Walking and bicycle catchment areas of tram stops in The Hague

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HTM

Walking and bicycle catchment areas of tram stops in The Hague

by

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Preface

This project marks the ending for over 7 years of studying at the TU Delft. I have enjoyed working on this research, especially because it was the first time that I could really think about a large project on my own and decide everything myself. First, I would like to thank HTM for providing me with the opportunity of doing this research with them. They provided a good working atmosphere. Thomas helped me to keep the larger goal in mind, Janiek was always a wizard with data, Sandra gave constructive feedback and Marije helped me with preparing the survey. Furthermore, great thanks go out to my TU Delft supervisors, Niels, Eric and Danique. In the first place they helped me by sharing their knowledge from their respective fields and secondly they managed to share their enthusiasm of scientific writing. Also, Serge made sure that no meeting was without laughter. Lastly, I would like to thank Matthijs, because of his enthusiasm in teaching me the basics of GIS, and Bram, for being a good surveyor and always giving me confidence when I needed it.

Lotte Rijsman
Delft, 24th of October 2018

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Introduction

The problem of unsustainable private motorized modes in terms of pollution and congestion is an important topic in urban mobility (Kager, Bertolini, & Te Brömmelstroet, 2016). The bicycle-transit combination benefits from the flexible aspect of the bicycle, and the larger spatial range of public transport. Together they compete with private motorised vehicles, in a more sustainable and space-efficient way (Kager et al., 2016). Although in urban areas the bicycle and transit might compete on single trips, they can complement each other at the total trip level (Kager et al., 2016; Martin & Shaheen, 2014).

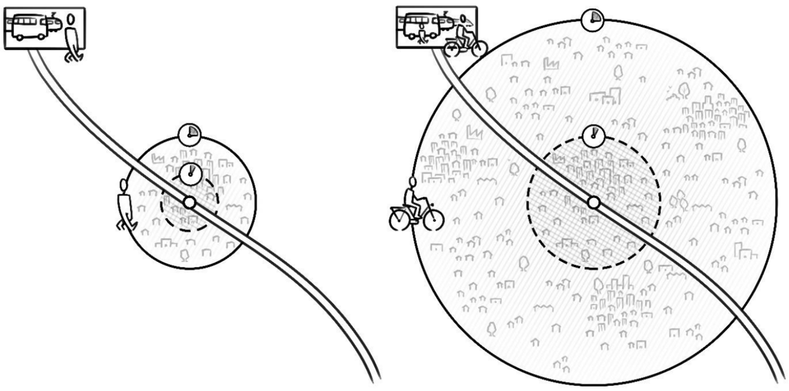

Figure 1: Mechanism of increased catchment areas (Kager & Harms, 2017)

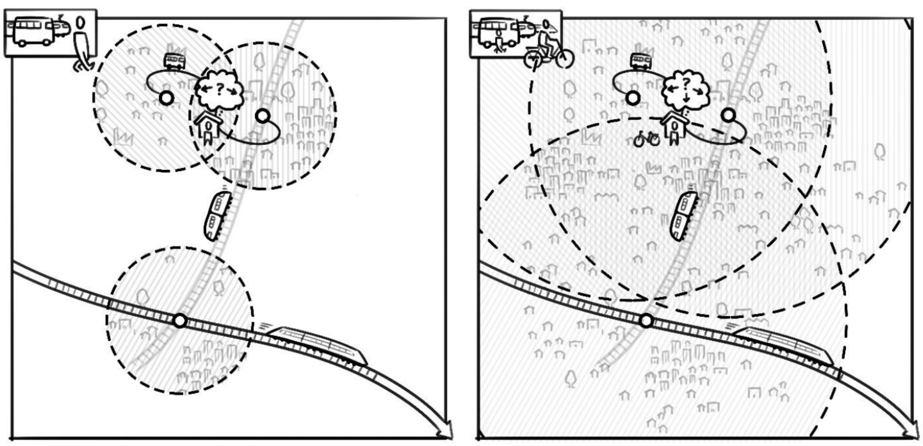

Figure 2: Mechanism of increased choice (Kager & Harms, 2017)

There are several synergetic beneficial consequences of the bicycle-transit combination. An important benefit is that the catchment areas of public transport stops can be increased greatly, as illustrated in Figure 1. The increased size of catchment areas leads to overlapping catchment areas, providing the traveller with the possibility of choosing between multiple stops (Kager & Harms, 2017). This allows them to optimise their journey better: they can always choose the option that fits best. Furthermore, option value emerges, which means that cyclists can obtain value from the possibility of using another tram stop, although they do not use it (Geurs, Haaijer, & Van Wee, 2006). The overlapping catchment areas are depicted in Figure 2.

A downside of using the bicycle-transit combination, however, is the need for additional investments and space for bicycle facilities at transit stops, while for the user it generates extra costs in terms of parking time and safety risks. Furthermore, at the activity-side of a trip the availability of bicycles is often much lower than at the home-side. Bike sharing systems can overcome this (Martin & Shaheen, 2014).
The influence area of a transit stop is often defined as the catchment area (Flamm & Rivasplata, 2014). However, not much is known about what influences their size, especially not for cycling catchment areas (Hochmair, 2015). An informative way to describe the catchment area of a transit stop is the distance-decay function, which is a tool to measure the impedance to travel (Iacono, Krizek, & El-Geneidy, 2008).
Compared with the train, less knowledge is available about bicycle access and egress of tram stops. In this research a first step is taken towards reaching an integrated bicycle-transit network by providing knowledge on the physical and network integration of bicycle and tram. This knowledge is delivered in the form of walking and cycling distance-decay functions of tram stops in The Hague, the factors that influence feeder distance and feeder mode choice. The underlying idea is that many of the same choice mechanisms result in longer feeder distances and cycling as feeder mode.

Research approach

The goal of this research is twofold: to understand the factors that influence walking and cycling catchment areas of tram stops, and to understand the factors that influence the choice for cycling as feeder mode of tram stops (see Figure 3.
The main research question is:

> "What factors affect walking and cycling feeder distance and feeder mode choice for tram stops in urban areas?"

The sub questions are as follows.

1. What are, according to literature, the factors affecting walking and cycling feeder distance and feeder mode choice?
2. What are the walking and cycling feeder distances and feeder mode choices for tram stops, and to what extent do the factors affect them?
3. Why do people choose for a tram stop further than the nearest?
4. Why do people choose the bicycle as feeder mode for tram stops?

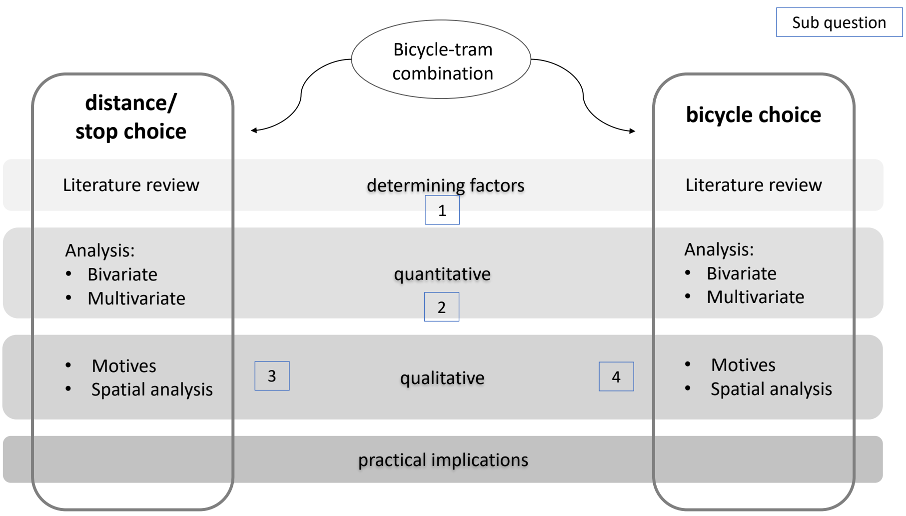

Figure 3: Research approach and corresponding research sub questions

The methodology of this research is as follows. First, a literature review is used to answer the first sub question; it provides information on factors that may influence distance to transit stops and feeder mode choice.

These are combined into a theoretical framework, which is used as a basis for this research. The theoretical framework consists of four clusters of factors: user characteristics, transport factors, built environment factors and context factors. The data needed for this research are gathered through a self-administered revealed preference survey, with tram traveller in the The Hague area as a case study. Smart card data approaches do not satisfy, because they only provide aggregate data, whereas also user and trip characteristics need to be obtained.
Then, the factors included in the theoretical framework are explored quantitatively for their effect on feeder distance and feeder mode choice. This is first done through bivariate analyses, which investigate the effect of the factors separately, through statistical tests. These statistical tests are supported by visualisations, often in the form of distance-decay functions or bar graphs. The factors that are found significant, are included in multivariate analyses. These investigate the effects of the factors simultaneously, in order to capture the interrelations between the factors. This is done in the form of two separate logistic regression models: a feeder distance model and a feeder mode model.
Lastly, a qualitative analysis is carried out, using the motives that respondents provide in the survey, as well as a spatial analysis. This way, the choice mechanisms behind choosing a stop further away and choosing the bicycle as a feeder mode can be examined.

Data gathering

This research includes a revealed preference survey to gather information on the origins and destinations of tram travellers. Revealed preference methods provide high validity of the results, because they concern real situations and choices (La Paix Puello & Geurs, 2016). The revealed preference method is carried out through self-administered transit on-board surveys, an efficient approach time and money wise. They generate high response rates and can reach many transit travellers simultaneously. A drawback of self-administered surveys is that respondents might misunderstand questions, which otherwise could have been elaborated on. Furthermore, short distance travellers are likely to be underrepresented. The survey is carried out in the case study area of The Hague.
The most important elements of the survey are about the journey of the tram traveller, because it forms the basis of the data: the distance-decay functions and the bicycle usage. Furthermore, some user characteristics of the respondents are asked, as well as their motives for choosing a stop further away or using the bicycle.

Results

Theoretical framework

Through a literature review, a theoretical framework is constructed. The expected influencing factors on both feeder distance (Figure 4) and feeder mode choice (Figure 5) form the theoretical framework.

Bivariate results

In bivariate analyses the expected relations from the theoretical framework are tested through statistical tests. The outcomes for feeder distance are visualised in Figure 4 and feeder mode choice in Figure 5.
The factors from the bivariate analyses that are significantly related with feeder distance, are feeder mode, amount of transfers, frequency at the stop, directness and transit stop density. So no user characteristics seem to have an influence on feeder distance. Furthermore, trip purpose, home-based/activity-based access/egress and total trip length are significant at a 75% level. All of these factors (also displayed in Table 4.2) will form the input for the logistic regression model for feeder distance in section 4.2.
For feeder mode choice the following factors are found significant: age, transit captivity, feeder options, frequency of cycling, trip purpose, home-based/activity-based, feeder distance, frequency at the stop, directness, transit stop density and availability of bicycle parking. The amount of transfers is significant at a 75% level. These factors (also displayed in Table 4.2) will be used as the input for the logistic regression model for feeder mode choice in section 4.2.

Multivariate results

The significant factors from the feeder distance bivariate analyses are used as input for the multivariate analysis, to control for the other factors. This is done in the form of a logistic regression model, containing distance classes. A model with three different distance classes leads to insufficient distinction between the classes. Therefore, a binomial logistic regression model with two distance classes is estimated, of which a cut-off

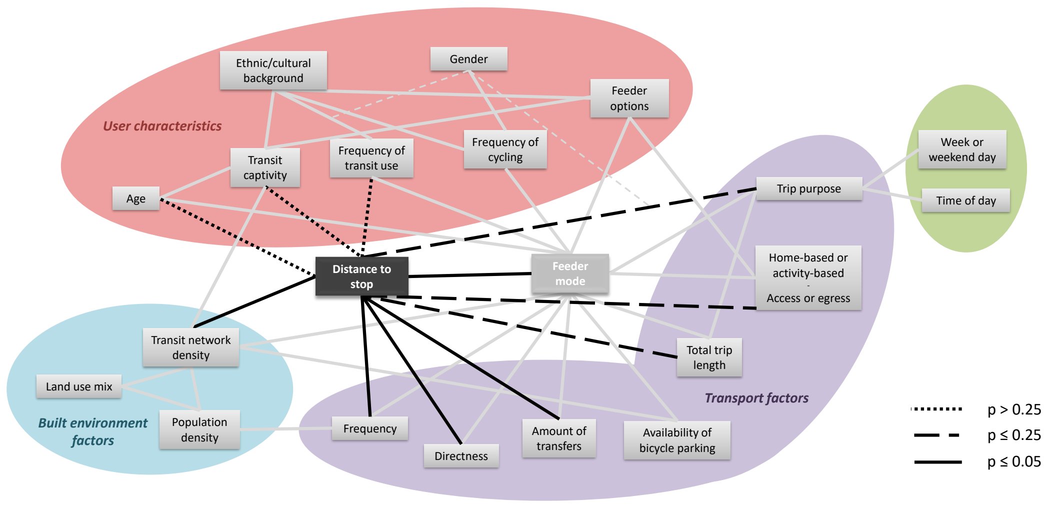

Figure 4: Results from the bivariate statistical tests for feeder distance

value of 500m performs best. In the feeder distance model, only feeder mode and transit stop density remain significant: a low tram stop density and cycling both increase the probability of bridging a longer feeder distance than 500m.
Some of the factors are only significantly related with feeder distance at a 75% confidence interval (trip purpose, home-based/activity-based access/egress and total trip length). To be able to detect repressive effects, they are still tested in the feeder distance model and added to the model together with the factors that are significant at a 95% confidence level. Only total trip length is significant: a longer trip decreases the probability of travelling more than 500m to or from a stop. The rest of the factors (age, transit captivity and frequency of transit use) is not found to be significantly related with feeder distance.
In the multivariate analysis of the feeder mode choice logistic regression model, only frequency of cycling, feeder distance, transit stop density and home-based versus activity-based are significant, where the first two factors have the most impact. A low frequency of cycling, a short feeder distance and an activity-based access/egress trip decrease the probability of choosing the bicycle as feeder mode. In the bivariate analysis, the amount of transfers and total trip length are significant at the 75% confidence level, but they are both not significant when added to the logistic regression model.
The user characteristics ethnic/cultural background and gender slightly improve the feeder mode choice model as interaction effects. Land use mix and population density hardly improve the feeder distance model, but do improve the feeder mode choice model.

Qualitative results

Most of the travellers that chose for a stop further away, did so to avoid a transfer. Surprisingly, also many travellers stated they walked to a further stop because they like to walk. This, together with the variety of reasons mentioned, indicates that minimising travel time, effort and costs are not always the main drivers behind tram stop choice, but that it is more complex.
Respondents provided answers to three hypothetical questions about what would them have made to choose a stop further away. Here it seems that a considerable amount of tram travellers will always choose for the closest stop. The relation between choosing a further stop to 'avoid transfer' and to 'have more options' is present more distinctly than between 'park your bike' and the service-quality related motives. This indicates that the choice for the bicycle as feeder mode is not necessarily a combined choice with other, service-quality related influences.

The motives respondents gave in the survey for not choosing the bicycle as a feeder mode, are mostly related to the sufficient proximity of the tram stop. Other common reasons concern the practicality of using the bicycle, such as the lack of a bicycle available, or parking concerns.
By far the most frequently mentioned motive for using the bicycle as feeder mode is reducing the total travel

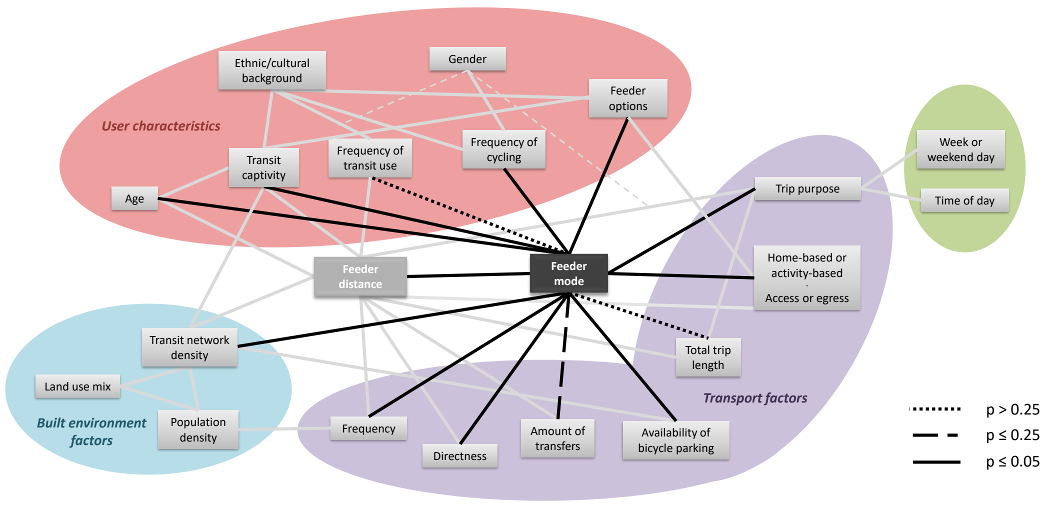

Figure 5: Results from the bivariate statistical tests for feeder mode choice

time. Some respondents did not have choice because the stop is too far away, and there are also some who stated they only use the bicycle to save time when they are in a hurry. For bicycle choice, reducing the total travel time seems to be a more obvious motive than for choosing a stop further away.
Also in the spatial analysis it comes forward that transfers (either bus or other tram line) are the largest reason to go for a stop further away. Furthermore, street patterns and natural barriers, such as water large buildings, appear to influence the stop choice.

Conclusions, discussion and recommendations

One of the main findings is that a few important factors are largely related: feeder distance, feeder mode and tram density. For feeder mode choice, also cycling habits and bicycle availability are important. Furthermore, three important barriers for the bicycle-tram combination have been discovered: the lack of an available bicycle, insufficient bicycle parking places and unsafe bicycle parking places. Respondents that sometimes use the bicycle-tram combination are more inclined to travel further to a stop that suits them better.
The median overall feeder distance found in this research is 400m. When considering the modes separately, it is 380m for walking and 1025m for cycling. The following factors from the theoretical framework were found to be significantly related with feeder distance, through bivariate analyses: feeder mode, amount of transfers, frequency at the stop, directness and transit stop density. This means that the statistical results indicate that user characteristics do not significantly influence feeder distance.
A logistic regression model with two distance classes and a cut-off point of 500m between those classes, is found to describe best the feeder distance data. In the feeder distance model, only feeder mode, transit network density and some categories of frequency at stop are significant. Total trip distance is also found to be significant when added to the model. For feeder mode choice, a logistic regression model is estimated as well, where only feeder distance, cycling frequency, home-based/activity-based and transit network density are significant factors. Although the amount of transfers could not be tested for its relation with feeder distance, because of errors in the logistic regression model, there are several indications that it is an important factor.
The motives that are mentioned for choosing a stop further away are quite common and mostly related with the quality of the transit service and comfort matters. Avoiding a transfer is named most often. In contrast, the motives for cycling are more common, and relate mostly to travel time reduction or the built environment.

Surprisingly, trip purpose is not significant when tested in both logistic regression models. It is possible that the effect is eliminated because of insufficient variation in the surveyed lines: other line characteristics, e.g. the directness or frequency, might interfere with the effect of trip purpose.
Then, several studies speak of the effect of high quality transit: it supposedly leads to longer feeder distances and the choice for the bicycle as a feeder mode. However, frequency at the stop and directnes of the line have

produced remarkable results in this research. This may be explained by how they are defined: frequency is measured as a cumulative value for all lines at the stop, while the frequency that is relevant for that specific trip is more appropriate. And the definition of directness is a combination of several other service quality aspects, which means that the combination of those separate effects may lead to the remarkable results. However, another explanation is that service factors are especially important between modes, instead of within modes.

The recommendations for practice are twofold. First, transit operators are advised to redesign their network by mapping the found distance-decay functions onto the network. This is because overlap in catchment area makes the network inefficient: the in-vehicle time and total travel times increase because of longer time wasted at stops (Wu & Levinson, 2018). Secondly, transit operators should encourage the bicycle-tram combination, to increase the competing position of the tram. They can do this by addressing the three found barriers for cycling as a feeder mode, which could potentially increase the amount of bicycle-tram users from 21.7% to 37.6% of travelers. The first barrier is about no or insufficient bicycle parking places at the stop. This can be addressed by placing more bicycle parking facilities at tram stops. The second concerns the fear for damage or theft of the bike. By providing safer parking spaces, e.g. guarded bicycle storages nearby the stop, bicycle lockers or security cameras, this barrier may be resolved. The third barrier for cycling is about the lack of an available bicycle. A solution, that is also regarded as an essential feature in the bicycle-transit combination, is to provide a bicycle sharing scheme at tram stops (Kager & Harms, 2017).

1
Introduction

The problem of unsustainable private motorized modes in terms of pollution and congestion is an important topic in urban mobility (Kager et al., 2016). Public transport, combined with active modes (walking and cycling), is seen as an important opportunity to improve the mobility in cities in a sustainable and environmentally friendly way Zuidgeest et al. (2009). Krygsman, Dijst, and Arentze (2004) note that access and egress are considered the weakest parts of transit, because of the relatively large travel disutility. From that aspect, the role of the bicycle as a feeder mode is considered highly important, because it increases the accessibility of transit stops (La Paix Puello & Geurs, 2016). The benefits of the bicycle include that it is healthy, relatively cheap, flexible and environmentally friendly. Furthermore, it occupies little space (Pucher & Buehler, 2017). The benefits of public transport are often underestimated, because they are usually overlooked. Van Oort, Van der Bijl, and Verhoof (2017) define these benefits as '5xE': effective mobility, efficient cities, economy, environment and equity.
Research on the bicycle as feeder mode for the train has been present for a longer time (Brons, Givoni, & Rietveld, 2009; Givoni & Rietveld, 2007; Rietveld, 2000). Also research on the bicycle as first and last mile transport for other transit than rail has emerged (Krizek & Stonebraker, 2010; Martens, 2004). These authors have already put forward some useful findings. For example, at the home-end the bicycle is much more used than at the activity-end (Martens, 2004). Martens (2004) also found that the higher the urbanisation level, the less the bicycle is used for access or egress, implicating that lower level transit and bicycle are competitors. However, it is important to note that bicycle and transit might compete on single trips, but that they can complement each other at the total trip level (Kager et al., 2016; Martin & Shaheen, 2014).

1.1. Problem context

1.1.1. Bicycle-transit combination

These aforementioned papers, however, do not regard bicycle and transit as an integrated combination, but merely as a way to increase the accessibility of public transport. Moreover, they often take a more practical approach, concentrating on factors that increase bicycle and transit usage by integrating the two (Givoni & Rietveld, 2007; Krizek & Stonebraker, 2010; Martens, 2007; Rietveld, 2000).
But only recently, authors started to consider the bicycle-transit combination as a distinct mode: the 'bicycle-transit mode', sometimes also called the bicycle-train mode (Kager et al., 2016; Kager & Harms, 2017). Kager et al. (2016) give an explicit definition of the bicycle-transit mode. They define two subsystems: a 'train-like' service, which is defined as a transport service offering high speed and capacity that is often combined with other qualities, and a feeder system. They consider three main conditions for a trip to be performed by the bicycle-transit mode. The first is that a 'train-like' service, in terms of frequency, speed and comfort, forms the main trip. The second is that at least one bicycle trip connects to the 'train' service. Lastly, the third condition is that no other modes than walking, cycling or transit are to be included in the trip. Leferink (2017) proposes a similar definition, but allows other modes than transit or bike as part of the bike-rail combination. Regardless of the way in which the cycling-transit combination is defined, the main purpose of providing a distinct definition is to acknowledge the importance of the topic and stimulate further research. Furthermore, it encourages integration of the bicycle and transit in practical planning and operation. In this research it will be referred to as the 'bicycle-transit combination'.

The recent interest in the bicycle-transit combination has been reinforced by the increasing popularity of the bicycle as an access and egress mode for public transport. For example, in the Netherlands the bicycle as access mode to train stations has increased from 36% to 43%, while for egress the increase has been from 10% to 13% between 2005 and 2014 (Harms & Kansen, 2018).

Benefits and disadvantages of the bicycle-transit combination

The combination of the bicycle and transit benefits from the flexible aspect of the bicycle (both space and time wise) and the high speed of public transportation. It can hereby offer better competition with the private car. There are several other synergetic beneficial consequences of the bicycle-transit combination, apart from the separate mode benefits of the bicycle and transit.

An important benefit is that the catchment areas of public transport stops can be increased greatly, as illustrated in Figure 1.1. Public transport operators must always balance between short access and egress distances and short in-vehicle times, so when access and egress distances become larger, the network can become coarser. This has great advantages in terms of the network quality, because frequencies and travel speeds can be increased (Wu & Levinson, 2018). Another benefit of the bicycle-transit combination is that the increased size of catchment areas leads to overlapping catchment areas, providing the traveller with the possibility of choosing between multiple stops (Kager & Harms, 2017). This allows them to optimise their journey better: they can always choose the option that fits best. Furthermore, option value emerges, which means that non-users can obtain value from the possibility of using public transport (Geurs et al., 2006). In the case of the bicycle, option value would be obtained from the possibility of using other tram stops. The overlapping catchment areas are depicted in Figure 1.2.

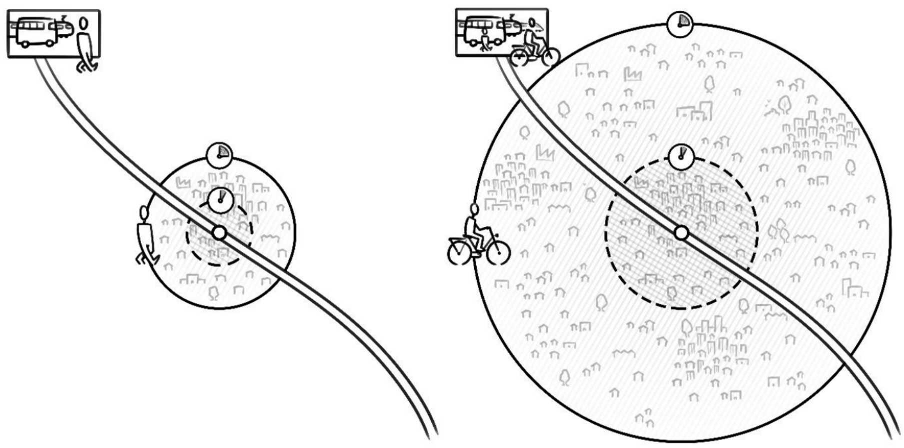

Figure 1.1: The bicycle increases catchment areas of public transport stops (Kager & Harms, 2017)

A downside of using the bicycle-transit combination, however, is the need for additional investments and space for bicycle facilities at transit stops, while for the user it generates extra costs in terms of parking time and safety risks. Another problem is that at the activity-side of a trip the availability of bicycles is often much lower than at the home-side (Kager & Harms, 2017). Bike sharing systems, which have become more common in recent years (Martin & Shaheen, 2014) can contribute to the use of the bicycle as an egress mode. Kager and Harms (2017) considers bike sharing systems as a vital part in the bike-train-bike combination. Martin and Shaheen (2014) provided research on the effects of combining public transport and bike-sharing systems, mainly focusing on the effect of bike sharing systems on the use of public transport in different parts of the city centre. They found that in high density areas, where public transport networks are more concentrated, bike sharing can substitute public transport trips, while in areas with lower densities and less available transit bike sharing mostly functions as the first or last mile to public transport.

Prerequisites for an integrated bicycle-transit network

Cycling and transit may be competitive modes at the single trip level, they complement each other at the total trip level (Kager et al., 2016; Martin & Shaheen, 2014). This is an important notion, because it supports the need for an integrated bicycle-transit network. However, there are several prerequisites in order to

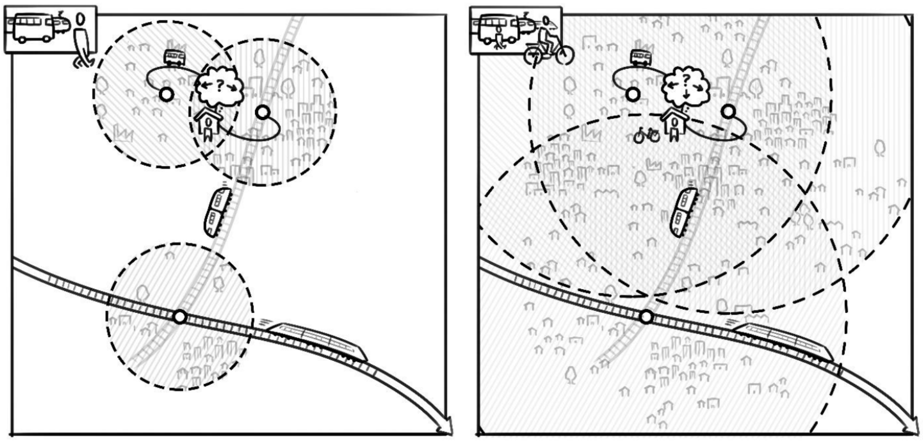

Figure 1.2: The bicycle increases choice options for a public transport stop (Kager & Harms, 2017)

achieve such an integrated bicycle-transit network. To combine the bicycle and transit in an effective way, physical and network integration is necessary. Physical integration includes the provision of bicycle infrastructure, bike sharing schemes to provide for bicycle egress, and bicycle parking at stops (Kager & Harms, 2017; Leferink, 2017). Leferink (2017) also mentions smooth bicycle access to and from the stop or station. With regard to network integration, Kager and Harms (2017) acknowledge that coordination in planning and operation is important. Furthermore, integration in terms of ticketing and information systems are needed, concerning both fares and payment systems (Kager & Harms, 2017; Leferink, 2017). The last prerequisite is supplying information on the bicycle-transit combination through promotion and sign postings at bicycle lanes and stops (Leferink, 2017). In addition, Kager and Harms (2017) point out that a bicycle and transit culture is necessary for the bicycle-transit combination to succeed.

1.1.2. Catchment areas and distance-decay

The influence area of a transit stop, or the distance that travellers are willing to bridge in order to reach the stop, is often defined as the catchment area (El-Geneidy, Grimsrud, Wasfi, Tétreault, & Surprenant-Legault, 2014; Flamm & Rivasplata, 2014; Hochmair, 2015). In principle, catchment areas are related to the transport mode they serve, and often become larger as the quality of the mode increases (Alshalalfah & Shalaby, 2007; Brand, Van Oort, Hoogendoorn, & Schalkwijk, 2017; Flamm & Rivasplata, 2014; Krygsman et al., 2004; Nijënstein, Van den Berg, & De Kruijff, 2016; O'Sullivan & Morrall, 1996; Van der Blij, Veger, & Slebos, 2010). Many transport guidelines assume a fixed catchment area for each transit mode, even though differences exist between transport stops of the same mode (El-Geneidy et al., 2014). Therefore, a more informative way than a fixed buffer to describe the influence area of a transit stop is the distance-decay function (Gutiérrez, Cardozo, & García-Palomares, 2011; F. Zhao, Chow, Li, Ubaka, & Gan, 2003) Distance-decay is defined as a way to measure the impedance to travel, or the willingness to travel to reach a certain destination, and shows the distribution of distances travelled to a stop (Iacono et al., 2008). The closer to a stop, the lower the impedance. The advantages of distance-decay include the ability to measure accessibility and to be used in gravity models (Iacono et al., 2008).

Either time or distance can be used to define impedance (Iacono et al., 2008). The distance measure can be useful for transport and land use planners, in order to assess the spatial accessibility of a specific location or public transport stop. The time measure can account for the speeds of different access modes of walking and cycling, and therefore better reflects the impact for the traveler (Krygsman et al., 2004). Bachand-Marleau, Larsen, and El-Geneidy (2011) carried out a survey on the willingness to use the bicycle-transit combination and reported the decay for access and egress in time, not distance. This allowed them to compare the walking and cycling times. Iacono et al. (2008) reported the decay functions in both travel time and distance. Furthermore, Shelat, Huisman, and Van Oort (2018) mention the measure of time as an important one next to distance. However, it can be difficult to transform distances into time, because of different spatial structures and travel speeds. Depending on the street pattern, the actual distances are usually about 1.2 longer than Euclidean distances (Kennisinstituut voor Mobiliteitsbeleid, 2015). Therefore, Gutiérrez et al. (2011) propose to use a network distance method instead of Euclidean distances, see Figure 1.3, which is also applied in this

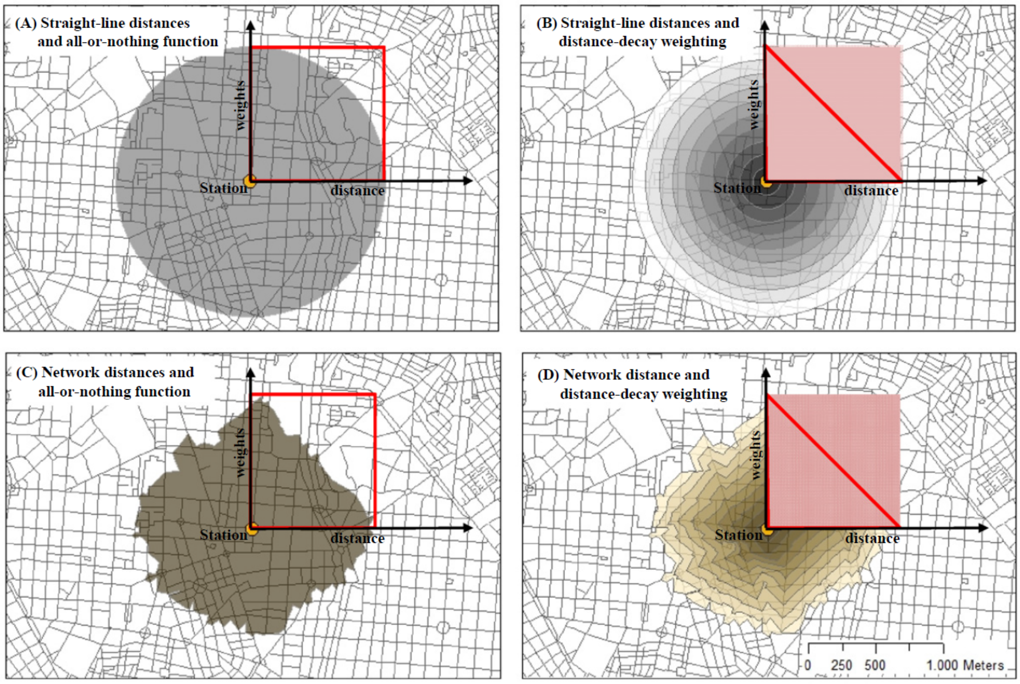

Figure 1.3: Methods for calculating variables around stations combining 'straight line versus network distances' and 'all-or-nothing versus distance decay weighting'

research.

1.2. Knowledge gap

Not much is known about the size of transit catchment areas and what influences them. Moreover, compared with walking, bicycle catchment areas have received even less attention (Hochmair, 2015). For the Netherlands Kennisinstituut voor Mobiliteitsbeleid (2015) reported that a clear overview for comfortable walking distances to public transport is lacking, but that some distances are available. For the bicycle, no such data was available at all. Many transport guidelines assume a fixed catchment area for each transit mode, even though differences exist between transport stops of the same mode (El-Geneidy et al., 2014). The influences on catchment areas are even more important to know in an urban environment, where choice possibilities are numerous, thus increasing the chance of a better travel option (Kager & Harms, 2017).

It has become apparent that many practical studies have been carried out on combining bicycle and transit. However, little effort has yet been attempted to take a holistic approach to understand the bicycle-transit combination as a whole. The work of Kager et al. (2016) on the bicycle-transit combination is highly explorative, and provides many recommendations for further research. Most studies on the bicycle as feeder mode concern the train as main mode, although some studies research the combination of bicycle and bus or metro. Researches on catchment areas are often about metro/light rail or the bus. But it is also interesting to combine the tram with the bicycle. Shelat et al. (2018) note the potential for the bicycle combined with tram, next to bus or metro. Although competition between bicycle and tram exists on single trip level, especially in urban areas, their combined use has also been observed. For example, in large cities in the Netherlands a trend has been noticed where, compared with the mid-nineties, the bicycle use towards tram and metro stops has more than doubled (Van Nes, Hansen, & Winnips, 2014). This indicates that the tram has some 'train-like' characteristics that make it suitable for the bicycle-transit combination. However, no studies of the bicycle and tram combined are known to have been carried out. The same holds for studies that investigate catchment areas of tram stops. Therefore, this research concerns walking and bicycle catchment areas of tram stops.

The underlying idea is that many of the same choice mechanisms result in longer feeder distances and cycling as feeder mode. For example, travellers are expected to travel to further stops by bicycle to obtain better transit quality or services (Kager & Harms, 2017). Similarly, Van Goeverden and Egeter (1993) suggest that the choice for avoiding a transfer and for choosing the bicycle as feeder mode are associated, because the bicycle could replace a transit journey-leg. But since it is not known what factors lead to travellers choosing certain tram stops or feeder modes, this knowledge gap is addressed in this research.

1.3. Scientific and societal relevance

The bicycle-transit combination has potential for future urban mobility, but needs a better understanding in order to obtain practical implications. In this research a first step is taken towards reaching an integrated bicycle-transit network by providing knowledge on the influences on transit catchment areas and on the physical and network integration of bicycle and tram. This knowledge is delivered in the form of walking and cycling distance-decay functions of tram stops in The Hague, and the factors that influence feeder distance and feeder mode choice. The qualitative analyses forms a valuable addition to the quantitative analyses: for scientific purposes it reveals influences that are not detected when using aggregate and objective data.
In the short term, public transport operators like HTM can use the results of this research to decide what locations in their network are suitable for bicycle-transit integration, and to provide bicycle facilities there. Furthermore, in the long term they can make a step towards network integration by using the knowledge of walking and cycling catchment area sizes to redesign their network incorporating the bicycle.

1.4. Research objective

The goal of this research is twofold: to understand the factors that influence walking and cycling catchment areas of tram stops, and to understand the factors that influence the choice for cycling as feeder mode of tram stops.
The main research question is:

> “What factors affect walking and cycling feeder distance and feeder mode choice for tram stops in urban areas?”

The sub questions are as follows.

1. What are, according to literature, the factors affecting walking and cycling feeder distance and feeder mode choice?
2. What are the walking and cycling feeder distances and feeder mode choices for tram stops, and to what extent do the factors affect them?
3. Why do people choose for a tram stop further than the nearest?
4. Why do people choose the bicycle as feeder mode for tram stops?

In Figure 1.4 the two-fold approach of the research is presented, along with the corresponding research sub questions. The first research sub question is used to construct a theoretical framework, which forms the basis of the research, because it determines the factors that are expected to affect feeder distance and/or feeder mode choice. The second sub question explores the effects of the factors found in sub question one on feeder distance and feeder mode choice. Then, the third and fourth sub questions will discover what the underlying motives are for tram stop choice and feeder mode choice.

1.5. Methodology

The methodology of this research comprises of multiple parts. First, a literature review is used to answer the first sub question; it provides information on factors that may influence distance to transit stops and feeder mode choice. These are combined into a theoretical framework, which is used as a basis for this research. The theoretical framework consists of four clusters of factors: user characteristics, transport factors, built environment factors and context factors. The data needed for this research are gathered through a self-administered revealed preference survey, with tram traveller in the The Hague area as a case study. Smart card data approaches do not satisfy, because they only provide aggregate data, whereas also user and trip characteristics need to be obtained. Precise origin and destination locations are used, as well as street network distances, which allow for more reliable and detailed analyses.
Then, the factors included in the theoretical framework are explored quantitatively for their effect on feeder distance and feeder mode choice. This is first done through bivariate analyses, which investigate the effect of the factors separately, through statistical tests. These statistical tests are supported by visualisations, often

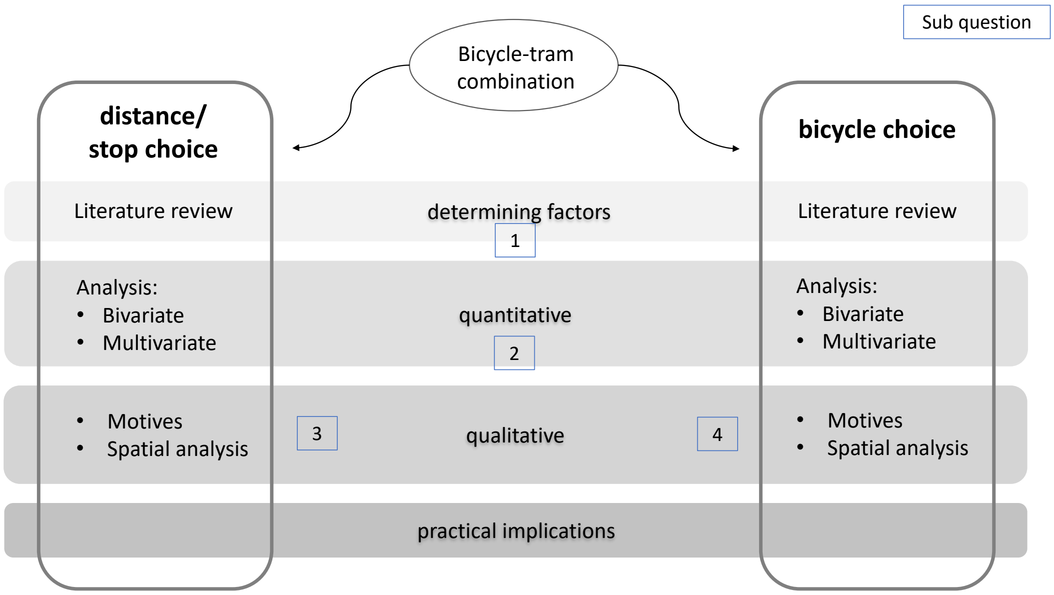

Figure 1.4: Research approach and corresponding research sub questions

in the form of distance-decay functions or bar graphs. The factors that are found significant, are included in multivariate analyses. These investigate the effects of the factors simultaneously, in order to capture the interrelations between the factors. This is done in the form of two separate logistic regression models: a feeder distance model and a feeder mode model.
Lastly, a qualitative analysis is carried out, using the motives that respondents provide in the survey, as well as a spatial analysis. This way, the choice mechanisms behind choosing a stop further away and choosing the bicycle as a feeder mode can be examined.

1.6. Scope

This research will take the tram network of HTM (a bus and tram company based in The Hague) as a case study, in which only tram stops will be considered. This means that neighbouring municipalities of The Hague that are part of the HTM tram network, are included. The case study area is further illustrated in section 3.2. The competition of other modes for the entire trip is not part of this research, because only the influences on catchment areas for people that already chose the tram as main mode are of interest.
Walking is the most regular feeder mode for the tram: in 2017 in The Hague the Randstadrail (high quality trams) had a walking feeder mode share of 74%. Cycling was 10%, and other was 16%. For regular trams 81% accounted for walking, 5% for cycling and 14% for other as feeder mode (CROW-KpVV, 2018). But since it was suggested that the choice for a further stop and the choice for the bicycle as feeder mode are related, it is especially of interest what makes travellers choose for the bicycle compared with walking. Therefore, other feeder modes than walking or cycling are not included in this research.

The focus of this research is from the public transport operator perspective. The information gathered is suitable for practical implications for the operator and largely related to transport factors. Furthermore, the focus is on tram trips, not tram users, because it has been argued that in a mature cycling country transport characteristics have a larger influence on catchment areas than user characteristics (Harms, Bertolini, & Te Brömmelstroet, 2014). Moreover, the street network is used to incorporate the network distances instead of Euclidean distances. Safety and bicycle infrastructure are not considered, since the Netherlands already has good and safe cycling paths.

1.7. Chapter outline

The structure of this report is as follows, also see Figure 1.5. Chapter 2 provides an extensive literature review of factors influencing feeder distance and feeder mode choice. These are used for the theoretical framework at the end of Chapter 2. In Chapter 3 the survey design and execution are reported, along with an introduction of the case study area in which the survey is conducted. Chapter 4 reports the results of this research. First, an exploration of the factors in the Theoretical Framework is done through bivariate analyses. Those found to be significantly of influence on feeder distance or feeder mode choice, are used as input for the logistic regression models. The last part of the results is a qualitative analysis: to obtain an indication of the motives behind tram stop and feeder mode choice, several arguments are analysed, as provided by the survey respondents. Also a spatial analysis of the origins/destinations and their corresponding stops is used. Lastly, Chapter 5 contains discussions, conclusions and recommendations for practice and further research.

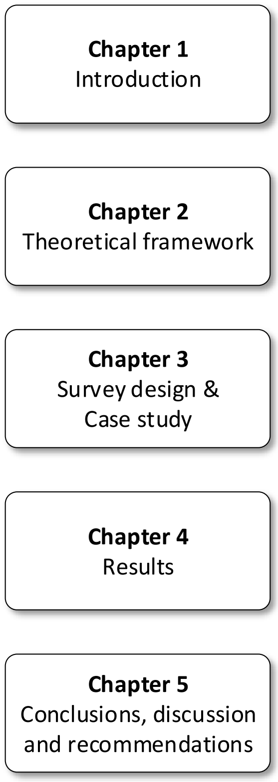

Figure 1.5: Chapter outline

2

Theoretical framework

In order to construct a theoretical framework, different factors that may influence the size of the catchment areas for tram stops and the feeder mode choice need to be identified. In this chapter, several factors that are found in the literature are discussed and the relevant ones are presented in the theoretical framework. Four clusters of influencing factors are identified: user characteristics, transport factors, built environment factors and context factors. The corresponding factors that are found in the literature, are depicted in Figure 2.1. The factors that are incorporated in the final theoretical framework, are depicted in grey. Apart from scientific literature, also a analysis of bicycle parking at tram stops in The Hague is used to examine the factors. The data used for this was gathered by Metropoolregio Rotterdam Den Haag (MRDH). The analysis of data carried out in this research contains of comparing the amount of bicycles parked at a stop with the amount of tram travellers that had boarded that stops.

For each factor, the influences on feeder distance and feeder mode choice are considered separately. At the end of each cluster a decision is made if and how to include the factors in the theoretical framework, which is then presented at the end of this chapter.

2.1. User characteristics

The kind of user characteristics mentioned in the literature differs, but many authors refer to socio-demographic factors (Alshalalfah & Shalaby, 2007; Chia, Lee, & Kamruzzaman, 2016; Daniels & Mulley, 2013; Leferink, 2017; Park, Kang, & Choi, 2014; P. Zhao & Li, 2017). These are sometimes divided in personal and household factors Chia et al. (2016); Park et al. (2014), but in this research that distinction is not regarded because the perspective is from the transport operator. Therefore, the transport related user characteristics are also considered as a distinct group. This group is expected to be more important than socio-demographics factors for feeder mode choice, because the setting of the survey is in The Netherlands, a mature cycling country.

2.1.1. Socio-demographic factors

Gender

Studies on the influence of gender on feeder distances are scarce. However, Molin and Timmermans (2010) and El-Geneidy et al. (2014) found that men are willing to bridge longer access or egress distances.

