.01835	.99467
KN11_1	.56036	.66205	1.00000	.02584	.56386	.71331	-.40579	.61769
KN12_1	-.14085	-.52732	.02584	1.00000	-.47364	-.19129	-.04775	-.54357
KN13_1	.76171	.90827	.56386	-.47364	1.00000	.85327	.22623	.92033
KN14_1	.57831	.87959	.71331	-.19129	.85327	1.00000	-.08253	.84987
KN15_1	.15818	.01835	-.40579	-.04775	.22623	-.08253	1.00000	.10751
KN22_1	.52841	.99467	.61769	-.54357	.92033	.84987	.10751	1.00000

Cor.Mat.	ISP1	ISP2	ISP3	ISP4	ISP5	ISP6	ISP7	KN3A
KN23_1	.73431	-.08020	-.38488	.37619	-.20454	-.45912	-.32897	-.96028
KN24_1	-.32387	-.23525	-.14149	-.17613	.90399	-.17145	.31758	.14521
KN25_1	-.63106	.88176	-.22195	-.00874	.13368	-.13873	.05126	.24535

Cor.Mat.	KN3B	KN4	KN5	KN16A	KN16B	KN17A	KN17B	KN18
KN23_1	-.72000	-.56197	-.33173	-.88020	-.75771	-.53991	-.11579	-.21383
KN24_1	.55942	.12587	.59288	.65885	.07226	.48696	.22191	.45139
KN25_1	.76958	-.13407	-.01935	.34035	.71270	.70857	.50112	.83403

Cor.Mat.	KN19A	KN19B	KN20	KN1_1	KN2_1	KN6_1	KN7_1	KN8_1
KN23_1	-.41180	-.11579	.54258	-.86239	.57057	.44291	.59601	.82268
KN24_1	.23780	.22191	.30621	.07625	.45664	-.59356	-.47787	-.27180
KN25_1	.82802	.50112	-.49452	.26002	-.38677	-.02723	.33108	.20260

Cor.Mat.	KN9_1	KN10_1	KN11_1	KN12_1	KN13_1	KN14_1	KN15_1	KN22_1
KN23_1	.69914	.80682	.77379	-.13016	.85959	.91968	-.15156	.78381
KN24_1	-.74048	-.24997	-.17427	.19610	-.54150	-.10296	-.50565	-.31013
KN25_1	-.31148	-.57952	-.11692	.94307	-.55540	-.35943	.08656	-.56988

Cor.Mat.	KN23_1	KN24_1	KN25_1
KN23_1	1.00000	-.33850	-.27810
KN24_1	-.33850	1.00000	.14926
KN25_1	-.27810	.14926	1.00000

Table 2. Correlation matrix

THE INFLUENCE OF TRAIN STATIONS' ENVIRONMENT ON TRAVELERS' ORIGIN STATION CHOICE BEHAVIOR: a TOD approach

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ABSTRACT
The purpose of this research is to determine the influence of the surrounding environment of train stations on Dutch travelers' origin train station choice behavior. The area surrounding the stations is characterized according to TOD theory. The research data was collected using a questionnaire distributed in 8 stations located in Amsterdam. A multinomial logit model was estimated to describe the effect of independent variables (station, trip related, personal and surrounding environment characteristics) on the dependent variable (origin station choice). The results show that distance, density, proximity and P+R play an important role in deciding to use a train station as origin station. Age, frequency of use, and travelers' general opinion about the station have an effect on the choice of an origin station as well. Understanding how travelers choose a departure station can help NS – Dutch Railway Company, to redistribute the flow of travelers from crowded stations towards less crowded stations.