As opposed to feeder distance, several studies have found that gender has a large influence on cycling rates; men cycle more often than women (Park et al., 2014; P. Zhao & Li, 2017). Moreover, men are more likely to walk or ride a bike at night (Molin & Timmermans, 2010). In the Netherlands, a mature cycling country, although both genders use the bicycle as main mode just as often, a small difference exists: women cycle more often than men for certain trip purposes (work and shopping trips) (Harms et al., 2014). Also P. Zhao and Li (2017) noted that women sometimes cycle more for work as trip purpose.

With regard to bike share usage mixed findings have come forward. (Buck et al., 2013; Pucher, Garrard, & Greaves, 2011, as cited in Ma, Yang, Ji, Jin, and Tan 2018) found that females use bike share systems more often than males, while Fishman 2016, as cited in Ma et al., 2018 produced results where males had higher bike share use. (Goodman & Cheshire, 2014, as cited in Ma et al. 2018) state that this is partly related to the level of cycling in a certain country: if that is low, less female bike share riders will be present.

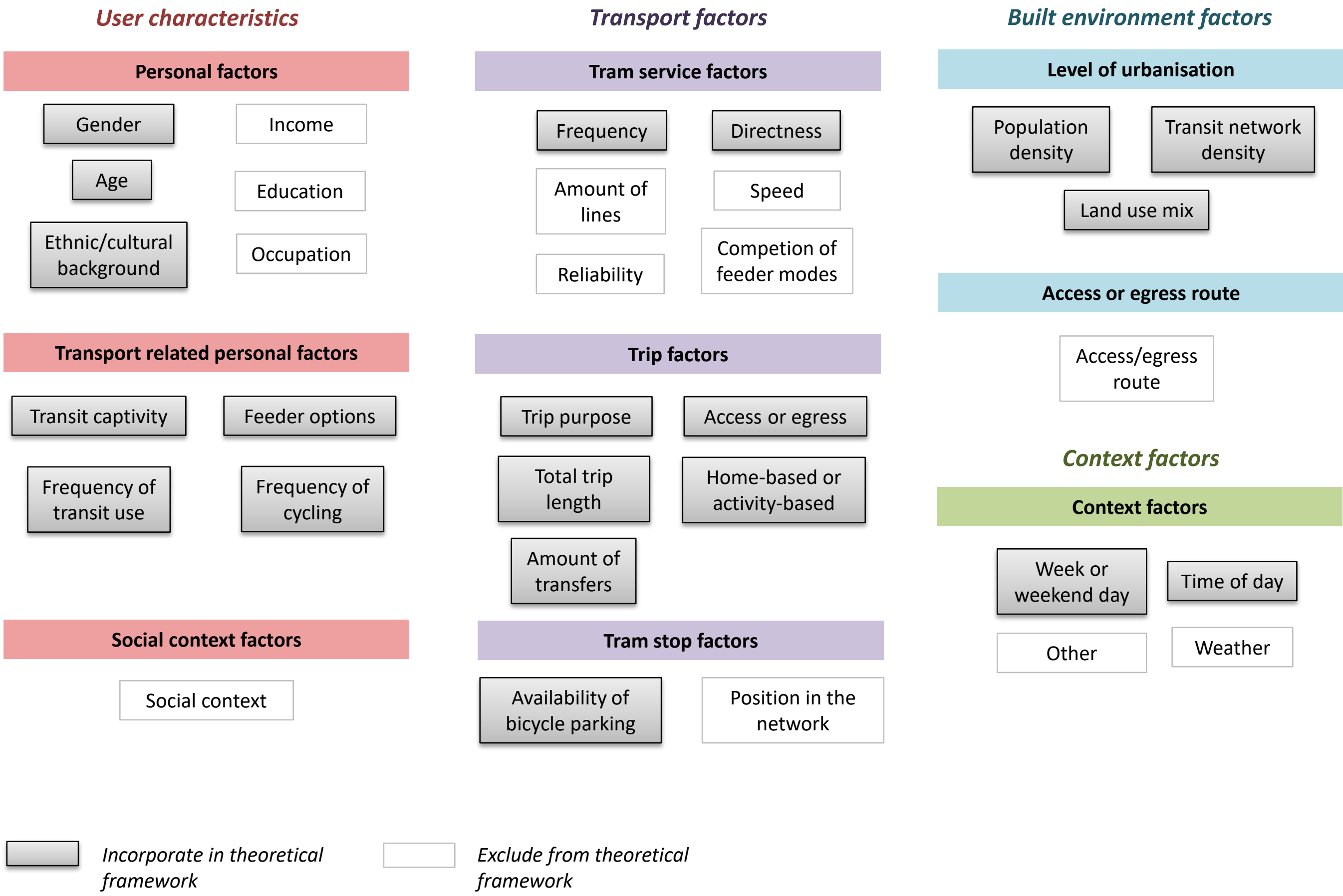

Figure 2.1: Summary of clusters and factors

Age
Chia et al. (2016) stated that the literature on age influencing walking distances to transit yields various results. Elderly people bridge the shortest distances and young adults the longest (El-Geneidy et al., 2014; Stinson & Bhat, 2004). However, Park et al. (2014) did not find any effects of age on feeder distances to stations.
Leferink (2017) states that age effects on the bicycle-transit combination differ per country, but that in general younger people use the bicycle as a feeder mode for train more often than older people. In the Netherlands, small age differences for cycling as the main mode levels: young people (under 18 years) cycle more and further than others (Harms et al., 2014) and older people cycle more when their knowledge of the route is good (Molin & Timmermans, 2010). Therefore, it is expected that younger people also cycle as a feeder mode more often. Ma et al. (2018) found that young people use bike sharing systems more than older people. This has partly to do with bike sharing being a fairly new phenomenon, whose early adopters are more often young people. So age seems to have more impact on feeder mode choice than feeder distance; younger people cycle more than elder people, as main mode and feeder mode.

Ethnic/cultural background
For feeder distance no researches of interest concerning ethnic or cultural background were found. By contrast, many papers regarded the relation between cycling and ethnic or cultural background.
In the USA a research of Singleton and Clifton (2014) found that both cycling and public transport levels for Caucasian people were higher than for non-Caucasians. Likewise, Park et al. (2014) found that white transit travellers were more likely to cycle to the stop, while Asians walked more often. P. Zhao and Li (2017) also states that ethnic minority groups cycle less. It has to be noted, however, that Park et al. (2014) found no significant difference for access mode choice between US-born and foreign-born travellers, but did find a difference between travellers of different races.

In the Netherlands, similar patterns are recognised. Non-western immigrants have lower cycling rates than non-immigrants, which holds for all trip purposes and age groups (Harms et al., 2014). This is underlined by (Kennisinstituut voor Mobiliteitsbeleid, 2017) who found the same difference in the Netherlands. In an earlier, more in-depth study of Olde Kalter (2008) on the differences in travel behaviour between Dutch people with different ethnic backgrounds, several explanations were given for the lower cycling rates of non-western immigrants. It appeared that the status of the bicycle, especially among Turkish and Moroccans, is quite low, which also leads to a high car usage among men in this group. Furthermore, many non-western, mainly older, women do not have the necessary cycling skills. Lastly, they often consider cycling dangerous, and therefore also do not encourage their children to cycle. Another aspect that was considered in the Olde Kalter (2008) study was the use of public transport among non-western immigrants. It is especially often used by Moroccan, Surinamese and Antillian women, partly because the car and bicycle are not always an option for them.
Therefore it is expected that many Moroccan, Surinamese and Antillian women make use of the tram, and walk to the stop more often instead of cycle compared with people of Dutch origin.

Income
Household income plays a different role in different countries (Krygsman et al., 2004; Pucher & Buehler, 2008), but according to Chia et al. (2016) and El-Geneidy et al. (2014) higher income is associated with shorter walking distances to stops. However, people of high income classes often belong to certain neighbourhoods with distinct characteristics, such as a low population density. These might influence the feeder distance more than income, as is made clear by El-Geneidy et al. (2014): households with high income walk less often, but longer distances to transit stops.
In the model of Park et al. (2014) income was not significant for access mode choice. However, Leferink (2017) stated that travellers with higher income have more chance of combining bicycle with rail. Fishman (2016) also mentioned that bike share users often have a higher income than non-bike share users. In any case, income is not convincingly associated with either feeder distance or mode, especially in the Netherlands with such a distinct bicycle culture.

Education
The influence of education level on catchment areas and mode choice has not been described extensively in the literature, indicating that education is not of high importance. Those that are available, mostly concern mode choice.
Molin and Timmermans (2010) describe that there are no large differences in egress choices between educational groups for cycling. However, Fishman (2016) and Shelat et al. (2018) mention that bike share users have a higher probability of having a higher education level. Shelat et al. (2018) attributes this aspect to the fact that the bicycle-transit combination is used more often for longer distances; people with a higher education level usually travel farther for work. This indicates that trip purpose and total trip distance are more determinant than education level.

Occupation
Chia et al. (2016) found that part time workers and full time earners with high income walk shortest distances to transit; mid-aged working parents, full time post-secondary students, teenagers and young working adults walk average distances; and young adults who study or work walk the longest distances. However, this research did not link the findings to for example trip purpose or neighbourhood and transit characteristics, while it is likely that they are related. Leferink (2017) states that several researches found higher shares for the bike-rail combination for students. However, occupation is largely related to trip purpose, and trip purpose was found more convincingly of influence in the literature, as is shown in subsection 2.2.1.

2.1.2. Transport related user characteristics

Transit captivity
In most papers transit captive riders are defined as travellers who rely on public transport, because they do not have a car available or can't drive one, as opposed to choice riders (Alshalalfah & Shalaby, 2007). Chia et al. (2016) calls them true captive riders, but extends this definition with non-true captive riders: transit riders who might be considered captive riders in different degrees. An example could be that they do have the car as an option, but prefer to save money by riding transit.

However, in the Netherlands with its concentrated development, high densities and cycle-friendly infrastructure, walking or cycling may be alternatives for transit other than the car. This is especially true for an urban setting. Moreover, some people have a scooter or moped as an option. So in this research, captive riders are defined as people who don't have another transport option other than public transport for their tram journey. Other than simply 'availability', also ease of access to a bicycle or car is relevant. For example, Bachand-Marleau et al. (2011) found that bike share users with a yearly membership used the combination of transit and bicycle sharing more often.

Chia et al. (2016) states that most literature findings suggest that for true transit captives the distance to transit is less important, because they have no other options, and their feeder distances will therefore be longer. The presence of vehicles in a household generally reduces the chance of walking as an access mode to transit stops (El-Geneidy et al., 2014). However, a contrasting occurrence is that when they do walk, their walking distances are longer, just like transit captives. This is assigned to the assumption that households with vehicle possession are usually located further from transit stops because of residential self-selection (Alshalalfah & Shalaby, 2007). Similar results were reported by El-Geneidy et al. (2014): households with more vehicles, more household members and high income walk less often, but longer distances to transit stops. These dissimilar effects might have as a consequence that transit captivity incorrectly appears to be non-significant.
On the other hand, for feeder mode choice, Krygsman et al. (2004) found car availability not to be statistically significant in a study in the Netherlands. Furthermore, they state that other literature found socio-economics and land use variables not to be of much influence on feeder mode choice (Krygsman et al., 2004). Flamm and Rivasplata (2014) looked into the alternatives of bicycle-transit users in the US, where they found that most of the users of the bicycle-transit combination could have made the trip in another way if the bicycle would not have been an option, meaning that those users were choice riders. This reinforces the previous statements about transit captivity hardly influencing feeder mode choice. However, this is dependent on the definition of a transit captive. In the setting of this research, it is expected that a substantial share of the choice riders consider the bicycle as alternative option for the total trip, which leads to believing that transit captivity and feeder mode choice are related.

Feeder options
Something that is inherently connected with the choice of the feeder mode, is the availability of the modes, thus the feeder options. As was mentioned in subsection 2.1.2 it is expected that the transit captivity is also related with the feeder options, depending on how transit captivity is defined.

Frequency of transit use
Frequent transit travellers are usually more willing to increase their feeder distance when this reduces their total travel time (Hochmair, 2015). This indicates that would they also be more willing to choose a further transit stops than their nearest.
High frequency of transit travelling is also associated with using the bicycle as a feeder mode more often (Leferink, 2017; Shelat et al., 2018), whether this is to choose a further transit stop or not. However, Shelat et al. (2018) notes that this is also related to trip purpose; transit trips for work, business and education are used more in combination with the bicycle than other trip purposes. Molin and Timmermans (2010) make the connection between frequency of transit travelling and route knowledge, and argue that travellers more often prefer to travel by transit when they are familiar with the route. The same holds for the active modes, walking and cycling. Therefore, the combination of bicycle and transit is more likely to occur when travellers are making a familiar trip.
So, literature findings suggest that frequency of transit travelling is positively related to both feeder distance and feeder mode choice. However, for feeder distance the evidence for the relation with frequency of transit use in not convincing.

Frequency of cycling
Although using the bicycle as feeder mode increases the catchment areas of transit stops, there is no reason to assume that frequent cyclists in general increase their feeder distance. The influence of frequency of cycling does, however, increase the probability of using the bicycle as feeder mode, which is related to longer feeder distances. This might be related to the lower perceived barriers for the cycling-transit combination that goes with a high frequency of cycling (Leferink, 2017). According to her, other literature findings suggest that riding a bicycle at least three times a week would be sufficient to remove the barrier to use the bicycle in combination with public transport.

2.1.3. Social context factors

Social context

No evidence could be found that relate social context with feeder distance. For cycling in general, the social context of travellers can influence their mobility pattern. For example, if the surrounding neighbourhood, family or workplace promote cycling, an individual has a higher probability of using the bicycle (Ton, Duives, Cats, Hoogendoorn-Lanser, & Hoogendoorn, 2018; P. Zhao & Li, 2017). Moreover, the attitude of a traveller itself towards cycling may influence the choice for the bicycle as a feeder mode; cyclists are more positive about cycling than travellers who don't cycle (P. Zhao & Li, 2017). Nonetheless, Ton et al. (2018) note that social surroundings influence walking more strongly than cycling. But since the perspective of this research is from the transit operator, the social context is not explored further.

2.2. Transport factors

Transport factors were, together with personal factors, mentioned most often by authors to be of influence on both feeder distance and feeder mode choice. This mostly concerns public transport supply (Daniels & Mulley, 2013; Leferink, 2017; Van Mil, Leferink, Annema, & Van Oort, 2018; P. Zhao & Li, 2017). Besides this, Leferink (2017) also acknowledges the difference between main mode and feeder aspects. Van Mil et al. (2018) adds a third aspect to this, namely transfer characteristics. Apart from public transport supply, also trip related factors appeared in the literature. Many authors only mentioned trip purpose as a trip related factor Daniels and Mulley (2013); Park et al. (2014); Van Mil et al. (2018), where some authors included more factors Chia et al. (2016); Leferink (2017). In principle, catchment areas are related to the transport mode they serve, and often become larger as the quality of the mode increases. Flamm and Rivasplata (2014) found that bicycle train users rode longer distances to heavy rail and ferries than bus or light rail; O'Sullivan and Morrall (1996) found that walking distances were larger for light rail stations than for bus stops; the research of Alshalalfah and Shalaby (2007) showed that metro stations have a range of 1.5-2.25 times larger catchments areas than bus stops; High Quality bus lines attracted travellers from a larger range than regular bus (Brand et al., 2017; Van der Blij et al., 2010); and light rail stops corresponded with larger catchment areas than tram stops, which were in turn larger than bus stops (Nijënstein et al., 2016). Lastly, it was found that catchment areas around train stations exceeded those of bus, tram and metro by around a factor of 1.5 (Krygsman et al., 2004). These findings are in line with Kager et al. (2016), who consider the bicycle-transit combination especially suitable for 'train-like' services.

2.2.1. Trip factors

Trip purpose

Trip purpose is named to be influencing both feeder distance and feeder mode choice by many authors. For example, Daniels and Mulley (2013) mention it as one of the main influences on distance to transit stops. In the work of Chia et al. (2016) the access distances for work trips were shorter than for school trips. El-Geneidy et al. (2014) found work trips to have longer access distances than other trip purposes, although they were shorter in the AM peak, something which also Nijënstein et al. (2016) found.

As for feeder mode choice, Wedderburn (2013) found that the bicycle is most commonly used for work and school trip purposes, because then speed and reliability are more important thus the value of time is higher. This also means that costs are less important for these trip purposes, as was observed by Molin and Timmermans (2010), and underpinned by Leferink (2017) who states that the bicycle-transit combination is most commonly used for utilitarian purposes and the least for recreational trip purposes. Also Ma et al. (2018) mention that the bicycle is used more often for work trips.

Home-based and activity-based access and egress

Access and egress are sometimes described in literature as the first journey-leg (access) and the last journey-leg (egress) (Krygsman et al., 2004). However, they could also be described as being the home-end and activity-end of the trip (Van Goeverden & Egeter, 1993). Both definitions are important and have distinct characteristics, which are elaborated on in this section. Combining them produces four separate definitions to be regarded: home-based access, home-based egress, activity-based access and activity-based egress.

access has some distinct characteristics compared with **egress**. Shelat et al. (2018) found that transit travellers have larger access than egress distances. Similarly, Bachand-Marleau et al. (2011), in a research from Canada, indicate that bicycle-train travellers are willing to spend more time on access than on egress. However, they

did not disentangle home versus activity-based effects and the reported times are 'acceptable times', not actual travel times. The seeming preference for longer access times can be partly explained by considering the time schedule that is inherent to transit services; as opposed to access, where choosing a certain stop can reduce the travel time because of reduced waiting time or a better transit option, for egress only a better transit option might reduce the total travel time. However, reversed results were made visible by Krygsman et al. (2004), who also looked at access and egress differences for time instead of distance. They plotted the time decay functions of access and egress (both home-based) and found that train travellers spend more time for egress than for access. The authors assign this to the value of time at the access side being higher, indicating that egress speeds are lower than access speeds.
For feeder mode choice, no researches were available that assess access and egress. This is not surprising, since the egress mode choice is usually dependent on the access mode choice. This changes, however, when dockless bicycle sharing systems are introduced, so travellers can choose their egress stop separately from their access stop.

The **home-end** of a journey is distinct from the **activity-end** in several ways. The traveller often has better route knowledge at the home-end, and depending on their frequency of transit travelling, most transit options are known. Krygsman et al. (2004) showed this in their study, where the amount of transfers did have an effect on the home-side, but not on the activity-side. They acknowledge that this is probably related to travellers' familiarity with their options at the home-side, compared with the activity-side of the journey. Therefore, at the activity-end people have higher probability of choosing the closest stop. It should be noted that the more regular an activity becomes, the more it resembles the home-end for the traveller. Lastly, home-end trips are more likely to be in a residential area. Wedderburn (2013) underlined this by stating that travellers are much more influenced by built environment factors at the home-end of their trip than at the activity end (see also section 2.3).
As opposed to access and egress, feeder mode choice is largely related with home-based versus activity-based trip legs, because of the higher availability of private modes at the home-end. This is also visible in the difference between bicycle use at the home-end compared with the activity-end; Shelat et al. (2018) found that the bicycle-transit combination was mostly used for home-based trips. Also the availability of bicycles at the activity-end could be increased through bicycle sharing systems, although here they do not have to be dockless.

So, the effect of access versus egress on feeder distance is not apparent, also because feeder time has been subject of more studies. However, when time and distance are fully correlated, distances at the home-end are expected to be longer than at the activity-end. Choosing the bicycle as feeder mode is not related to access or egress, but largely with home-based versus activity-based trip legs. Furthermore, it is likely that the specific combination of these concepts also have an influence on feeder distance and feeder mode choice, because they reinforce each other.

Feeder mode
The mode used for access or egress partly influences the distance the traveller is willing to bridge. Obviously, the faster the mode, the longer distances people tend to travel to or from a stop. It is also related the other way around: the longer distances travellers have to bridge, the higher the probability of choosing the bicycle. However, when looking at the time spent for different modes, it appears that travellers are willing to accept longer feeder times when the feeder mode is faster. This is something that was suggested by Krygsman et al. (2004) who found that train travellers spend slightly more time on access to stations by bicycle compared with walking. Similar results were described by Bachand-Marleau et al. (2011).
But more differences between walking and cycling have become evident. Ton et al. (2018), although their research concerns mode choice at the total trip level, argue that the active modes (walking and cycling) need to be separately defined, because they are essentially different. For example, individual characteristics affect cycling more strongly than walking, while the opposite is true for social context. Trip purpose has a larger effect on cycling compared with walking, although the effects of other trip characteristics are similar.

Amount of transfers
In general, people do not like transfers (Van Mil et al., 2018). For trips with more transfers, the access distance in usually smaller (Chia et al., 2016; El-Geneidy et al., 2014). This implies that travellers walk or cycle farther to stops if they can avoid a transfer, something that was noticed as well by Van Mil et al. (2018): he discovered that obtaining a direct trip was the second most important factor in choosing a train station to cycle to.

The amount of transfers is also related with feeder mode choice. Leferink (2017) stated that more direct a trip is, the more bike-rail users it attracts. In their study on the feasibility of the bicycle as feeder mode for transit, Van Goeverden and Egeter (1993) argued that to avoid a transfer, the bicycle could be used for the first part of the journey. Here holds that the faster and more frequent the vehicle, the less feasible this option would be in terms of travel time. This suggests that the choice for avoiding a transfer and for choosing the bicycle as feeder mode are associated.

Total trip length

In the literature the authors make common statements about the relation between the access or egress distance and the total trip length: as the transit trip becomes longer, the catchment area of a stop increases (El-Geneidy et al., 2014; Krygsman et al., 2004; Leferink, 2017; Shelat et al., 2018; Van der Blij et al., 2010; Van Mil et al., 2018). Shelat et al. (2018) mention that this increase rate is even larger for bus, tram and metro trips compared with train. Therefore, total trip length is considered an important influence on feeder distance in this research.

The bicycle is also used more often for longer main trips, as the bicycle and longer access or egress distances seem to be related. This has to do with the fact that travellers tend to accept longer access and egress distances as the total trip becomes longer, which increases the chance of choosing the bicycle (Molin & Timmermans, 2010). This is visible when the train, which is often used for longer distances, is compared with metro, tram or bus: the bicycle is used much more in combination with the train. This might, however, also be related to the fact that for short distances the bicycle and transit compete with each other on single trip level (Kager et al., 2016; Martin & Shaheen, 2014).

2.2.2. Service factors

Frequency at the stop

The frequency offered by the lines at a certain stop is also mentioned often by authors. It is largely related to waiting time; the lower the frequency, the longer the waiting time when one doesn't take into account the schedule. Moreover, there is a difference between the added frequencies of all lines at a certain stop, and the frequencies of the lines that actually take the traveller to his destination. It has to be mentioned, however, that the frequency offered at a stop is often closely related to the population density and the density of the public transport network, which will be discussed in section 2.3.

Van Mil et al. (2018) found that frequency is an important factor for cyclists in choosing a station. El-Geneidy et al. (2014) and O'Sullivan and Morrall (1996) found that a stop offering higher frequency attracts longer access distances. However, this could be a conservative portrayal of the attraction of high frequencies, because high frequency stops or lines are expected to be located near high density places, reducing average walking distances (El-Geneidy et al., 2014). However, Nijënstein et al. (2016) found no direct influence of frequency offered on the distance travelled to transit stops. It might be that people bridge longer distances to stops at the outskirts of the city, where frequencies are often lower, thus cancelling out the phenomenon that transit travellers walk or cycle further to stops with higher frequencies.

On the other hand, less cycle access trips might be expected when taking into consideration that waiting time is less of an issue for higher frequencies: the bicycle parking analysis (Figure 2.2) shows that stops which offer a frequency of 4 trams per hour differ significantly from stops which offer more trams per hour. It appears that more people cycle to stops offering lower frequencies, and that 6 frequencies per hour is the threshold. Therefore, gaining time by cycling might be less appealing for higher frequencies.

So, it is not entirely clear yet what the role of frequency could be on catchment areas and feeder mode choice, and this will be tested in section 4.1.

Amount of lines

The amount of lines offered at a stop is partly related to the frequency offered, as was mentioned in the previous paragraph. Van der Blij et al. (2010) found in their research that with high quality bus services the amount of lines positively influenced the size of the catchment area. However, the amount of lines was found to be less significant than frequency. For example, Nijënstein et al. (2016) found that the presence of multiple lines at a stop only had effect on catchment areas for bus, not for tram. And while F. Zhao et al. (2003) noticed that more lines offered at a stop increased the willingness to walk farther distances.

From the bicycle parking analysis in The Hague (Figure 2.3) it becomes apparent that in The Hague hardly any difference exists in cycling between stops that offer one or two lines. All in all, the amount of lines less seems

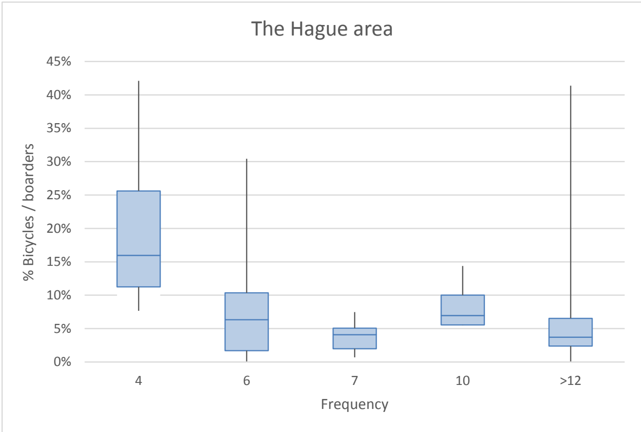

Figure 2.2: Bicycle parking analysis: ratio of bicycles/boarders by frequency (MRDH, 2017), own analysis

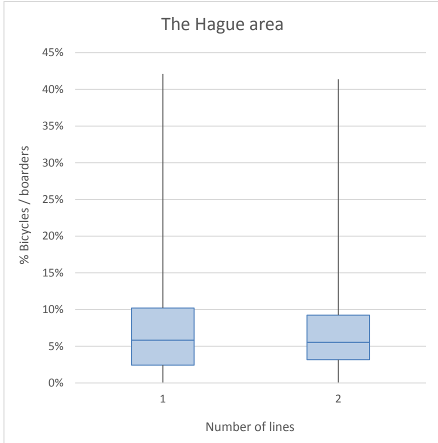

Figure 2.3: Bicycle parking analysis: ratio of bicycles/boarders by amount of lines (MRDH, 2017), own analysis

to be less important than frequency for both feeder distance and mode choice, so it will not be included in the theoretical framework.

Competition of feeder modes

The competition of feeder modes concerns the availability of alternatives for the chosen feeder mode of the traveller. The connection between feeder distance and competition of feeder modes is mostly related to transit stop density, and in particular for bus stops, since they can be considered a feeder mode for tram. However, no researches were available describing the effect that connection.

For feeder mode choice, more information is accessible. For example, Rietveld and Daniel (2004) and P. Zhao and Li (2017) state that more available bus lines decrease the chance of cycling to metro stations. Leferink (2017) mentions that the quality of the bus/tram/metro network influences the choice for cycling to train stations. However, for the bicycle-tram combination this is less of an issue: the tram is usually close by, so transit alternatives as feeder mode are often not available.
Competition does exist between cycling and walking, but this doesn't apply for every tram traveller. Partly because of their cycling capabilities and bicycle availability, but also because some people simply do not consider the bicycle as an option for such small feeder distances. Therefore in this research, walking and cycling are the main feeder modes considered.

Reliability

Reliability is a factor that has not been apparent in many studies on catchment areas to transit stops. It is about variances in travel time and is partly related to frequency, because the shorter the time between two vehicles, the less important reliability becomes (Van Mil et al., 2018). Annema (2013) says that the uncertainty of unreliable services make it an important topic, but also that the impact of it can be partly reduced by providing travel information. Moreover, in this light frequent transit travellers are less affected by unreliability, because they are better aware of their options and also have more experience dealing with changes in the schedule.

El-Geneidy et al. (2014) only mentions reliability as recommendation for further research into feeder distances, in the sense that it could be considered part of the service attractiveness of a stop. For feeder mode choice, Van Mil et al. (2018) rated reliability as a rather important factor in choosing station by bicycle.
However, for tram stops the frequency is usually quite high (compared with for example train). Furthermore, because of the link with frequency, it is less interesting to take it into account.

Directness of transit

From the perspective of transit service factors, directness is defined in terms of transit quality: a combination of the vehicle speed and the degree in which the tram goes in a straight line instead of making detours. This is further explained in Chapter 3. Directness of transit should not be confused with the directness of an individual trip, which could be described as the amount of transfers (see subsection 2.2.1). As became clear in Chapter 1, modes with different qualities are associated with different catchment sizes (Alshalalfah & Shalaby, 2007; Brand et al., 2017; Flamm & Rivasplata, 2014; Krygsman et al., 2004; Nijënstein et al., 2016; O'Sullivan & Morrall, 1996; Van der Blij et al., 2010). However, it is not known if this also holds true for directness differences within a mode.

Directness is also related with feeder mode choice. Leferink (2017) stated that more directness in a trip attracts more bike-rail users. However, the relation between directness of transit and feeder mode choice has not been explored often, and is therefore incorporated in the theoretical framewor.

Vehicle speed

The speed of the transit vehicle is something not many authors take into account, although differences in feeder distances have been apparent between different main modes and mostly related to train, as was stated in Chapter 1. For example, Martens (2004) says that people cycle longer distances for faster services. Likewise, Leferink (2017) mentions that a higher vehicle speed can attract more bike-rail users. The effect of different vehicle speeds within one main mode is not convincingly related with either feeder distance or mode choice. Furthermore, the 'directness' factor (see Figure 2.2.2) also incorporates the speed of the vehicle. Therefore, the speed of the tram is not included in the theoretical framework.

2.2.3. Stop factors

The stop itself is part of the attractiveness of the transit service: Kennisinstituut voor Mobiliteitsbeleid (2015) mentions that the overall quality of the transit stop influences the size of its catchment area. For this research only the availability of bicycle parking and the position of the stop in the network are relevant.

Availability of bicycle parking

Naturally, the impact of availability of bicycle parking, which is here defined as having bicycle parking racks at the stop or not, only relates to feeder mode choice, not feeder distance. Van Mil et al. (2018) partly looked into bicycle parking influencing station choice, and found that cyclists regard the time to park as a rather important factor in choosing a station. However, for the tram this is likely to be of less importance, because the distances from bicycle racks to the stop are much shorter than for train.

What probably plays a larger role for parking at tram stops, is the availability of bicycle parking. As opposed to train stations in the Netherlands, tram stops do not always provide bicycle parking. Furthermore, bicycle racks at tram stops often offer less protection than those at train stations, which might be a concern for travellers as well. This concerns shelter, but also theft protection.

Position in transit network

According to Nijënstein et al. (2016), if a stop is at the beginning or end of a line the distances to and from the stop are larger. Feeder mode choice is apparently also related with the position of a stop in the network, something which also became clear from the bicycle parking analysis. Here differences are examined between stops that are situated at the end of a line, stops where two lines join or part, and stops that are situated in between (see Figure 2.4. The latter two stop types show similar results of low bicycle use, while the end-of-line stops clearly have more bicycle use. However, the position of the stop in the transit network is related with the public transport density and other built environment factors (see section 2.3), and will therefore be further described there.

2.3. Built environment factors

Some authors mentioned built environment as influencing factors, although Krygsman et al. (2004) saw a minimal role of neighbourhood characteristics influencing catchment areas. Other authors looked at elements of feeder routes as part of the built environment (Chia et al., 2016; Daniels & Mulley, 2013; Leferink, 2017; Van Mil et al., 2018), thus it could also be argued that feeder mode choice is dependent on built environment factors. But others concern density and land use mix (Daniels & Mulley, 2013; Park et al., 2014), which are together with density of public transport part of the 'level of urbanisation'.

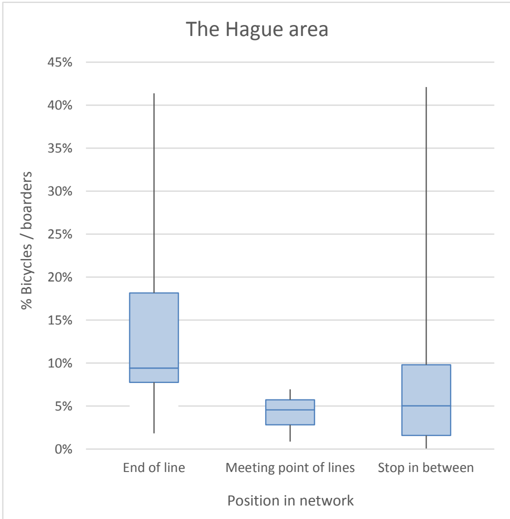

Figure 2.4: Bicycle parking analysis: ratio bicycles/boarders by position in network (MRDH, 2017), own analysis

2.3.1. Level of urbanisation

Population density

The different levels of urbanisation are most clearly represented by the difference between city centres and suburbs. The most common finding of authors is that catchment areas in residential areas or suburbs (with low population densities) are larger than those in city centres or Central Business Districts (with high population densities) (Alshalalfah & Shalaby, 2007; Chia et al., 2016; El-Geneidy et al., 2014). However, since these researches originated from different countries with different environments, it is difficult to say which reasons lay behind this finding.

For feeder mode choice the same distinction can be made. Less cycling to public transport was noted in city centres compared with suburbs (Leferink, 2017; Ma et al., 2018; Martin & Shaheen, 2014; Wedderburn, 2013). An explanation for this is provided by Martens (2004): walking as a feeder mode is dependent on dense areas, and often corresponds to high stop and line densities. Cycling, on the other hand, is able to bridge longer distances, and therefore close stops are not necessary for the bike-transit traveller.
A different pattern is visible for walking and cycling as main mode instead of feeder mode. In the Netherlands, people in the city cycle more as the main mode than those in rural areas, which can partly be explained by socio-economic variables Harms et al. (2014).

However, possible explanations for the different effects of the level of urbanisation exceed population density only. Also transit stop density and land use mix are related to the level of urbanisation.

Transit stop density

The effects of the built environment on catchment areas, such as density or land use mix, are hard to regard separately from public transport supply (Daniels & Mulley, 2013). This is because a close relationship exists between feeder distances and stop and line densities. The position of a stop in the network, as was observed in subsection 2.2.3, is also related with feeder distance: the end or beginning of a line, with little surrounding stops and lines, attract longer feeder distances. Furthermore, with a higher level of urbanisation often come higher stop or line densities and a higher amount of lines and frequency offered at the stops (El-Geneidy et al., 2014), which is reflected in the theoretical framework.
Daniels and Mulley (2013) relates to transit stop density as a factor that influences the feeder distance, while population density and land use mix determine the convenience of walking. The latter explanation is important for feeder mode choice, because it suggest that transit stop density merely affects feeder mode choice because it is related with feeder distance, whereas population density and land use mix are also involved with the quality aspect of the built environment. This is something that is connected with the feeder route, see subsection 2.3.2.

Land use mix

Although less often mentioned than population density or public transport density, the land use mix may also influence feeder mode choice. However, the effect of land use mix on feeder distance was not found in the literature, although a connection with transit stop density and population density exists.

Wedderburn (2013) stated that a lack of land use diversity discourages the active modes in general. El-Geneidy et al. (2014) also mentions that a combination of high densities and high land use mix induces more walking. Walking and cycling also show different characteristics for the degree of land use mix. A high land use mix is considered to be related with more walking trips, because the closeness of facilities makes walking possible. For cycling trips, closeness is less important (Wedderburn, 2013). Land use mix in the sense of providing an attractive environment, does encourage both walking and cycling (Jones, 2001, as cited in Wedderburn, 2013). However, these findings are mostly about the active modes in general, not about the choice to walk or cycle to transit stops.

2.3.2. Feeder route

Several elements of the feeder route might influence the choice for the feeder mode and the distance to or from the stop. Hilly terrain discourages cycling (P. Zhao & Li, 2017), just like darkness outside and feeling unsafe (Annema, 2013). El-Geneidy et al. (2014) also mention that a safer environment leads to more walking. Then, bicycle infrastructure is named as a factor (Leferink, 2017; Van Mil et al., 2018). But apart from that, the design of the streets is important as well (Kennisinstituut voor Mobiliteitsbeleid, 2015; Ton et al., 2018). However, since the feeder route extends outside the environment of the stop and transit service itself, it is outside the scope of this research.

2.4. Context factors

Context factors are variable factors that can change even though the trip is exactly the same. Ton et al. (2018) mention that the state in which the individual is currently in influences their choice for using the active modes, thus it can also influence the tram feeder mode choice. Similarly, Molin and Timmermans (2010) note that context factors, or external circumstances, might influence mode choice.

Weather

The literature for weather mostly concerns the decision to use a certain means of transport for the total trip or stay at home. It is not apparent whether people walk or cycle smaller distances to or from transit stops in bad weather, something which would be plausible. El-Geneidy et al. (2014) note that temperatures lower than 18 °C are discouraging for walking in the U.S., but that the walking distances are longer in winter compared with summer.

Weather conditions influencing mode choice are especially applicable for active modes, since then no protection is present. Molin and Timmermans (2010) observed that people would choose walking and cycling as egress mode more often in good weather. Ma et al. (2018); P. Zhao and Li (2017) noted that cold and rainy weather discourages cycling. The importance of weather conditions really becomes clear in Daniels and Mulley (2013), where chance of rain was found to be the only factor influencing the decision to walk However, Ton et al. (2018) found contrary results on weather influences; they stated that in the Netherlands bicycle usage is not related to weather conditions, meaning that most people will still cycle in bad weather, which underlines the large difference between cycling cultures.

In this research, the weather will not directly taken into account, since the period of surveying does not provide sufficient variation in weather conditions, as is often the case with specific attributes in revealed preference studies Molin and Timmermans (2010). However, if irregular weather conditions are present during the survey, these will be noted, since they might influence that sub set of responses.

Time of day

For different times of the day, different travel patterns are present. Molin and Timmermans (2010) state that people, and especially women, are less inclined to travel during the evening and at night, because the latter decreases the sense of safety. This holds especially for the active modes, but also public transport is affected by dark hours. However, it is not known if people travel different access or egress length when travelling in the evening or at night.

As stated in subsection 2.2.1 work trips in the AM peak had the smallest access distances compared with work trips during other times of the day according to El-Geneidy et al. (2014). As the bicycle is used most often for work and school trips, it is expected that the bicycle is mostly used in AM and PM peak hours, something that

was made visible by Ma et al. (2018), who found that the combination of the bicycle with the metro was use more in peak hours on work days.
So, especially the peak hours and the hours when it's dark outside are probable to show different results in terms of feeder mode choice and access or egress distance. However, because of the limited resources of this research and the fact that the survey is conducted in April when the dark hours only make up a small portion of tram trips, the survey is conducted between 7:30 and 22:00.

Day of week
Just like time of day, also week days might show different results than weekend days. However, this has mostly to do with trip purpose, where the largest difference is that work trips have a much lower proportion of trips on weekend days. Therefore, peaks are not really visible on weekend days.

Other context factors
Other context factors mentioned by authors to influence feeder distance or feeder mode choice, are route knowledge, mental strain, luggage and travel party.
Route and mode information may reduce stress Annema (2013), and when travellers have a high frequency of transit travelling and cycling, they are usually better informed. Therefore, only the regularity of travelling by transit and bicycle are included in this research, while route knowledge and mental strain are left out.
Also carrying luggage might influence the mode choice of travellers, especially when transfers or active modes are concerned, but feeder mode appeared not be affected by travel party (Molin & Timmermans, 2010).

2.5. Conclusion: theoretical framework

In Figure 2.5, Figure 2.6 and Figure 2.7 the findings from the literature discussed in the previous sections are summarised, and show which factors will be explored in this research (see Chapter 4. Figure 2.5 describes the factors for feeder distance, Figure 2.6 the factors for feeder mode choice, and Figure 2.7 the interrelations between the factors.
Here, per cluster a summary of the findings is provided for both feeder distance and feeder mode choice.

User characteristics
Of the user characteristics, mainly age and transit captivity are expected to influence **feeder distance**. Little evidence exists yet about the effect of frequency of transit use on feeder distance, so therefore it will be tested in this research. The literature does not indicate that the other user characteristics mentioned in Figure 2.1 are worth looking into.
This is in line with Krygsman et al. (2004), who performed research on catchment areas in the Netherlands and found that individual characteristics hardly play a role in the distances to stops. Likewise, (Cervero, 2001, as cited in Park et al., 2014) could not identify significant socio-economics influencing walking distance to transit stops. However, (Loutzenheiser, 1997, as cited in El-Geneidy et al. 2014), in their research concerning walking distances, found that individual characteristics have the most influence on walking distances to transit stops.

As section 2.1 showed, a considerate amount of factors relating to user characteristics are mentioned by authors to have an influence on **feeder mode choice**. However, when considering the Netherlands, a country with a distinct cycling culture, this does not apply. Ton et al. (2018) found that, contrary to other studies, the use of the bicycle as a transport mode in the Netherlands is hardly related to socio-demographic factors such as age, gender, income and ethnicity. This is in line with Harms et al. (2014) and (Pucher & Buehler, 2008, as cited in P. Zhao and Li 2017), who stated in their researches that in areas where the bicycle is commonly used, demographic groups show more similar bicycle use. However, Harms et al. (2014) did find some socio-economic differences in cycling use in the Netherlands: age, gender and immigration background. The social context is only expected to affect feeder mode choice and not feeder distance. But it is outside the scope of the transit operator perspective in this research. Many of the user characteristics relating to bicycle sharing usage can be linked to the fact that it is a fairly new phenomenon, whose users are often associated with certain socio-demographic characteristics.
Because this research is applied in the Netherlands and focuses mostly on transport-related factors, only the socio-demographic factors age, gender and ethnic/cultural background are included for feeder mode choice in the theoretical framework, where the latter two only serve as interaction effects instead of direct effects. Furthermore, frequency of transit use and feeder options are explored.

Transport factors
The transport factors are divided into trip, service and stop factors. Trip purpose and total trip length are deemed the most important trip factors on **feeder distance**. Also feeder mode is expected to have a significant influence, because the faster the mode, the longer distance can be travelled. The effect of home-based/activity-based access/egress is not entirely clear yet from the literature, which is why it is tested in this research.
For the amount of transfers it is expected that travellers bridge longer distances to get to a stop where they can avoid a transfer, which is an important hypothesis that will be explored. The service characteristics frequency at stop and directness of transit are both included in the theoretical framework, because their effects on feeder distance are not yet clear.

For **feeder mode choice** some of the expected significant related effects are trip purpose and home-based/activity-based, which is strongly related with feeder options. The feeder distance is again related with feeder mode choice. Similarly to feeder distance, for the amount of transfers it is expected that travellers use the bicycle to get to a stop where they can avoid a transfer. The effect of frequency is expected to be negatively related with bicycle use, because longer waiting times induce more cyclists to and from the stop. Directness of transit is also included in the theoretical framework, just like availability of bicycle parking. Lastly, also total trip length is expected to be of influence, but not as strongly as for feeder distance.

Built environment factors
The built environment contains many aspects. As for **feeder distance**, the level of urbanisation is most important. But also the transit stop density plays a large role. For the **feeder mode choice** the routes to transit are most decisive. The feeder route, however, is left out of the theoretical framework. This is partly because it is hard to assign to one stop or line, which is preferable because the perspective of this research is the public transport operator. Furthermore, in one city such as The Hague, no large difference are visible for street design, safety, and especially for hilliness. Since transit stop density is closely related with population density and land use mix, all three factors are included in this research, of which only transit stop density is explored as a direct effect in Chapter 4.

Context factors
As Molin and Timmermans (2010) noted, context factors are difficult to research in travel behaviour, because often insufficient variation is present. Moreover, this research is carried out from the perspective of the transit operator, and context factors tend to change so rapidly, that they have no real connection to long term transit planning. Consequently, only time of day and day of the week will be taken into account, however not as direct effects. Weather will only be used to adjust the results in case of extreme weather circumstances.

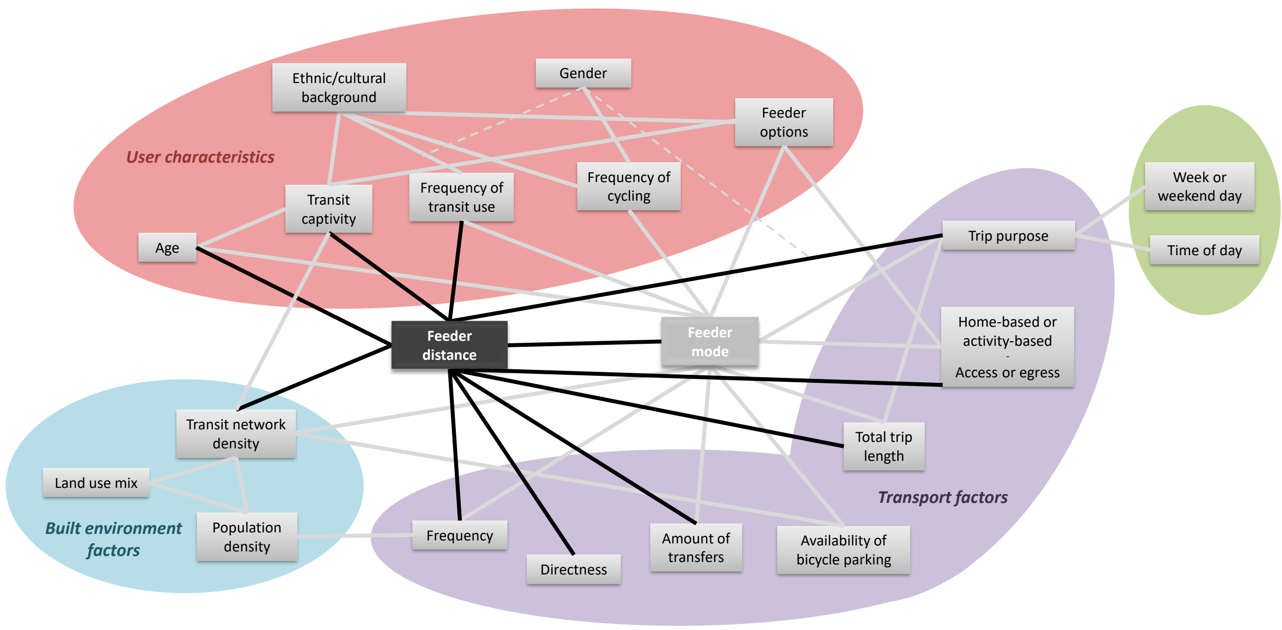

Figure 2.5: Theoretical framework: factors influencing feeder distance included in the research

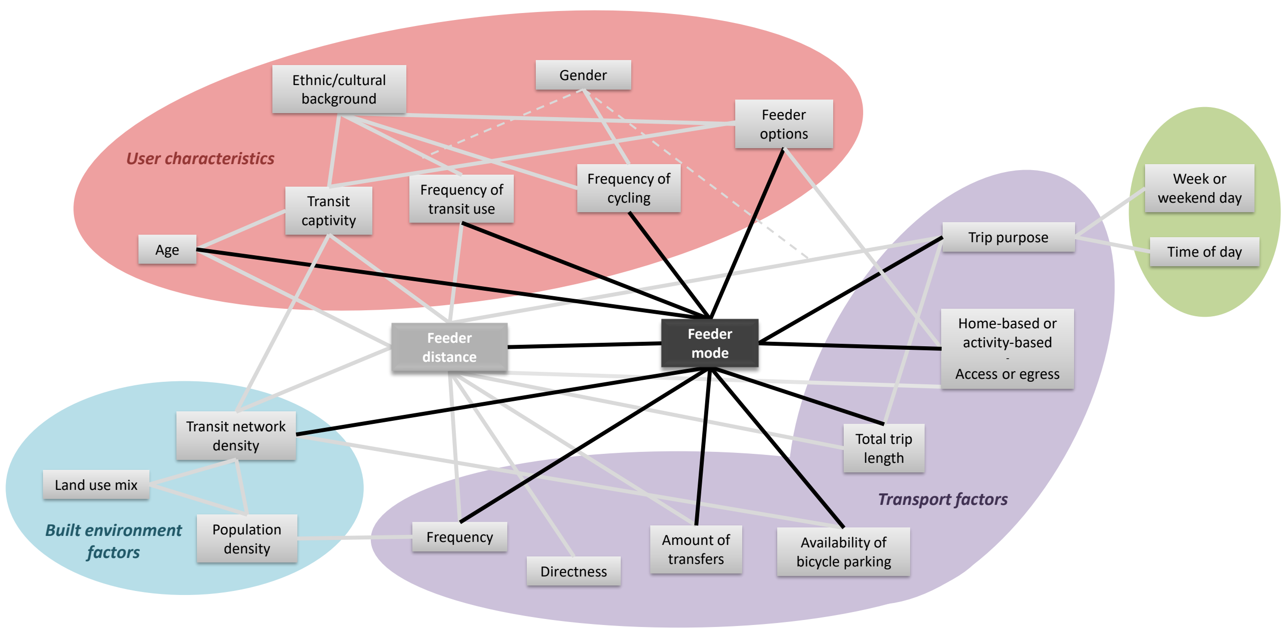

Figure 2.6: Theoretical framework: factors influencing feeder mode included in the research

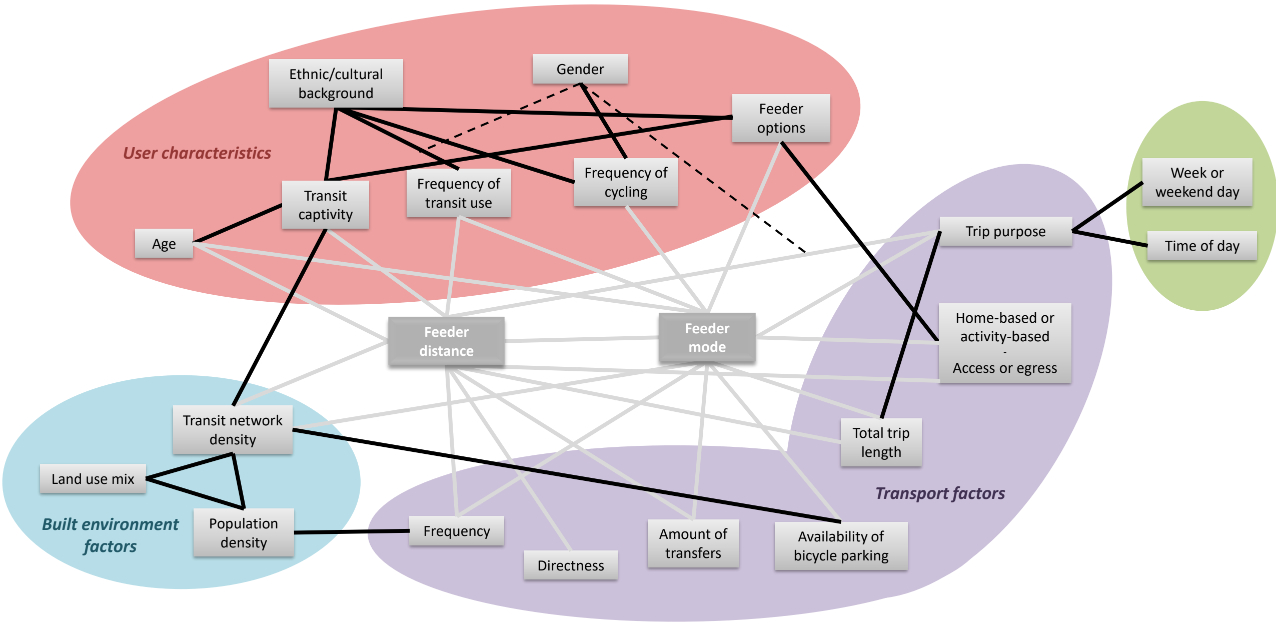

Figure 2.7: Theoretical framework: inter-dependencies between factors

3
Data gathering

In order to obtain the needed data on access and egress to and from tram stops in The Hague a revealed preference survey is carried out. In this chapter, first the survey method will be explained, after which the design of the survey itself is described, including the results of the test survey, the sampling and the approach for carrying out the survey.

3.1. Survey

3.1.1. Method

As stated in the introduction, this research includes a revealed preference survey. Smart card data approaches do not satisfy, because they only provide aggregate data, whereas also user and trip characteristics need to be obtained. La Paix Puello and Geurs (2016) mention that revealed preference methods can generate information about travel behaviour in real situations, because they are about the actual choice that travellers made, providing high validity of the results. Furthermore, they are suitable to use when situations are examined that will not change much in the future Molin and Timmermans (2010). Therefore, a revealed preference survey is a relevant method for this research, because the goal is to learn more about the current travel choices of tram travellers in The Hague.
However, there are some disadvantages of revealed preference surveys. Sometimes effects are difficult to disentangle, partly because high correlations may be present. Furthermore, it is not known from what alternatives people choose from Molin and Timmermans (2010). These disadvantages need to be taken into account when analysing the results of the survey.

Transit on-board surveys

There are several ways to target tram travellers in The Hague, but the most efficient way is to approach them when they are travelling, via on-board surveys. Telephone or household surveys would generate more detailed and accurate results, but for this research that level of detail is not needed. Furthermore, a large number of respondents is necessary, which is more difficult to achieve with in-depth interviews.
Transit on-board surveys are surveys executed inside a transit vehicle, where travellers are intercepted (Zhang & Viswanathan, n.d.). On-board surveys could be self-administered, thus written questionnaires, which are possible with surveyors or without. A third option for on-board surveys is personal interviews.
The advantage of self-administered surveys over interviews is that travellers feel more anonymous, thus the chance that they provide truthful answers to sensitive questions increases (Tucker, 1998). Moreover, personal interviews take up more time and effort of the surveyors, resources that are not available for this research. Therefore, self-administered surveys are carried out. Unfortunately, this does increase the chance that respondents misunderstand questions, which otherwise could have been elaborated on.

On-board surveys can be used with questionnaires that are not too long or complex (Schaller, 2005), something that suits this research. One of the advantages of using an on-board survey is that travellers are unlikely to forget their trip characteristics, because they are asked about their trip while they travel. Thus, their responses are usually more accurate, reliable and detailed (Schaller, 2005; Zhang & Viswanathan, n.d.).
On-board surveys generate higher response rates and are less costly compared with other survey methods,

mainly because they can reach many transit travellers in an easy way and also cover the target group well. Also, on-board surveys provide travellers time to fill out the survey questions. Lastly, survey forms can be immediately returned, reducing the chance of people forgetting to return the form (Schaller, 2005).
The only problem is that short-distance travellers have insufficient time to fill out the survey, and are therefore likely to be underrepresented. Furthermore, question wording and layout become critical aspects, because if not done well, they may cause non response and measurement errors due to unwillingness to answer or misunderstanding.

3.1.2. Survey design

Elements

The theoretical framework (see section 2.5) produced several factors that will be examined in this research. Some of the information for these factors are obtained through the survey, while some of the information needs other data sources, such as data about the trams and tram stops from HTM.
The most important part of the survey is the journey of the tram traveller, which includes their begin and end address, boarding and deboarding stops, and access and egress modes. Travellers are also asked about their activities before and after the journey, possible transfers, and other feeder options they have. With this information about the journey, the distance decay functions can be estimated. In order to clearify about which part of the journey the questions are, they are asked in the sequence in which the traveller encounters them.
After the questions about the journey, several topics are included. Two questions are about tram stop choice, to find out if the respondent chose the closest stop possible, and to get an idea about motives for travellers to choose for stops farther away. There is also a question about whether the respondent occasionally cycles to a tram stop, again motives to do so are asked.
Furthermore, questions asking about transit captivity and travel habits are posed. One includes alternative travel options for the total trip, and two others inquire about the ability to walk and cycle. Two questions ask the respondent about their frequency of travelling by public transport and bicycle.

An important criterion is that the questionnaire is not longer than two A4 sheets, so a single paper could be handed out to the travellers, because non-response increases as the amount of questions goes up Memarian, Jeong, and Uhm (2012). Routine questions are asked at the end, while the most important questions are asked at the beginning of the survey. This is done because the percentage of questions completed by respondents tends to get lower as the survey proceeds (Zhang & Viswanathan, n.d.). Questions involving explaining a decision in writing are not placed directly after each other, to avoid discouraging the respondents. The sequence of the stops is put in the same order as the direction of the vehicle, in order to ease the process of finding the right stops.
The wording of the questions, a critical aspect to reduce non response and improve data collection, is chosen carefully. Since the target population includes people of all education levels, as well as different levels of Dutch or English, the phrasing of the questions is kept as simple as possible. Lastly, no cross-question directions are included to avoid complex structures.

Test survey

According to Memarian et al. (2012), testing of the survey is important. Before the test survey, the questionnaire was pretested by presenting it to several colleagues and thereafter adjusting it multiple times. Thereafter, a test survey among tram travellers in The Hague was conducted on a tram line between 15:00 and 16:00 on a week day, in order to test the survey on intelligibility and desired results.
The test survey showed that people made several mistakes, either because they did not understand some questions well or because they did not execute the survey according to instructions. The most common mistake was that respondents filled in 'not applicable' for all three hypothetical questions about choosing a stop further away, while this box was only meant for one of the three questions. So for the final survey the 'not applicable' box was added for all three questions. Another common mistake was adding the home postal code twice or the (de)boarding stop as begin or end address. This was attempted to be improved by asking the journey questions in the sequence of the actual journey, and by adding icons for each part of the journey. Furthermore, some of the writing was illegible, which was improved in the actual survey by providing clip boards to the respondents. Then, some travellers failed to fill in the back side, which is why the survey was altered to include a 'see other side' sign. Moreover, in the actual survey it was pointed out to the travellers that the questionnaire is two-sided.

Another observation of the test survey was that question about the maximum walking or cycling time to a tram stop generated too general results; therefore the question was skipped. Lastly, some respondents did not fill in all questions. So to make the survey more manageable for the respondents, the amount of answer options for some questions were further reduced and the lay out was improved. Moreover, two questions related to choosing a stop further away were added.

The test survey and the final version of the survey are found in Appendix A.

3.1.3. Planning

Representative sampling

Ideally, the sampled population is the same as the target population, thus all tram travellers in The Hague. However, this is very difficult to achieve. Therefore, sampling is needed (Lohr, 1999; Tucker, 1998). The sampled population is visualised in Figure 3.1. Due to people who are not capable or refuse to answer, and people who are not approached by the surveyor, a part of the sampling frame does not end up in the sampled population. In the case of this research, people who are not eligible are not included in the sampling frame in the first place, because the target population is all HTM riders. This is a large plus point of on-board surveys. One exception is that HTM employees are not deemed eligible, since they are technically not travellers. Therefore, they are not targeted.
Three common ways in which the sampled population becomes different from the target population are selection bias, undercoverage and non-response. In Figure 3.1.3 it is explained how the survey approach is set up to reduce these sample errors as much as possible.

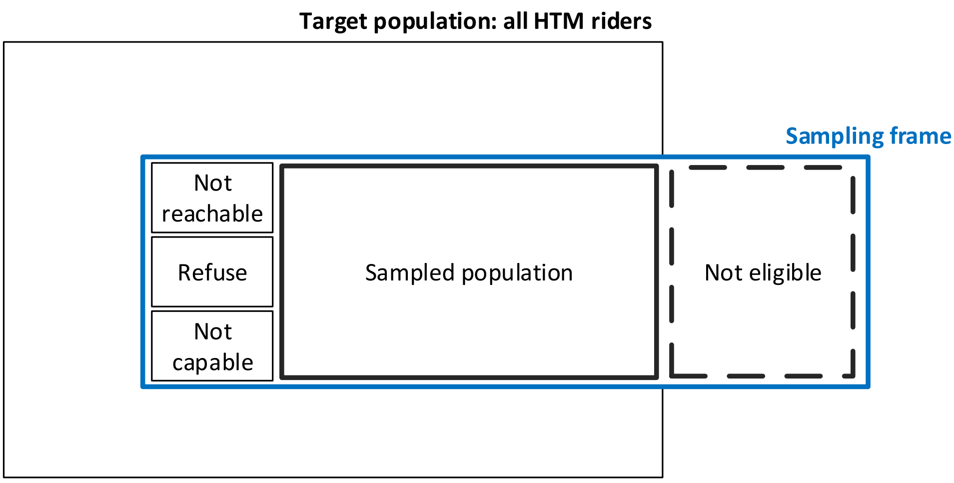

Figure 3.1: Sampling of the survey, based on (Lohr, 1999)

Selection bias

Selection bias most likely influences the results, and happens when specific parts of the target population are not included in the sampled population. Selection bias may occur consciously or unconsciously. An example is when only the units that are easiest to reach are included in the sampling frame (Lohr, 1999).

Undercoverage

Undercoverage, a phenomenon where some parts of the target population are not included in the sampling frame (Lohr, 1999), might be present. This is most likely the case for short-distance tram travellers. They are likely to be missed more often than long-distance tram travellers, because they simply spent less time in the tram. Moreover, they are more likely to be not capable of returning the survey, so even if they are included in the sampling frame, are more likely to not end up in the sampled population.

Non-response
Another issue is nonresponse. Travellers who do not return a survey or do not want or cannot fill out the survey, often have different characteristics than travellers who do return a completed survey. Therefore, the results are not as representative of the target population when many travellers refuse to respond, and some groups are likely to be undercovered. Lastly, when some questions are not completed, a form of non-response is present.

Practical survey approach
Reducing sampling error
Memarian et al. (2012) investigated the effectiveness of different on-board survey approaches on the response rate. They found that the length of the questionnaire had an effect on the response rate, however, this was only observed with the shortest questionnaire (which were only essential origin/destination questions). Between the other two questionnaire lengths, which included demographic and marketing questions, little difference was shown. Since for the The Hague survey more than just origin/destination questions are needed, sampling error is attempted to be reduced by fitting all questions on a two-sided A4 sheet.
Selection bias is mostly ruled out by the procedure of the surveyor, which is to systematically going by a part of the tram and addressing travellers. People seemingly wanting not to be disturbed (e.g. having head phones on or looking straight out the window) are addressed anyway. However, people speaking on the phone are not approached out of politeness. Furthermore, travellers standing are usually also addressed, however probably not as much as travellers in seats. **Undercoverage** of short trip travellers is attempted to be prevented by encouraging those travellers to still fill out the survey, even if completing it entirely is not possible. For people who do not comprehend the language fully, the surveyor can sometimes write down the answers for them, in order to help them through the form. Lastly, the reducing of **non-response** is done by pursuading travellers as much as possible to participate. The fact that the research is carried out for a graduation project at the TU Delft is mentioned and shown to travellers, in order to create goodwill. A surveyor is used to distribute the surveys instead of boxes, somethings which Memarian et al. (2012) found to be more efficient. They also found that female surveyors generate a higher response rate than males, which is mostly the case in this project as well. Lastly, experience from practice learns that passengers are more willing to fill out a survey when it is distributed by a surveyor of the same racial or ethnic background (Memarian et al., 2012). However, this is hard to carry out in practice, since in this research only one surveyor is available, occasionally assisted by an additional surveyor.

Scheduling the survey
The amount of time scheduled for surveying the tram travellers was deducted from the test survey, which yielded approximately 30 responses per hour. According to Rodriguez-Gonzalez and Aguero-Valverde (2017) 300 surveys are sufficient for having statistically significant result. However, more are needed in order to generate a sufficient amount of bicycle-tram riders, so in total 6 subsequent days were scheduled for surveying.

3.2. Case study area: The Hague

This section goes into detail about the case study area where the survey is conducted. The area, its tram n characteristics of the respondents are discussed.network and tThe Hague area
The Hague is the third-largest city of The Netherlands and the capital of the South Holland province. Furthermore, it houses the Dutch parliament and many embassies and international organisations (Gemeente Den Haag, 2018a).

The Hague: transport
The modal split of trips within the municipality of The Hague is as follows: 36% car, 13% public transport, 21% bicycle and 30% walking (Gemeente Den Haag, 2016).
In a research of the municipality of The Hague, it became clear that the accessibility of transit stops accounted for 41% of the reasons why public transport in The Hague is hard to use. Furthermore, the time duration (59%) and the price (49%) were the most common reasons mentioned. Public transport is most often used for shopping in the city centre (31%). For visiting friends/relatives outside of the city and for going out in the city centre, public transport is used (27% for both) (DIMENSUS, 2018). For the bicycle, respondents named 'dangerous' most commonly (69%) as a reason for cycling being difficult in The Hague. Bad cycling paths

(58%) and inefficient routes (55%) were other reasons mentioned often (DIMENSUS, 2018). In the same survey respondents reported their cycling frequency: 32% uses the bicycle 6-7 times a week; 16% 3-5 times a week; 7% 2 times a week; and 10% less than 2 times a week (DIMENSUS, 2018).

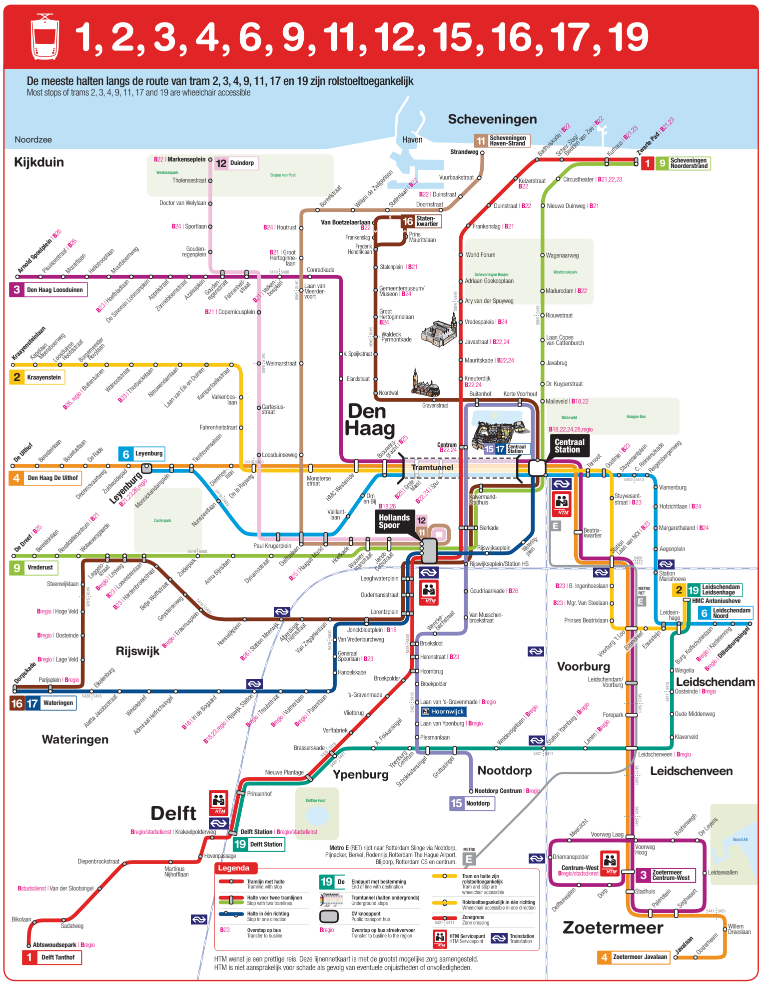

Figure 3.2: Map of The Hague area tram network (HTM, 2018)

The Hague: tram network

HTM establishes a 400m 'as the crow flies' distance and an estimated 500m network distance as the maximum buffer for all transit stops in urban areas (Teijl, 2018). Their tram network can be seen in Figure 3.2. In this research, the four lines for surveying need to include various characteristics. For different stop densities line 3 (low) and 12 (high) are included. The four lines stop at different neighbourhoods, where different riders are expected (the city centre, the Vinex area of Ypenburg, expat neighbourhoods, tourists close to Scheveningen and the museums, and the 'Schilderswijk').

The definition for directness of transit line that is used in this research, is based on HTM's categorization. In the tram network of the The Hague area, three different types of tram lines are distinguished in terms of directness of the line. The types are based on a combination of stop densities, frequency and speed, and directness The first is a connecting line, which covers longer distances and serves destinations on the outskirts of the city. The frequency and speed are relatively high. Overall, those lines are direct. Then on the other hand there is the covering line, with higher stop densities, lower speed and more area coverage leading to shorter average feeder distances. In this light lines 1, 2, 3, 4, 9 and 17 can be considered as connecting lines; 6, 12 and

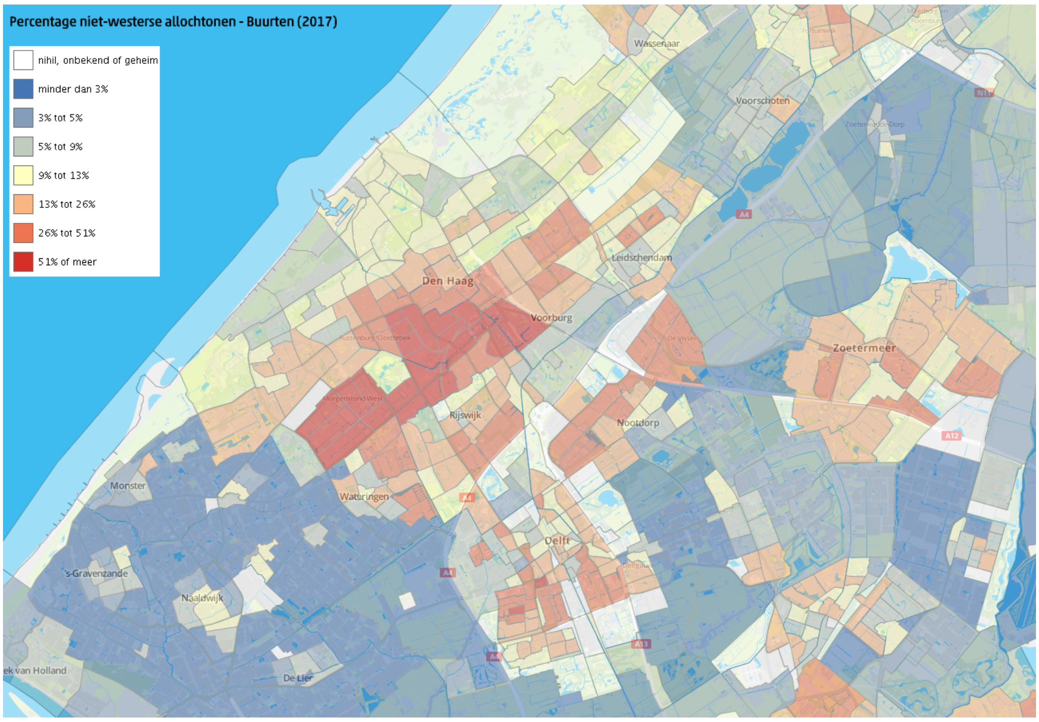

Figure 3.3: Non-western immigrants in The Hague area (Gemeente Den Haag, 2018b)

16 as covering lines. However, some lines fall inbetween, because they host characteristics of both. Therefore, lines 11, 15 and 19 are considered as the 'inbetween' type.

The Hague: population

On January the 1st of 2018, The Hague had 533,026 inhabitants (Gemeente Den Haag, 2018b). Figure 3.4 shows the ethnic background of those inhabitants, where it is visible that less than 50% is of Dutch origin, while Turkish, Moroccan and Surinamese people form the largest minority groups. Previous research has found that these minority groups have different mobility patterns than people of Dutch origin (Olde Kalter, 2008). The distribution of ethnic/cultural backgrounds around the The Hague area is visualised in Figure 3.3, where it can be noticed that large concentrations of ethnic groups are present. This needs to be accounted for in the survey.

3.2.1. Characteristics respondents

In Figure 3.5 and Figure 3.6 some characteristics of the respondents are visible. More women than men responded to the survey, which is as expected. The different ethnic/cultural backgrounds, as was described earlier in this chapter, vary for the different lines, because the lines cross different types of neighbourhoods. Other than The Hague inhabitants, also many non-Dutch speaking respondents were found to have travelled the tram, as can be indicated by the many respondents who asked for an English survey.

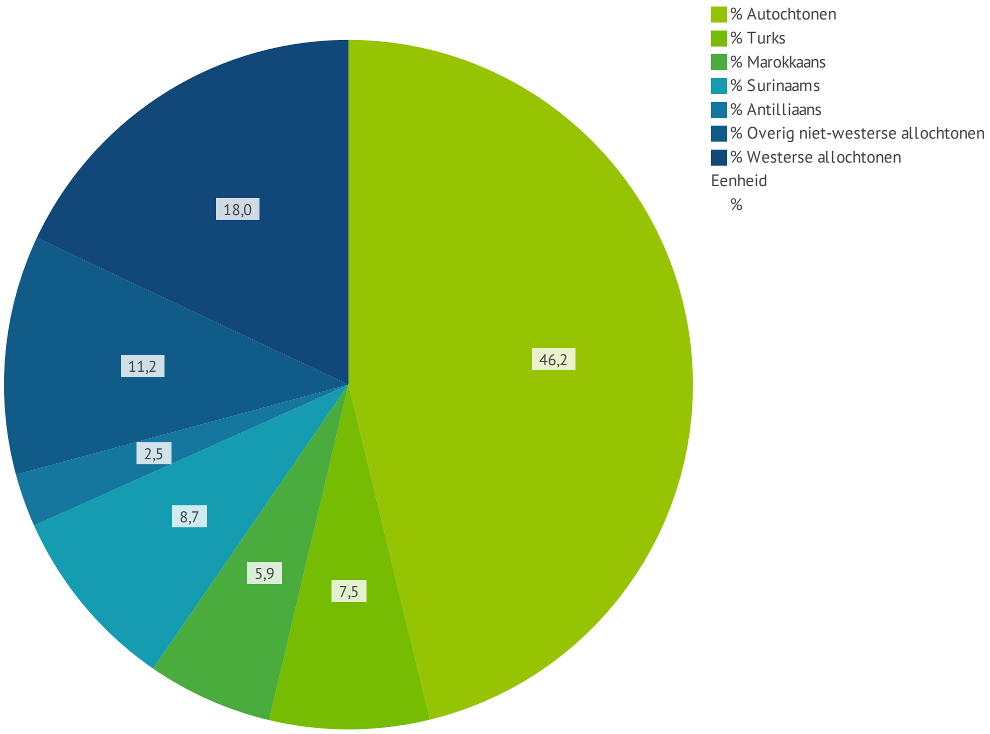

Figure 3.4: Ethnic background of inhabitants of The Hague: less than 50% is of Dutch origin (Gemeente Den Haag, 2018b)

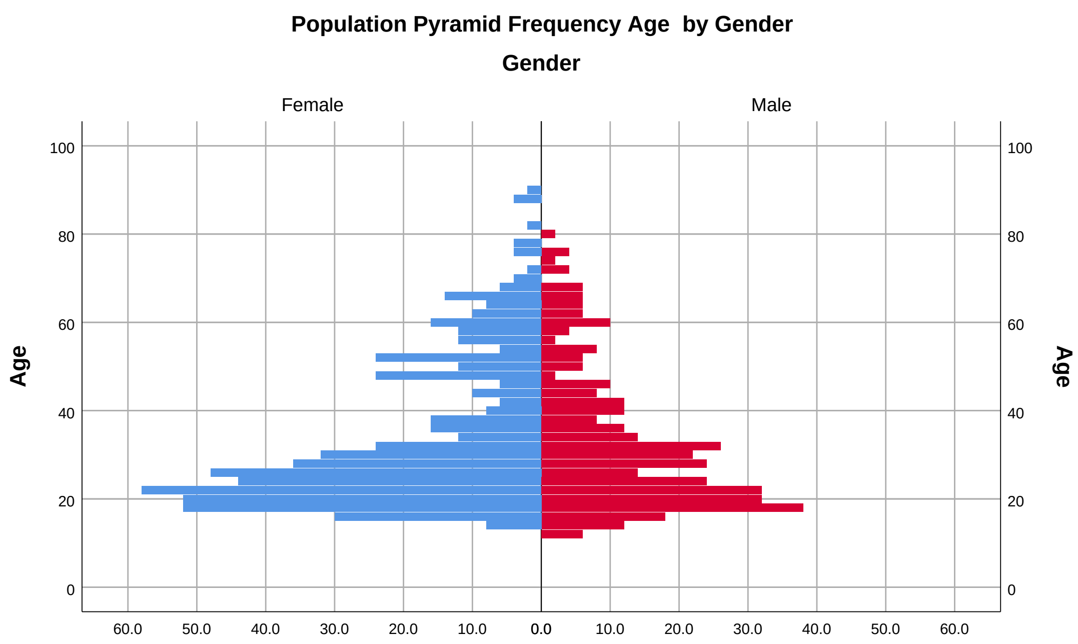

Figure 3.5: Population pyramid

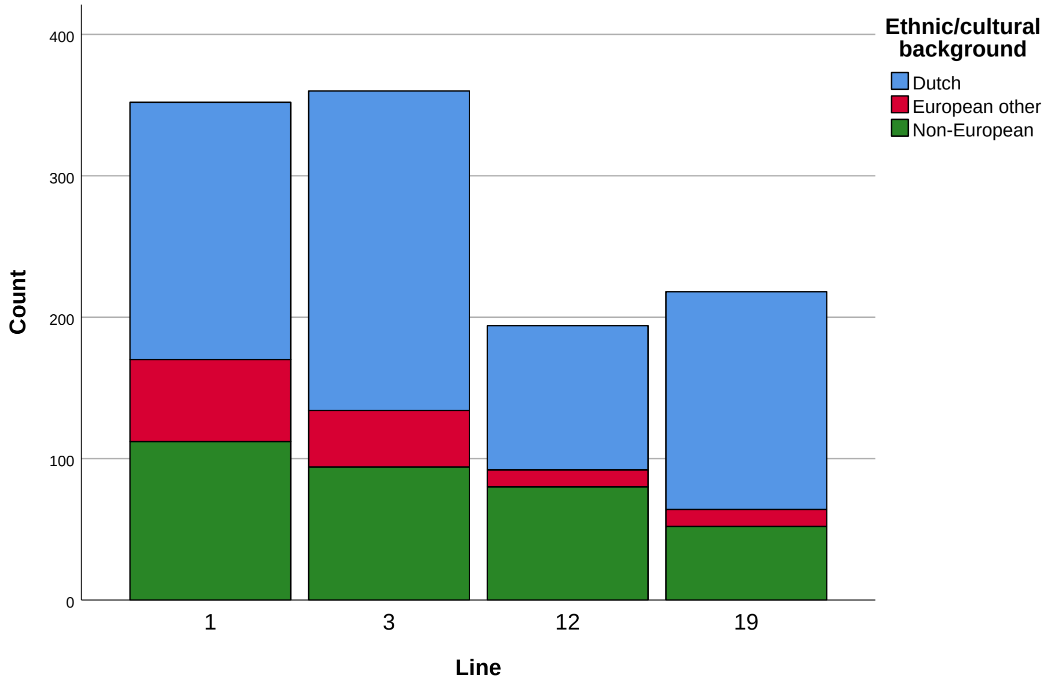

Figure 3.6: Ethnic/cultural background per surveyed line

4

Results

This chapter processes the data that was gathered during the revealed preference survey in The Hague. This is done both quantitatively and qualitatively. The bivariate analysis in section 4.1 forms the input for the multivariate analysis in section 4.2. section 4.3 supports the findings of the quantitative analyses by executing a qualitative analysis.

4.1. Bivariate analysis: exploring the factors

In this section, the separate effects of each factor from the theoretical framework on the two dependent variables, feeder distance and feeder mode choice, are explored by means of statistical tests. The factors that are significantly related with feeder distance or feeder mode choice, form the input for the two statistical models in section 4.2. This is visualised in an adjusted theoretical framework at the end of this section. The statistical tests in this chapter are supported by the display of distance-decay functions and bar graphs where possible. The figures that are not discussed in this section, are displayed in Appendix B. For the effects on feeder distance, the two modes of interest (walking and cycling) are separately visualised, because otherwise the effects of feeder mode choice are included as well. The distance-decay functions are shown for walking, and cycling where sufficient data points are available. Some continuous predictor variables are shown in scatter plots. The statistical tests are separately executed for walking and cycling.

4.1.1. Methods used

Feeder distance is based on the notion of distance-decay: the further a stop, the smaller the probability of choosing that stop. Parametric statistical tests use the mean values for estimating the value and significance of the effect. However, these means may be heavily influenced by the distribution of the distance-decay data, because the distribution of the data residuals is non-normal. Medians, however, which are used for non-parametric tests, are much less affected by outliers and is more appropriate for skewed data such as distance decay (Alshalalfah & Shalaby, 2007; Daniels & Mulley, 2013).
Therefore, although parametric tests could be performed because the N is large enough, non-parametric statistical tests are used for examining the effects on feeder distance. However, they are often deemed less powerful than parametric tests (Field, 2009). Furthermore, as Heinze and Dunkler (2017) note, not only factors that are significant in a bivariate analysis should be included in multivariate models, because important effects may be overlooked. Therefore, aside from the factors that are statistically significant at a 95% confidence interval, also those at a 75% confidence interval are tested in the logistic regression models. The non-parametric tests used here are the Mann-Whitney U test, the Kruskal-Wallis test and both Spearman's Correlation and Kendall's Tau.
The Mann-Whitney U test is used for categorical predictor variables with only two categories is applied. The Kruskal-Wallis test is a similar test, but used for categorical predictor variables with more than two categories. The null-hypothesis assumes that the different categorical groups are drawn from identical populations, while the alternative hypothesis is that the two groups are statistically significantly different from each other. The Kruskal-Wallis test explores if at least two of the groups are significantly different from each other, although the test does not indicate which groups (Field, 2009). This could be tested by follow-up tests, how-

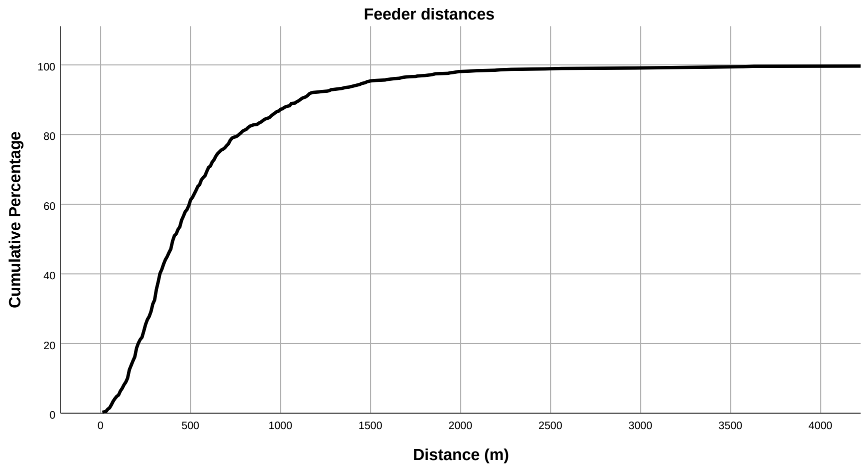

Figure 4.1: Overall distance-decay function (walking and cycling combined), in meters

Table 4.1: Overall feeder distance values

	N	min	max	median	mean
Walking	657	10	2470	380	466.18
Cycling	56	80	3170	1025	1159.11
Total	713	10	3170	400	520.60

ever, in this research the distance-decay functions and other figures are used to visually inspect the difference between the groups. For continuous predictor variables both Spearman Correlation and Kendall's Tau are applied. They they both have benefits and drawbacks, so therefore it is useful to examine them both. Kendall's Tau is more insensitive to large deviations, while S will better detect rare and unusual cases (Field, 2009).
For the effects on feeder mode choice non-normality of residuals is irrelevant, because the outcome variable is categorical. For the categorical predictors a combination of cross-tabulation and the Pearson chi-square test is applied, as well as a bar graph to visually inspection the relations. The continuous predictor variables are tested through point-biserial correlation (Field, 2009).

4.1.2. Factors affecting feeder distance

In this section, the effects of the factors on feeder distance are explored, of which the results are represented in Table 4.2 and Figure 4.2. The distance-decay function including all data points (see Figure 4.1) shows the distribution of the feeder distances for all walking and cycling feeder trips. And Table 4.1 contains descriptive values on the feeder distances. The medians of walking and of walking and cycling combined, are comparable with the fixed buffer area that most transit operators use (400m). The median is considered more suitable to describe the feeder distance than the mean, because the data is skewed to the left. This means that outliers with high values have a large influences on the mean, but less on the median. Feeder distance is largely related with transit stop density, which is roughly 500m (based on the street network) in the The Hague area (Teijl, 2018). Around 60% of travellers walk or cycle less than this value.

Age

The effect of age on feeder walking distance was found to be non-significant through both Spearman's Rho and Kendall's Tau: r_s = -.003; p = .947; r_τ = -.002; p = .943. This holds as well for the effect on cycling: r_s = .072; p = .620; r_τ = .040; p = .687. This supports the statements of Park et al. (2014), who found no effect of age on feeder distance. On the other hand, El-Geneidy et al. (2014) found that elderly people bridge the shortest distances, while young adults the longest. This pattern is slightly, but not convincingly, found Appendix B. For cycling no feeder trips were made by travellers above 60 years old, where ages for walking go above 80 years.It should be noted, though, that age is not directly correlated with walking with difficulty: elderly people may be able to walk a regular distance to a stop, while some younger travellers could have a certain handicap. Furthermore, the difference between younger and older people might only be visible when it concerns larger

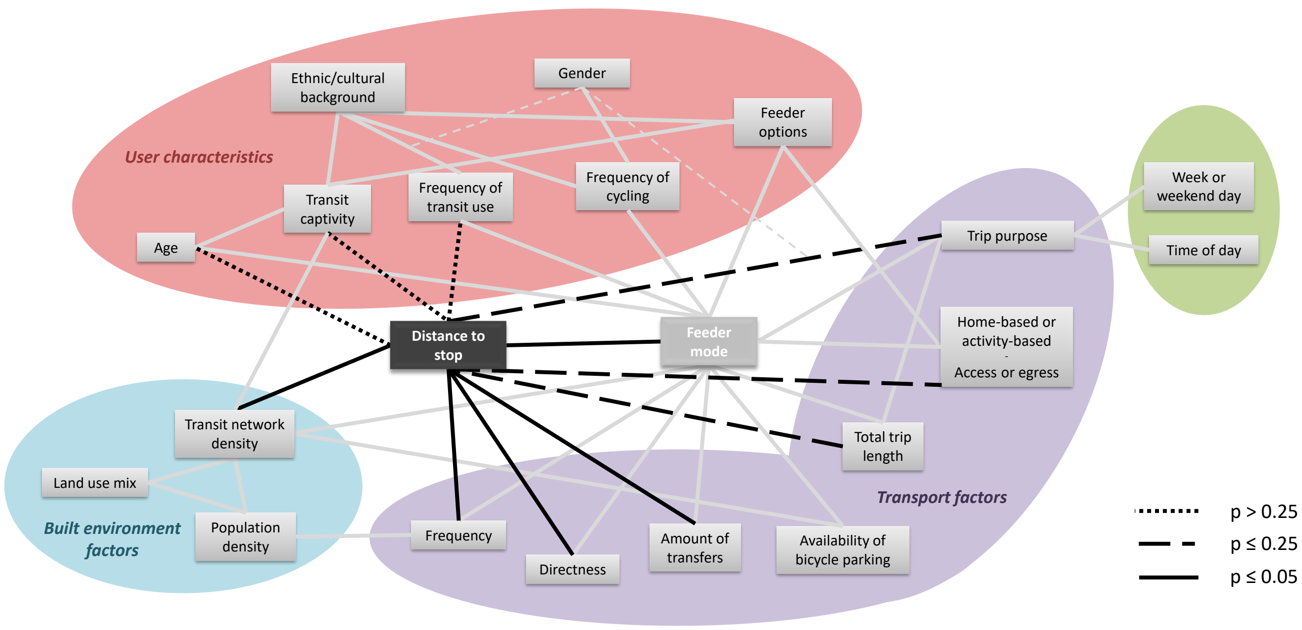

Figure 4.2: Results from the bivariate statistical tests for feeder distance

distances.

Transit captivity
Transit captivity, defined as having the possibility to take the trip in another way or not, has no significant influence on walking feeder distance (U = 33657.5, p = .478). The same holds for cycling feeder distance (U = 118.0, p = .290).
However, residential self-selection may play a role, where captive transit riders are likely to live closer to a transit stops (Alshalalfah & Shalaby, 2007; El-Geneidy et al., 2014). This is an opposing effect from Chia et al. (2016), who stated that people who are reliant on public transport are in general more willing to walk longer distances to and from stops. So, transit captivity might still have an effect on feeder distance, despite the non-significant test results. Therefore, the combined effects of transit captivity, feeder mode options and built environment factors are examined in the logistic regression model.

Frequency of transit use
When considering walking to the stop, the Kruskal Wallis test shows no significant relation between frequency of transit use and feeder distance (χ^2 = 4.021 and p = .403). The results for cycling feeder distances show non-significant results as well (χ^2 = 3.949 and p = .413). These are no surprising results, since Hochmair (2015) is the only author that stated frequent transit travellers are more often willing to increase their feeder distance than non-frequent transit travellers, when this reduces their total travel time.
Therefore, this factor will not be included in the logistic regression model for feeder distance.

Trip purpose
For walking, the Kruskal Wallis test reveals non-significant values for the effect of trip purpose on feeder distance (χ^2 = 1.805 and p = .875). This is visible in Figure 4.3, where the categories show very similar distributions.
When cycling is concerned, the effects of trip purpose on feeder distance seems to have a larger influence than for walking, see Figure 4.4. However, these results are not significant, either (χ^2 = 8.899 and p = .113).
The non-significance of the results is surprising, because many authors mentioned the relation between feeder distance and trip purpose (Chia et al., 2016; Daniels & Mulley, 2013; El-Geneidy et al., 2014; Nijënstein et al., 2016). An explanation could be that feeder distances in the AM peak are shorter (El-Geneidy et

al., 2014; Nijënstein et al., 2016), averaging out the longer feeder distances for work purpose. Furthermore, residential self selection could play a role in the non-significant test results.
The utilitarian trip purposes (work and school/internship) do show the longest distances for cycling (Figure 4.4), which is in compliance with literature expectations. Although the results from the test do not indicate that trip purpose influences the feeder distance, the factor is still tested in the logistic regression model, because for cycling the p-value falls under 0.25.

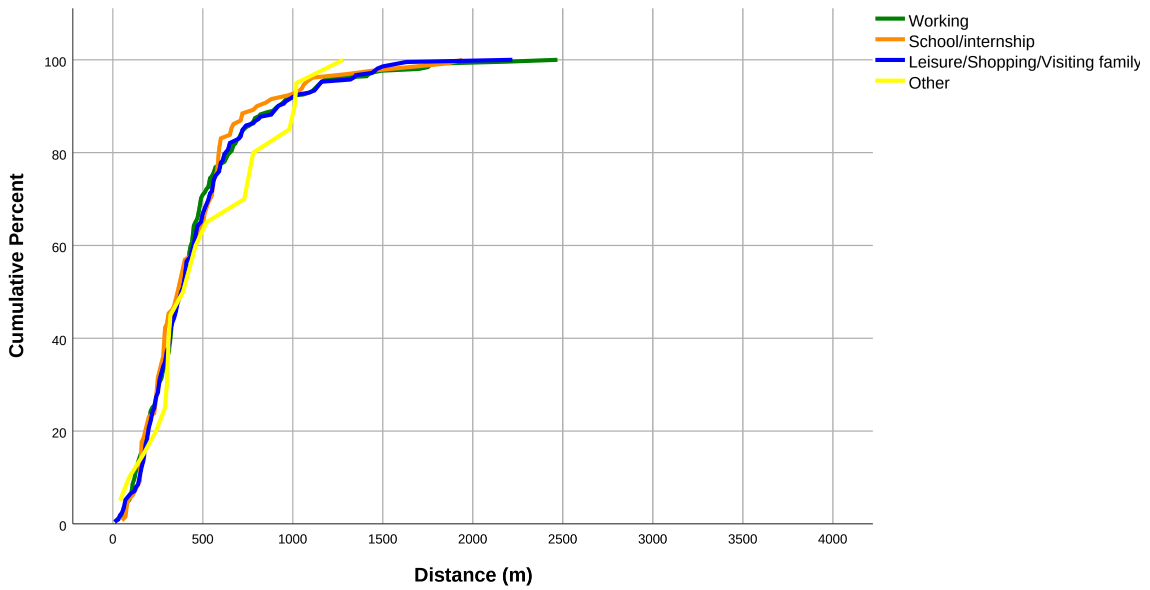

Figure 4.3: The distance-decay functions for trip purpose (walking)

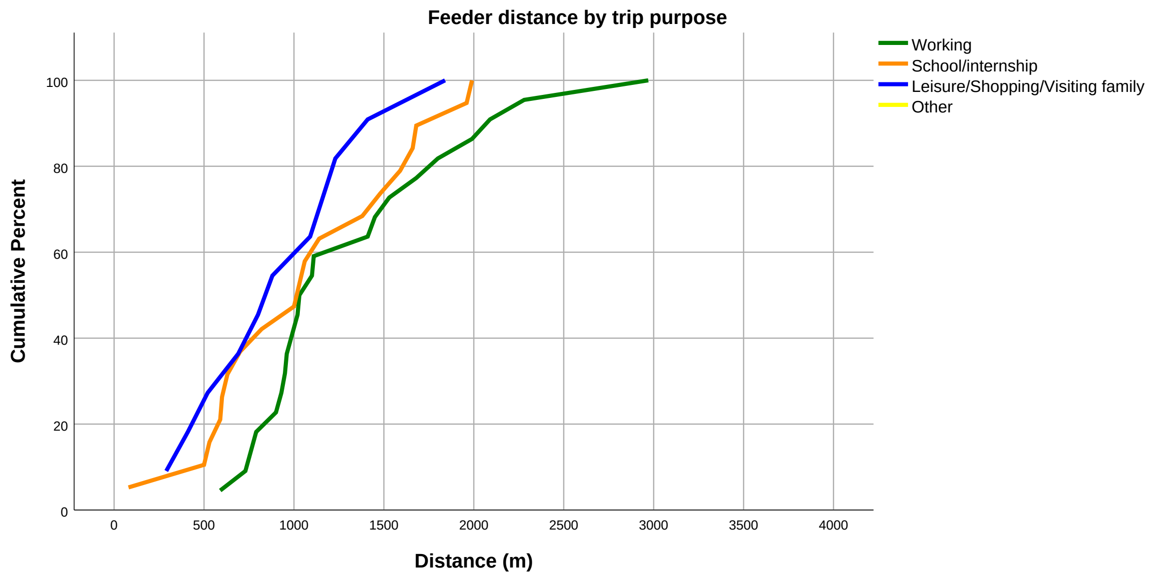

Figure 4.4: The distance-decay functions for trip purpose (cycling). Distances travelled for utilitarian purposes are generally higher.