Keywords: train station choice behavior, Transit-Oriented Development (TOD), revealed preference (RP), Multinominal logit (MNL), sustainable transport

INTRODUCTION
Transport infrastructure and urban development have always had a strong and complex connection and in the Netherlands, great interest has been shown in defining this relationship. Dutch urban planners sensed the benefits of a compact development around transport infrastructure since 1980s, but nowadays another planning method captured their attention, namely Transit-Oriented Development (TOD). TOD theory emphasizes how public transport and urban planning can favor each other, providing the means, the directions in which the environment around a station *can* (as opposed to *must*) be organized. TOD is characterized in terms of 5Ds: density, diversity, design, distance to transit, and destination accessibility. By focusing on the implementation of TOD, sustainability is enhanced. Another reason for which TOD received increased attention is the economic crisis, which limited the means to invest in large-scale spatial development and infrastructure projects, as well as the demand for new housing and office locations.

Not only contributes the organization of the station's surrounding area to a better (sustainable) urban development, but it is demostrated in the literature that it plays a role in travelers' station choice behavior as well (Debrezion, et al., 2009; Cascetta, 2013). The focus of the present research is on train, as a transport mode, since railway transport represents a considerable proportion of daily travel mode chosen by Dutch travellers (Debrezion, et al., 2009). Moreover, one particularity of the Dutch context is the centrality of train stations for TOD approach.

Problem statement and research questions

Nederlandse Spoorwegen (NS) is the Dutch national Railway Company which operates in public transport sector, providing trains and busses, in the Netherlands. Nowadays, NS is confronting with congestion-related issues at the main station level (e.g. Utrecht Centraal, Amsterdam Centraal etc.), while alternative stations that offer less opportunities in terms of shops, cafes, train frecquency, connecting public transport etc., are not very well used. An increased demand for particular station is affecting not only the station itself (high crowding level on the platforms, access-way, in-vehicle, etc.), but also the surrounding area of a station: crowded buses, taxis, no available spaces for parking the bikes and cars. This situation is affecting travelers' experience of the station in a negative way, which might lead to a decrease in the number of people using the train and a decrease in the turnover of the company. One solution to prevent travelers to move to alternative transport modes (e.g. car) is to redirect the flow from main stations towards other stations. In analyzing this possibility, NS is interested in exteding its focus, from station only to the surrounding environment of the station as well, since it plays a role in the travelers' satisfaction. In order to determine which characteristics describing the surrounding environment of a train station are attracting the travelers, it is important to understand how travelers choose their train station. Being one of the first attempts to determine the role of the surrounding environment in the station choice decision-making process of the travelers, the focus is on the origin station of their trip with the train since on the short-run the choice stays the same and the station (and the area around) is (well) known by the traveler.However, additional developments at the other stations can determine the travelers to choose diferently.

In order to address the issue stated above, the main research question can be formulated as follows:

"What attributes of train stations' environment are influencing travelers' origin station choice behavior?"

To give an answer to this central question, some sub-questions need to be addressed as well:

1. How can train stations and their surrounding area be characterized in the context of travel behavior related aspects?
2. What influence do these features have on Dutch passengers' choice of origin station to enter a train?

Relevance

The relation between urban form and travel behavior is not amply addressed (e.g. Estupiñán & Rodríguez, 2008). As far as the author knows, limited literature is available on station choice behavior in connection with built environment/urban form. This study aims to determine characteristics from the available literature regarding urban form and transportation and build a measure instrument to determine their influence on travelers' station choice behavior. Moreover, this research project emphasizes how travelers can be redistributed to other stations if new services or improvements are introduced. By redistributing travelers among the stations, the usage of stations is leveled, leading to more benefits: decrease congestion at the big stations, increase the usage of smaller stations, and achieve regional success as opposed to node or station success for the service operator (here, NS).

RELATED WORK

Railway station choice behavior

Once the choice is made for the train as a transport mode to travel from A to B, the next issue to decide upon is which station to use; train stations are the access points to train service. Nevertheless, even if it is the next logical step, the choice of the departure station did not receive a great attention from researchers.