Home-based or activity-based access and egress
For both walking and cycling the results of the Kruskal-Wallis test are not significant (χ^2 = 5.336 and p = .149 for walking and χ^2 = 2.470 and p = .481 for cycling). The results are non-significant as well for access versus

egress ($U = 51898.0$, $p = .412$ for walking and ($U = 305.0$, $p = .215$ for cycling) and home-based versus activity-based ($U = 48818.5.0$, $p = .087$ for walking and ($U = 224.5$, $p = .337$ for cycling). Nonetheless, some of the p-values fall below .25, which indicates that this factor should be examined in the logistic regression model.

However, the differences between the four categories are more distinct than when only access/egress or home-based/activity-based are concerned (see Figure 4.5 and Figure 4.6). This suggests that the two effects can magnify each other, creating larger differences between the shortest and longest distances. Therefore, only the factor with four categories is used the in logistic regression model. For walking, home-based access distances are shorter than home-based egress distances, while for cycling this is the other way around. Furthermore, activity-based egress for walking show shorter distances than activity-based access.

This is partly in line with literature expectations, from which home-based distances would be longer than activity-based. However, this appears to be only true for cycling.

The differences between access/egress and home-based/activity-based when looked at separately, only appear distinct for cycling (see Appendix B), where access and home-based distances are the longest.

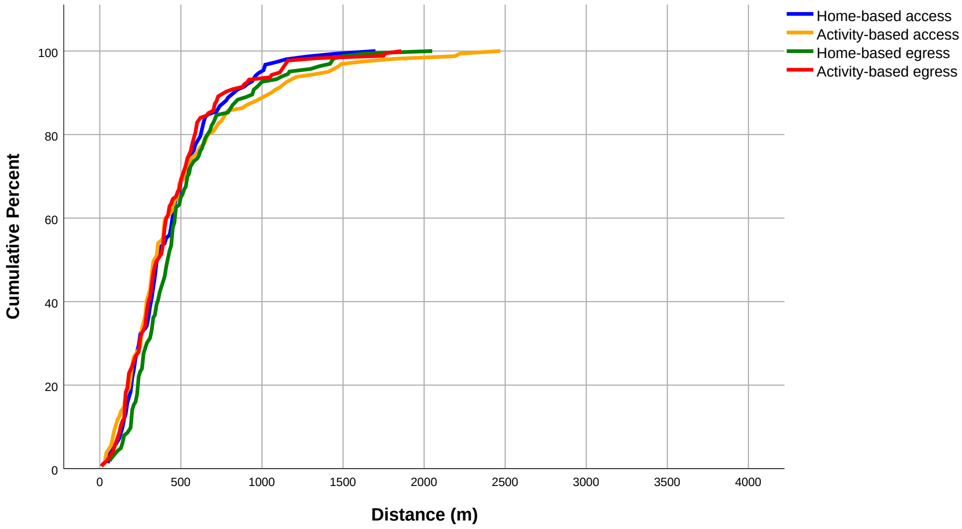

Figure 4.5: The distance-decay functions for home-based/activity-based access/egress (walking)

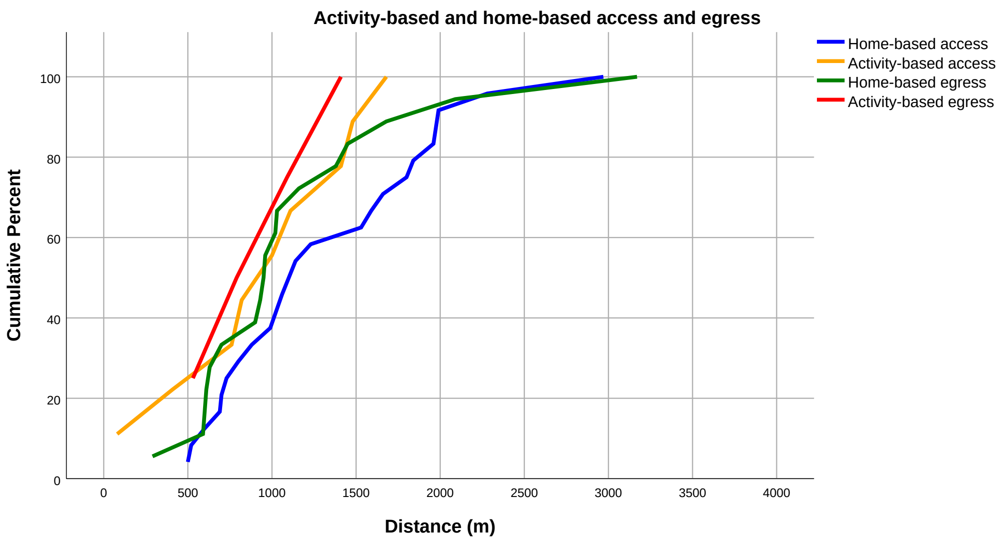

Figure 4.6: The distance-decay functions for home-based/activity-based access/egress (cycling)

Feeder mode

According to the Kruskal Wallis test, feeder mode is a factor which is largely significant for feeder distance (χ^2 = 103.991 and $p = .000$). This is also shown in the distance decay function in Figure 4.7, from which it becomes clear that the feeder distances increase as the speed of the feeder mode goes up (from walking to bicycle and finally car). These results are as expected from the theoretical framework.

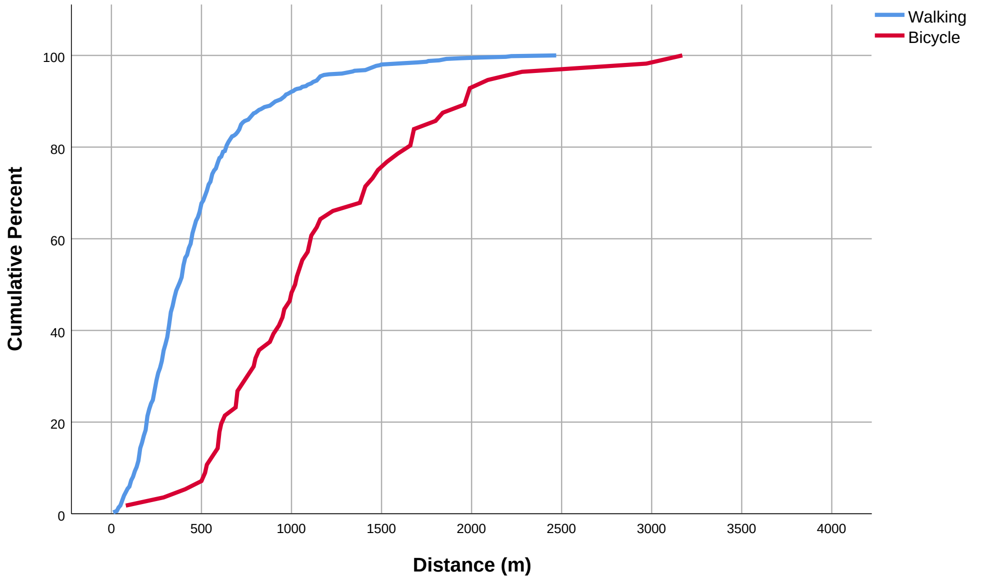

Figure 4.7: Distance decay functions of walking and cycling. Overall holds: the faster the feeder mode, the longer the distances covered

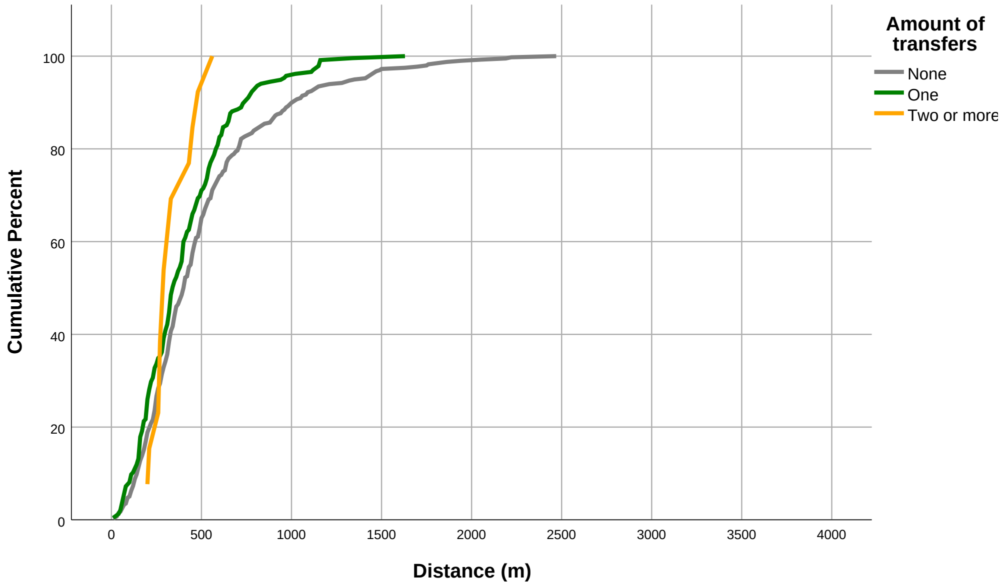

Figure 4.8: The distance-decay functions for amount of transfers (walking). Feeder distances are shorter when the journey included transfers.

Amount of transfers

The amount of transfers and feeder walking distance are significantly related (χ^2 = 8.373 and p = .015). Figure 4.8 and Figure 4.9 show the distance-decay functions of zero, one and two transfers. As the amount of transfers increases, the feeder distance becomes shorter. This supports the assumption that people will travel

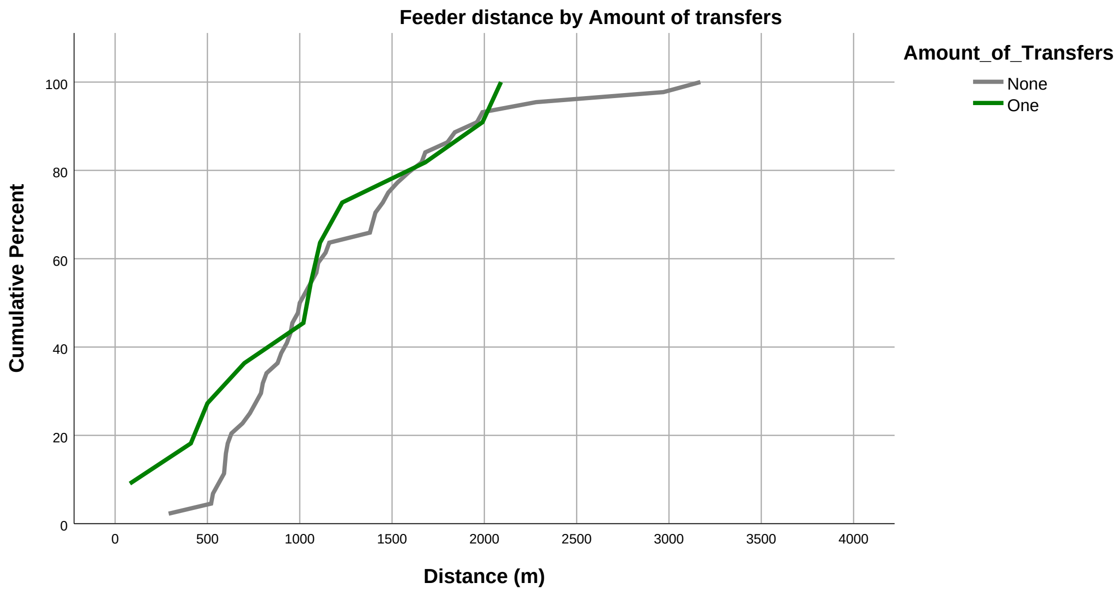

Figure 4.9: The distance-decay functions for amount of transfers (cycling). Feeder distances are shorter when the journey included transfers.

further to or from a stop when this allows them to reduces the amount of transfers in their journey (Chia et al., 2016; El-Geneidy et al., 2014; Van Mil et al., 2018).
Feeder distance and the amount of transfers are not significantly related when cycling is concerned (χ^2 = .069 and p = .793), although Van Goeverden and Egeter (1993) and Kager and Harms (2017) suggested that travellers can use the bicycle to avoid a transfer.
However, the amount of transfers is not a direct measure of avoiding a stop. For example, a longer total trip might attract more bicycle-transit travellers who avoid a transfer, while it also increases the chance of having more transfers (although no significant relation was found in Figure 4.1.2). Furthermore, in the survey some transfers were under-reported, because travellers were not asked if they made a transfer before or after travelling by metro/train.

Total trip length
For feeder walking distance the total trip length seems not to be significantly correlated with the feeder walking distance (r_s = -.012; p = .772; r_τ = -.008; p = .768), although several authors mentioned that the feeder distance would be higher for longer total trips (El-Geneidy et al., 2014; Krygsman et al., 2004; Leferink, 2017; Shelat et al., 2018; Van der Blij et al., 2010; Van Mil et al., 2018). For feeder cycling distance the effect is larger, but still not significant (r_s = .233; p = .087; r_τ = .164; p = .080). Therefore, total trip length is not included in the logistic regression model for feeder distance.

Frequency at the stop
Frequency at stop is divided into three categories, as was explained in Chapter 3: low = frequency<6 trams per hour; medium = frequency 6-10 trams per hour; high = frequency>10 trams per hour. The distance-decay function for walking in Figure 4.10shows that the three frequency categories are quite distinct. This is also reflected in the results of the Kruskall-Wallis test: χ^2 = 9.831 and p = .007. It is remarkable that the 'medium' category results in the shortest distances. The 'low' category has the largest distances and lastly, the 'high' category results in between the other categories.
For cycling, similar significant results come up (χ^2 = 9.275 and p = .010). The difference here is that the distance-decay function in Figure Figure 4.11 shows the 'high' category having the largest distances. However, too little observations for 'low' and 'medium' are available to form a continuous distance-decay function.
Some studies expected that high frequencies attract travellers from a larger range (El-Geneidy et al., 2014; O'Sullivan & Morrall, 1996). On the other hand, the relation with the built environment may reduce this

effect, because the densities around high frequency stops are usually higher (El-Geneidy et al., 2014).
From the box plots in Figure 4.12 and Figure 4.13, it is suspected that the relation between feeder distance and frequency is not linear. This could explain the unexpected results from the distance-decay functions of the three frequency groups. A solution would be to analyse the frequency of the tram line chosen by the traveller, instead of the cumulative frequencies of the stop. However, the relation between frequency at the stop and built environment factors could potentially also explain this.

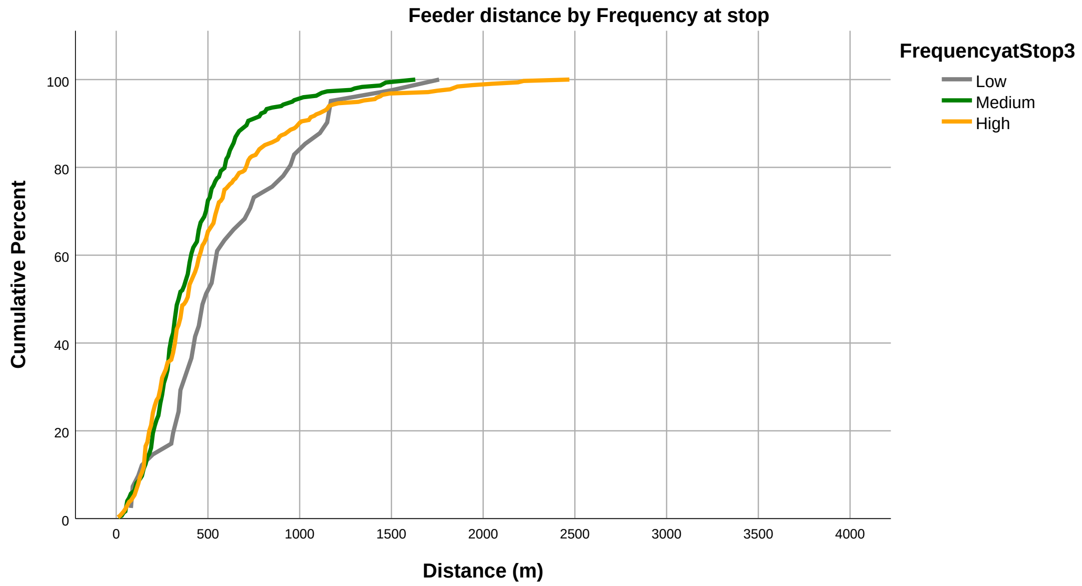

Figure 4.10: Distance-decay functions of frequency at stop (walking). Unexpected results: 'medium' distances are the shortest.

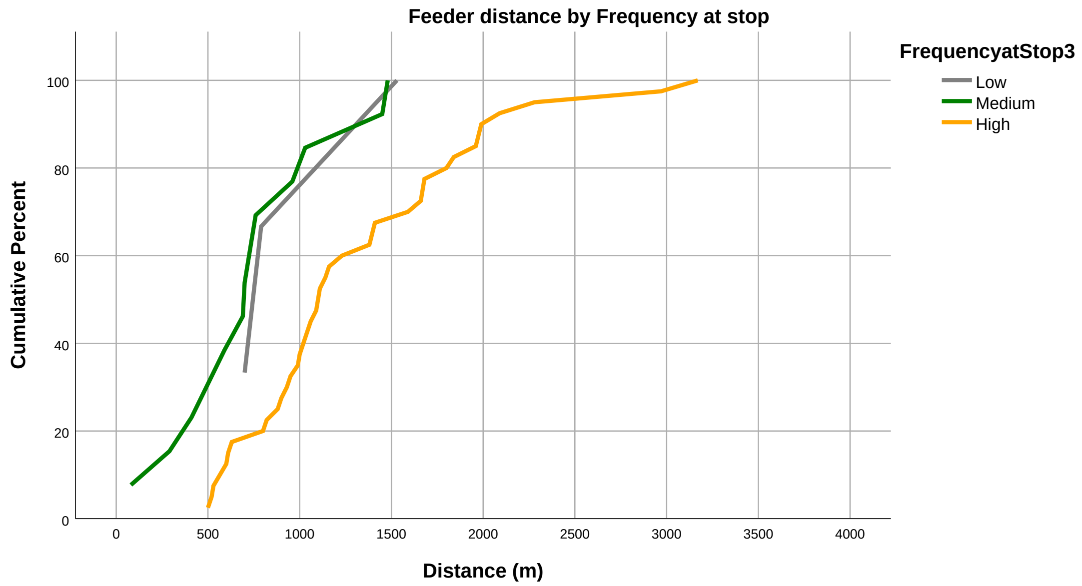

Figure 4.11: Distance-decay functions of frequency at stop (cycling). Unexpected results: 'medium' distances are the shortest.

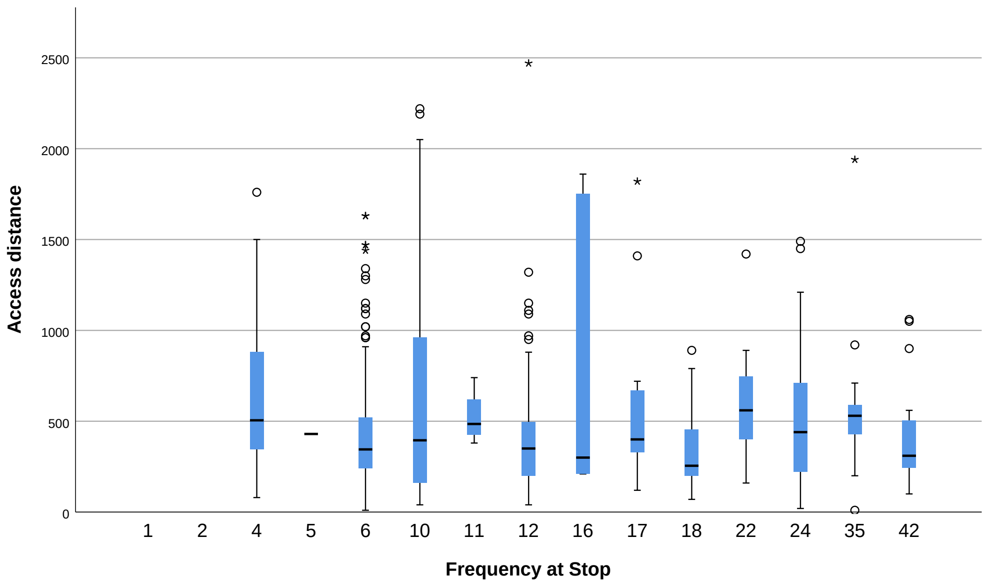

Figure 4.12: Box plot of frequency at stop (walking)

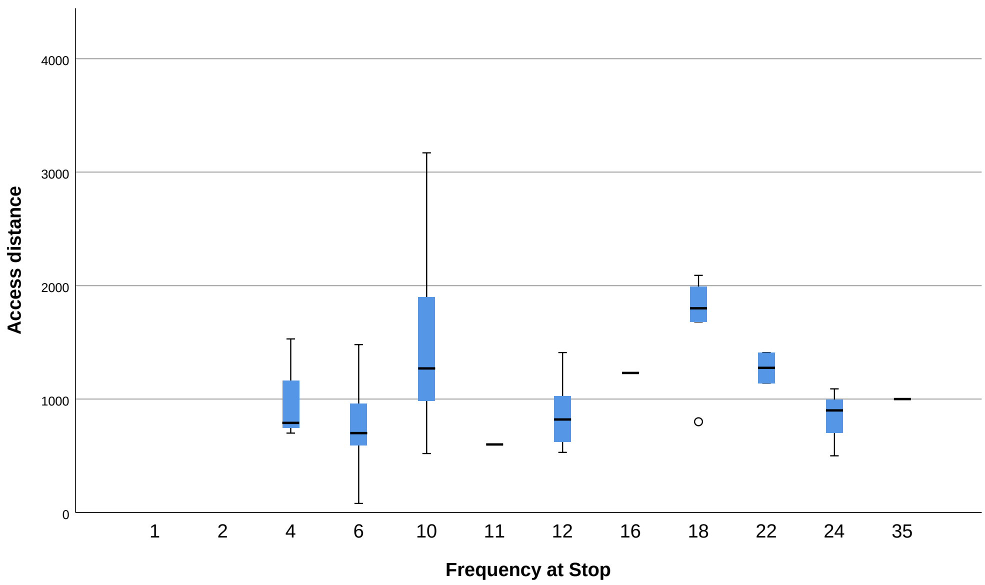

Figure 4.13: Box plot of frequency at stop (cycling)

Directness of tram line

The directness of the tram line, which is a measure of quality, is found to have a significant effect on feeder walking distance: $\chi^2 = 7.021$ and $p = .03$. In Figure 4.14 it is visible that only the 'inbetween' category shows longer feeder distances compared with the others. For cycling, however less convincing, the same pattern as for walking is visible in Figure 4.15. Also here the effect seems significant ($\chi^2 = 7.105$ and $p = .029$).

These patterns are different from the literature expectations, which were that the 'direct' tram line type would attract the longest distances. This can be explained in several ways. The directness of the tram line might be related with built environment factors, especially because the diversity of lines in the case study area might not be large enough to ensure independence. Also the categorisation of the directness types (as described in section 3.2) could influence the outcome. Lastly, directness could be capturing other factors, that have more influence, e.g. tram speed or built environment factors. This is tested in the logistic regression model.

Transit stop density

Transit stop density is tested twice: once for bus and tram stops together, and once for tram stops only. The effects for walking are both found significant at the 0.01 level; the effect size of 'tram stop density' is even larger than for 'bus and tram stop density' (r_s = -.203; p = .000; r_τ = -.148; p = .000). Remarkably, for cycling the results are not significant for 'bus and tram stop density' (r_s = -.119; p = .381; r_τ = -.087; p = .380), but they are for 'tram stop density' (r_s = -.442; p = .001; r_τ = -.344; p = .001).

These results confirm the statement of Daniels and Mulley (2013) that public transport supply is largely related with the distance people bridge to or from the stop. The outcomes also suggest that many travellers, especially cyclists, will overtake a bus stop to bridge a longer distance to or from a tram stop. However, it is not known if this is due to an inherent preference for tram over bus, or that the lower service quality of the bus lines makes travellers choose to overtake a bus stop.

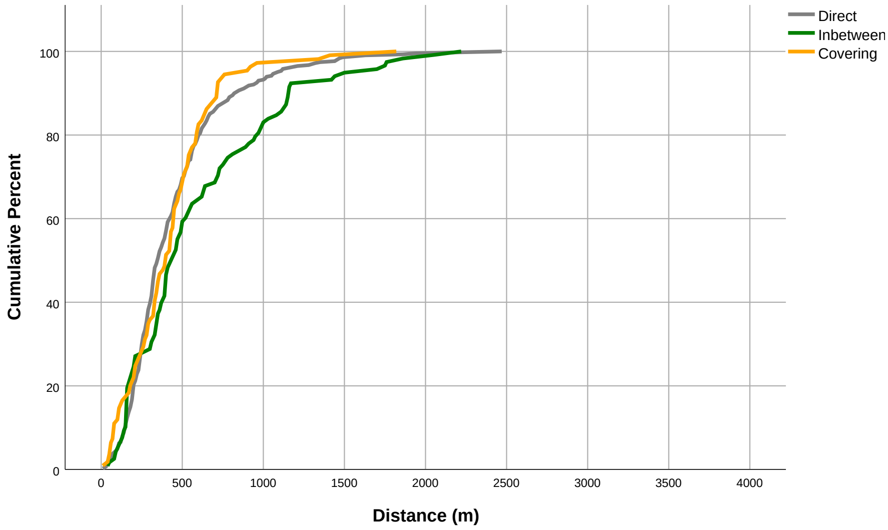

Figure 4.14: The distance-decay functions for directness of line (walking)

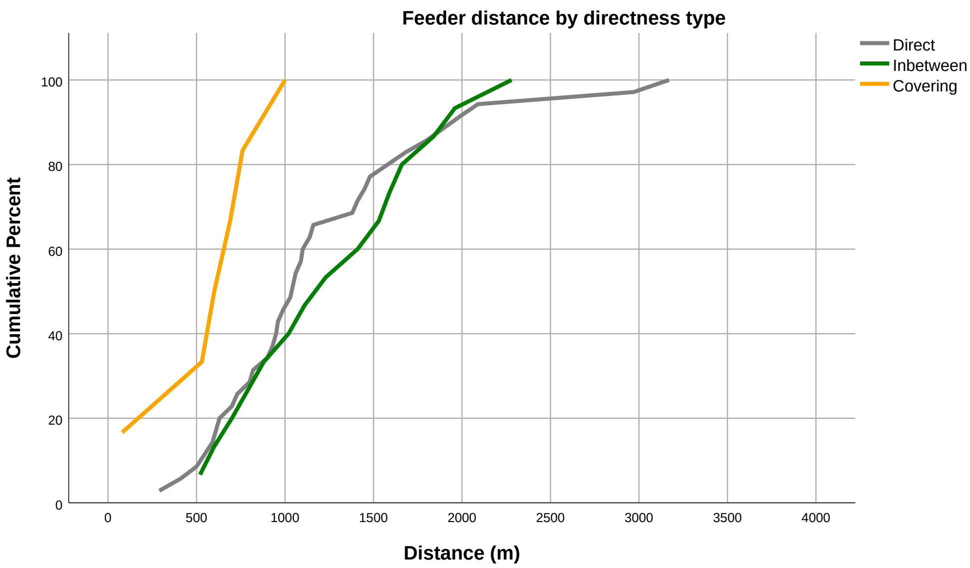

Figure 4.15: The distance-decay functions for directness of line (cycling)

4.1.3. Factors affecting feeder mode choice

In this section, the effects of the factors on feeder mode choice are explored, of which the results are represented in Table 4.2 and Figure 4.16. Only the choice for either walking or cycling is examined, so other feeder modes are left out of the results.

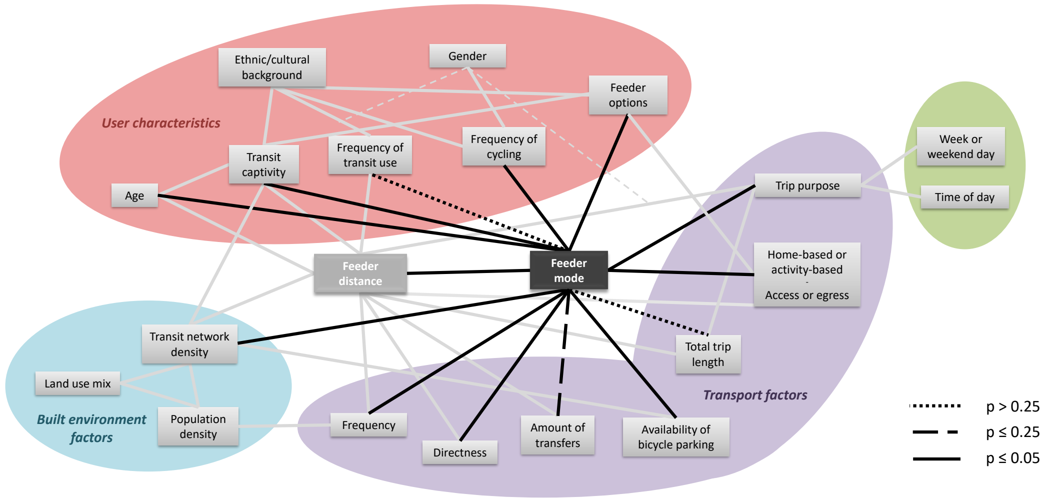

Figure 4.16: Results from the bivariate statistical tests for feeder mode choice

Age

The effect of age on feeder mode choice are significant: r_{pb} = -.116 and p = .001. The expectation from section 2.5 was that younger people cycle more often to tram stops than older people (Harms et al., 2014; Leferink, 2017), which is the same pattern as in Figure 4.17.

Transit captivity

Transit captivity is was found significant (χ^2 = 4.415 and p = .036). It appears that people who do have other options for making the total trip, cycle more than those who do not. This is in line with the findings of Flamm and Rivasplata (2014) who found that most bicycle-transit users were choice riders. However, a relation exists between the available options that the bicycle-tram users had (which could be the bicycle) and their bicycle availability. So the relation between bicycle as a feeder mode and having a car available or not, remains unclear.

Feeder options

Feeder options are defined here as having access to a bicycle or not, because the bicycle is the main mode of interest in this research. The factor is highly significant (χ^2 = 201.624 and p = .000). Having a bicycle available increases the probability of using one to get to or from a tram stop, which is as anticipated.

Frequency of transit use

Frequency of transit use leads to a non-significant result for the chi square test (χ^2 = 4.526 and p = .339), although Leferink (2017) and Shelat et al. (2018) noted that frequent transit travellers are more likely to use the bicycle as feeder mode.

Frequency of cycling

The effect of frequency of transit on feeder mode choice is highly significant as well (χ^2 = 47.649 and p = .000), which is again as expected. The results in Figure 4.20) confirm the statement of Van Mil et al. (2018) that travellers who cycle at least 3 times a week, are more likely to use cycling as a feeder mode. People who rarely or never cycle, use walking much more often as a feeder mode than cycling. Still, of the people who stated they cycle 4-7 days per week, 85% walked to the tram.

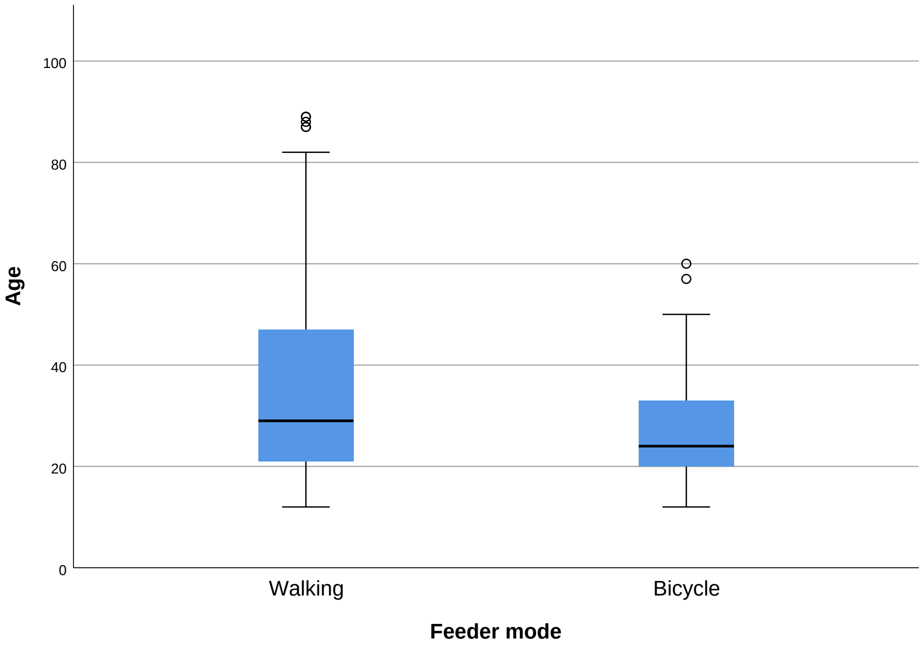

Figure 4.17: Feeder mode choice by age

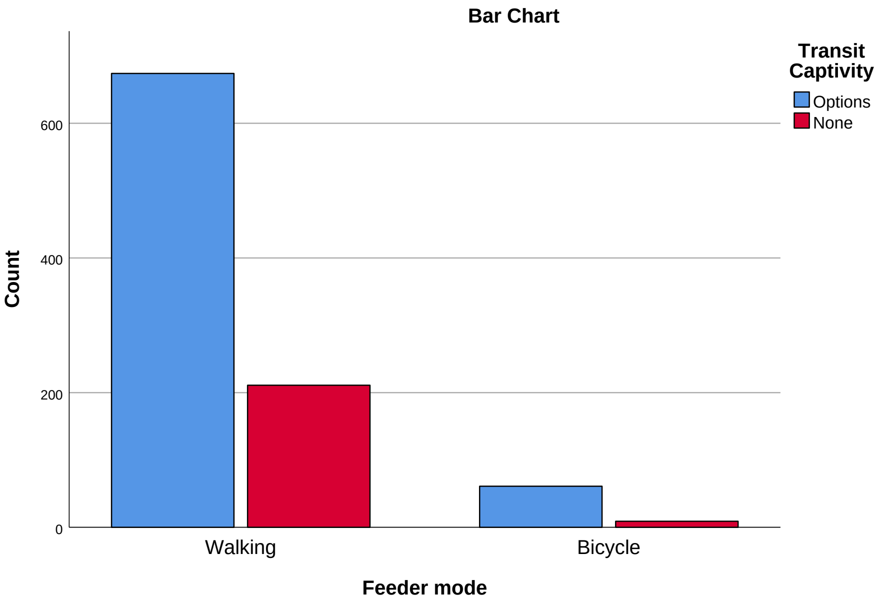

Figure 4.18: Feeder mode choice by transit captivity

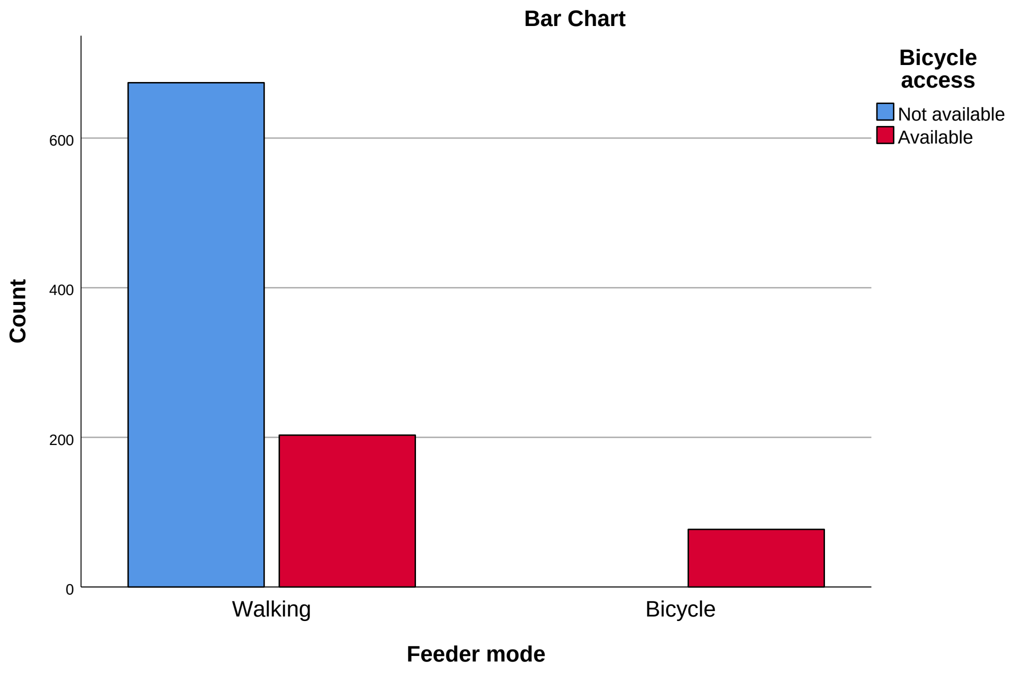

Figure 4.19: Feeder mode choice by feeder options

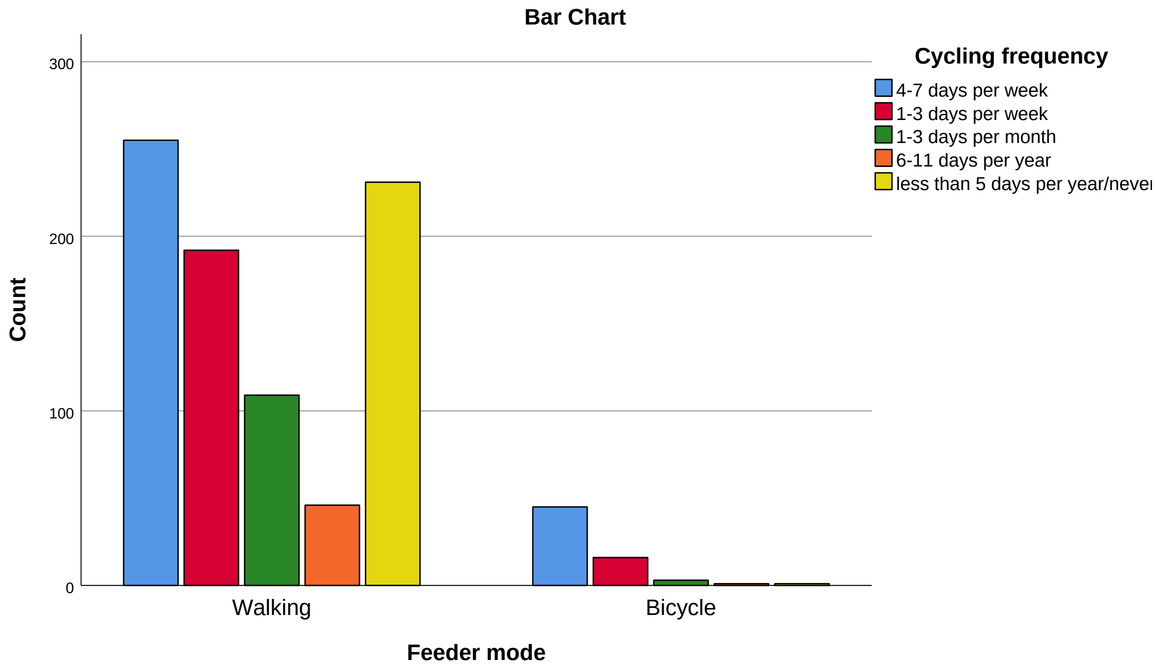

Figure 4.20: Feeder mode choice by cycling frequency

Trip purpose

The effect of trip purpose on feeder mode choice is significant ($\chi^2 = 12.282$ and $p = .031$). For utilitarian purposes the bicycle is used relatively more often than for non-utilitarian purposes (Figure 4.21). When looking more closely into the results, it can be noticed that school purpose has the highest share of bicycle use when controlling for total amount of observations. Of the non-utilitarian purposes, for visiting family or friends the bicycle is used most often.

Home-based or activity-based access and egress

When the four categories (home-based access, activity-based access, home-based egress and activity-based egress) are considered, significant results come up ($\chi^2 = 25.911$ and $p = .000$). For feeder mode choice home-based versus activity-based was expected to be more influential than access versus egress.

This is confirmed when looking at the separate results. The effect of access versus egress on feeder mode choice is non-significant ($\chi^2 = .865$ and $p = .352$), but the effect of home-based versus activity-based is significant ($\chi^2 = 24.538$ and $p = .000$). It is clear that more travellers use the bicycle at the home-end compared with the activity-end (see Figure 4.22). However, this is likely to be largely related with feeder options. Home-based versus activity-based will be the factor that is used in the model.

The widespread unavailability of the bicycle at the activity-end shows the potential for bicycle sharing systems in areas with many activities as opposed to residential areas, something which was already suggested by Kager and Harms (2017) and Martin and Shaheen (2014).

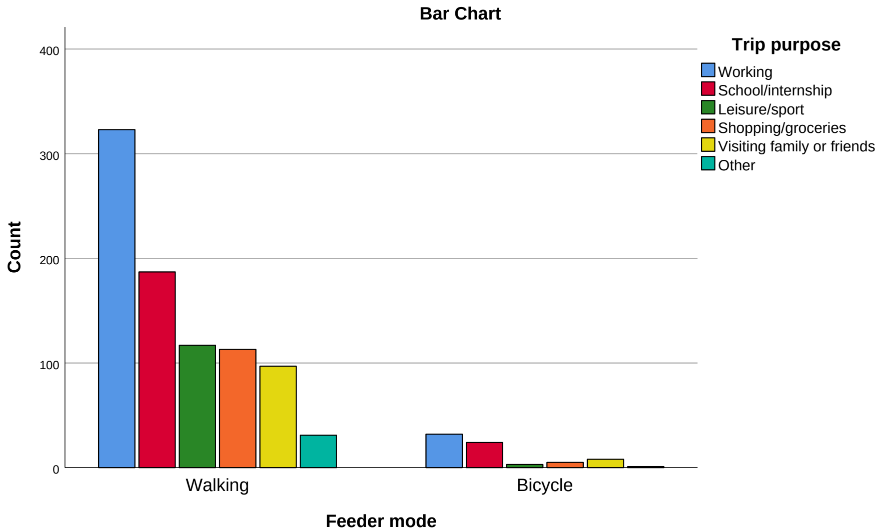

Figure 4.21: Feeder mode choice by trip purpose

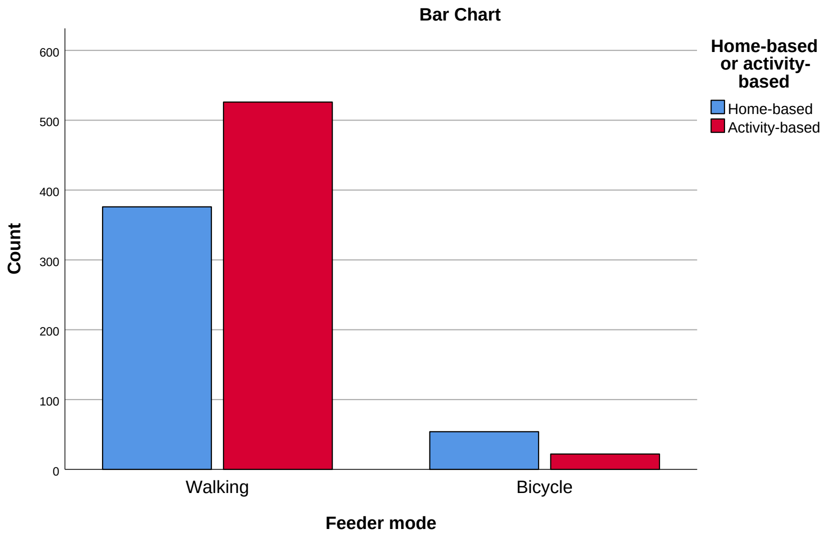

Figure 4.22: Feeder mode choice by home-based versus activity-based

Feeder distance
A significant effect on feeder mode choice is found for feeder distance (r_{pb} = .438; p = .000). This is as expected, because the same result was described for the relation between feeder mode and feeder distance in subsection 4.1.2.

Amount of transfers
The amount of transfers are not significantly related with feeder mode choice (χ^2 = 5.372 and p = .068). This is remarkable, because from the theoretical framework it was expected that people would use a bicycle in order to avoid a transfer (Kager & Harms, 2017; Van Goeverden & Egeter, 1993). And although the data show a trend towards that phenomenon (see Appendix B), no large effects are visible. However, the p-value is under .25, so it will be tested in the logistic regression model.

Total trip length
The total trip length has a non-significant effect on feeder mode choice (r_{pb} = -.023; p = .519. Since longer trip lengths were also non-significantly related with longer feeder distances, which was described in section 2.5, this outcome about feeder mode choice is not surprising. This might be related with how the trip length calculation was carried out: 'as the crow flies' distances, which is only a rough indication of the total trip length.

Frequency at the stop
Frequency at the stop is significant for feeder mode choice: r_{pb} = .232 and p = .000. This confirms the expectations from section 2.5, where from the The Hague bicycle analysis low frequencies (<5) were related with more bicycle-tram use. However, because for feeder distance some unexpected results came up, which might be related with the measurement of the cumulative frequency, the same might be the case with feeder mode choice. Also, opposite effects might be present. On the one hand, higher frequencies are expected to attract more cyclists because they chose for a stop further away. On the other hand, low frequencies could also attract more cyclists, because travellers want to avoid missing a tram because of the waiting time. Lastly, it is hard to disentangle the effects of the frequency with other built environment factors, especially with the low amount of lines that was covered in this research.

Directness of tram line
The effect of the directness of a tram line on the feeder mode choice was found to be significant (χ^2 = 10.067 and p = .007). However, p < 0.25. What is noticeable from Figure 4.23, is that for the 'covering' lines the bicycle is clearly less used than for the 'direct' lines. The values for the 'inbetween' lines lay in the middle. These trends are in line with the expectations from the theoretical framework.

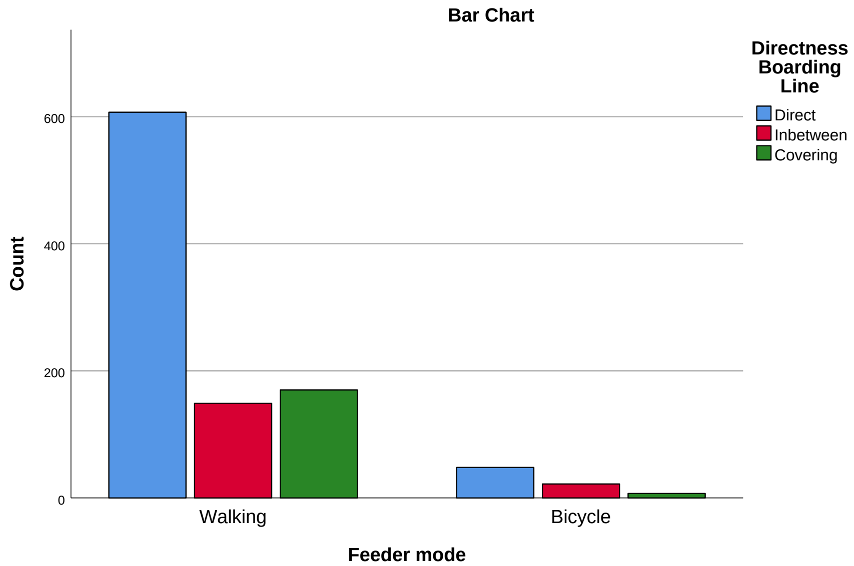

Figure 4.23: Feeder mode choice by directness

Transit stop density
Significant effects on feeder mode choice are found for both bus and tram stop density, and tram stop density. This is defined as the amount of tram stops within a 400m radius of the origin/destination. For bus and tram stop density, r_{pb} = -.253 and p = .000. For tram only stop density, r_{pb} = -.167 and p = .000. This is as expected, because transit stop density is largely related with feeder distance, which also affects feeder mode choice.

Availability of bicycle parking
The relation between the availability of bicycle parking and feeder mode choice is clearly visible from **??**, and is significant (χ^2 = 18.488 and p = .000). However, this is likely to be closely related with built environment factors, so the logistic regression model should be used to control for this.
Only free parking spaces were considered, and train station parking places were also taken into account.

4.1.4. Conclusion
In Table 4.2 the results of the statistical tests exploring the effects are summarised for both feeder distance and feeder mode choice. It stands out that more factors appear to influence feeder mode choice than feeder distance.
The factors from the bivariate analyses that are significantly related with feeder distance, are feeder mode, amount of transfers, frequency at the stop, directness and transit stop density. So no user characteristics seem to have an influence on feeder distance. Furthermore, trip purpose, home-based/activity-based access/egress and total trip length are significant at a 75% level. All of these factors (also displayed in Table 4.2) will form the input for the logistic regression model for feeder distance in section 4.2.
For feeder mode choice the following factors are found significant: age, transit captivity, feeder options, frequency of cycling, trip purpose, home-based/activity-based, feeder distance, frequency at the stop, directness, transit stop density and availability of bicycle parking. The amount of transfers is significant at a 75% level. These factors (also displayed in Table 4.2) will be used as the input for the logistic regression model for feeder mode choice in section 4.2.

Table 4.2: Results of the bivariate statistical tests for both feeder distance and feeder mode choice. The factors of which the results are displayed in bold, are further tested in the logistic regression models.

	Distance		Feeder mode	
	Test	Outcome	Test	Outcome

Age	Spearman's Rho and Kendall's Tau	walk: r_s = -.003; p = .947;
		r_s = -.002; p = .943.
		cycle: r_s = .072; p = .620;
		r_τ = .040; p = .687
			Point-biserial correlation	**r_{pb} = -.116; p = .001**

Transit captivity	Mann-Whitney U test	walk: U = 33657.5; p = .478 cycle: U = 118.0; p = .290	χ^2 test	**χ^2 = 4.415; p = .036**
Feeder options	N/A		χ^2 test	**χ^2 = 201.624; p = .000**
Frequency of transit use	Kruskal Wallis test	walk: χ^2 = 4.021; p = .403 cycle: χ^2 = 3.949; p = .413	χ^2 test	χ^2 = 4.526; p = .339
Frequency of cycling	N/A		χ^2 test	**χ^2 = 47.649; p = .000**
Trip purpose	Kruskal Wallis test	**walk: χ^2 = 1.805; p = .875** **cycle: χ^2 = 8.899; p = .113**	χ^2 test	**χ^2 = 12.282; p = .031**
Access/egress	Mann-Whitney U test	walk: U= 51898.0; p = .412 cycle: U = 305.0; p = .215	χ^2 test	χ^2 = .865; p = .352
HB/AB	Mann-Whitney U test	walk: U= 48818.5.0; p = .087 cycle: U = 224.5; p = .337	χ^2 test	**χ^2 = 24.538; p = .000**
HB/AB Access/egress	Kruskal Wallis test	**walk: χ^2 = 5.336; p = .149** **cycle: χ^2 = 2.470 and p = .481**	χ^2 test	χ^2 = 25.911; p = .000
Feeder mode	Kruskal Wallis test	χ^2 = 103.991; p = .000	N/A	
Feeder distance	N/A		Point-biserial correlation	**r_{pb} = .438; p = .000**
Amount of transfers	Kruskal Wallis test	**walk: χ^2 = 8.373; p = .015** **cycle: χ^2 = .069; p = .793**	χ^2 test	**χ^2 = 5.372; p = .068**
Total trip length	Spearman's Rho and Kendall's Tau	**walk: r_s = -.012; p = .772;** **r_τ = -.008; p = .768** **cycle: r_s = .233; p = .087;** **r_τ = .164; p = .080**	Point-biserial correlation	r_{pb} = -.023; p = .519
Frequency at stop	Spearman's Rho and Kendall's Tau	**walk: χ^2 = 9.831 and p = .007** **cycle: χ^2 = 9.275 and p = .010**	Point-biserial correlation	**r_{pb} = .232; p = .000**
Directness of tram line	Kruskal Wallis test	**walk: χ^2 = 7.021; p = .03** **cycle: χ^2 = 7.105; p = .029**	χ^2 test	**χ^2 = 10.067; p = .007**
Transit stop density	Spearman's Rho and Kendall's Tau	**walk, tram only:** **r_s = -.203; p = .000; r_τ = -.148; p = .000.** **cycle:** **bus and tram: r_s = -.119; p = .381; r_τ = -.087; p = .380** **tram only: r_s = -.442; p = .001; r_τ = -.344; p = .001**	Point-biserial correlation	**bus and tram:** **r_{pb} = -.167; p =.000;** **tram only:** **r_{pb} = -.253; p = .000**
Availability of bicycle parking	N/A		χ^2 test	**χ^2 = 18.488; p = .000**

Table 4.3: The results for three models with each two distance classes. The thresholds between the classes are 400m, 500m and 600m.

	Model 400m	Model 500m	Model 600m
χ^2	197.289	253.205	208.176
p	.000	.000	.000
Cox & Snell R2	.243	.301	.255
Nagelkerke R2	.325	.411	.369

4.2. Multivariate analysis: logistic regression

In section 4.1 the bivariate analyses, which investigate the relation between the factors and the two subjects of interest (feeder distance and feeder mode choice), have been carried out. In this section, multivariate analyses are carried out, using the factors that were found significant in the bivariate analyses. This is done in the form of two separate logistic regression models: a feeder distance model and a feeder mode model. These investigate the effects of the factors simultaneously, in order to capture the interrelations between the factors.

Although feeder distance is measured on a continuous scale, multiple linear regression could not be applied: the residuals of the data follow a non-normal distribution, which means one the conditions for using multiple linear regression is violated (Field, 2009). Therefore, the originally continuous distance data is regarded as separate distance classes, so that logistic regression can be performed, a method that is independent from the distribution of the data (Field, 2009). Another advantage of looking at distance classes instead of distance as a continuous variable is that they better represent the choice that travellers make. The low distance classes are expected to be in line with the choice for the closest stop, based on the transit stop density. The larger distance classes are associated with the choice for a stop further away. For feeder mode choice, a logistic regression model is suitable as well, because the outcome variable is binary: either walking or cycling .

4.2.1. Feeder distance model

The first step in estimating the logistic regression model for feeder distance, is forcing all significant effects from section 4.1 into the model. This is first done for several models with three distance classes, to compare which distance classes reflect the differences in feeder distances best. The thresholds between the classes are as follows.

Model 1: 200m and 400m
Model 2: 300m and 600m
Model 3: 400m and 600m

The lowest distance category is used as the reference category for each model. The results of those models, that are described in Appendix C, indicate that three distance classes do not accurately describe the feeder distance data, because for all three models, two groups show insufficient distinction.

Based on those results, either 400m or 600m is deemed a suitable cut-off point for a logistic regression model with two groups of feeder distance. Because 500m lies in between those values, three models with two groups are estimated, of which the 500m cut-off value performs best, as can be seen from the results in Table 4.3. 500m is in line with the 400m 'as the crow flies' buffer area that HTM maintains, which leads to roughly a network distance of 500m. Different additions are made to the standard model, which are then compared, as depicted in Table 4.5.

Standard model

The standard model is thus estimated with two distance classes: 0-500m and >500m. The significant factors from the bivariate analyses, which are used as input for the standard model, are: feeder mode, frequency at stop, transit stop density, directness of line and amount of transfers. However, the amount of transfers produces errors in the model, and is therefore left out of it. Cycling increases the probability of bridging a distance that is farther than 500m. This effect is large: when all other variables stay the same, cycling increases the relative risk of travelling farther than 500m by 11.453. A higher tram stop density decreases the probability of bridging more than 500m to a stop. This effect gets larger as the tram stop density increases, and is also substantial: Exp(B) ranges from .029 to .050.

The model is significant ($\chi^2 = 253.205$ and $p = .000$). The amount of cases that is estimated correctly, increased from 62.8% to 79.2%; the Cox Snell R2 = .301; Nagelkerke R2 = .411. Feeder mode (cycling increases the probability for >500m group) and tram stop density (higher density decreases probability for >500m group) are

Table 4.4: Feeder distance model: results

	Standard model			Model + factors sign. at 75%			Model + land use mix/ population density%		
Variable	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Constant	2,575	**,000*** **	13,136	2,775	**,000*** **	16,044	2,511	**,000*** **	12,312
Feeder mode (base: walking)	2,438	**,000*** **	11,453	2,116	**,000*** **	8,302	2,481	**,000*** **	11,956
Frequency at the stop (base: low)									
Medium	-,693	,186	,500	-,511	,397	,600	-,603	,261	,547
High	-,043	,930	,958	,153	,788	1,166	-,099	,844	,906
Directness of the line (base: direct)									
Inbetween	-,412	,213	,662	-,517	,163	,596	-,343	,307	,710
Covering	,192	,446	1,212	,248	,382	1,281	,362	,182	1,436
Tram stop density (Base: 0 stops within 400m)									
1 stop within 400m	-2,996	**,000*** **	,050	-3,448	**,000*** **	,032	-2,924	**,000*** **	,054
2 stops within 400m	-3,533	**,000*** **	,029	-4,016	**,000*** **	,018	-3,445	**,000*** **	,032
3 stops within 400m	-3,688	**,000*** **	,025	-4,128	**,000*** **	,016	-3,275	**,000*** **	,038
4 or more stops within 400m	-3,557	**,000*** **	,029	-3,889	**,000*** **	,020	-2,409	**,000*** **	,090
Trip purpose (base: working)									
School/internship				,176	,526	1,192			
Leisure/sport				,316	,362	1,372			
Shopping/groceries				-,244	,493	,784			
Visiting family/ friends				,055	,885	1,057			
Other				,392	,526	1,480			
Total trip distance				-,021	**,017***	,980			
Feeder type (base: home-based access)									
Activity-based access				,262	,383	1,300			
Home-based egress				,257	,416	1,293			
Activity-based egress				-,001	,997	,999			
Interaction (base: land use mix/pop. density/ 0 stops within400m)									
land use mix/pop. density/1 stop							,000	,721	1,000
land use mix/pop. density/2 stops							,000	,635	1,000
land use mix/pop. density/3 stops							,000	,134	1,000
land use mix/pop. density/>3 stops							,000	**,008****	1,000

Table 4.5: Feeder distance model: comparison between the standard model, the added factors, significant. at 75% level and the added interaction effects

	Standard model	Standard model + factors sign. at 75%	Standard model + land use mix and population density
χ^2	253.205	241.438	267.353
p	.000	.000	.000
Cox & Snell R2	.301	.319	.315
Nagelkerke R2	.411	.437	.430

only ones that are completely significant; frequency at stop and directness are not significant.

Factors significant at 75% level
In addition to the factors in the standard model, the factors with a significance value of under .25 in the bivariate analyses are also tested. These are trip purpose, home-based/activity-based access/egress and total trip distance. The added factors are not significant, except for total trip distance. A longer total trip distance decreases the probability of belonging to the >500m group, while from section 2.5 it was expected the other way around. It could be that other factors, that are also related with total trip length, are more influential than just total trip distance. Furthermore, maybe this factor has little influence within a single mode and within one city. The significant factors remain the same, although the effect of cycling is slightly reduced (Exp(B)=8.302), while the tram stop density is slightly increased (Exp(B) ranges from .016 to .032).
The model is significant (χ^2 = 241.438 and p = .000) and improves slightly compared with the standard model, although the χ^2 is lower. Cox Snell R2 = .319; Nagelkerke R2 = .437. The amount of cases that is estimated correctly, increases from 63.9% to 80.1%.

Land use mix and transit stop density
The combined interaction effect of land use mix and population density with transit stop density slightly improves the standard model. The binary logistic model is significant (χ^2 = 267.535; p = .000). Cox Snell R2 = .315; Nagelkerke R2 = .430. Compared with the null model, which excludes all factors, the model increases it percentage of correctly classified cases from 62.7% to 79.3%.
The interaction factor is not significant for most categories, only for the highest transit stop density (although the effect size is zero). Frequency at stop not significant anymore. This indicates that the built environment factors partly capture the characteristics of frequency at stop.

4.2.2. Feeder mode model

Standard model
The standard logistic regression model for feeder mode choice is defined as the model with all input variables that were found to have a significant effect in **??**. So age, transit captivity, frequency of cycling, home-based versus activity-based, availability of bicycle parking, frequency at the stop, directness of the line and transit stop density and distance to the stop. Feeder options is left out of the model, because it leads to irregular, very high standard errors, so that the odds ratio (Exp(B)) is estimated at zero. After estimating the standard model, the factors that are significant at the 75% level, and the user characteristics and built environment factors are added. This is done to test if they improve the model.

The model is significant χ^2 = 159.425; (p = .000). The Cox & Snell pseudo R^2 = .236; Nagelkerke pseudo R^2 = .574. Compared with the null model, which excludes all factors, the model increases it percentage of correctly classified cases from 92.6% to 95.4%.
However, many of the variables are non-significant in the model; only feeder distance, cycling frequency, home-based/activity-based and transit stop density have significant values. Every meter that is added to the feeder distance, increases the probability of cycling by 1.002. Furthermore, the effect of a low frequency of cycling is substantial: compared with cycling 4-7 days a week, cycling with a lower frequency decreases the probability of cycling as a feeder mode by .042 (for cycling less than 11 days per year) and by .091 (for cycling 1-3 days per month). The difference between cycling 1-3 days per week and 4-7 days per week is not significant.

Table 4.6: Feeder mode choice model: comparison between the standard model, the added factors significant at 75% level and the added interaction effects

	Standard model	Standard model + factors sign. at 75%	Standard model + ethnic/cultural background and gender	Standard model + land use mix and population density
χ^2	159.425	162.246	150.787	160.580
p	.000	.000	.000	.000
Cox & Snell R2	.236	.249	.253	.238
Nagelkerke R2	.574	.592	.611	.578

An activity-based feeder trip decreases the probability of choosing the bicycle as feeder mode by .273. Compared with a tram stop density of 0 stops within 400m, a tram stop density of 1 stop within 400m decreases the probability of cycling to the stop by .111. The other tram stop density categories are not significant.
Most of these effects are as expected. However, it is unexpected that bicycle parking availability is not significant in the model. This might have to do with the relation between the built environment; tram stops in areas that are suitable for bicycle as feeder mode, are likely to have been already designed for it.

Factors significant at 75% level
From the bivariate analyses the amount of transfers and the total trip distance are found to be below the .25 significance level threshold. When adding them to the logistic regression model, it improves slightly. However, both factors are insignificant in the model. All other have more or less the same values as the standard model.

Ethnic/cultural background and gender
The combined interaction effect of gender and ethnic/cultural background with transit captivity is added, just like the combined interaction effect of gender and ethnic/cultural background with frequency of cycling. The binary logistic model with interaction effects is significant χ^2 = 150.787; (p = .000) and performs slightly better with the interaction effects (see Table 4.6). Compared with the null model, which excludes all factors, the model increases the percentage of correctly classified cases from 92.5% to 96.1%.
None of the interaction effects are significant in the model. And although the χ^2 of the model with interaction effects is slightly lower than the standard model, the pseudo R2 test indicate that more variance is explained by the model. Also, more cases are correctly classified.

Land use mix and transit stop density
The combined interaction effect of land use mix and population density with transit stop density hardly improves the standard model. The binary logistic model is significant χ^2 = 160.580; (p = .000). Compared with the null model, which excludes all factors, the model increases it percentage of correctly classified cases from 92.6% to 95.6%.

4.2.3. Conclusion

A logistic regression model with two distance classes and a cut-off point of 500m between those classes, is deemed to describe the feeder distance data best. In the feeder distance model, only feeder mode and transit stop density are significant. Total trip distance is also found to be significant when added to the model. For feeder mode choice, a logistic regression model is estimated as well, where feeder distance, cycling frequency, home-based/activity-based and transit stop density are significant factors. Other factors are not found significant when added the model. The user characteristics ethnic/cultural background and gender slightly improve the feeder mode choice model as interaction effects. Land use mix and population density hardly improve the feeder distance model, but do improve the feeder mode choice model. section 4.3 further explores the factors in a qualitative way.

Table 4.7: Feeder mode model: results

	Standard model			Model + factors sign. at 75%			Model + ethnicity/gender			Model + land use mix/ population density		
Variable	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Constant	-1,944	0,201	0,143	-1,832	0,234	0,160	-3,208	0,098	0,040	-1,713	0,266	0,180
Feeder distance	0,002	**0,000*****	1,002	0,002	**0,000*****	1,002	0,003	**0,000*****	1,003	0,002	**0,000*****	1,002
Age	-0,030	0,130	0,970	-0,032	0,120	0,968	-0,041	0,087	0,960	-0,031	0,130	0,970
Transit captivity (base: other options for trip)												
No other options for trip	0,186	0,756	1,204	0,329	0,595	1,390	0,471	0,506	1,601	0,145	0,807	1,156
Frequency of cycling (base: 4-7 days per week)												
1-3 days per week	-0,924	0,067	0,397	-0,876	0,086	0,416	-0,812	0,159	0,444	-0,949	0,061	0,387
1-3 days per month	-2,396	**0,035***	0,091	-2,437	**0,035***	0,087	-1,848	0,111	0,158	-2,466	**0,033***	0,085
less than 11 days per year/never	-3,181	**0,004****	0,042	-3,276	**0,003****	0,038	-18,973	0,995	0,000	-3,213	**0,004****	0,040
Trip purpose (base: working)												
School/internship	0,218	0,727	1,243	0,120	0,853	1,127	0,422	0,549	1,526	0,179	0,776	1,196
Leisure/sport	-0,694	0,415	0,499	-0,669	0,443	0,512	-0,512	0,566	0,599	-0,672	0,433	0,511
Shopping/groceries	-0,713	0,428	0,490	-0,846	0,354	0,429	-0,561	0,562	0,571	-0,734	0,419	0,480
Visiting family/ friends	-0,453	0,562	0,636	0,356	0,653	1,427	0,113	0,892	1,120	-0,520	0,510	0,594
Other	-3,228	0,267	0,040	-3,454	0,264	0,032	-3,331	0,364	0,036	-3,311	0,271	0,036
Home-based/ activity-based (base: home-based)												
Activity-based	-1,299	**0,012***	0,273	-1,423	**0,007****	0,241	-1,745	**0,005****	0,175	-1,408	**0,008****	0,245
Bicycle parking (base: not available)												
Available	-0,153	0,798	0,858	-0,012	0,984	0,988	-0,063	0,924	0,939	-0,277	0,650	0,758
Frequency at the stop (base: low)												
Medium	0,949	0,421	2,583	1,262	0,291	3,534	1,906	0,197	6,727	0,811	0,497	2,250
High	1,068	0,318	2,911	1,296	0,229	3,656	2,400	0,083	11,021	0,979	0,365	2,660
Directness of the line (base: direct)												
Inbetween	0,320	0,676	1,377	0,120	0,879	1,128	0,229	0,779	1,257	0,287	0,709	1,332
Covering	0,423	0,566	1,527	0,313	0,686	1,368	0,226	0,800	1,253	0,626	0,414	1,871
Tram stop density (Base: 0 stops within 400m)												
1 stop within 400m	-2,196	**0,010***	0,111	-2,278	**0,008****	0,102	-1,737	0,052	0,176	-1,669	0,142	0,188
2 stops within 400m	-1,348	0,061	0,260	-1,423	**0,047***	0,241	-0,985	0,188	0,374	-0,880	0,322	0,415
3 stops within 400m	-1,389	0,074	0,249	-1,575	**0,040***	0,207	-1,362	0,115	0,256	-1,669	0,094	0,188
Amount of transfers (base: no transfers)												
One or more transfers				0,069	0,908	1,072						
Total trip distance				-0,030	0,226	0,970						
Interaction (base: Dutch by Female by Options for total trip)												
Non-dutch/male/ no options							-0,948	0,603	0,387			
Interaction (base: Dutch by female by cycling 4-7 days p. wk.)												
Non-dutch/male/ 1-3 days p. week							-1,476	0,305	0,229			
Non-dutch/male/ 1-3 days p. month							-16,479	0,999	0,000			
Non-dutch/male/ <11 days p. year							17,759	0,996	5,16E+07			
Interaction (base: 0 tram stops within 400m by land use mix by pop. density)												
1 tram stop/l. use mix/pop. density										0,000	0,552	1,000
2 tram stops/l. use mix/pop. density										0,000	0,440	1,000
>3 tram stops/l. use mix/pop. density										0,000	0,720	1,000

4.3. Qualitative analysis: motives behind stop and feeder mode choice

This section provides an exploration of the motives behind tram stop and feeder mode choices. If the motives of tram travellers for choosing certain stops or feeder modes are known, measures can be taken to for example decrease barriers to use the bicycle-tram combination. First, underlying motives for tram stop and feeder mode choice, as stated by respondents in the survey, are examined in subsection 4.3.1 and subsection 4.3.2. Then, in subsection 4.3.3 a spatial analysis is carried out to map the origins and destinations and their corresponding stops for the The Hague area, in order to discover patterns.

4.3.1. Tram stop choice: underlying motives

Motives for choosing a further stop

Around 9% of travellers indicated that they chose for a stop further away than their nearest stop. It has to be mentioned, however, that the spatial analysis in subsection 4.3.3 revealed that several tram travellers chose a stop further away, while they did not declare so in the survey. 43 respondents stated their reason for doing so in the form of an open answer. This gives insight in the motives of travellers for choosing a stop further away than their nearest, thus skipping one or more stops. In Figure 4.24 those responses are summarised. When multiple reasons were stated, they were processed separately.

'Avoiding a transfer' is the most common reason given for using a transit stop that is further than the nearest. This is as expected, because it is known from literature that a large penalty exists for transferring. Moreover, some people stated that they want to travel by a certain mode that is not offered at their nearest stop. This mostly concerns avoiding a bus trip leg, so could also be regarded as 'avoiding a transfer'. It is surprising that many people stated 'I like to walk' as a reason why they did not choose the closest stop. Apparently not all people optimise their journey to reduce travel time or inconvenience.

Respondents gave 'Avoiding waiting by walking' as a motive when travellers had just missed a tram and decided to walk to the next stop instead of waiting. Thus, this does not improve the total travel time and is not planned for. 'Stop better accessible' was mostly a reason given by people who used a different feeder mode than walking. The 'visit another location' motive is most often mentioned when another feeder mode than walking is involved. However, 'other location' is actually part of a tour and not a trip, and it reveals little information about the feeder distance between a stop and an origin/destination.

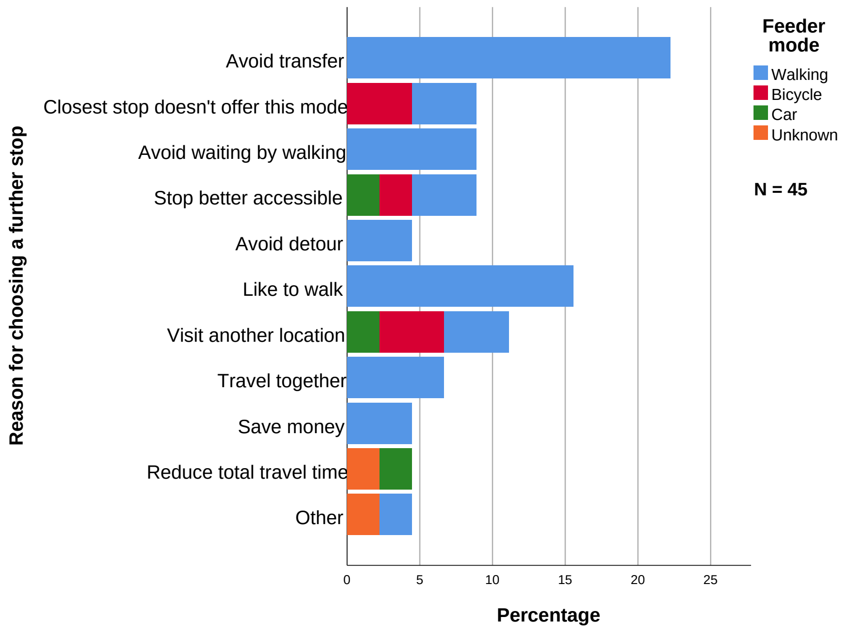

Figure 4.24: Motives for choosing a stop further away, as mentioned by the respondents

'Travel together', 'reducing the total travel time' and 'save money' were also mentioned motives for choosing a further stop. Especially the latter one is remarkable, since in most cases avoiding a transfer only saves a few eurocents with the Dutch smart card when travelling with multiple vehicles. Alternatively, the HTM day card is a fixed price and independent of transfers. It might be that these respondents are not aware of the price structure. 'Avoiding a detour' concerns the route of the line itself. Lastly, 'reduce total travel time' was stated as a motive, which is an evident reason.

Would you have chosen for a stop further away if...?
In the survey, respondents were also asked to state in which of three situations they would have chosen for a stop further away. The three situations are as follows.

... if you could avoid a transfer?
... if you could park your bike better at that stop?
... if more tram lines to your destination leave from that stop?

The answer possibilities were Yes, No or Not applicable. The answers distributions are visualised in Figure 4.25. The answer distributions of the 'avoid transfer' and 'more lines' questions are almost identical. For the 'park bicycle better' question more people answered 'No' or 'Not applicable'.

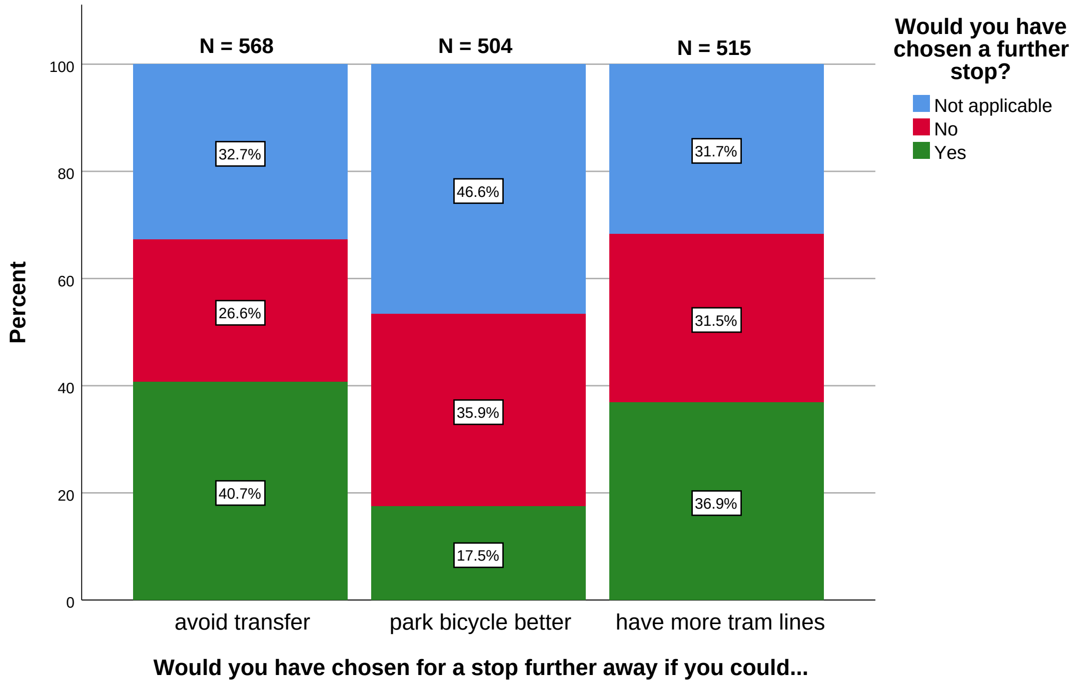

Figure 4.25: Distribution of answers for the three hypothetical questions concerning choosing a stop further away.

Figure 4.26 shows the combinations of answers given for all respondents. For clarity, the Not applicable answer category has been filtered out. There is a large group among the respondents that would always choose the nearest stop (around 37%). Another large group among the respondents, form the people who answered Yes for all questions (around 20%).
The values shift slightly when only considering the respondents that indicated they sometimes cycle to the stop, see Figure 4.27. Here, only around 25% would always choose the nearest stop, while the respondents who answered Yes for all questions increases to 33%. 34% of them is willing to cycle to a further stop if they could park their bike better there. Lastly, travelers who sometimes cycle to a tram stop, are more likely to choose a stop further away when they can avoid a transfer or have more options for their trip: this is around 55%, which is substantially higher than the 40% that corresponds with all respondents.

4.3.2. Feeder mode choice: underlying motives

In Figure 4.28 the usage of the bicycle-tram combination (travellers who used a bicycle to or from the tram stop, or both) is shown. The actual percentage of bicycle-tram users in the survey is around 16%. Figure 4.29 shows the amount of people stating they sometimes cycle to a tram stop: most respondents never cycle to the

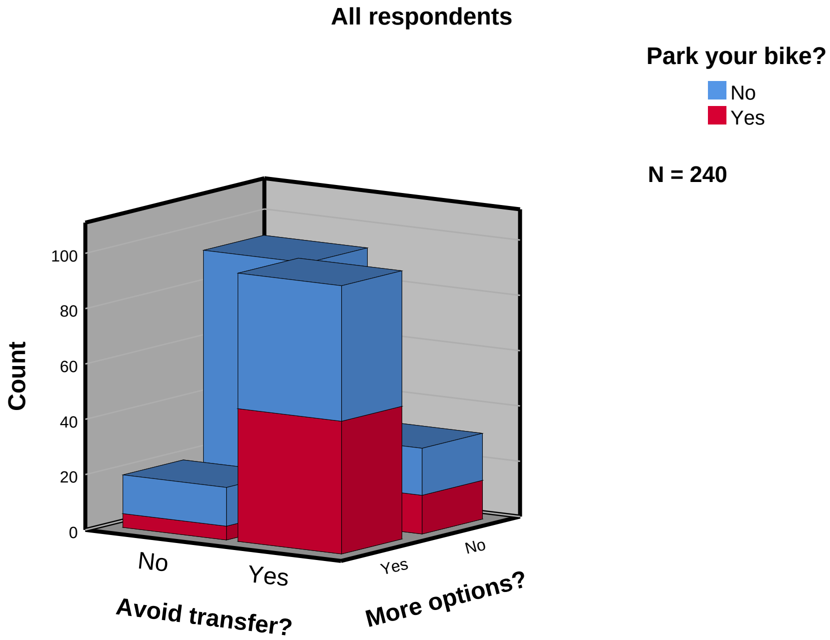

Figure 4.26: Exploring the three hypothetical questions concerning choosing a stop further away more in depth.

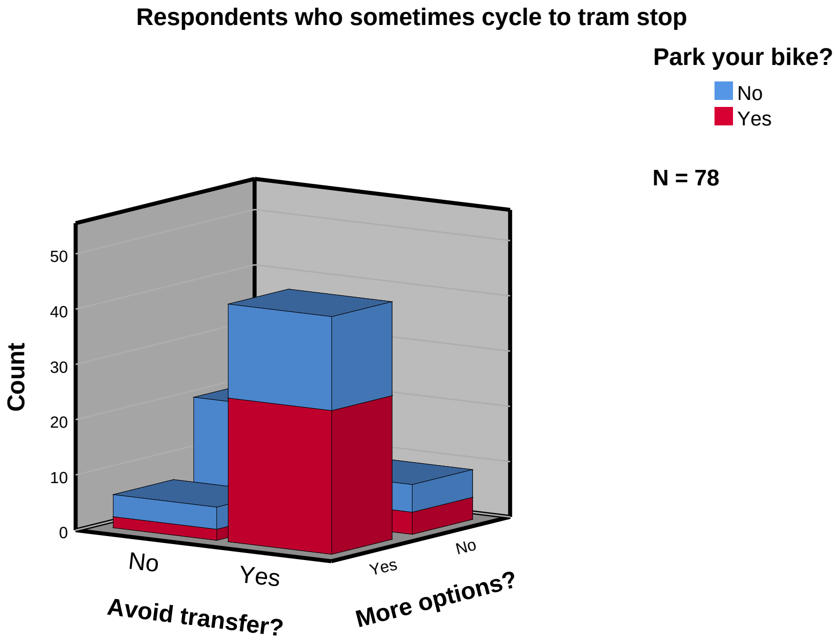

Figure 4.27: Exploring the three hypothetical questions concerning choosing a stop further away for respondents who sometimes cycle to a tram stop.

stop, but around 22% sometimes uses the bicycle-tram combination. The frequency of cycling of those 22% are visualised in Figure 4.30, where it becomes clear that almost 90% cycles at least once a week.

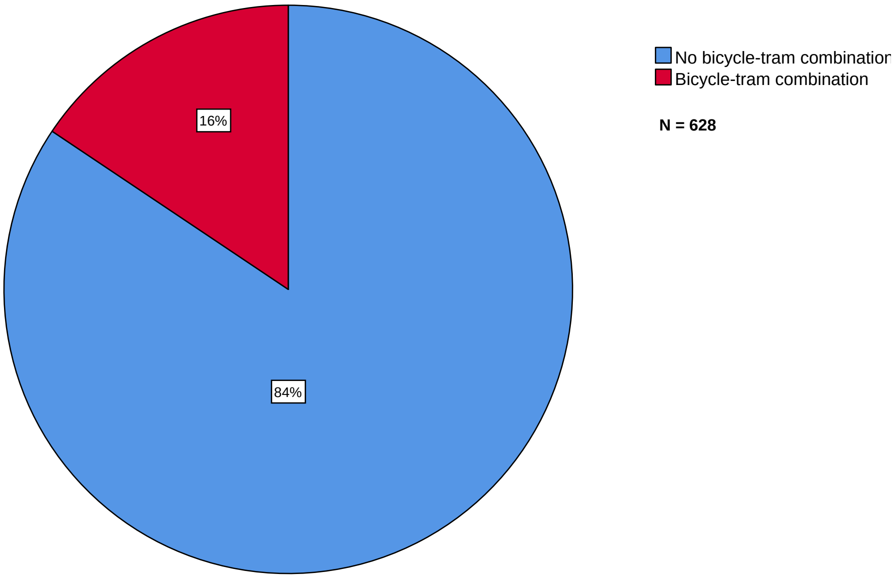

Figure 4.28: Percentage of respondents who uses the bicycle-tram combination in the trip made during the survey

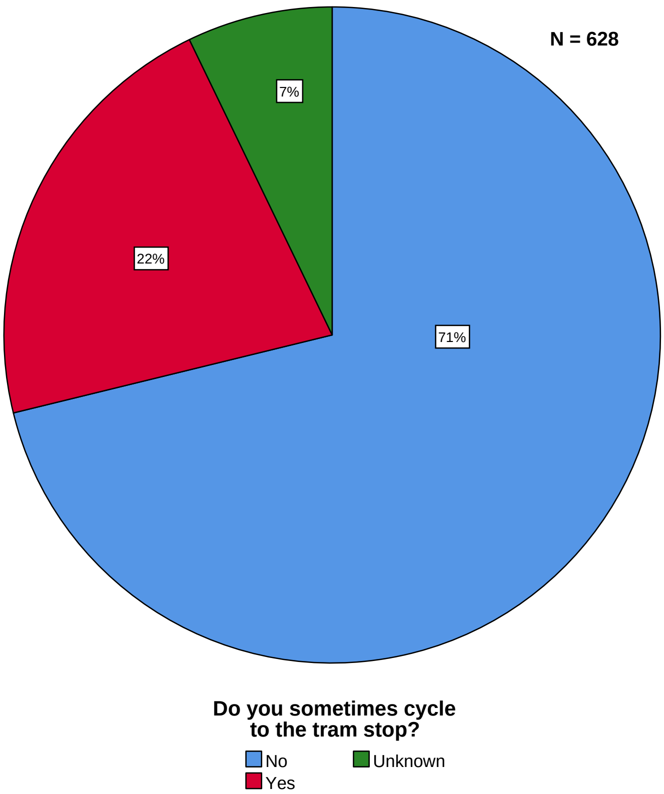

Figure 4.29: Percentage of respondents who sometimes cycle to the tram stop.

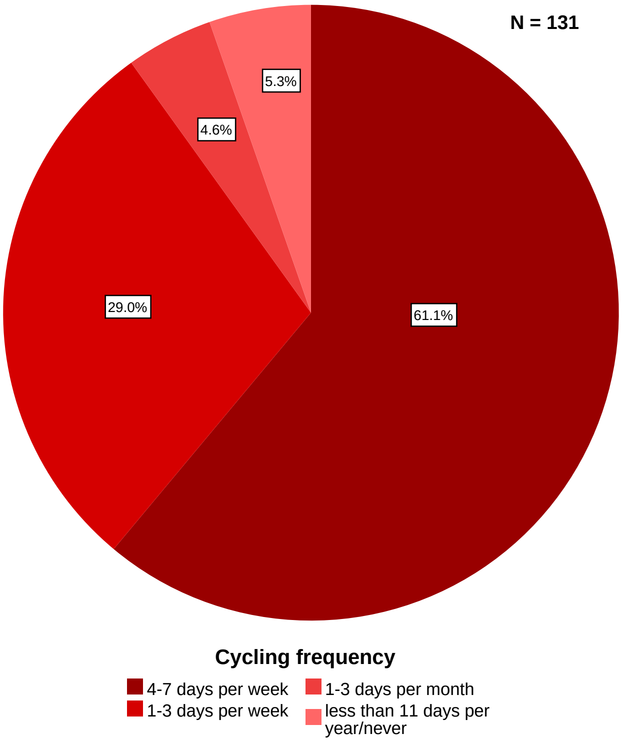

Figure 4.30: Cycling frequency of respondents who sometimes cycle to the tram stop.

Motives for using the bicycle-tram combination

94 respondents provided a reason for using the bicycle-tram combination. Several people stated they only use the bicycle when they are in a hurry, which is most likely to be interpreted as: otherwise they wouldn't have made the tram they were going for. Then, for some people the distance is an issue; their nearest stop is too far to walk. Here, the relationship with transit density is likely to be related. The most often given motive for using the bicycle-tram combination was 'reduce total travel time'. This is different from people who are in a hurry, because they would only use the bicycle when otherwise they would miss the tram, while people who want to reduce their total travel time decide in advance that they will use the bicycle in order to save time.

The convenience of using the bicycle as a feeder mode for tram was also mentioned several times. It is not clear, however, in what sense the respondents refer to this. It could be related to the time benefit, but this is not certain. Then, there are people who, like the choice for a further stop, visited a location before or after travelling by tram. Just like choosing a stop further away, 'save money' was sometimes given as a reason to cycle to or from a stop. However, again it is not immediately clear how this money is saved; the bicycle-tram combination could be cheaper in comparison with the car, or in comparison with using transit instead of the bicycle. As was already concluded in subsection 4.3.1, the latter hardly saves money.

There are some people who simply prefer cycling over walking. From the comments people gave, it became clear that differences in attitude towards the two modes exist between people. Exemplary, but opposite statements are 'I'm lazy so I walk' and 'I'm lazy so I cycle'. This might have to do with cultural differences and different perceived barriers for cycling by different people, perhaps due to different levels of cycling experience.

Avoiding a transfer was also mentioned several times, a motive that has also been noted in subsection 4.3.1.

Motives for not using the bicycle-tram combination

345 respondents provided a reason for not using the bicycle-tram combination. The majority states the simple fact that the stop is 'close enough for walking', thus the small distance is not suitable for cycling. This is also reflected in the answer 'too much time/effort', that several respondents gave. For some travellers the fact that they have to park their bicycle at a tram stop is a concern: 'no/not enough place for bicycle parking' and 'safety concerns' were mentioned several times, sometimes both by one respondent. Just like the preference for cycling over walking was mentioned as a motivation for choosing the bicycle (Figure 4.3.2), preferring

walking over cycling seems a motive for not choosing the bicycle as a feeder mode.

Then there are some practical matters concerning bicycle availability; some respondents 'don't have a bike' or have 'insufficient cycling skills'. Also, several travellers who do not live in the The Hague area, mentioned 'no trams in my home town' as a reason for not cycling to or from a tram stop. So apparently, they do not consider using the bicycle at the activity-side of their trip. For a small amount of respondents, the tram stop is too far away to cycle. And lastly, with 'then I would cycle all the way', some travellers mention the competition between the bicycle and the tram for single trips that was observed by Kager et al. (2016) and Martin and Shaheen (2014).

From these motives, three barriers for the bicycle-tram combination can be defined, that can be solved with bicycle facilities: no or insufficient bicycle parking places at the stop, the fear for damage or theft of the bike and the lack of an available bicycle. When these barriers are removed, the amount of bicycle-tram users could potentially rise from 21.7% to 37.6% of travelers, which is a substantial increase.

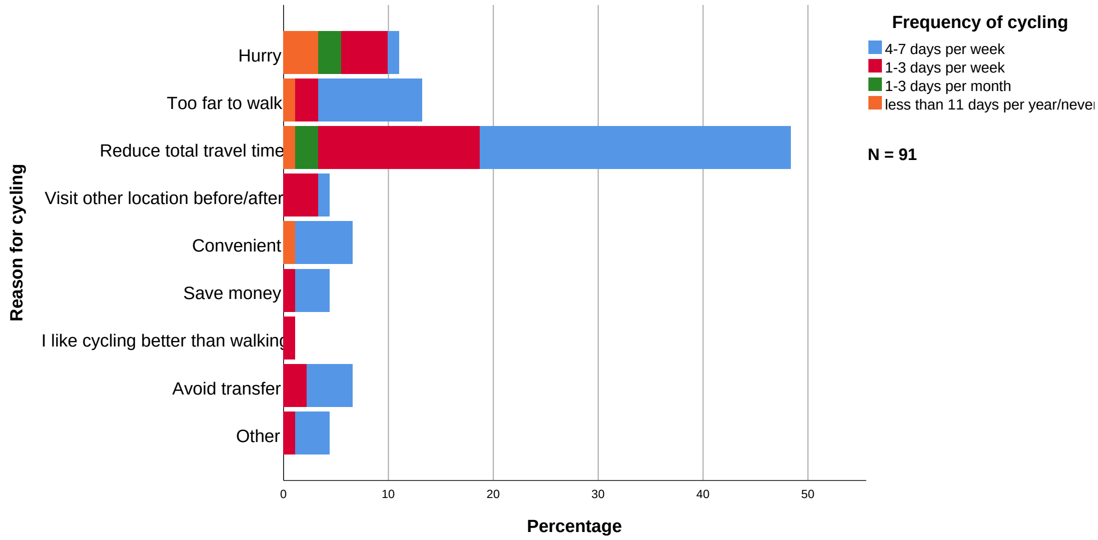

Figure 4.31: Motives for using the bicycle-tram combination, as mentioned by the respondents

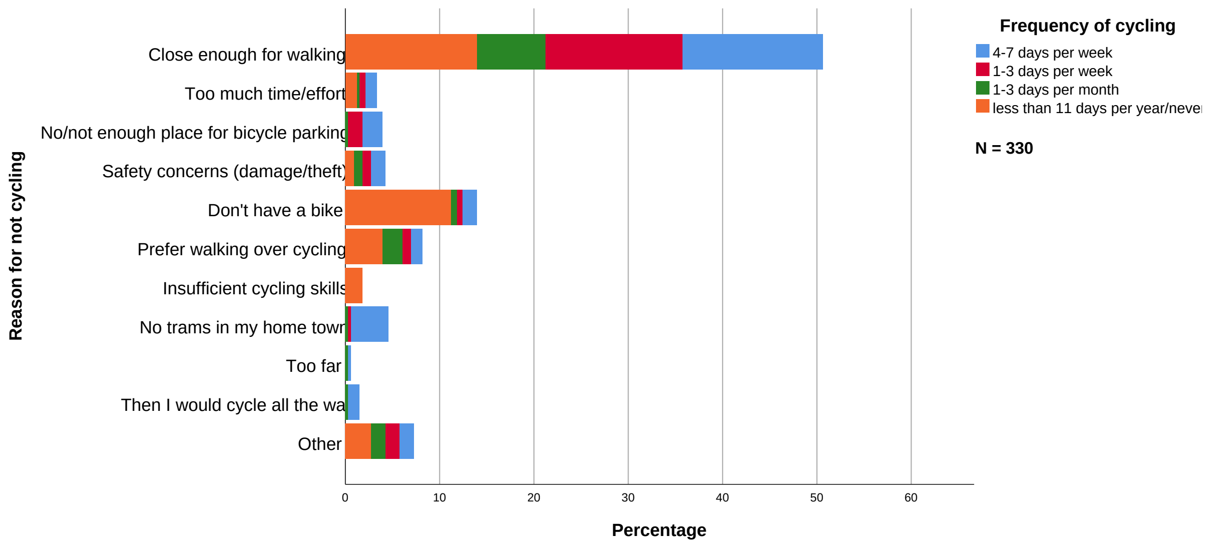

Figure 4.32: Motives for not using the bicycle-tram combination, as mentioned by the respondents

4.3.3. Spatial analysis

In this section the origins and destinations for three different regions in the The Hague are mapped and discussed. The regions are different from each other, especially the tram stop density. In Delft, it is quite low, while in the Goudenregenstraat region it is rather high. The tram stop density in Leidschenveen and Ypenburg falls inbetween. Furthermore, these regions contain a sufficient amount of data points. The coloured dots refer to the stops they relate to. Except when indicated otherwise by a bicycle or car icon, the mode for getting to or from the tram stop is walking. Black dots represent tram stops not included in the analysis, while grey dots correspond with bus access or egress. For all tram stops, the 400m buffer area has been mapped.