One of the firsts to address the issue of rail transit station choice was Kastrenakes (Kastrenakes, 1988). The results of the choice model developed for New Jersey transit agency (NJ TRANSIT) indicated that the location of the station in the residential area of the travelers and the frequency of service had a positive effect, while the access time to reach the station and the generalized cost of the rail trip from the departure station had a negative one on the choice of a particular departure train station. Even though it is not focused on train, but metro station and it is closer to the idea of TOD, the study of Cascetta (2013), of the present research thesis, analyzed the value of beauty/design, travel and access time, service frequency and monetary costs in Naples. The findings suggested that the choice is influenced by the aesthetics of the station/area, total waiting time and ticket fare. Access, egress and tranfer time, as well as total in-vehicle time parameters proved not to be statistically significant.

In the Netherlands, two studies are of special interest. Debrezion et al. (2007) applied a multinominal logit model to analyze the choice behavior. The results revealed that distance, calculated as a Euclidean measure between the centroid of the post-code center and the station in the choice set, frequency of service, intercity status of the station and the presence of park and ride facilities have a significant effect on the choice of departure station. The intercity status of the station has the biggest effect on the choice of the departure station, followed by the presence of a park and ride facility in the station. The probability of choosing a specific station diminishes with the distance, while it increases as the service frequency increases. One of the latest researches on railway station choice is provided by Givoni & Rietveld (2014). Amsterdam region was used as a case study, data from NS customer satisfaction survey and a discrete choice model was employed. Their findings reinforced the idea that not many Dutch passengers are choosing the nearest departure station. To estimate the choice of a departure station, a nested logit model was applied, built upon two factors: railway service (number of destinations served directly, the service frequency at each station level and travelers' direction) and the accessibility of the departure station. The results suggested the importance of accessibility of the station and that distance plays an important role. Regarding the quality of the train station facilities in relation to the access modes, the coefficient for the quality of the bicycle parking was found "positive, relatively very high and significant" (Givoni & Rietveld, 2014).

As a general conclusion, one of the features defining the literature on train station choice is scarcity, as Debrezion et al. (2007) noted in their article. The above brief literature review highlights some shortcomings. The present research thesis is trying to address and indicates in which way this research differs from previous efforts to address the choice of a departure station. First, the focus in the past research was on station's features (facilities and level of service) and mainly on accessibility. In addition the latter, was examined in relation to mode choice decision. The other TOD characteristics were included as variables in a model, but in a different manner that the present study does, and on international level, not for the Netherlands case. In the present research thesis, the analysis of the organization of the surrounding environment of the station is made from TOD perspective. A literature review about the concept of TOD is presented in the next section.

Transit-Oriented Development

In their highly acclaimed paper, Cervero & Kockelman (1997) grouped the TOD planning strategies in relation to transportation objectives into 3 dimensions (3 Ds): increased *density* to stimulate the transit ridership, enhancing *diversity* of land use for a better coverage of public transport, and pedestrian-oriented *design* to increase the number of non-motorized trips. Later on, Cervero & Murakami (2008) added two more dimensions (4^{th} D and 5^{th} D): *distance to travel* and *destination accessibility,* referring to the extent to which public transport is connecting in an efficient manner the station area and the activities within it. Regarding distance to travel, Cervero & Landis (1993) found that more people are using public transport instead of their own cars if the public transport stop is close to their home/work. By overlapping all this 5 Ds, sustainability and high quality of environments can be achieved (Cervero & Murakami, 2008).

In order to determine the 5 Ds sub-attributes characterizing the built environment in relation to transportation objectives and in particular affecting travel behavior, a literature search was realized. The reason for focusing on the general view of travel behavior and not only station choice behavior is the scarcity of the literature available for the latter purpose mentioned. The review of the available literature revealed the fact that travel behavior is not affected only by the built environment, but by station characteristics, personal characteristics of the traveler and trip attributes, as well. The main feature defining the analysis related to the relationship between urban form and built environment is diversity. Some selection rules needed to be developed and these criteria are presented in the "research approach" section of this summary.