Delft

The map in Figure 4.33 shows the origins and destinations of several tram stops in Delft. Bus stops are shown as well, but only if they are within a 400m buffer of one of the origins or destination. In Delft, the tram stop density is not high, while the bus stop density is. All stops in this area offer bicycle parking. Krakeelpolderweg, Hovenpassage and Martinus Nijhofflaan, which are all only serviced by Tram 1 and not Tram 19, have relatively short feeder distances and no reported case of the bicycle as feeder mode. Furthermore, they are all the closest transit stop available for their corresponding origins and destinations. Nieuwe Plantage and Prinsenhof, however, show larger feeder distances and more bicycle use. Especially for Nieuwe Plantage, many travellers choose not to ride the bus but go to the tram stop immediately. The Delft Station stop clearly attracts travellers from a wider area than the other stops, as well as more bicycle users. This is most likely due to a combination of factors. For example the sheltered and protected bicycle facilities and the wider range of transit possibilities. Furthermore, Tram 19 does not go further south than Delft Station. From Figure 4.33 it is noticeable that many people skip a bus stop in order to get to a tram stop. Only four skipped a tram stop. These were almost all cases of people taking Tram 19, thus they avoided a transfer. However, the quality of the bus connections is not known, thus nor the impact of choosing the tram stop over the bus stop.

Goudenregenstraat

In the Goudenregenstraat area of The Hague Figure 4.34 not many bus stops are available; however there are sufficient tram lines. The most interesting stops are Azaleaplein, Goudenregenplein and Goudenregenstraat stops, because at Goudenregenstraat two lines join, while the other two are the stops just before Goudenregenstraat. Azaleaplein and Goudenregenstraat Upon inspection, it seems that travellers skipping a stop to go to or from Goudenregenstraat almost always avoid a transfer. The Fahrenheitstraat stop seems to have similar feeder distances as Goudenregenstraat. Of the four stops analysed in the Goudenregenstraat area, only Goudenregenplein has bicycle parking spots. However, for the stops in this area the bicycle is not used often; seemingly twice for avoiding a transfer and once due to a lack of closer stops. One of these also chose Goudenregenplein over Goudenregenstraat, which might be because of the availability of bicycle parking.

Leidschenveen and Ypenburg

Figure 4.35 and Figure 4.36 show the Leidschenveen and Ypenburg areas, which are similar in built environment and tram line types. The transit stop density is much lower than in Delft and the Goudenregenstraat area. This is reflected in the feeder distances as well. In Leidschenveen especially the stops Leidschenveen, Leidschenveen Centrum and Klaverveld show longer feeder distances, while in Ypenburg both stops attract travellers from a wider area. What stands out is that, even for the origins and destinations that are close to a bus stop, only one traveller used the bus.

At Leidschenveen, both lines 3 and 19 are present, however, when compared with the other areas, few travelers skipped a stop to avoid a transfer. In Ypenburg, Scholekstersingel offers both line 15 and line 19, while Ypenburg Centrum is only serviced by line 19. However, since line 15 was not part of the survey, it is not known whether many travellers skip a stop to reach it. This either means that their destinations can be reached by both lines All mentioned stops feature bicycle parking spots, and there is no stop that attracts cyclists more than the others, except for Scholekstersingel, which some cyclists chose over Ypenburg Centrum, perhaps because Scholekstersingel offers two lines instead of one.

4.3.4. Conclusion

Most of the travellers that chose for a stop further away, did so to avoid a transfer. Surprisingly, also many travellers stated they walked to further stop because they like to walk. Respondents provided answers to three hypothetical questions about what would them have made to choose a stop further away. Here it seems that a considerable amount of tram travellers will always choose for the closest stop (around 40%). Respondents

that sometimes use the bicycle-tram combination are more inclined to travel further to a stop that suits them better.
The motives respondents gave in the survey for not choosing the bicycle as a feeder mode, were mostly related to the sufficient proximity of the tram stop. Other common reasons concerned the practicality of using the bicycle, such as the lack of a bicycle available, or parking concerns. By far the most frequently mentioned motive for using the bicycle as feeder mode is reducing the total travel time. Some respondents did not have choice because the stop is too far away, and there were also some who stated they only use the bicycle to save time when they are in a hurry. For bicycle choice, reducing the total travel time seems to be a more obvious motive than for choosing a stop further away. So the motives that are mentioned for choosing a stop further away are quite common and mostly related with the quality of the transit service and comfort matters. In contrast, the motives for cycling are more common, and relate mostly to travel time reduction or the built environment. Three important barriers for the bicycle-tram combination have been discovered: the lack of an available bicycle, insufficient bicycle parking places and unsafe bicycle parking places.
Also in the spatial analysis it came forward that avoiding transfers (either bus or other tram line) seem to be the main reason to go for a stop further away. Furthermore, street pattern and natural barriers, such as water or large buildings, appear to influence the stop choice. This has also been mentioned by F. Zhao et al. (2003).

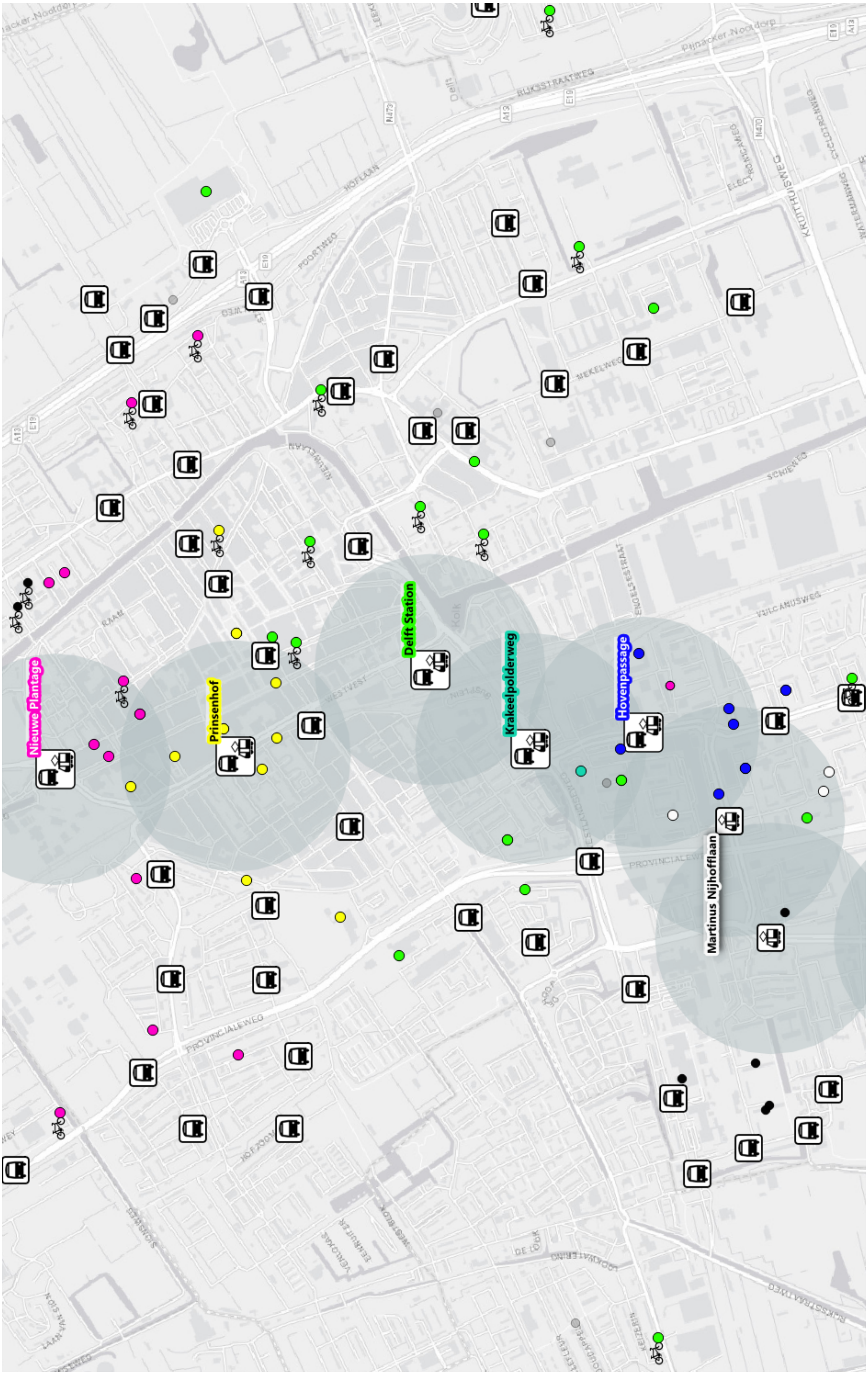

Figure 4.33: Delft

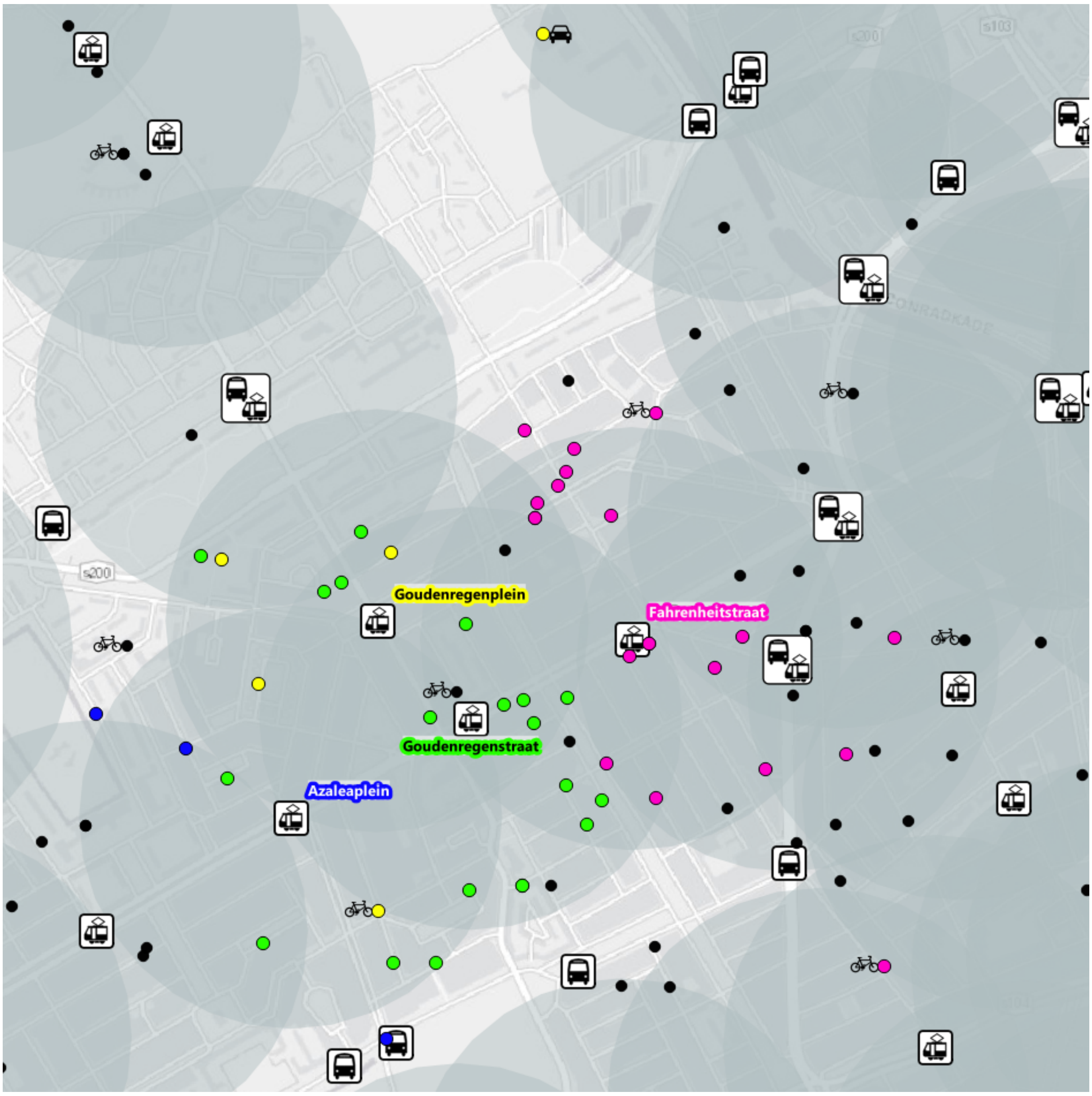

Figure 4.34: Goudenregenstraat

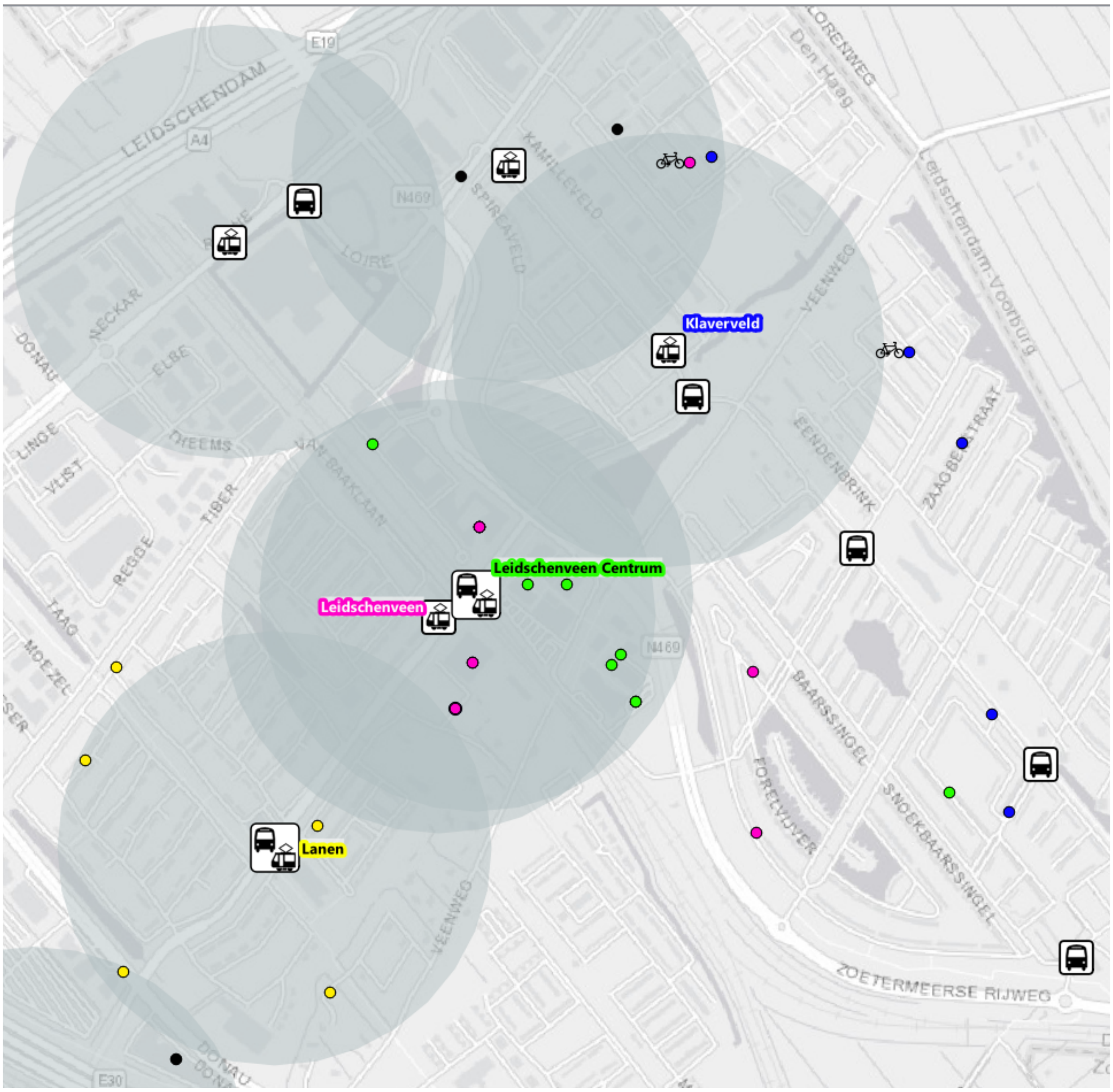

Figure 4.35: Leidschenveen

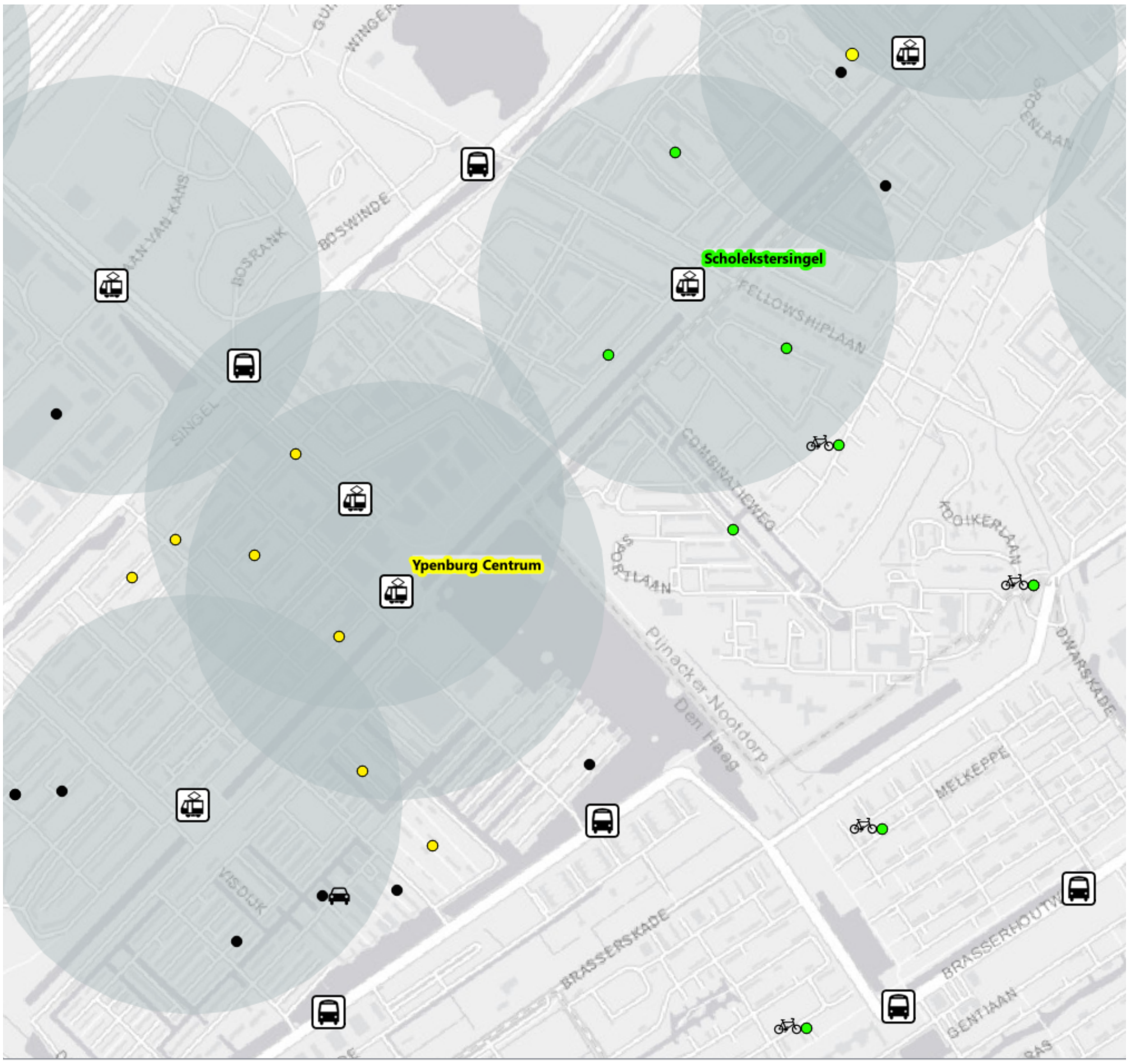

Figure 4.36: Ypenburg

5 Conclusions, discussion and recommendations

This research has for the first time explored in detail what factors influence feeder distance and feeder mode choice (and partially stop choice as well) for trams, using the case study of The Hague. The theoretical framework, which was established based on literature review, forms the basis of this research. Both bivariate analyses (through statistical tests) and multivariate analyses (through logistic regression models) explore the factors from the theoretical framework quantitatively. A qualitative analysis examines the motives behind stop and feeder mode choice. It forms a valuable addition to these statistical tests and models: for scientific purposes it reveals influences that are not detected when using aggregate and objective data. For practice, it provides tools to improve the bicycle-transit integration. Precise origin and destination locations are used, as well as street network distances, which allow for more reliable and detailed analyses.
This chapter considers the main conclusions, based on the results from the previous chapters, in section 5.1. Then, in section 5.2 the most important differences between the findings and the expectations from the theoretical framework are discussed. Lastly, in section 5.3 the recommendations for practice and further research are explained.

5.1. Conclusions

One of the main findings is that a few important factors are largely related: feeder distance, feeder mode and tram density. For feeder mode choice, also cycling habits and bicycle availability are important. Furthermore, three important barriers for the bicycle-tram combination have been discovered: the lack of an available bicycle, insufficient bicycle parking places and unsafe bicycle parking places. Respondents that sometimes use the bicycle-tram combination are more inclined to travel further to a stop that suits them better.
The literature review has shown that catchment areas of public transport stops need more understanding, especially what factors influence them. And although the bicycle-transit combination is deemed increasingly important, less knowledge is available about the bicycle as a feeder mode compared with walking. The influences on cycling catchment areas are especially important to know in urban areas, where more competition is present between cycling and transit for single trips, but where they can complement each other at the total trip level. When transit and the bicycle are better integrated, catchment areas can increase because of the larger distances that the bicycle can bridge. This benefits individual travellers, because they have more options, allowing them to optimise their journey better: they can always choose the option that fits best. There are also network advantages. The network can be coarser, more efficient and have a higher quality. This in turn attracts more travellers, again increasing efficiency.
Currently, many transit operators regard catchment areas as fixed radiuses. However, distance-decay is a much better way of capturing catchment areas, because it models more accurately the impedance of distance. A theoretical framework has been constructed in this research, containing four clusters of factors that are expected to affect feeder distance and feeder mode choice. The first cluster is about user characteristics, subdivided into personal and transport-related personal factors. The second cluster concerns transport factors (trip, service and stop factors). The third cluster is about built environment factors, and the last about context factors.

Feeder distance

The median overall feeder distance found in this research is 400m. When considering the modes separately, it is 380m for walking and 1025m for cycling. The following factors from the theoretical framework were found to be significantly related with feeder distance, through bivariate analyses: feeder mode, amount of transfers, frequency at the stop, directness and transit stop density. This means that the statistical results indicate that user characteristics do not significantly influence feeder distance.

The significant factors from the bivariate analyses are used as input for the he multivariate analysis, to control for the other factors. This is done in the form of a logistic regression model, containing distance classes. A model with three different distance classes leads to insufficient distinction between the classes. Therefore, a binomial logistic regression model with two distance classes is estimated, of which a cut-off value of 500m performs best. In the feeder distance model, only feeder mode and transit stop density remain significant: a low tram stop density and cycling both increase the probability of bridging a longer feeder distance than 500m. Some of the factors are only significantly related with feeder distance at a 75% confidence interval (trip purpose, home-based/activity-based access/egress and total trip length). To be able to detect repressive effects, they are still tested in the feeder distance model and added to the model together with the factors that are significant at a 95% confidence level. Only total trip length is significant: a longer trip decreases the probability of travelling more than 500m to or from a stop. The rest of the factors (age, transit captivity and frequency of transit use) is not found to be significantly related with feeder distance. When population density and land use mix are added as an interaction effect with transit stop density, the model improves only marginally.

Although the amount of transfers could not be tested for its relation with feeder distance, because of errors in the logistic regression model, there are several indications that it is an important factor. The most common motive mentioned by respondents for choosing a stop further away is 'to avoid a transfer'. Moreover, in the spatial analysis it is shown that stops at a meeting point of two lines attract travellers from a larger area, indicating that they do so to avoid a transfer. The same holds for frequency and directness: there are indications that they are not rightly defined to be tested in a good way, but are still expected to be important for feeder distance.

Feeder mode choice

The percentage of bicycle-tram users in the survey is almost 16%. Compared with feeder distance, more factors are found to be significant in the bivariate analyses for feeder mode choice: age, transit captivity, feeder options, frequency of cycling, trip purpose, home-based/activity-based, feeder distance, frequency at the stop, directness, transit stop density and availability of bicycle parking. However, in the multivariate analysis of the feeder mode choice logistic regression model, only frequency of cycling, feeder distance, transit stop density and home-based versus activity-based are significant, where the first two factors have the most impact. A low frequency of cycling, a short feeder distance and an activity-based access/egress trip decrease the probability of choosing the bicycle as feeder mode. In the bivariate analysis, the amount of transfers and total trip length are significant at the 75% confidence level, but they are both not significant when added to the logistic regression model. Adding the combined factors of land use mix and population density to the model as an interaction effect, hardly improves it.

Motives for choosing a stop and feeder mode

The motives that are mentioned for choosing a stop further away are quite common and mostly related with the quality of the transit service and comfort matters. Avoiding a transfer is named most often. In contrast, the motives for cycling are more common, and relate mostly to travel time reduction or the built environment. The most often named reasons for not cycling to the stop, apart from considering the feeder distance too short for cycling, are the lack of a bicycle, and insufficient and unsafe bicycle parking places. When asked what would tempt travellers to choose a stop further away, 'avoiding a transfer' and 'having more options to your destination' are motives that are more related than stop choices based on 'park your bike': most respondents either always choose the nearest stop, or would choose a further stop for both tram-related motives. When they are willing to travel further for either of the tram-related motives, the willingness to travel further to 'park your bike better' seems roughly equally distributed. However, respondents that sometimes cycle to the stop are less likely to always choose the nearest stop compared with all respondents. This indicates that they are more inclined to travel further to a stop that suits them better.

Table 5.1: Comparison of feeder distances (in meters) found in this study with other studies. Where multiple values per study were available, the range of distances is given.

	N	mean	25th percentile	median	75th percentile	85th percentile
Walking						
Tram: The Hague, the Netherlands	**657**	**466**	**240**	**380**	**580**	**730**
Regular bus: Amsterdam, the Netherlands *(Brand et al., 2017)*	-	-	-	393-760	-	-
Express bus: Amsterdam, the Netherlands *(Brand et al., 2017)*	-	-	-	526-1033	-	-
Regular bus: Sydney, Australia *(Daniels & Mulley, 2013)*	1084	461	162	364	655	-
Regular bus: Montreal, Canada *(El-Geneidy et al., 2014)*	538-8745	276-489	-	214-402	371-654	484-897
Cycling						
Tram: The Hague, the Netherlands	**56**	**1159**	**700**	**1025**	**1518**	**1818**
Regular bus: Amsterdam, the Netherlands *(Brand et al., 2017)*	-	-	-	-	1245-3217	-
Express bus: Amsterdam, the Netherlands *(Brand et al., 2017)*	-	-	-	-	1008-2772	-
Regular bus: Atlanta, USA *(Hochmair, 2015)*	29	2034	-	904	-	3924
Regular bus: Twin Cities, USA *(Hochmair, 2015)*	36	1530	-	844	-	2737
Express bus: Twin Cities, USA *(Hochmair, 2015)*	17	2313	-	2275	-	4539

5.2. Discussion

The survey findings show that the median overall feeder distance for the active modes is 400m. When considering the modes separately, it is 380m for walking and 1025m for cycling. The fixed buffer that many transit operators use is 400m, so exactly half of the respondents in the The Hague survey travel further than that, something which Daniels and Mulley (2013) already noted. Table 5.1 contains a comparison with distances of other studies (both regular and express bus). When comparing the median walking distances with the findings of Brand et al. (2017), who examined bus feeder distances in the Amsterdam region, it can be noticed that the feeder distances in The Hague are substantially shorter. This also applies when express bus stops are concerned, where the difference is even larger. On the other hand, when comparing The Hague with Sydney, the The Hague median is slightly higher. However, the median, 75th and 85th percentiles in The Hague seem rather similar to the feeder distances from Montreal (El-Geneidy et al., 2014). For cycling, the median and 85th percentile of The Hague are considerably higher than those from the regular bus stops in Atlanta and the Twin Cities, which might be because the tram is considered higher in quality than regular bus. They are quite low compared with the values from Amsterdam (both regular and express bus stops) and the express bus stops in the Twin Cities. However, the amount of respondents of the latter is very low. The mentioned differences can also be explained through built environment influences, and especially the different transit stop density.

Factors from the theoretical framework

In the theoretical framework, four clusters of factors that may affect feeder distance and feeder mode choice were identified. The first cluster is about user characteristics. The second cluster concerns transport factors and the third cluster is about built environment factors. The fourth cluster, context factors, is not considered here because its effects were not directly tested in the analyses.

In the **user characteristics** cluster, it is expected that socio-economic factors hardly affect feeder distance (Cervero, 2001; Krygsman et al., 2004). This is confirmed when testing these factors in a logistic regression model, because no socio-economic factors are significant in the feeder distance model.

For cycling, user characteristics generally have more impact. However, the Netherlands is a mature cycling country, where user characteristics have little influence on cycling. Only age, gender and ethnic/cultural background are expected to affect cycling as main mode (Harms et al., 2014). The feeder mode choice model, which was estimated to test the interrelation between various factors, improves slightly when ethnic/cultural background and gender are added as interaction effects, but age is non-significant in the model. So it appears that, for cycling as feeder mode, socio-economic factors are not as influential as for cycling as main mode. It is also important to realise that the findings of this research that concern cycling, are not necessarily applicable to other countries, where more socio-economic factors are expected to be applicable (Van der Blij et al., 2010).

Of the cluster of **transport factors**, trip purpose is considered important for both feeder distance and feeder mode choice: utilitarian trips are generally deemed more sensitive to travel time than non-utilitarian trips. Surprisingly, trip purpose is not significant when tested in both logistic regression models. It is possible that the effect is eliminated because of insufficient variation in the surveyed lines: other line characteristics, e.g. the directness or frequency, might interfere with the effect of trip purpose.
Total trip length is also expected to affect feeder distance and feeder mode. However, both are found to be non-significant. This could be explained by the differences in average trip length between tram trips and train trips or high quality bus lines, which concerned most studies that researched total trip length (Krygsman et al., 2004; Leferink, 2017; Shelat et al., 2018; Van Mil et al., 2018). The distances travelled by those modes are generally longer than tram trips, which could be why the effect is non-significant in this study.
The amount of transfers could not be included in the feeder distance model because of errors in the model, so its significance when controlling for other factors cannot be established. Furthermore, the amount of transfers is only a proxy and does not have a one to one correlation with avoiding a transfer. However, there are several indications that it is an important factor for feeder distance. In the qualitative analysis 'avoid transfer' is the most common motive for choosing a stop further away. Moreover, in the spatial analysis it is shown that stops at a meeting point of two lines attract travellers from a larger area, indicating that they do so to avoid a transfer. It remains unclear, though, if cyclists use the bicycle to avoid a transfer.
Several studies speak of the effect of high quality transit: it supposedly leads to longer feeder distances and the choice for the bicycle as a feeder mode. Examples are frequency at the stop and directness of the line, but their effects are not entirely clear from the theoretical framework. For frequency at the stop contradictory effects have been mentioned, while for directness of the line insufficient research has been carried out to establish its effect. When they are tested in the bivariate analysis, they both yield remarkable results; in the multivariate analysis they are both non-significant. This may be explained by how they are defined: frequency is measured as a cumulative value for all lines at the stop, while the frequency that is relevant for that specific trip is more appropriate. And the definition of directness is a combination of several other service quality aspects, which means that the combination of those separate effects may lead to the remarkable results. However, another explanation is that service factors are especially important between modes, instead of within modes. This would mean that once the tram is chosen, the service of the tram is not of great importance. However, this cannot be confirmed in this study, because of the definition of those factors. Differences between lines of the same mode were found by Brand et al. (2017) and Hochmair (2015), but those concerned regular bus stops and express bus stops, between which the differences in quality are much larger than within the tram lines in The Hague. The preference of tram over bus, which has already been observed in the literature (Bunschoten, Molin, & Van Nes, 2012), comes forward as well. However, in this case it is not known if people really dislike a bus-tram trip compared with tram-tram trip because the quality of the bus service is not explored, so it is not known if simply the poorer service of the bus is the reason they avoid it, or the bus mode itself.
It stands out that bicycle parking availability is not significant after controlling for other factors. This might have to do with the relation with the built environment; tram stops in areas that are suitable for bicycle as feeder mode, are likely to have been already designed for it. Furthermore, from the motives for not cycling, parking issues were mentioned, such as not enough parking space or safety concerns. This indicates that only providing parking spaces is insufficient, because the quality/safety is also important.

The **built environment** cluster consists mainly of level of urbanisation. This includes the population density, tram stop density and land use mix, and is deemed important in influencing the feeder distance and feeder mode choice. However, it is very hard to capture and many more factors are expected to be part of the built environment. Although adding the combined factors of land use mix and population density to the feeder mode choice model hardly improves it, this is not surprising. It was established that for feeder mode choice, the feeder route may be an important built environment factor (Daniels & Mulley, 2013), which is not included in this research. A factor that is not included in this research, but is related with the built environment, is residential self-selection.

5.3. Recommendations

5.3.1. Recommendations for practice

At a single trip level, the tram and the bicycle compete with each other, so for the tram the bicycle is less chosen as a feeder mode compared with for example the train. Walking is the most important feeder mode for tram: from the survey it resulted that 89.4% of the tram feeder trips are done by walking. In this research, catchment areas of tram stops were investigated, which can be used to improve the tram network. This thus forms the first part of the recommendations for practice.

Although walking is expected to remain the main feeder mode for the tram, several benefits come forward when the bicycle is added as feeder option. The bicycle could be a feeder mode for everyone who wants to use it, when the right conditions are provided. Therefore, the bicycle and public transport should form an integrated network. In this research, data have been gathered to achieve this, because factors and motives that influence the choice for the bicycle as feeder mode, were explored. Therefore, the second part of the recommendations for practice concerns the integrated bicycle-tram network.

Network improvements based on walking catchment areas

At the moment HTM roughly has a fixed buffer area of 500m (based on the network distance). However, in the tram network of The Hague, the buffer areas are smaller in some areas, as could be seen in the spatial analysis. This leads to overlap in catchment areas. And although this allows for smaller feeder distances, it makes the network inefficient: the in-vehicle time and total travel times increase because of longer time wasted at stops (Wu & Levinson, 2018). So there is always a trade-off between short feeder distances and higher quality services (for example in terms of faster vehicles or higher frequencies). So, the stop densities of tram lines should be based on the catchment areas, so that they do not overlap too much. These have been found in this research. They can be mapped onto the network of The Hague in the form of distance-decay, so that the coverage of the network can be assessed.

However, this can only be done if the transit operator has established its goal. When the transit operator wants to be inclusive and also serve people walking with difficulty, a maximum feeder distance should be determined, perhaps decreasing the optimal size of the catchment areas. Another possibility is that the transit operator wants to attract as many passengers as possible. In this case, the distance-decay information should be used to provide a network with catchment areas that form an optimum between feeder distances and qualitatively high transit lines, drawing the most passengers.

Integrated bicycle-tram network

While keeping the network suitable for walking, it is still beneficial to encourage the bicycle-tram combination. Because those that can use the bicycle as a feeder mode, increase their journey options by enlarging the catchment area. This allows them to better optimize their journey, and therefore increase its utility. Consequently, the competing position of the tram journey increases. Furthermore, option value emerges, which means that cyclists can obtain value from the possibility of using another tram stop, although they do not use it.

There are three barriers for cycling to or from a stop that can be dealt with by providing better cycling facilities that resulted from the motives respondents gave. The first is about no or insufficient bicycle parking places at the stop, a motive that is mentioned by 4% of respondents that never use the bicycle-tram combination. This can be addressed by placing more bicycle parking facilities at tram stops. The second (mentioned by 4.6% of non bicycle-tram users) concerns the fear for damage or theft of the bike. By providing safer parking spaces, e.g. guarded bicycle storages nearby the stop, bicycle lockers or security cameras, this barrier may be resolved. The third barrier for cycling is about bicycle availability: 13.8% of respondents who do not use the bicycle-tram combination say the reason is that they do not have a bike. A solution, that is also regarded as an essential feature in the bicycle-transit combination, is to provide a bicycle sharing scheme at tram stops (Kager & Harms, 2017).

When these three barriers for the bicycle-tram combination are removed, assuming that these travelers will then sometimes use the bicycle as a feeder mode, the amount of bicycle-tram users rises from 21.7% to 37.6% of travelers, which is a substantial increase. However, it is not needed to provide solutions for these barriers

at all stops. For example, 34% of travelers who sometimes cycle to a stop, is willing to cycle to a further stop if they could park their bike better there. This is also visible in the bicycle catchment area, of which the median distance is 1025m, which far exceeds that of walking (380m).
Therefore, it is beneficial to only offer the bicycle facilities at stops that are expected to attract a high number of bicycle-tram users. An important indicator for this is a low transit stop density around the stop, a factor that is very important for both feeder distance and feeder mode choice. The second is stops that offer higher quality lines in terms of frequency and directness: although Also stops where two lines join are expected to attract more cyclists, because there a transfer may be avoided, a factor that is also deemed important from the quantitative analyses. Then, because it seems that many tram travelers dislike the bus, stops that are serviced by bus lines are also suitable for both bicycle parking facilities and bike sharing systems.Bike sharing systems will especially make a difference in areas with great potential for the bicycle-transit combination in terms of tram network density and cycling frequencies, but do not have a bicycle at their disposal, such as most of the activity-based areas. Lastly, areas with many frequent cyclists have potential for the bicycle-tram combination. This is especially applicable for bicycle parking issues, because the motive of no or insufficient bicycle parking space was mostly given by frequent cyclists. Bicycle sharing systems are less important here, because many of them already travel by bike regularly.

The target group of the bicycle-tram combination is three-fold. First, there are the current bicycle-tram users that may use it more often when the right facilities are there. Then, there are current tram travelers who might want to use the bicycle, but do not have one. Lastly, 47.5% of tram travelers that never use the bicycle as a feeder mode, cycles frequently. This makes them a large target audience for the bicycle-tram combination. They will not use it often, but could consider it in specific situations, for example in areas with little public transport, or during service disruptions. This could change their mobility patterns on the long term: when all trips are possible with either transit, the bicycle, or a combination, they are not dependent on private motorised modes. However, the possibility of using a bicycle, as main mode or combined with the tram, should be communicated extensively, because this target group is currently not used to combining the two modes.

5.3.2. Recommendations for further research

This research has focussed on the factors that affect feeder distance and feeder mode choice separately, it has not provided knowledge on the combined choice for a stop and a mode. With the data generated during the survey, the information is available to estimate a choice model (e.g. a nested logit model) to assess the combined choice. This could be used to establish if the bicycle is indeed used as a feeder mode in order to avoid a transfer, and also the role of tram service characteristics can be better established. Another important aspect that can be discovered this way, is the sensitivity of travellers for distance that influences both stop choice and feeder mode choice. Because from this research only the actual walking and cycling distances emerged, not the distance that travellers were willing to bridge.
Similarly, it is important to know the choices made at the total trip level, so to also include travellers who chose a different mode for their journey than the tram. The survey did not include those, so a new research set up is needed to investigate the choices at total trip level. Gaining this knowledge is deemed important, because bicycle and transit together, in an integrated bicycle-transit network, can compete better with motorised modes at the total trip level (Kager et al., 2016; Martin & Shaheen, 2014).
Another topic that could be explored further in scientific research is the built environment. This is, together with residential self-selection, expected to play a large role for both feeder distance and feeder mode choice. For example, it is important if the activities around a stop are largely concentrated, or far more evenly distributed in space, something which has not been incorporated in this research (El-Geneidy et al., 2014).
Lastly, in this research only correlations were explored and tested. However, causation could not be established. Therefore in depth testing should happen, for example through longitudinal surveys or through factor analysis.

A
Surveys

Datum: Tijd:
Voertuignr:

Onderzoek: de tramreis van deur tot deur

Deze vragenlijst is onderdeel van een afstudeeronderzoek van de TU Delft. Het doel is om verschillende manieren om naar de tramhalte te komen in kaart te brengen. De resultaten worden anoniem verwerkt, en deze vragenlijst zal ongeveer 4 minuten duren. Heeft u vragen? Stel ze gerust aan de enquêteur!

1. Wat is de postcode van het beginadres waar u uw reis bent begonnen? Als u dit niet weet, kunt u het adres of het gebouw opschrijven.

Postcode ☐☐☐☐☐☐ *of* ________ Adres, gebouw, school, bedrijf of organisatie

2. Hoe bent u van uw beginadres naar uw **opstaphalte** van deze OV-reis gegaan? Dit is de eerste halte van uw reis, en kan ook een station of bushalte zijn.

❑ Lopen
❑ Fiets
❑ Auto/brommer/scooter
❑ Anders, namelijk: ________

3. Welke andere opties had u tot uw beschikking om naar uw eerste **opstaphalte** te reizen?

❑ Lopen
❑ Fiets
❑ Bus/tram
❑ Metro/trein
❑ Auto/brommer/scooter
❑ Anders, namelijk: ________

4. Wat heeft u gedaan op uw beginadres?

❑ Wonen
❑ Werken
❑ School/stage
❑ Winkelen/boodschappen doen
❑ Vrije tijd/sport/recreatie
❑ Familie of vrienden bezoeken
❑ Anders, namelijk: ________

5. Wat zijn uw in- en uitstaphalte van **deze tramlijn**? Kruis aan welke van toepassing zijn.

In	*Lijn 16*	Uit	In	*Lijn 16*	Uit	In	*Lijn 16*	Uit
❑	Dorpskade	❑	❑	Heeswijkplein	❑	❑	Buitenhof	❑
❑	Parijsplein	❑	❑	Station Moerwijk	❑	❑	Gravenstraat	❑
❑	Lage Veld	❑	❑	Alberdingk Thijmstraat	❑	❑	Noordwal	❑
❑	Oosteinde	❑	❑	Van Zeggelenlaan	❑	❑	Elandstraat	❑
❑	Hoge Veld	❑	❑	Jonckbloetplein	❑	❑	Van Speijkstraat	❑
❑	Steenwijklaan	❑	❑	Lorentzplein	❑	❑	Waldeck Pyrmontkade	❑
❑	Leggelostraat	❑	❑	Oudemansstraat	❑	❑	Groot Hertoginnelaan	❑
❑	Leyweg	❑	❑	Leeghwaterplein	❑	❑	Gemeentem./Museon	❑
❑	Loevesteinlaan	❑	❑	Station Hollands Spoor	❑	❑	Statenplein	❑
❑	Hardenbroekstraat	❑	❑	Bierkade	❑	❑	Frederik Hendriklaan	❑
❑	Betje Wolffstraat	❑	❑	Kalvermarkt-Stadhuis	❑	❑	Prins Mauritslaan	❑
❑	Geysterenweg	❑	❑	Centraal Station	❑	❑	Van Boetzelaerlaan	❑
❑	Erasmusplein	❑	❑	Korte Voorhout	❑			

6. Heeft u **vóór** deze tramrit een overstap gemaakt vanaf **ander OV** dan deze tramlijn?

❑ Ja, tramlijn ____ met beginhalte ________ ❑ Ja, metro of trein
❑ Ja, buslijn ____ met beginhalte ________ ❑ Nee

7. Gaat u **na** deze tramrit een overstap maken naar **ander OV** dan deze tramlijn?

❑ Ja, tramlijn ____ met eindhalte ________ ❑ Ja, metro of trein
❑ Ja, buslijn ____ met eindhalte ________ ❑ Nee

8. Zou u vandaag hebben gekozen voor één **instaphalte** verder weg als ….

… u daardoor uw fiets bij de halte kon parkeren? ❑ Ja ❑ Nee
… u daardoor hoefde over te stappen? ❑ Ja ❑ Nee ❑ Niet van toepassing
… daar meer tramlijnen stoppen naar uw bestemming? ❑ Ja ❑ Nee

Figure A.1: Test survey (Dutch, front side)

11. Wat is de postcode uw eindbestemming? Als u dit niet weet, kunt u het adres of het gebouw opschrijven.

Postcode: [| | | | |] *of* Adres, gebouw, school, bedrijf of organisatie: [ ]

12. Wat gaat u doen op uw eindbestemming?

- ❑ Wonen
- ❑ Werken
- ❑ School/stage
- ❑ Winkelen/boodschappen doen
- ❑ Vrije tijd/sport/recreatie
- ❑ Familie of vrienden bezoeken
- ❑ Anders, namelijk: [ ]

13. Hoe gaat u van uw **uitstaphalte** van deze OV-reis naar uw eindbestemming reizen? Dit is de laatste halte van uw reis, en kan ook een station of bushalte zijn.

- ❑ Lopen
- ❑ Fiets
- ❑ Auto/brommer/scooter
- ❑ Anders, namelijk: [ ]

14. Welke andere opties heeft u tot uw beschikking om van uw **uitstaphalte** naar uw eindbestemming te reizen?

- ❑ Lopen
- ❑ Fiets
- ❑ Bus/tram
- ❑ Metro/trein
- ❑ Auto/brommer/scooter
- ❑ Anders, namelijk: [ ]

15. Hoe vaak reist u met de tram in Den Haag?

- ❑ 4-7 dagen per week
- ❑ 1-3 dagen per week
- ❑ 1-3 dagen per maand
- ❑ 6-11 dagen per jaar
- ❑ minder dan 5 dagen per jaar

16. Hoe vaak fietst u in Den Haag?

- ❑ 4-7 dagen per week
- ❑ 1-3 dagen per week
- ❑ 1-3 dagen per maand
- ❑ 6-11 dagen per jaar
- ❑ minder dan 5 dagen per jaar

17. Gaat u wel eens met de fiets naar een tramhalte?

- ❑ Ja, want…
- ❑ Nee, want…

[ ]

18. Hoe lang wilt u maximaal **lopen** van of naar een tramhalte?

………… minuten

19. Hoe lang wilt u maximaal **fietsen** van of naar een tramhalte?

………… minuten

20. Heeft u van tevoren gepland welke opstaphalte en tramlijn u ging nemen?

- ❑ Ja, via een reisplanner
- ❑ Ja, maar ik wist de halte en vertrektijden zelf al
- ❑ Ja, ik wist de halte, maar niet de vertrektijden
- ❑ Nee, ik ben naar een halte gegaan voor de vertrektijden
- ❑ Anders, namelijk: [ ]

21. Wat is uw etnische/culturele achtergrond?

- ❑ Nederlands
- ❑ Duits
- ❑ Belgisch
- ❑ Brits
- ❑ Marokkaans
- ❑ Turks
- ❑ Surinaams
- ❑ Antilliaans
- ❑ Anders, namelijk: [ ]
- ❑ Zeg ik liever niet

22. Wat is uw geboortejaar? [| | |]

23. Wat is uw geslacht?

- ❑ Man
- ❑ Vrouw
- ❑ Overig/zeg ik liever niet

Bedankt voor het invullen van deze vragenlijst! Uw hulp is belangrijk voor dit onderzoek.
Lever de lijst weer in bij de enquêteur.

TUDelft

Figure A.2: Test survey (Dutch, back side)

Datum: Tijd:
Voertuignr:

Survey: the door-to-door tram journey

This survey is part of a graduation project of Delft University of Technology. The goal is to map the different aspects of the tram journey. The results will be processed anonymously and the survey will take approximately 4 minutes. If you have questions, please ask them to the surveyor.

TUDelft

1. What is the postal code of the address where you started your journey? If you don't know, please write down the address or name of the building.

Postal code ☐☐☐☐☐☐ *or* ____________
Address, building, school, company or organisation

2. How did you get from your start address to the **boarding stop** of this public transport journey? This is the first stop of your journey, and could also be a station or bus stop.

- ❑ Walking
- ❑ Bicycle
- ❑ Car/moped/scooter
- ❑ Other, namely: ____________

3. What other options did you have to get to your first **boarding stop**?

- ❑ Walking
- ❑ Bicycle
- ❑ Bus/tram
- ❑ Metro/train
- ❑ Car/moped/scooter
- ❑ Other, namely: ____________

4. What did you do at your start address?

- ❑ Living
- ❑ Working
- ❑ School/internship
- ❑ Shopping/groceries
- ❑ Leisure/sport
- ❑ Visiting family or friends
- ❑ Other, namely: ____________

5. What are your boarding and deboarding stop of **this tram line**? Mark the stops that apply with a cross.

Board	*Line 16*	**Deboard**	**Board**	*Line 16*	**Deboard**	**Board**	*Line 16*	**Deboard**
❑	Dorpskade	❑	❑	Heeswijkplein	❑	❑	Buitenhof	❑
❑	Parijsplein	❑	❑	Station Moerwijk	❑	❑	Gravenstraat	❑
❑	Lage Veld	❑	❑	Alberdingk Thijmstraat	❑	❑	Noordwal	❑
❑	Oosteinde	❑	❑	Van Zeggelenlaan	❑	❑	Elandstraat	❑
❑	Hoge Veld	❑	❑	Jonckbloetplein	❑	❑	Van Speijkstraat	❑
❑	Steenwijklaan	❑	❑	Lorentzplein	❑	❑	Waldeck Pyrmontkade	❑
❑	Leggelostraat	❑	❑	Oudemansstraat	❑	❑	Groot Hertoginnelaan	❑
❑	Leyweg	❑	❑	Leeghwaterplein	❑	❑	Gemeentem./Museon	❑
❑	Loevesteinlaan	❑	❑	Station Hollands Spoor	❑	❑	Statenplein	❑
❑	Hardenbroekstraat	❑	❑	Bierkade	❑	❑	Frederik Hendriklaan	❑
❑	Betje Wolffstraat	❑	❑	Kalvermarkt-Stadhuis	❑	❑	Prins Mauritslaan	❑
❑	Geysterenweg	❑	❑	Centraal Station	❑	❑	Van Boetzelaerlaan	❑
❑	Erasmusplein	❑	❑	Korte Voorhout	❑			

6. Did you make a transfer **before** this tram line from **another transit** line?

- ❑ Yes, tram line ☐ with boarding stop ____________
- ❑ Yes, bus line ☐ with boarding stop ____________
- ❑ Yes, metro or train
- ❑ No

7. Will you make a transfer **after** this tram line to **another transit** line?

- ❑ Yes, tram line ☐ with deboarding stop ____________
- ❑ Yes, bus line ☐ with deboarding stop ____________
- ❑ Yes, metro or train
- ❑ No

8. Would you have chosen for one **boarding stop** further away if …

… you could park your bike at that stop?	❑ Yes	❑ No	
… you could avoid a transfer?	❑ Yes	❑ No	❑ Not applicable
… there are more tram lines to you destination?	❑ Yes	❑ No	

Figure A.3: Test survey (English, front side)

11. What is the postal code of your final destination? If you don't know, please write down the address or name of the building.

Postal code ☐☐☐☐☐☐ *or* ______________

Address, building, school, company or organisation

12. What are you going to do at your final destination?

- ❑ Living
- ❑ Working
- ❑ School/internship
- ❑ Shopping/groceries
- ❑ Leisure/sport
- ❑ Visiting family or friends
- ❑ Other, namely: ______________

13. How will you get from your final **deboarding stop** (this can also be a station or bus stop) to your final destination?

- ❑ Walking
- ❑ Bicycle
- ❑ Car/moped/scooter
- ❑ Other, namely: ______________

14. What other options do you have to get from your **deboarding stop** to your final destination?

- ❑ Walking
- ❑ Bicycle
- ❑ Bus/tram
- ❑ Metro/train
- ❑ Car/moped/scooter
- ❑ Other, namely: ______________

15. How often do you travel by tram in The Hague?

- ❑ 4-7 days per week
- ❑ 1-3 days per week
- ❑ 1-3 days per month
- ❑ 6-11 days per year
- ❑ less than 5 days per year

16. How often do you cycle in The Hague?

- ❑ 4-7 days per week
- ❑ 1-3 days per week
- ❑ 1-3 days per month
- ❑ 6-11 days per year
- ❑ less than 5 days per year

17. Do you sometimes go to or from the tram stop by bicycle?

- ❑ Yes, because…
- ❑ No, because…

____

18. What is the maximum time you would want to **walk** to or from a tram stop?

………… minutes

19. What is the maximum time you would want to **cycle** to or from a tram stop?

………… minutes

20. Did you plan in advance which boarding stop and tram line you would take?

- ❑ Yes, via a trip planner
- ❑ Yes, but I already knew the stop and departure times
- ❑ Yes, I knew the stop, but not the departure times
- ❑ No, I just went to the nearest stop for a timetable
- ❑ Other, namely: ______________

21. Wat is your etnic/cultural background?

- ❑ Dutch
- ❑ German
- ❑ Belgian
- ❑ British
- ❑ Surinamese
- ❑ Moroccan
- ❑ Turkish
- ❑ Antillian
- ❑ Other, namely: ______________
- ❑ I would rather not say

22. What is your year of birth? ☐☐☐☐

23. What is your gender?

❑ Male ❑ Female ❑ Other/I would rather not say

Thank you for your help in this survey! It is important for the research.
Hand the form to the surveyor.

TUDelft

Figure A.4: Test survey (English, back side)

Onderzoek: de tramreis van deur tot deur

Deze vragenlijst is onderdeel van een afstudeeronderzoek van de TU Delft. Het doel is om de tramreis van deur tot deur in kaart te brengen. De resultaten worden anoniem verwerkt. Heeft u vragen? Stel ze gerust aan de enquêteur!

TUDelft

Begin-locatie

1. Wat is de postcode van de locatie waar u uw reis bent begonnen? Als u dit niet weet, kunt u het adres of het gebouw opschrijven.

Post code ☐☐☐☐☐☐ *of* ________

Straat + huisnr., gebouw, school of bedrijf

2. Wat heeft u gedaan op uw beginlocatie?

❑ Wonen ❑ School/stage ❑ Vrije tijd/sport ❑ Anders, namelijk:
❑ Werken ❑ Winkelen/boodschappen ❑ Familie of vrienden bezoeken

Naar de halte

3. Hoe bent u van uw beginlocatie naar de **eerste instaphalte** van uw reis gegaan? *(dit hoeft geen halte van tramlijn 1 te zijn)*

❑ Lopen ❑ Anders, namelijk:
❑ Fiets

4. Welke andere opties had u vandaag om naar uw **eerste instaphalte** te komen?

❑ Lopen ❑ Anders, namelijk:
❑ Fiets
❑ Geen

5. Heeft u **vóór tramlijn 1** nog met ander OV gereisd?

❑ Ja, metro of trein ❑ Ja, vanaf <u>bus</u>halte …………………………………… met <u>bus</u> …….
❑ Nee ❑ Ja, vanaf <u>tram</u>halte…………………………………… met <u>tram</u> ……..

6. Wat zijn uw <u>in</u>- en <u>uit</u>staphaltes van **tramlijn 1**? Kruis aan de linkerkant uw instaphalte, en aan de rechterkant uw uitstaphalte aan.

Tram 1

Instaphalte		Uitstaphalte	Instaphalte		Uitstaphalte
❑	Zwarte Pad	❑	❑	Broeksloot	❑
❑	Kurhaus	❑	❑	Herenstraat	❑
❑	Schev. Slag/Beelden aan Zee	❑	❑	Hoornbrug	❑
❑	Badhuiskade	❑	❑	Broekpolder	❑
❑	Keizerstraat	❑	❑	's-Gravenmade	❑
❑	Duinstraat	❑	❑	Vlietbrug	❑
❑	Frankenslag	❑	❑	Verffabriek	❑
❑	World Forum	❑	❑	Brasserskade	❑
❑	Adriaan Goekooplaan	❑	❑	Nieuwe Plantage	❑
❑	Ary van der Spuyweg	❑	❑	Prinsenhof	❑
❑	Vredespaleis	❑	❑	Delft Station	❑
❑	Javastraat	❑	❑	Krakeelpolderweg	❑
❑	Mauritskade	❑	❑	Hovenpassage	❑
❑	Kneuterdijk	❑	❑	Martinus Nijhofflaan	❑
❑	Centrum	❑	❑	Diepenbrockstraat	❑
❑	Bierkade	❑	❑	Van der Slootsingel	❑
❑	Station Hollands Spoor	❑	❑	Sadatweg	❑
❑	Leeghwaterplein	❑	❑	Bikolaan	❑
❑	Oudemansstraat	❑	❑	Abtswoudsepark	❑
❑	Lorentzplein	❑			

7. Gaat u **na tramlijn 1** nog met ander OV reizen?

❑ Ja, metro of trein ❑ Ja, naar <u>bus</u>halte …………………………………… met <u>bus</u> …….
❑ Nee ❑ Ja, naar <u>tram</u>halte…………………………………… met <u>tram</u> ……..

Z.o.z. voor blad 2

Figure A.5: Final survey (Dutch, front side)

Vanaf de halte

8. Hoe gaat u van uw **laatste uitstaphalte** naar uw eindbestemming reizen? *(dit hoeft geen halte van tramlijn 1 te zijn)*

❑ Lopen
❑ Fiets
❑ Anders, namelijk:

9. Welke andere opties heeft u vandaag om van uw **laatste uitstaphalte** naar uw eindbestemming te komen?

❑ Lopen
❑ Fiets
❑ Geen
❑ Anders, namelijk:

Eindbe-stemming

10. Wat is de postcode van uw eindbestemming? Als u dit niet weet, kunt u het adres of het gebouw opschrijven.

Post code *of*

Straat + huisnr., gebouw, school of bedrijf

11. Wat gaat u doen op uw eindbestemming?

❑ Wonen
❑ Werken
❑ School/stage
❑ Winkelen/boodschappen
❑ Vrije tijd/sport
❑ Familie of vrienden bezoeken
❑ Anders, namelijk:

12. Deze vraag gaat over uw **<u>eerste</u> instaphalte** van deze reis *(dit hoeft geen halte van tramlijn 1 te zijn).* Was dit voor u de dichtstbijzijnde halte?

❑ Ja ❑ Nee, ik heb voor een halte verder weg gekozen omdat…

13. Zou u hebben gekozen voor één **instaphalte** verder weg als …

… u daardoor niet hoefde over te stappen?	❑ Ja	❑ Nee	❑ Niet van toepassing
… u daardoor uw fiets beter bij de halte kon parkeren?	❑ Ja	❑ Nee	❑ Niet van toepassing
… daar meer tramlijnen vertrekken naar uw bestemming?	❑ Ja	❑ Nee	❑ Niet van toepassing

14. Behalve het OV, welke andere opties had u om te reizen van uw **beginlocatie** naar uw **eindbestemming**?

❑ Lopen
❑ Fiets
❑ Auto
❑ Brommer/scooter
❑ Geen
❑ Anders, namelijk:

15. Heeft u moeite met lopen?

❑ Nee
❑ Ja, ik kan maximaal …………. minuten lopen

16. Kunt u fietsen?

❑ Ja
❑ Nee

17. Hoe vaak reist u met de tram?

❑ 4-7 dagen per week
❑ 1-3 dagen per week
❑ 1-3 dagen per maand
❑ 6-11 dagen per jaar
❑ minder dan 5 dagen per jaar

18. Hoe vaak fietst u?

❑ 4-7 dagen per week
❑ 1-3 dagen per week
❑ 1-3 dagen per maand
❑ 6-11 dagen per jaar
❑ minder dan 5 dagen per jaar/nooit

19. Gaat u wel eens met de fiets naar een tramhalte?

❑ Ja, want…
❑ Nee, want…

20. Wat is uw etnische/culturele achtergrond?

❑ Nederlands
❑ Duits
❑ Belgisch
❑ Brits
❑ Marokkaans
❑ Turks
❑ Surinaams
❑ Antilliaans
❑ Zeg ik liever niet
❑ Anders, namelijk:

21. Wat is uw geslacht?

❑ Man
❑ Vrouw
❑ Overig/zeg ik liever niet

22. Wat is uw geboortejaar?

23. Heeft u nog opmerkingen over deze vragenlijst?

Bedankt voor het invullen van deze vragenlijst! Lever de lijst weer in bij de enquêteur.

Figure A.6: Final survey (Dutch, back side)

Survey: the door-to-door tram journey

This survey is part of a graduation project of Delft University of Technology. The goal is to map the different aspects of the tram journey. The results will be processed anonymously. If you have questions, please ask them to the surveyor.

TUDelft

Begin location

1. What is the postal code of the address where you started your journey? If you don't know, please write down the address or name of the building.

Postal code ☐☐☐☐☐☐ *or* ______________
Street + number, building, school or company

2. What did you do at your begin location?

❑ Living ❑ School/internship ❑ Leisure/sport ❑ Other, namely:
❑ Working ❑ Shopping/groceries ❑ Visiting family or friends

To the stop

3. How did you get from your begin location to the **first boarding stop** of your journy? *(this can be a stop of a different line than tram 1)*

❑ Walking ❑ Other, namely:
❑ Bicycle

4. What other options did you have to get to your **first boarding stop** today?

❑ Walking ❑ Other, namely:
❑ Bicycle
❑ None

5. **Before tram line 1**, did you travel by other public transport?

❑ Yes, metro or train ❑ Yes, from bus stop .... with bus ....
❑ No ❑ Yes, from tram stop.. with tram ....

Tram 1

6. What are your boarding and deboarding stop of **tram 1**? Mark a cross on the left side for your boarding stop and on the right for your deboarding stop.

Boarding stop		Deboarding stop	Boarding stop		Deboarding stop
❑	Abtswoudsepark	❑	❑	Oudemansstraat	❑
❑	Bikolaan	❑	❑	Leeghwaterplein	❑
❑	Sadatweg	❑	❑	Station Hollands Spoor	❑
❑	Van der Slootsingel	❑	❑	Bierkade	❑
❑	Diepenbrockstraat	❑	❑	Centrum	❑
❑	Martinus Nijhofflaan	❑	❑	Kneuterdijk	❑
❑	Hovenpassage	❑	❑	Mauritskade	❑
❑	Krakeelpolderweg	❑	❑	Javastraat	❑
❑	Delft Station	❑	❑	Vredespaleis	❑
❑	Prinsenhof	❑	❑	Ary van der Spuyweg	❑
❑	Nieuwe Plantage	❑	❑	Adriaan Goekooplaan	❑
❑	Brasserskade	❑	❑	World Forum	❑
❑	Verffabriek	❑	❑	Frankenslag	❑
❑	Vlietbrug	❑	❑	Duinstraat	❑
❑	's-Gravenmade	❑	❑	Keizerstraat	❑
❑	Broekpolder	❑	❑	Badhuiskade	❑
❑	Hoornbrug	❑	❑	Schev. Slag/Beelden aan Zee	❑
❑	Herenstraat	❑	❑	Kurhaus	❑
❑	Broeksloot	❑	❑	Zwarte Pad	❑
❑	Lorentzplein	❑			

7. **After tram line 1**, will you travel by other public transport?

❑ Yes, metro or train ❑ Yes, to bus stop .... with bus ....
❑ No ❑ Yes, to tram stop.. with tram ....

See other side for page 2

Figure A.7: Final survey (English, front side)

From the stop

8. How will you get from your **final deboarding stop** to your final destination? *(this can be a stop of a different line than tram 1)*

❑ Walking
❑ Bicycle
❑ Other, namely:

9. What other options do you have to get from your **deboarding stop** to your final destination today?

❑ Walking ❑ Other, namely:
❑ Bicycle
❑ None

Final desti-nation

10. What is the postal code of your final destination? If you don't know, please write down the address or name of the building.

Postal code | | | | | | | *or* Street + number, building, school or company

11. What are you going to do at your final destination?

❑ Living ❑ School/internship ❑ Leisure/sport ❑ Other, namely:
❑ Working ❑ Shopping/groceries ❑ Visiting family or friends

12. This question is about the **<u>first</u> boarding stop** of your journey *(this can be a stop of a different line than tram 1)*. Was this the closest stop for you?

❑ Yes ❑ No, I chose a stop further away because…

13. Would you have chosen for one **boarding stop** further away if …

… you could avoid a transfer?	❑ Yes	❑ No	❑ Not applicable
… you could park your bike better at that stop?	❑ Yes	❑ No	❑ Not applicable
… there are more trams to your destination at that stop?	❑ Yes	❑ No	❑ Not applicable

14. Except for public transport, what other options did you have to travel from your **begin location** to your **final destination**?

❑ Walking ❑ None
❑ Bicycle ❑ Other, namely:
❑ Car
❑ Moped/scooter

15. Do have trouble walking?

❑ No
❑ Yes, i can only walk for ………… minutes

16. Can you cycle?

❑ Yes
❑ No

17. How often do you travel by tram?

❑ 4-7 days per week ❑ 6-11 days per year
❑ 1-3 days per week ❑ less than 5 days per year
❑ 1-3 days per month

18. How often do you cycle?

❑ 4-7 days per week ❑ 6-11 days per year
❑ 1-3 days per week ❑ less than 5 days per year/never
❑ 1-3 days per month

19. Do you sometimes go to or from the tram stop by bicycle?

❑ Yes, because…
❑ No, because…

20. What is your ethnic/cultural background?

❑ Dutch ❑ British ❑ Surinamese ❑ Other, namely:
❑ German ❑ Moroccan ❑ Antillian
❑ Belgian ❑ Turkish ❑ I would rather not say

21. What is your gender?

❑ Male
❑ Female
❑ Other/I'd rather not say

22. What is your year of birth?

23. Do you have any comments on this survey?

Thank you for your help in this survey! Hand the form to the surveyor.

Figure A.8: Final survey (English, back side)

B

Exploring influences: other results

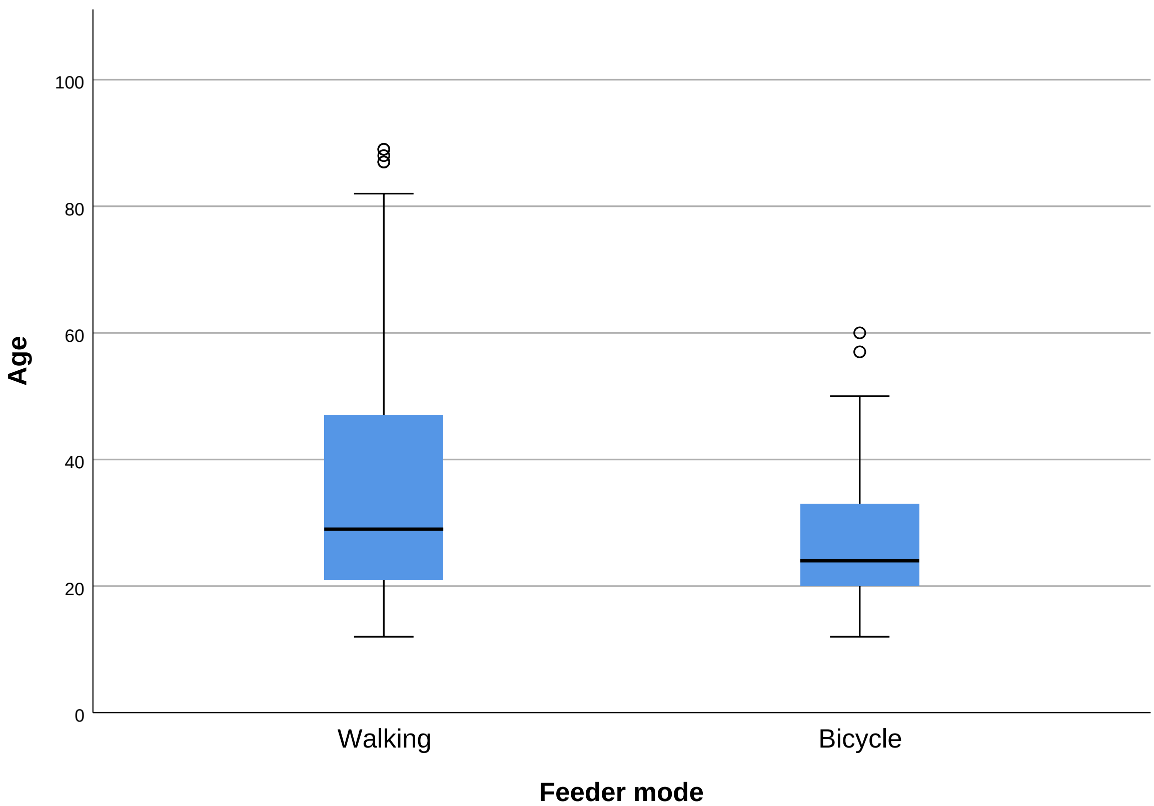

Figure B.1: Feeder mode choice by age

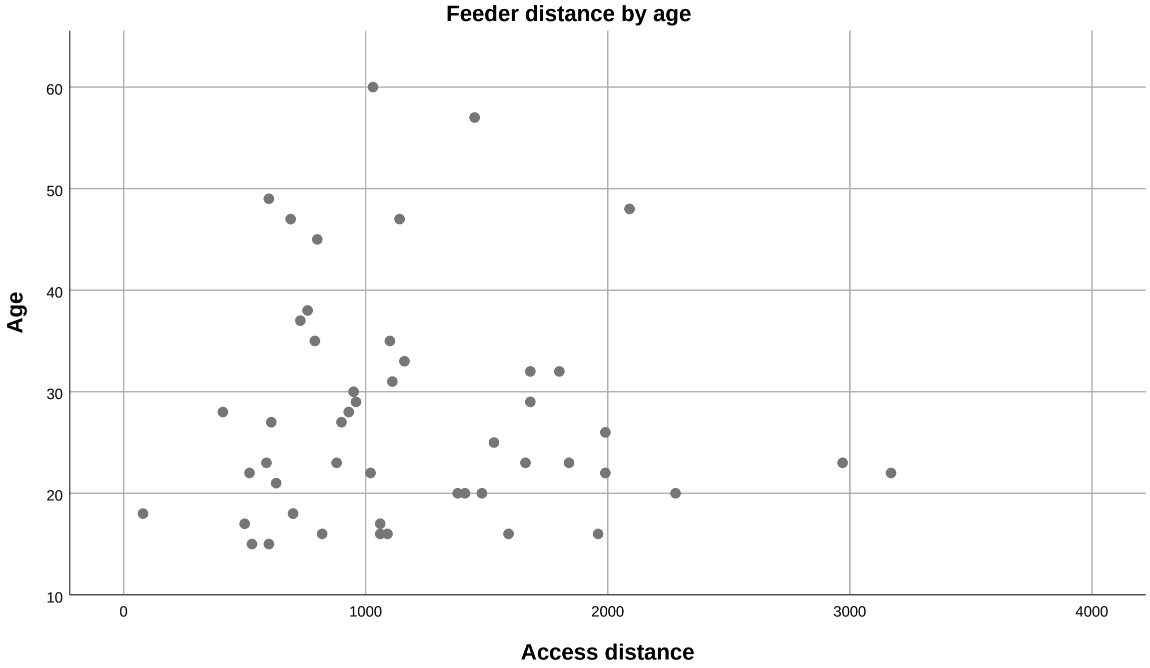

Figure B.2: Feeder distance by age (cycling)

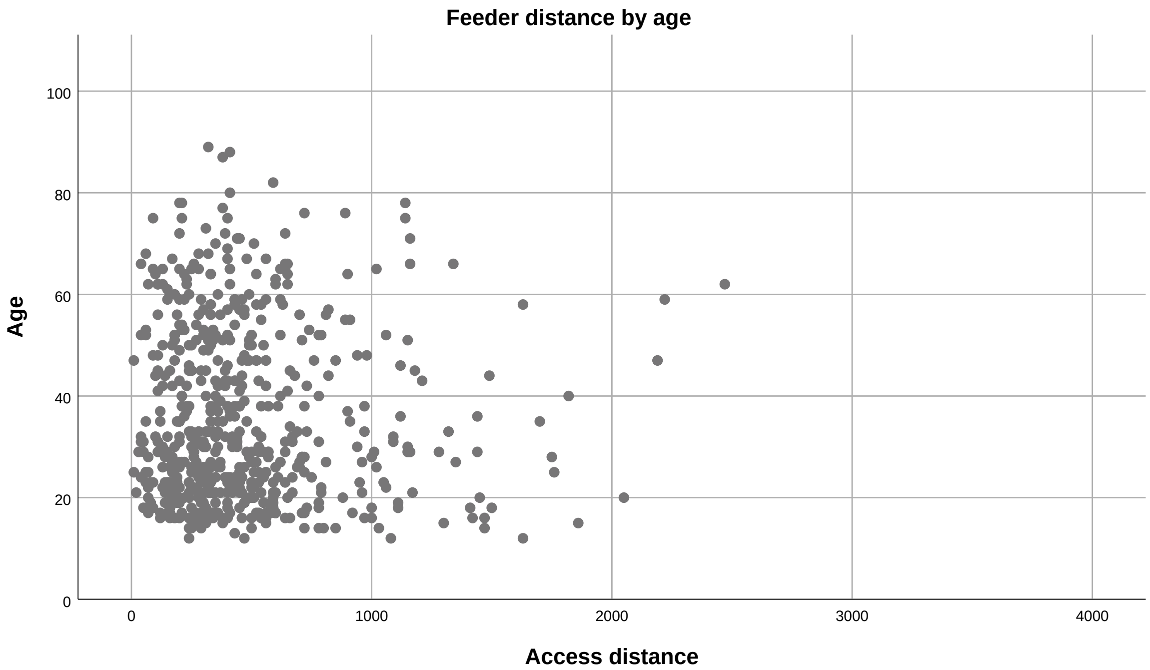

Figure B.3: Feeder distance by age (Walking)

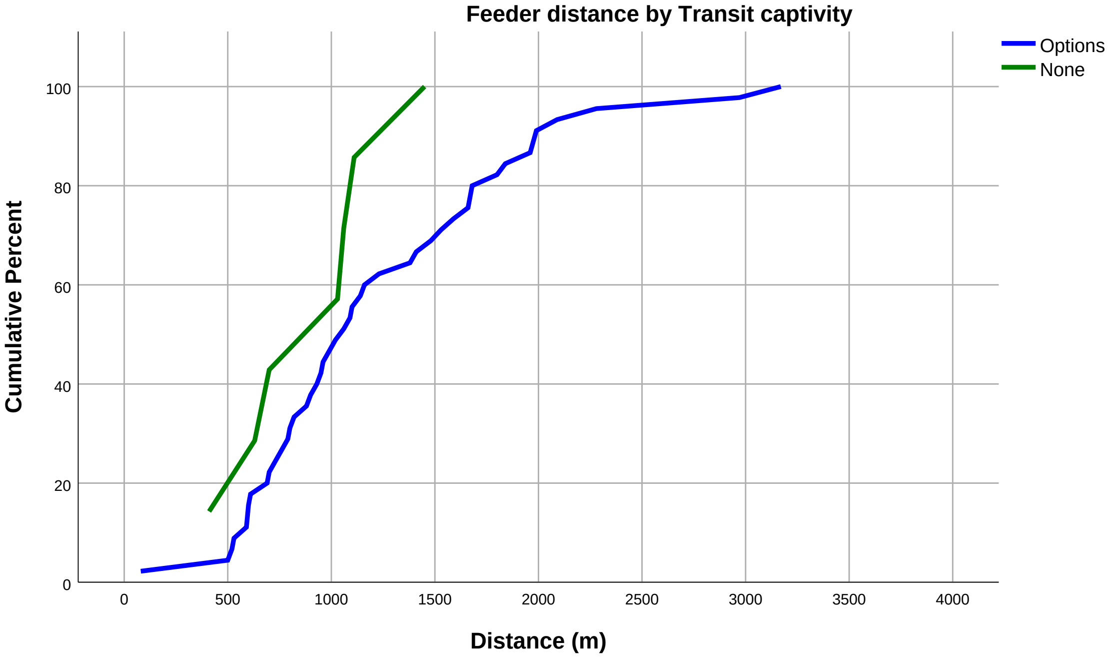

Figure B.4: Feeder distance by transit captivity (cycling)

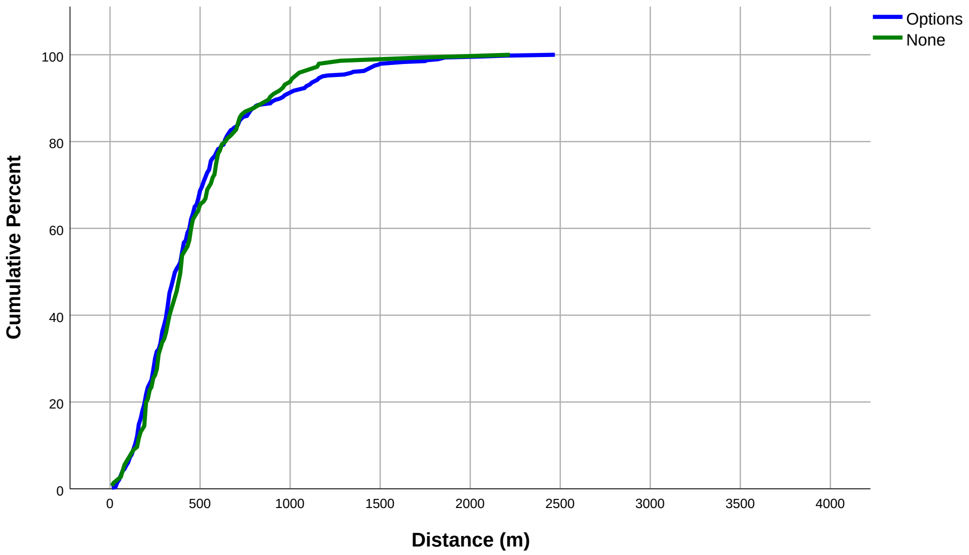

Figure B.5: Feeder distance by transit captivity (walking)

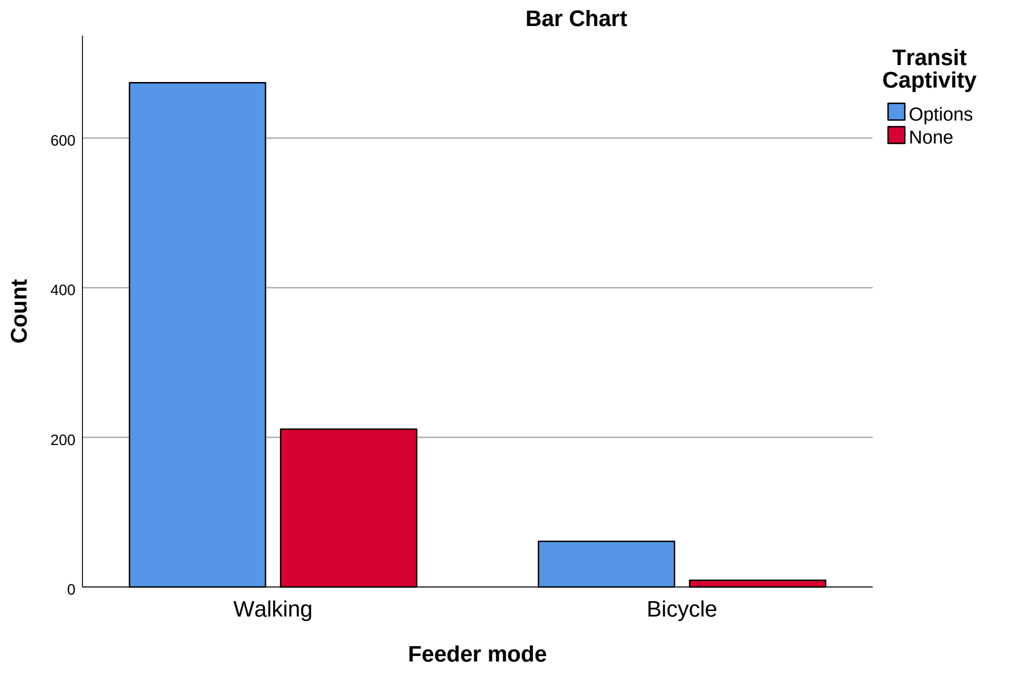

Figure B.6: Feeder mode choice by transit captivity

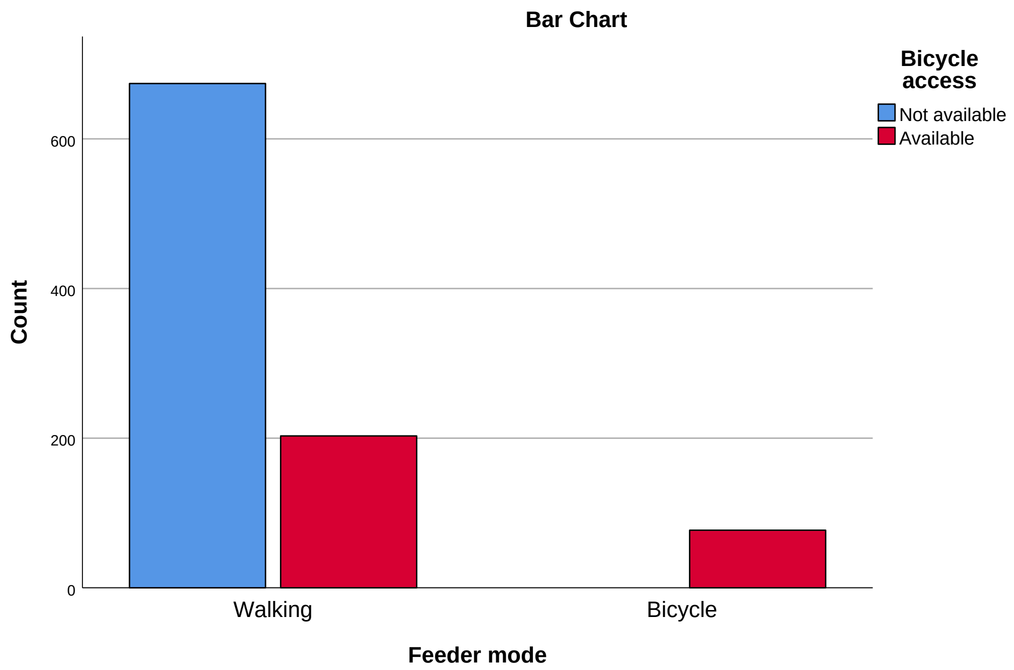

Figure B.7: Feeder mode choice by feeder options

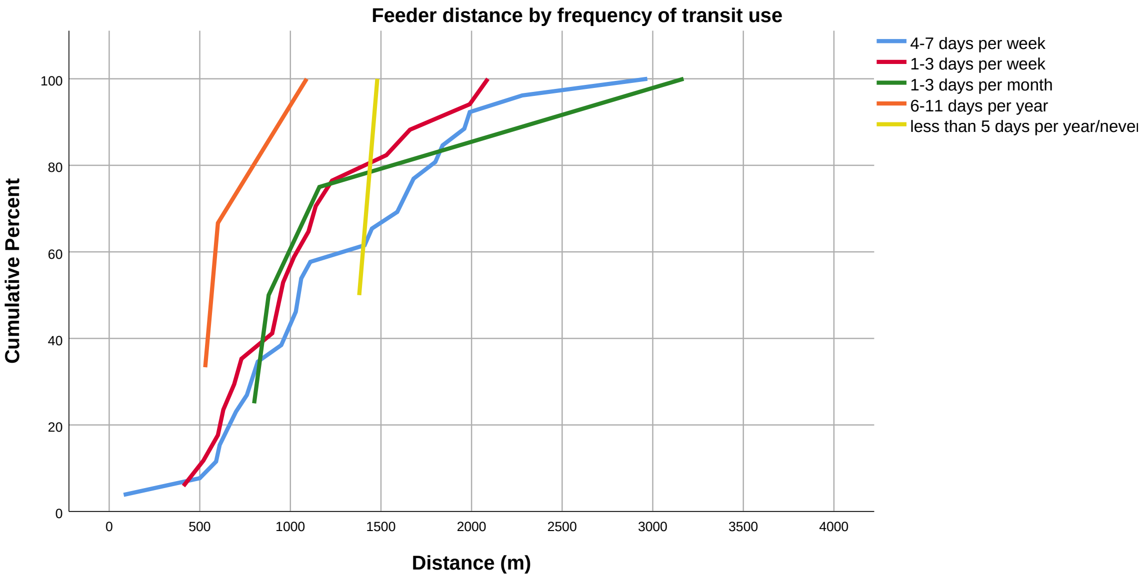

Figure B.8: Feeder distance by frequency of transit travelling (cycling)

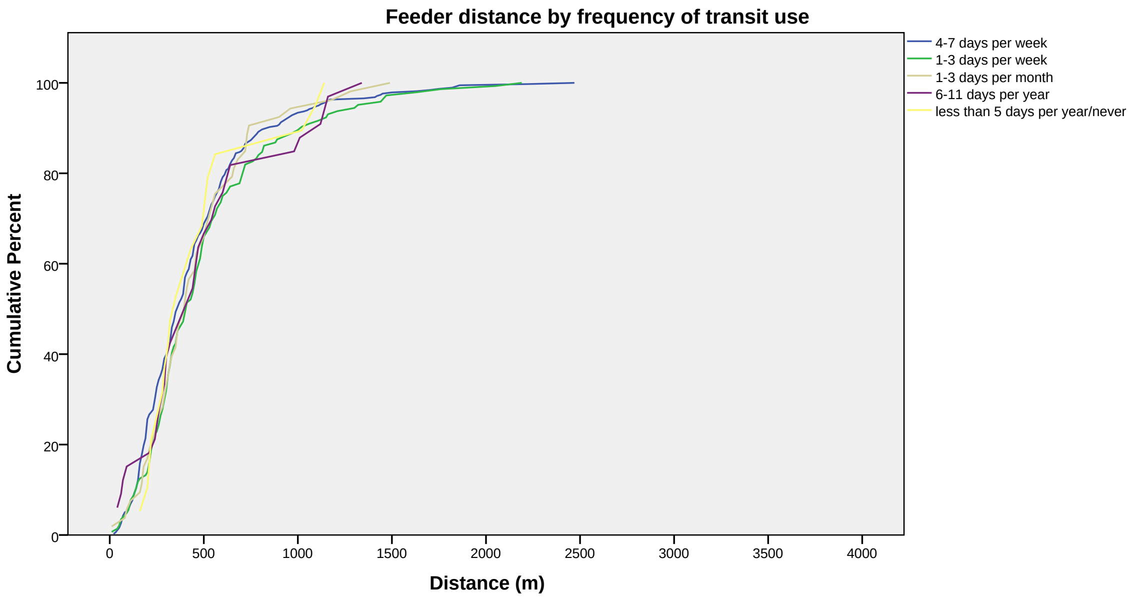

Figure B.9: Feeder distance by frequency of transit travelling (walking)

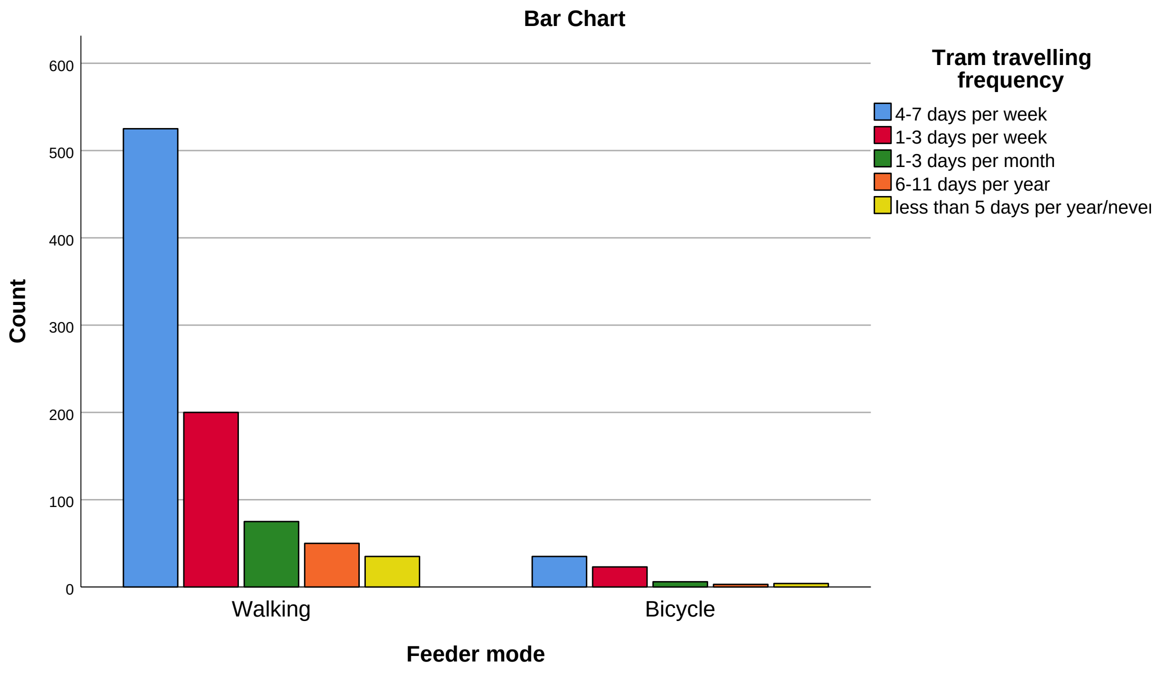

Figure B.10: Feeder distance by frequency of transit travelling (cycling)

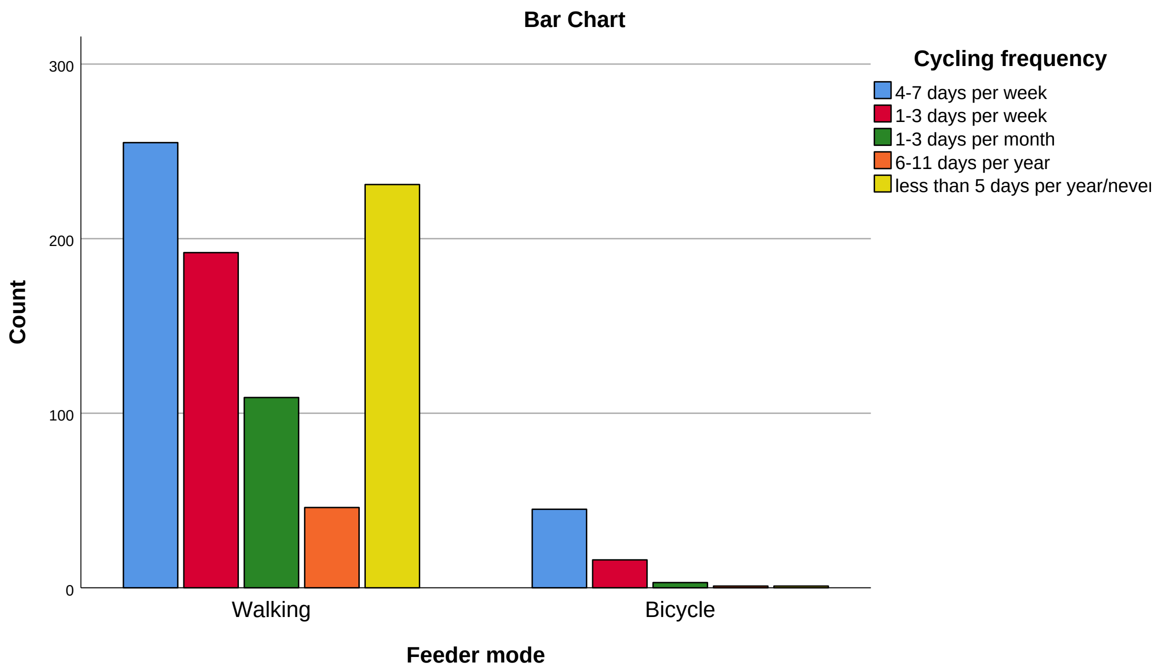

Figure B.11: Feeder mode choice by frequency of cycling

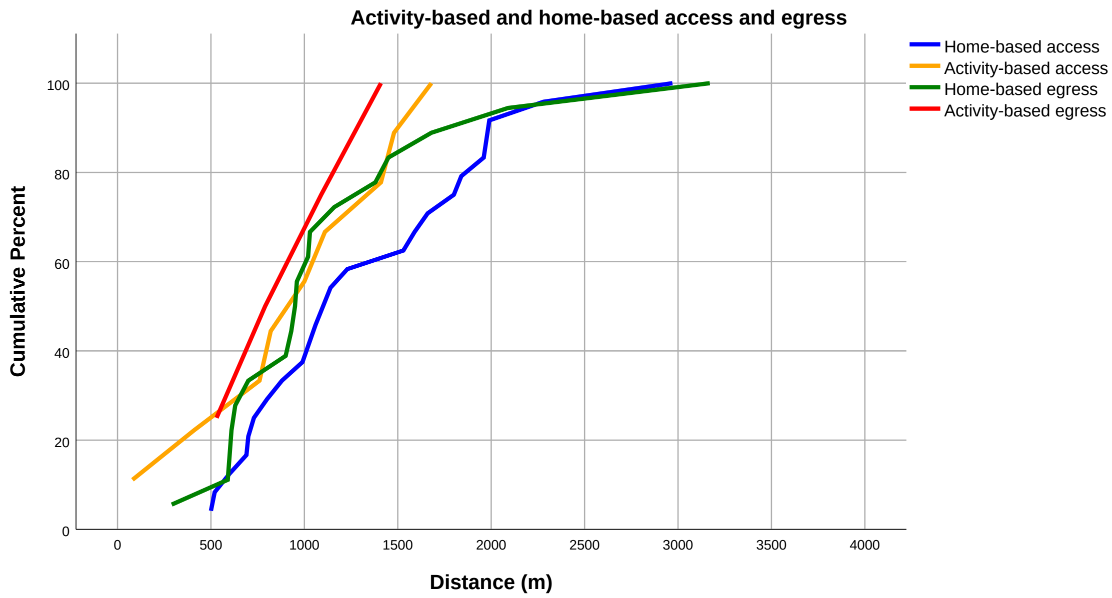

Figure B.12: Feeder distance by feeder type (cycling)