RESEARCH APPROACH

A conceptual framework was developed to define the way in which the answers to the questions will be sought. The review of the literature represents the starting point of this research project. This phase gave an insight into the theory of TOD and station choice behavior; besides, it helped in the identification of the built environment dimensions, station aspects, travel makers and trip characteristics and their definition in relation to travel behavior. Therefore, the conceptual framework proposed here assumes that there is a

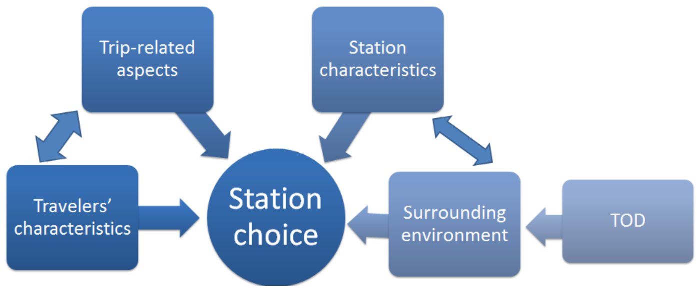

Figure 1. Conceptual framework

relationship between the station choice and the attributes divided into the presented four categories and it can be seen in Figure 1.

This study represents an effort to determine the attributes of a surrounding area of a train station which are attracting travelers to use the train station as origin for their train trip. The travelers' preferences were collected by employing revealed preference approach, in a relevant context (a multi-station city from which the travelers can consider feasible alternatives). A case study was set up, consisting in 8 stations (included in Table 1) from Amsterdam Metropolitan area. These 8 stations formed the choice set. The targeted respondents were asked in a paper-based questionnaire to indicate their most often used origin station and the alternative train station. The collected data is analyzed by using a discrete choice method, Multinominal Logit Model (MNL).

Based on the findings from the literature review, some characteristics defining trip-related aspects, travelers' characteristics and stations' surrounding environment were selected as attributes to be included in the questionnaire. Station characteristics were not considered at this stage due to the widespread analysis of them in the literature and within NS. Due to the lack of "standardized" descriptions for the 5Ds some selection rules were developed. An overview of the attributes describing the surrounding environment of a train station is given in the table 1. The main principles used for the selection are: the built environment dimensions are categorized under the 5 Ds (core dimensions), the selection of the attributes under the 5D categories will take the issue of multicolinearity into consideration and discussions with experts involved in TOD domain.

Built environment (5Ds of TOD)	Density	Number of people in the catchment area
	Diversity	Presence of supermarkets
		Provision of a variety of shops
		Presence of restaurants, fast-food restaurants and cafes
		Overall (shops offer)
	Design	Presence of sidewalks, sidewalks quality, width, and presence of crossing aids
		Presence of pedestrian friendly amenities (benches, trash bins etc.)
		Bike-friendly design (presence of bike lines, speed, quality and width of them, presence of crossing aids)
		Car-friendly design (presence of roads, their quality, traffic speed, safety, stoplights provision etc)
		Aesthetics of the station's environment (art/architecture/building height)
		Presence of open/green spaces
		Overall design
	Destination accessibility	Provision of bike shelters
		Public transport connectivity
		P + R provision
		Kiss and Ride provision
		Overall accessibility of the station
	Distance to transit	The distance between the origin point of the trip and the origin station

Table 1. Selected built environment variables

Regarding the respondents' characteristics and travel related aspects, these were selected based on the assumption that they can explain station choice behavior.

The questionnaire has three parts aiming to collect data about the travel experience - actual origin station choice and reason to choose it (part I), the composition on choice set (question 2) and reasons why it is chosen (part II) and data on personal travelers' characteristics (part III). The influence of built environment dimension on travelers' choice station behavior is assessed using a five-points rating scale (very negative, negative, neutral, positive, and very positive). The questionnaire was distributed by the fieldwork company Almere Marktonderzoek Advies B.V., in the selected stations during 2 working days in April 2014. According to Hensher et al. (2005), the choice-based sampling (CBS) is suitable for the collection of RP choice data and the rule of thumb suggests that at least 50 decision makers must be sampled for each alternative. Therefore, in each station, 50 respondents were asked to fill in the questionnaire. A total of 382 respondents were approached. The minimum 50 respondents was met for all the station, except for Amsterdam Sciencepark.

ANALYSIS

Only three stations were chosen as origin stations more than 50 times (Amsterdam Central, Amsterdam Amstel and Amsterdam Muiderpoort), out of which Amsterdam Central is by far the most used one (25,4%). This finding it is not surprising, but reflecting the real case and supporting the problem statement of this research paper: high crowding level at the stations offering more opportunities, while the stations with fewer opportunities are not among travelers' preferences. Table 2 presents a brief summary of the travelers' characteristics (research sample) and trip-related aspects (current travel experience).

Attribute	Level	Frequency	Percentage (%)
Gender (N=380)	Women	173	45,5
	Men	207	54,5
Age (N=380)	Younger than 45 years old	299	78,7
	Older than 45 years old	81	21,3
Education (N=376)	Middle-educated	105	28,1
	Higher- educated	271	71,9
Car owners (N=347)	Yes	134	38,6
	No	213	61,4
Travel time to the station (N=377)	Less than 8 minutes	118	31,3
	9 to 12 minutes	120	31,8
	More than 13 minutes	139	36,9
Frequency of use (N=382)	More than 4 days/week	162	42,4
	1-3 days/week	118	30,9
	1-3 days/month	45	11,8
	Less than 2 days/month	36	9,4
	Less than 2 days/year	21	5,5
Access mode (N=382)	Walking	100	26,2
	Bike	109	28,5
	Car as a driver	5	1,3
	Car as a passenger	7	1,8
	Public transport	161	42,1

Table 2. Travelers' characteristics and trip-related aspects

In what concerns the research sample, it can be stated that there were a large proportion of younger than 45 years old travelers filling in the questionnaire than old travelers and more women. The present research sample is not a particular sample in comparison with the NS's sample. The majority of the respondents are living in Amsterdam and surrounding areas of

Amsterdam (almost 80%), do not own a car (more than 61%) and are higher-educated. To arrive at the station, the highest number of travelers have a time duration of more than 15 minutes and are using as transport modes public transport (42,1%), followed by bike (28,5%) and walking (26,2). Public transport as being the most used transport mode to access the station is not a surprising finding for the Amsterdam case. In addition more than 70% are frequent travelers, using the train between 1 to more than 4 days/week.

The findings related to the influence of the surrounding area on Dutch travelers' origin station choice behavior revealed that all the attributes included under the 5Ds category have a positive effect, rather than negative. Distance and Destination accessibility (2 out of 5Ds) have the highest influence on the origin station choice. The other 3 Ds (Diversity, Design, and Density) have less influence, but they still affect the choice in a positive way. The positive influence of proximity and intensity (density) is supported by the model results as well. On the other hand, the Distance attribute has a negative influence on the choice. "Sidewalks", "Bike-friendly design", "Pedestrian amenities", "Public transport" and "Bike shelters" are attracting travelers, while "Presence of a variety of shops" and "Car-friendly design" sub-attributes have a negative influence. "Buildings", "Open Space", "P+R" and "K+R" have a more neutral influence on travelers' station choice behavior.

The outcome of the questionnaire and the findings from the literature review were combined in a characterization of the train stations in station-choice behavior context (see Table 3). The levels of these variables for each station (not detailed in this summary due to confidentiality reasons for some of them), together with respondents' age, frequency of use, main origin train station and their alternative were the input of the MNL model.