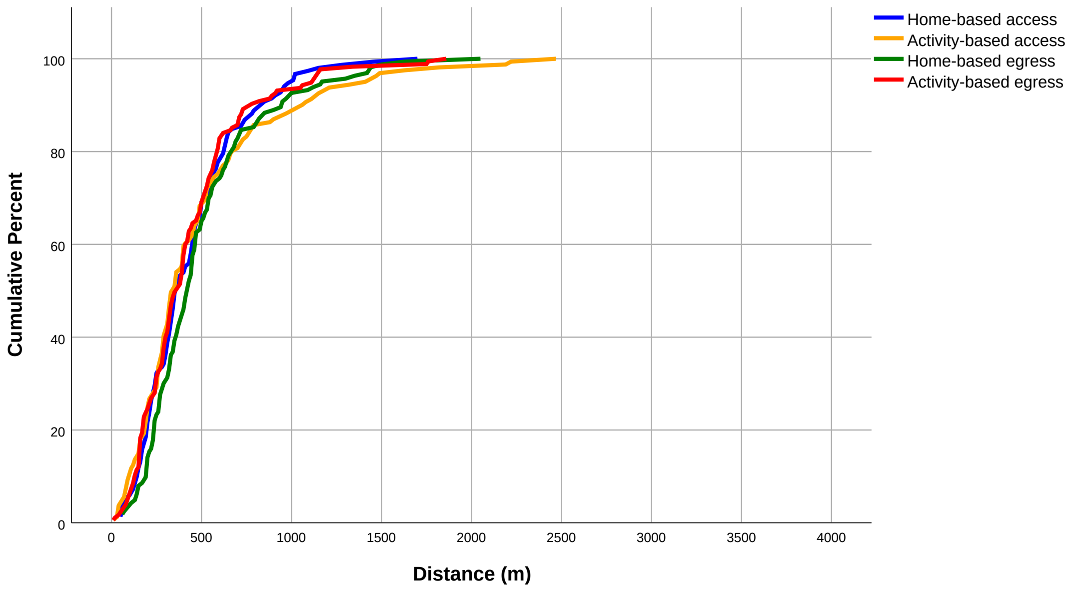

Figure B.13: Feeder distance by feeder type (walking)

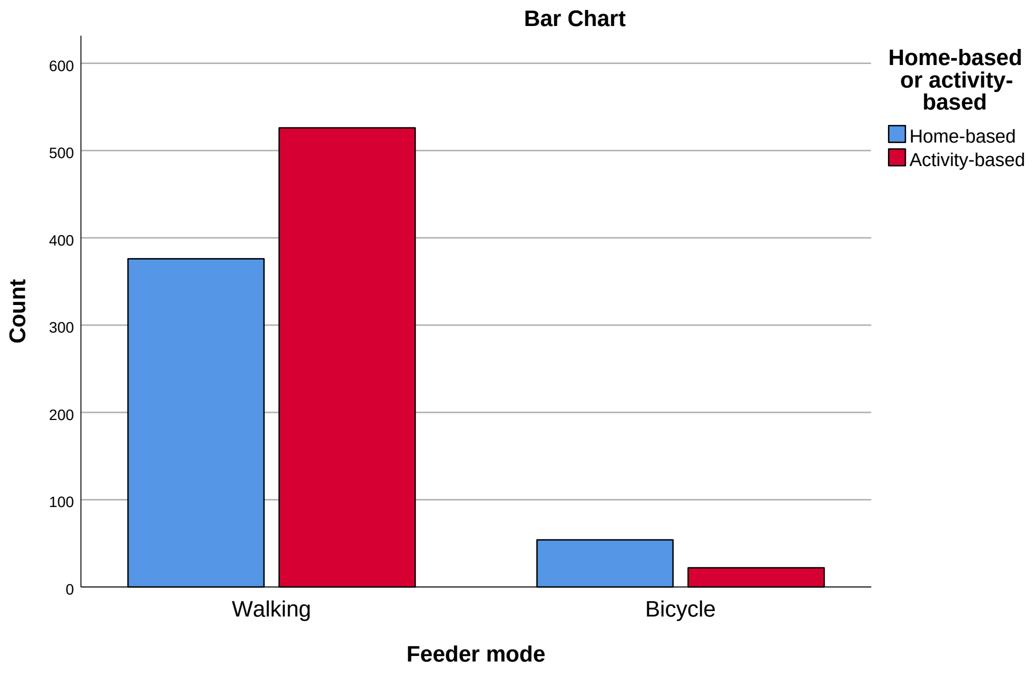

Figure B.14: Feeder mode by feeder type

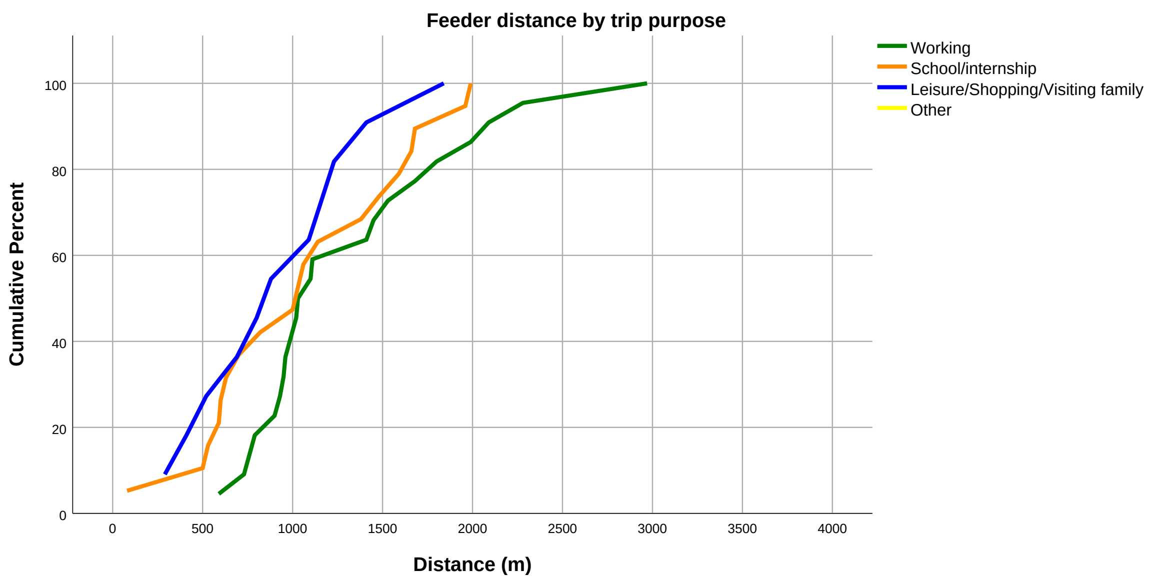

Figure B.15: Feeder distance by trip purpose (cycling)

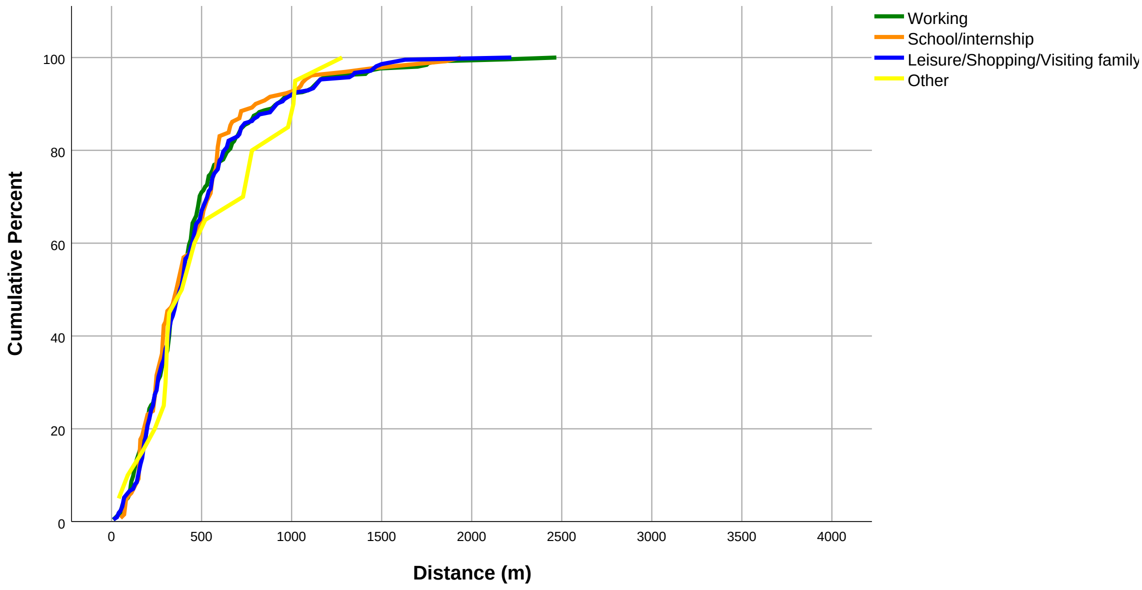

Figure B.16: Feeder distance by trip purpose (walking)

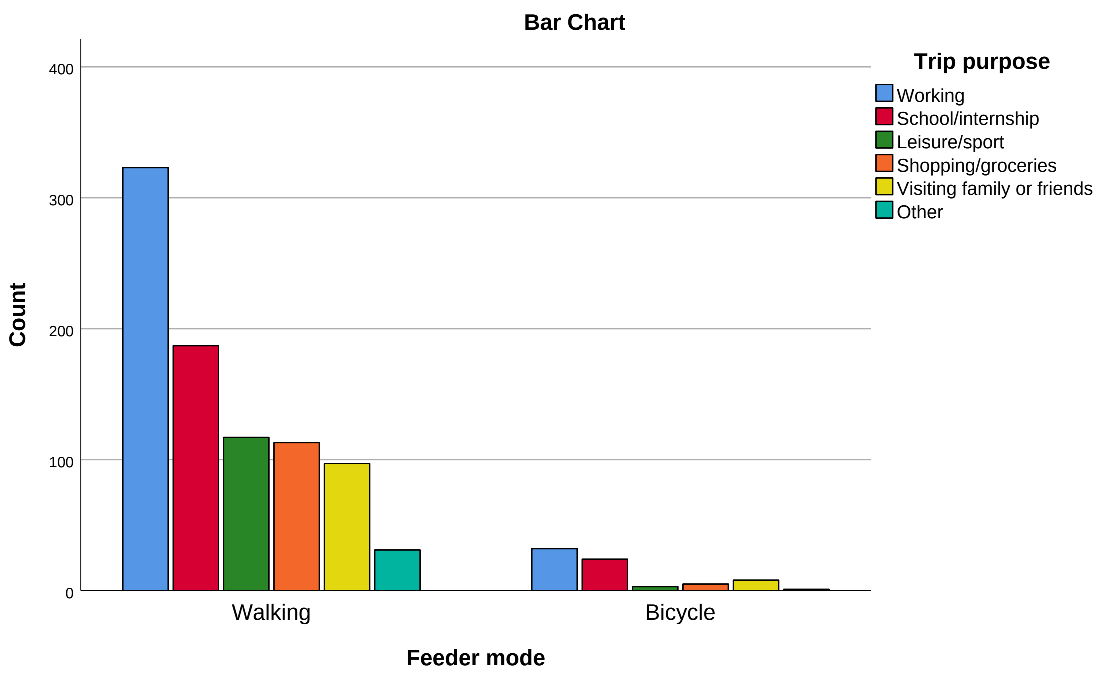

Figure B.17: Feeder mode choice by trip purpose

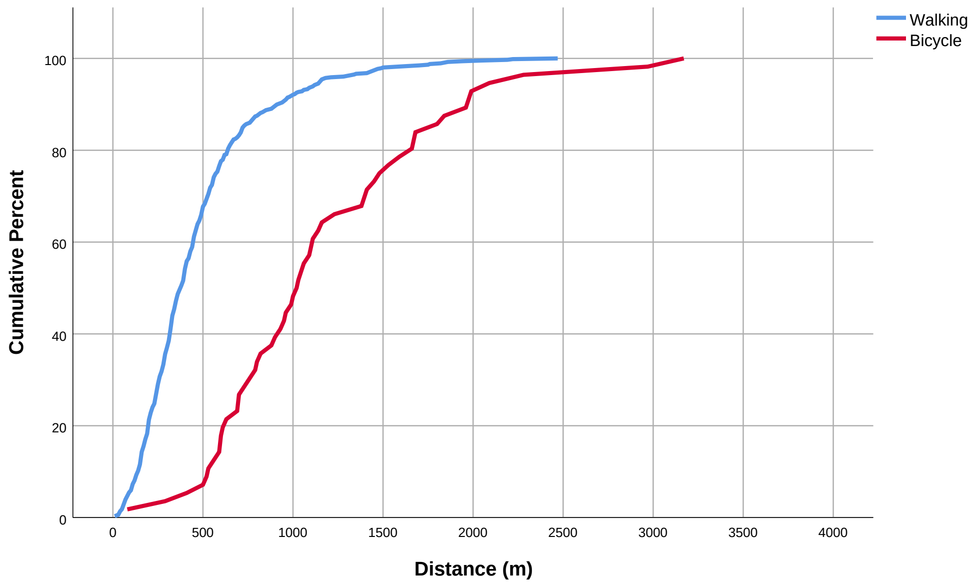

Figure B.18: Feeder distance by feeder mode

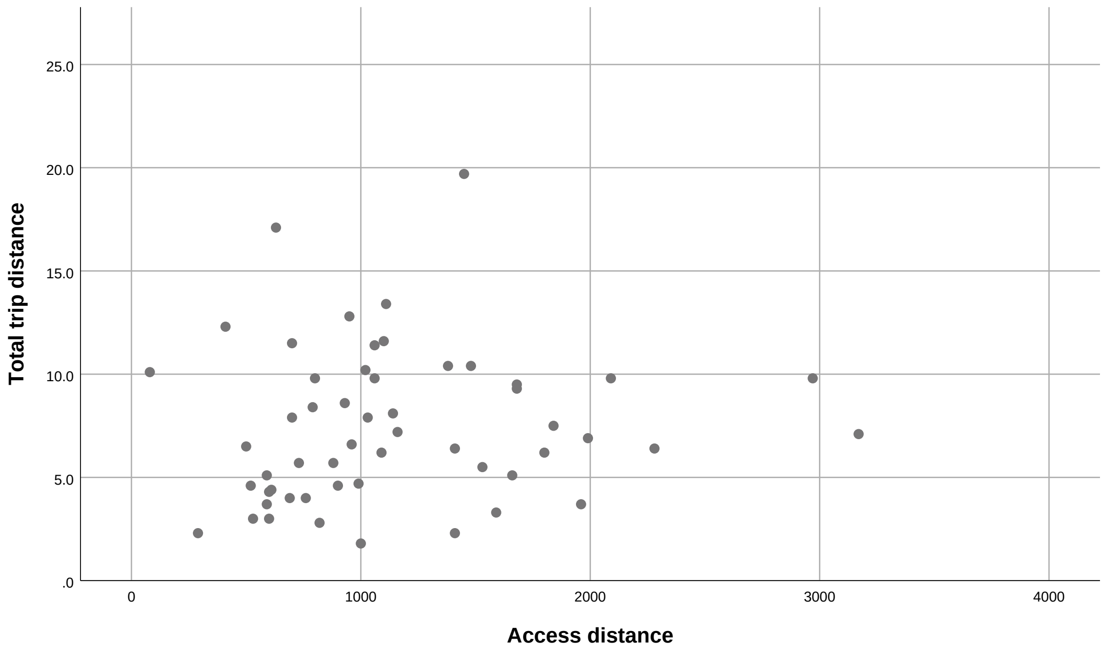

Figure B.19: Feeder distance by total trip distance (cycling)

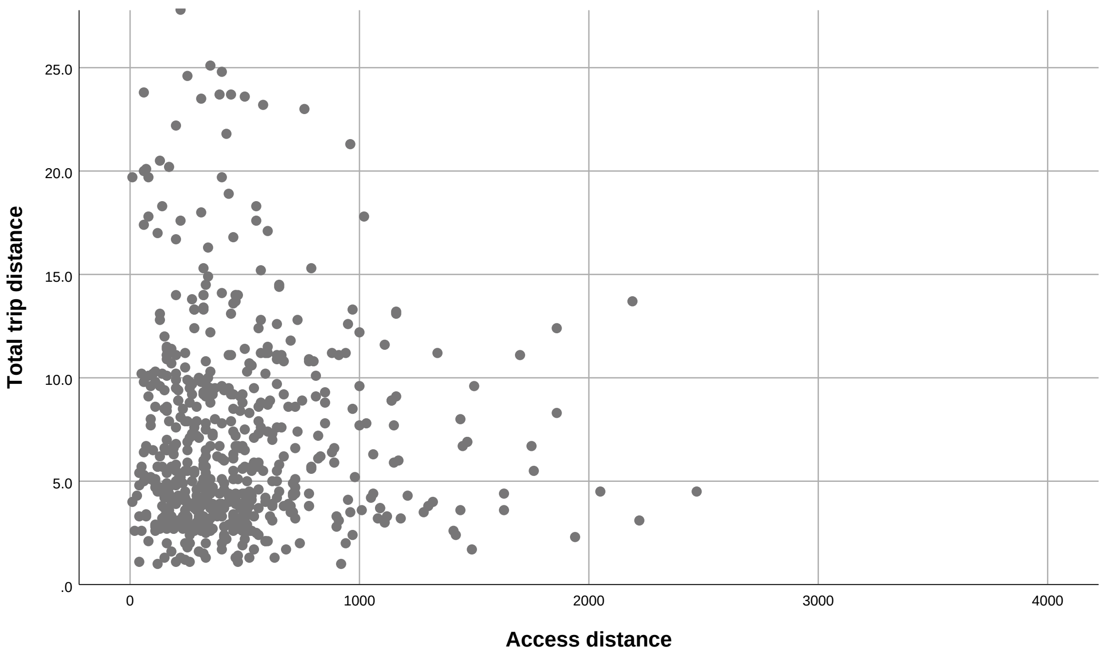

Figure B.20: Feeder distance by total trip distance (walking)

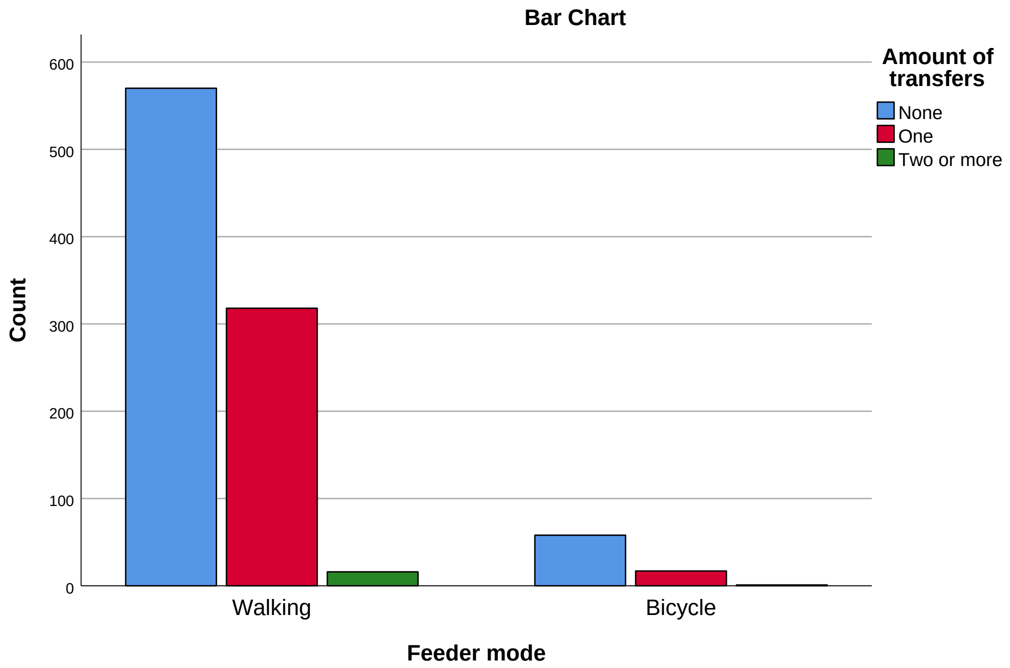

Figure B.21: Feeder mode choice by amount of transfers

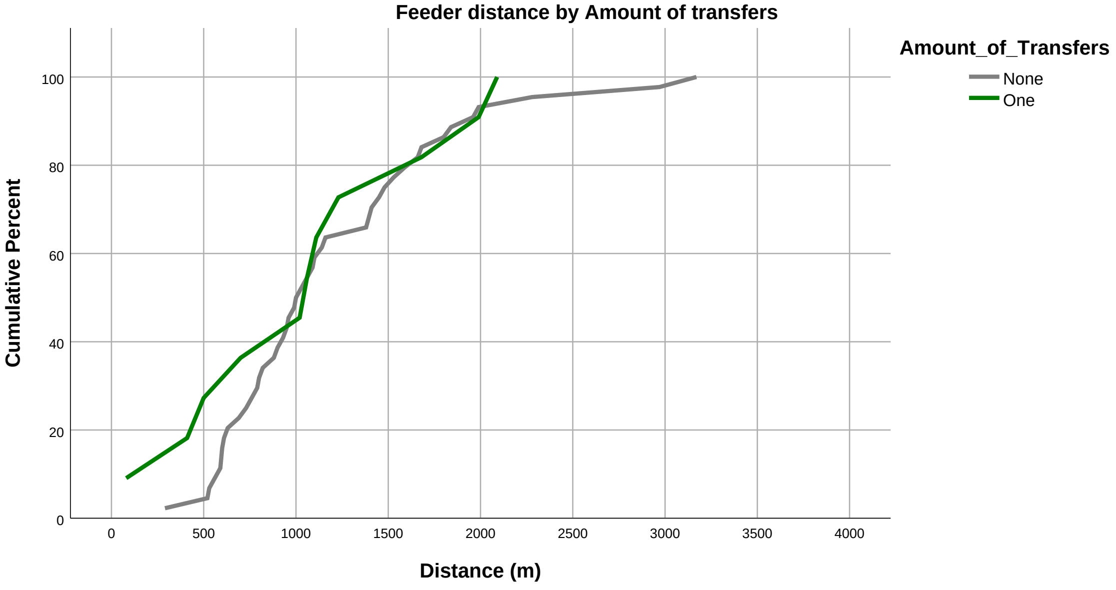

Figure B.22: Feeder distance by amount of transfers (cycling)

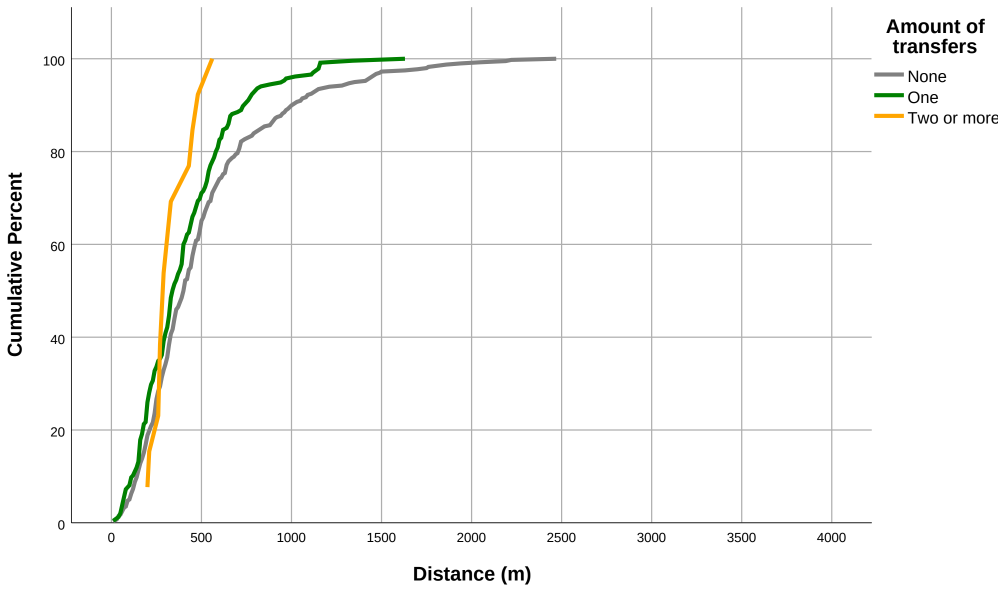

Figure B.23: Feeder distance by amount of transfers (walking)

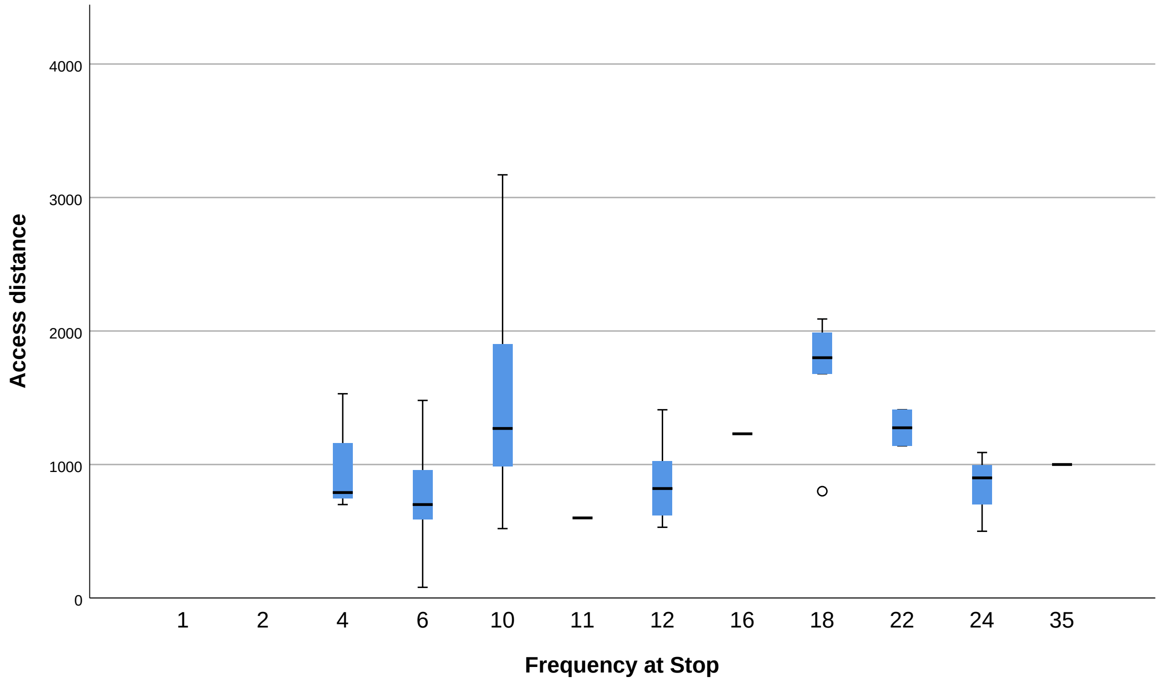

Figure B.24: Feeder distance by frequency at stop (cycling)

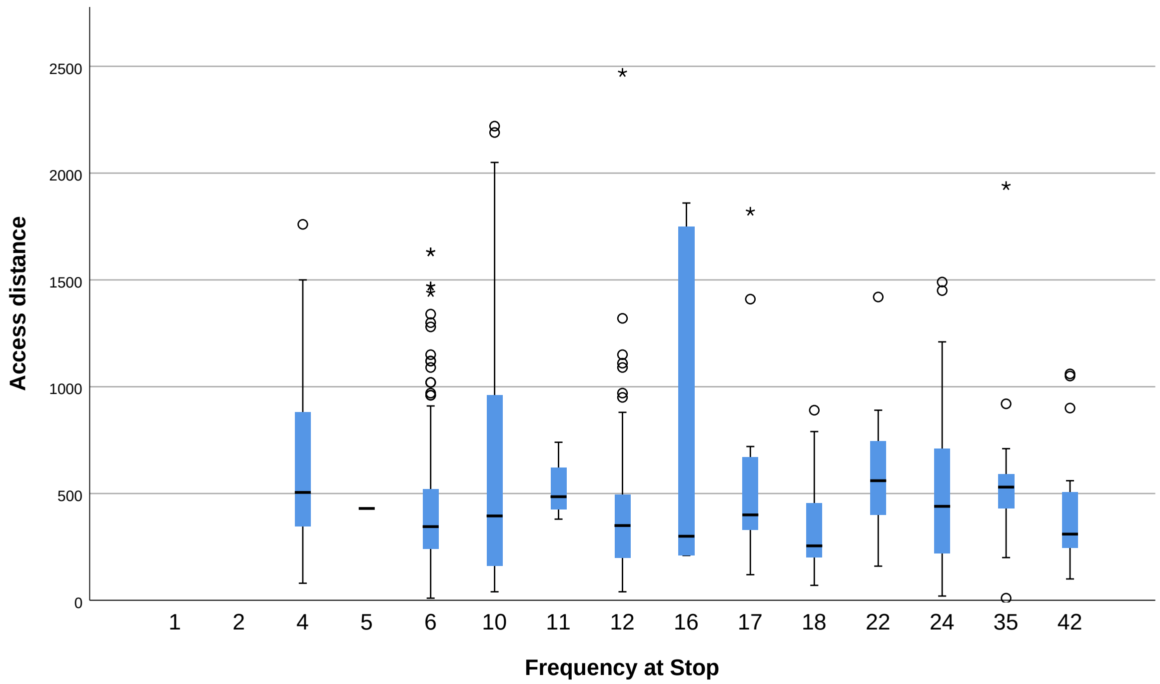

Figure B.25: Feeder distance by frequency at stop (walking)

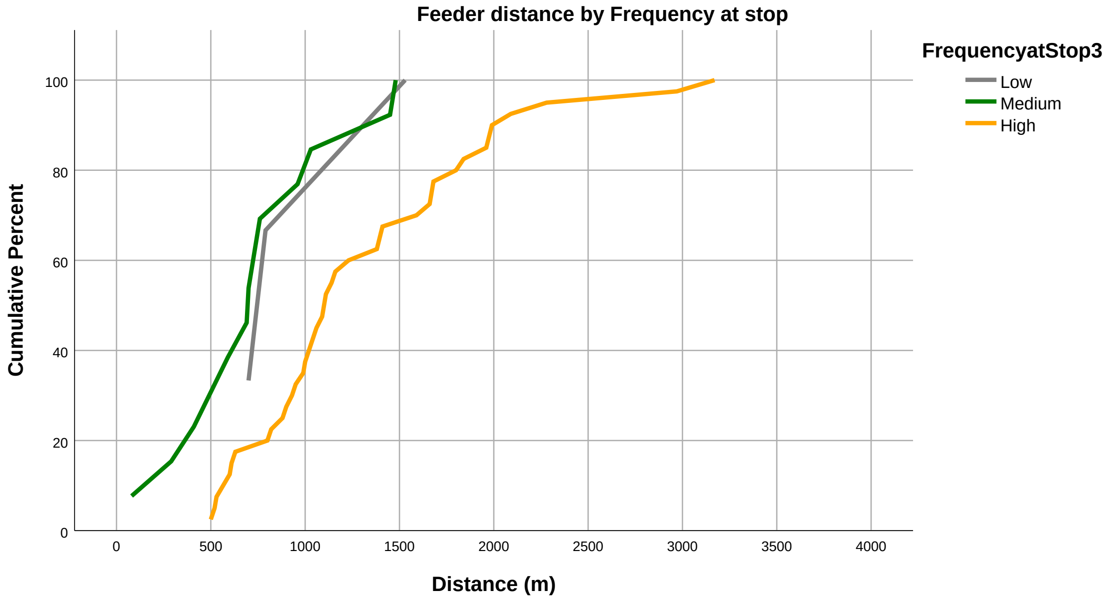

Figure B.26: Feeder distance by frequency at stop (cycling)

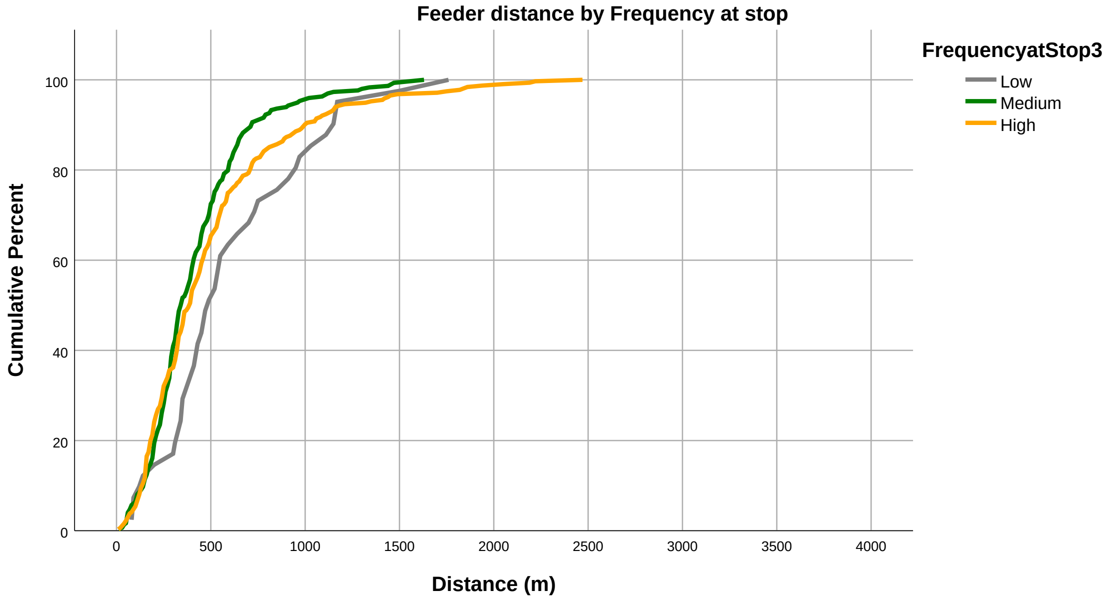

Figure B.27: Feeder distance by frequency at stop (walking)

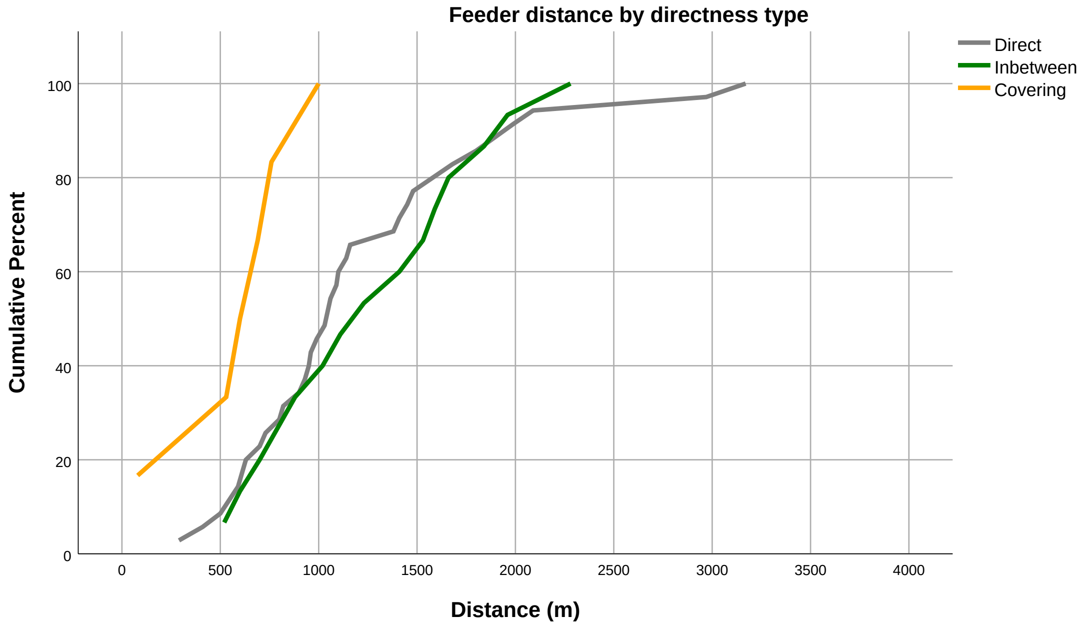

Figure B.28: Feeder distance by directness (cycling)

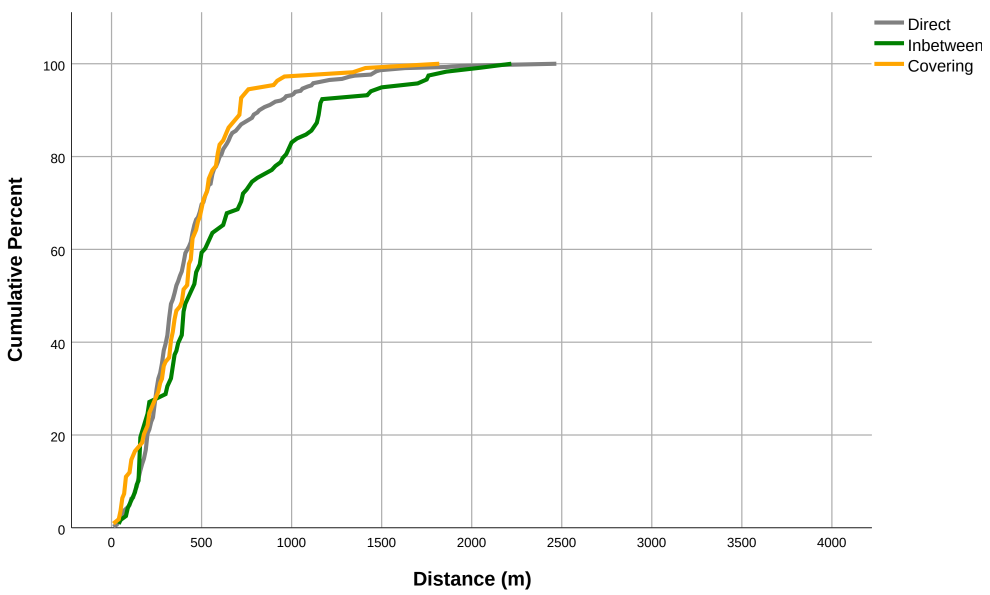

Figure B.29: Feeder distance by directness (walking)

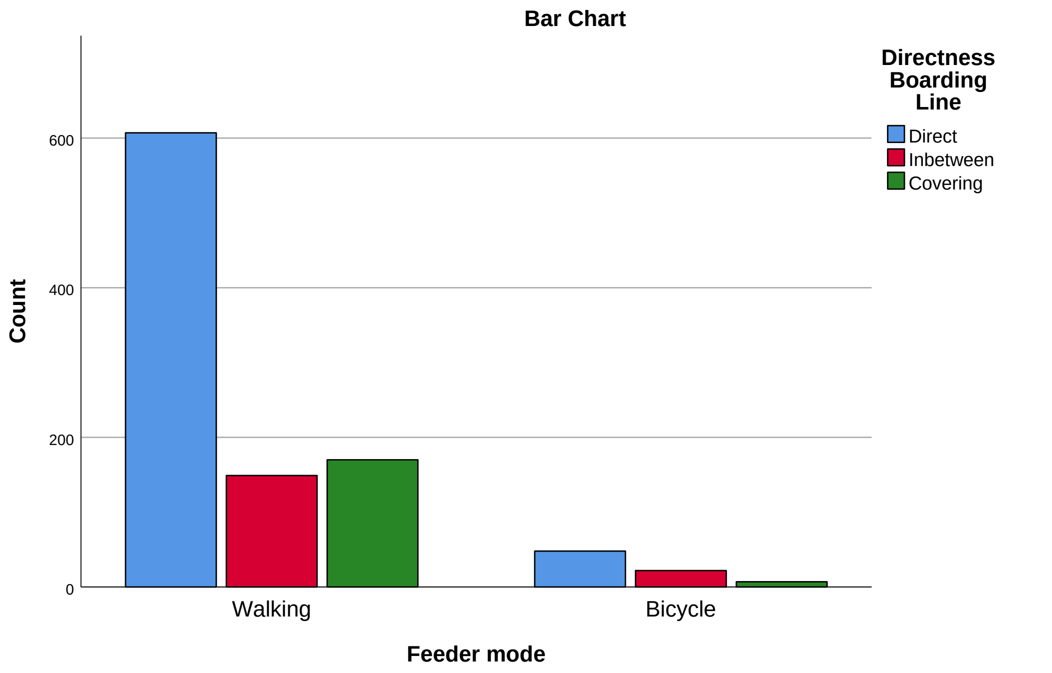

Figure B.30: Feeder mode choice by directness

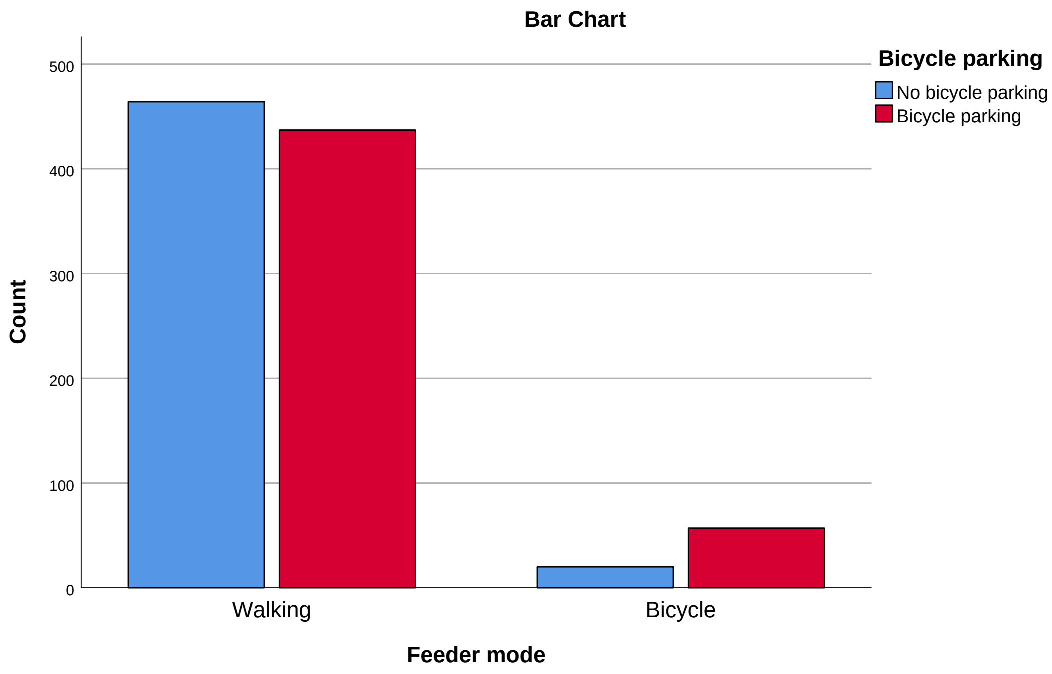

Figure B.31: Feeder mode choice by bicycle parking availability

C

Logistic regression models

'200-400m' model

The '200-400m' model is significant (χ^2 = 199.298; p = .000). However, the Pearson goodness-of-fit test also shows significance (χ^2 = 44.512p = .043), indicating a poor model fit. Nagelkerke pseudo R^2 test has a value of .282, indicating that 28.2% of variance is explained by the model.

The '210-400m' category is only significantly different for the second 'frequency at stop' group, indicating that when the frequency at a stop is between 6 and 10 compared with over 10, the probability of being in the '210-400m' distance category compared with the 'under 210m' distance category increases. No such significant effect of 'frequency at stop' was found when the 'over 400m' distance category is compared with the '0-200m' distance category.

'Feeder mode' and 'tram density' are both significant factors when the 'over 400m' distance category is compared with the 'under 210m' distance category. With walking as a feeder mode, the probability of belonging to the 'over 400m' distance category decreases with respect to cycling. A density of 0 tram stops within 400m of the origin/destination increases the probability of being classified in the 'over 400m' distance category compared with a tram density of five stops or higher.

So, different factors distinct the '210-400m' distance category and the 'over 400m' distance category from the reference category, the 'under 210m' distance category.

'300-600m' model

The '300-600m' model shows significance(χ^2 = 236.627; p = .000). However, the Pearson goodness-of-fit test also shows significance (χ^2 = 29.893; p = .471), indicating a good model fit. Nagelkerke pseudo test indicates that 32.1% of variance is explained by the model (R^2 = .321). So, this model seems to fit better with the data than the '200-400m' model according to the test statistics. Just like the '200-400m' model, also in the '300-600m' model feeder mode, frequency at stop and tram density all show significant effects. However, they differ slightly in their effects.

Frequency at stop has clearly different results for the '300-600m' model than the '200-400m' model. The probability of belonging to the highest distance category ('over 600m') decreased with a frequency at stop between 6 and 10 compared with 10 or higher, while it had no significant effect for the highest distance category of 'over 400m'. On the other hand, frequency at stop does not show a significant effect on the middle category of '310-600m', but it does on the middle category of '210-400m'. This difference might originate with the same data problems as frequency in **??**.

The feeder mode factor is only significant for the 'over 600m' distance category, where walking decreases the probability of belonging to the category related with the 'under 310m' category.

Compared with a density of 5 or more tram stops within 400m, a tram density of both 0 and 1 increases the probability of belonging to the '310-600m' distance category, with the reference category of 'under 310'. The same holds for the 'over 600m' distance category, but there only a tram density of 0 shows a significant difference with the reference category. The first model ('200-400m' model) showed only a significant effect of tram density for the distance category of 'over 400m'. This indicates that the threshold distance in order for tram density to have an effect, lies under 600m.

’400-800m’ model
The model of ’400-800m’ thresholds, like the other models shows the highest χ^2 of 272.114 and is significant ($p = .000$). The Pearson goodness-of-fit test is non-significant ($\chi^2 = 29.586$; $p = .487$), which indicates that the model has a good fit. The Nagelkerke pseudo R^2 test has the highest value of all models (.368), so 36.8% of the variance is explained by the model.
For this model both distance categories are significantly different from the reference category (’under 410m’) for feeder mode: walking decreases the probability of being assigned to both categories. Also a tram stop density of 0 within 400m has similar effects for both distance categories: it increases the likelihood of being assigned to the two higher distance categories, in comparison with the ’under 410m’ distance category.
A frequency at stop between 6 and 10 has no significant effect on the ’410-800m’ distance category, but decreases the probability of being associated with the ’over 800m’ distance category.
Because the two highest distance categories have more in common than for the 200-400m and 300-600m models, it is assumed that the 400m bandwidth best represents the different choices of travellers.

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