Characteristics		Type of variable	Levels					
			Level1	K1	K2	Level 2	K1	K2
	Station type	Continous	Number					
	Types of trains*	Discrete	Sprinter*	1	0	Sprinter+Intercity*	0	1
	Number of trains/hour	Continous	Number					
	Crowding level	Discrete	High*	1	0	Average*	0	1
	Transfer station	Discrete	Yes*	1		No*	-1	
	Monument building	Discrete	Yes*	1		No*	-1	
	General opinion	Continous	Number					
	Atmosphere	Continous	Number					
	Functionality	Continous	Number					
	Safety	Continous	Number					
Station	Number of passenger (average on a working day)*	Continous	Number					
Surrounding environment	Distance (average in minutes)	Continous	Number					
	Proximity*	Continous	Number					
	Intensity*	Continous	Number					
	Offices (nr of people working)*	Continous	Number					
	Residential location*	Continous	Number					
	Eateries/cafes/hotels	Discrete	Many*	1	0	Average*	0	1
	Shops	Discrete	Many*	1	0	Average*	0	1
	Supermarkets	Discrete	Yes*	1		No*	0	
	Leisure/touristic attractions	Discrete	Many*	1	0	Average*	0	1
	Parks	Discrete	Yes*	1		No*	-1	
	Public transport connectivity*	Continous	Number					
	Bike shelters	Continous	Number					
	P+R	Continous	Number					
	K+R	Continous	Number					

Table 3. Variables charaxterizing the station and its surrounding environment; coding (*effect coding) (Source: NS 2012, OPS Type 4,5,6, 2013, *Maak Plaats, 2013)

Some steps were taken before the modeling process (effect coding, correlation checks). Effect coding was used to represent the discrete variables. By employing this coding system, a two level variable is represented by one parameter, while a three level variable is represented by two levels. For example, the presence of parks (named "Parks" in table 3) has two values -1 (level one for “No”) and +1 (level 2 for “Yes”), while crowding level has three levels coded as: “low”=1 (level 1: -1 -1), “medium”=2 (level 2: 0 +1) and “high”=3 (level 3: +1 0). Due to high correlation among the variables (a drawback of the data collection approach –RP), several alternative choice models were estimated.

An optimal model was selected to further analysis, based on some relevant criteria (high log likelihood value; should include at least one alternative-specific constant (due to its role of capturing the unobserved effect associated with a particular alternative, and include more variables describing the built environment dimension). An overview of the statistically significant variables which entered the utility function underlying the model is given in Table 4 (age and frequency of use proved to be significant as well, but they can be employed further only for group corrections for which the alternative-specific constant is referring to – here, Amsterdam Rai). The parameters (β coefficients for the variables) have the expected directions. The alternative-specific constant is referring to Amsterdam Rai station and has a positive sign because it needs a correction, an increase to reach the average of selected stations (it has been chosen 33 times by the respondents, in comparison with Amsterdam Central 97 times). The other positive coefficients of the variables mean that the higher the variable’s value, the more chances the station has to be chosen. On the other hand, the negative values of the coefficients for the rest of the variables suggest that a decrease in the value of the variables leads to a decrease in the chances that a station it is chosen (e.g. distance: the longer the distance, the lower the chance of a station to be chosen).

To illustrate the working of the model, the model was applied for a choice situation of two train stations: Amsterdam Central and Amsterdam Amstel. The utilities related to these stations and the probabilities of being chosen were calculated according to the formula:

$$V_i = \beta_{0i} + \beta_{1i} * f(X_{1i}) + \beta_{2i} * f(X_{2i}) + \cdots + \beta_{ki} * f(X_{ki}) \quad (1)$$

The results did not match entirely the expected findings since the model predicts the higher likelihood of Amsterdam Amstel to be chosen by the travelers instead of Amsterdam Central.

Xi	Coefficient value	Amsterdam Central station	Amsterdam Amstel
Alternative specific constant (X3=1)	6,04686	0	0
General opinion	13,7204	0,1368	0,1408
Distance	-75,8923	0,1601	0,1413
Proximity	12,3546	0,03	0,31
Intensity	27,1067	0,29	0,12
P+R	4,92334	0	0
Vi		-2,04182551	-1,70901967
		0,129791559	0,181043188
P(Vi)		0,417558076	0,582441924
100 travelers		41,75580761	58,24419239

Table 4. The choice details of Amsterdam Central and Amsterdam Amstel

After calculating the probabilities of choosing the station revealed that the model is not predicting that Amsterdam Central is still the station with the highest chance to be chosen, but Amsterdam Amstel (0.42 probability of choosing Amsterdam Central, in comparison with

0.58 for Amsterdam Amstel). Some explanations for this outcome are being discussed. Firstly, in the file used as a input for the MNL model containing the origin and alternative stations for all the respondents, Amsterdam Central is more often not chosen than chosen (108 times not chosen versus 63 times chosen). Secondly, in the research sample, the proportion of travelers choosing Amsterdam Central vs Amsterdam Amstel is 1.89, while in the reality this value is 6.76. Therefore, the research sample used in this study is not entirely reflecting the reality, fact leading to this uncommon prediction.

Scenario	Number of travelers using Amsterdam Centraal	Number of travelers using Amsterdam Amstel	Total number of travelres
Increase to 65% the general opinion about Amsterdam Amstel Station	40,49	59,51	100
Increase with 50 the number of available parking spaces at Amsterdam Amstel Station	24,23	75,77	100
Descrease with 1 minute the travel time to Amsterdam Amstel Station	29,62	70,38	100
Increase to 22% the proximity at Amsterdam Amstel Station	27,72	72,28	100
Increase to 250 the intensity around Amsterdam Amstel Station	18,67	81,33	100

Table 5. Forecasting the use of stations analysis under 5 scenarios

Table 5 represents a summary of the scenarios and their outcomes. It can be seen that under all of the scenarios the probability of choosing Amsterdam Amstel (since one of the goals of the project was to determine how the flow of travelers could be redirected from Amsterdam Central to other station, or Amsterdam Amstel in this case) is increased at least with 1.27% in case of an increase to 65% of the general opinion. Two of the best improvements that can be developed at Amsterdam Amstel station level in order to determine more travelers to use it are: increase the number of available parking spaces and increase the intensity around the station.

CONCLUSIONS

This research thesis addresses a study of travelers' choice of a train station as an origin station in the Netherlands. The selection of the 5Ds's, sub-attributes, and insights in the travelers' origin station choice behavior in relation to the surrounding area of a station are significant results of this research. The lack of "standardized" sub-attributes for the 5Ds forced the development of selection criteria. The selected sub-attributes can be employed in further research. The results presented in this thesis , together with the literature review, provide the answers on two research questions that were the input to define the outline of the main question of this research: *"What attributes of train stations' environment are influencing travelers' origin station choice behavior?"*

The results indicate that the distance has one of the highest effects on the choice. Destination accessibility can be considered as a trigger, while the other 3 Ds (Diversity, Design, and Density) have less influence, but they still affect the choice in a positive way. The positive influence of proximity and intensity (density) is supported by the model results as well. One special sub-attribute is "P+R" because the outcome of the questionnaire is that it has a neutral influence on the station choice behavior, while the model showed that it has a positive effect.

This research provided valuable insights about origin train station choice behavior of the travelers and how the surrounding environment of a station can be characterized in the context of travel behavior. Moreover, the present study suggests some developments through which the travelers can be stimulated to choose another origin station. Additional collection of data and the inclusion of destination station in the analysis are recommended for further research.

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"In a sector in which smart meters, smart grids, solar panels and photovoltaic cells are the means for sustainable developments, TOD comes to extend the list. The difference is the fact that TOD is less tangible."

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