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Bicycle sharing for better use of bicycle parking capacity at railway stations

An empirical study into preferences of current cyclists for using a shared bicycle as access or egress mode

TU Delft

Master thesis

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Bicycle sharing for better use of bicycle parking capacity at railway stations

An empirical study into preferences of current cyclists for using a shared bicycle as access or egress mode

By

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Preface

This study is conducted on behalf of consultancy firm Mobycon and the Delft University of Technology. With this thesis, I conclude my master program Transport, Infrastructure and Logistics at the faculty of Civil Engineering and Geosciences at the Delft University of Technology.

I would like to express my gratitude to everyone who helped me during the process of writing this master thesis.

My first word of thanks goes to my graduation committee. I would like to thank my supervisor, Dr. Kees Maat, for his comments, especially on the story line. I would like to thank my supervisor, Dr. Eric Molin, for his expertise on the design of stated choice experiments and his help with discrete choice modelling aspects. Furthermore, I would like to thank Prof. dr. Bert van Wee, the chairman of my committee, for his critical feedback and enthusiasm. The positive comments at the three key meetings were a mental support to me. Thanks also to Ir. Helene van Heijningen, my external supervisor, for the useful feedback and help. Because of your own experience with conducting a stated preference study on shared bicycle use as a graduate student, I think no one could have helped me better than you. Finally, I would like to thank my external supervisor, Drs. Lennart Nout, for his great enthusiasm on the topic which kept me motivated.

I would like to thank Mobycon for providing me the opportunity to do this research and thank all Mobycon colleagues for their interest and help. In particular, Michel Felkers who helped me to coordinate the distribution of the survey invitation flyers and Oliver Blake who read parts of my thesis and commented on my English writing.

Special thanks goes to the Vervoerregio Amsterdam (Transport Authority Amsterdam) for granting me the opportunity to do this research by funding the data collection together with Mobycon. I also would like to thank the Vervoerregio Amsterdam for the great opportunity to present the results of this thesis to all parties involved in bicycle parking at railway stations.

I am grateful for the workers who woke up at 5:00 AM to help me distribute the survey invitations and I am also grateful for all cyclists at the Amsterdam railway stations who took the time to participate in the online survey.

I want to thank Drs. Kees van Goeverden, researcher at the TU Delft, for his help on the use of travellers data in order to estimate potential capacity savings as a result of bicycle sharing.

Furthermore, I would like to thank Metrocov, a platform for travellers interests regarding PT transportation in the Metropolitan area Rotterdam-The Hague, for nominating my essay on the topic of this thesis. The opportunity to pitch the idea of efficient and hybrid bicycle sharing at their symposium and awarding the idea with the first prize, gave me the energy to finish the final parts of this thesis.

Last but not least, I would like to thank my friends and family. I am grateful for the support, the reading of parts of my thesis, the discussions about my research, the chocolate bars to stay focussed and the distraction from my graduation work when I needed it.

The process of conducting this research was challenging and sometimes difficult for me, but I am happy with and proud of the result. I am especially proud of the fact that Mobycon and the Vervoerregio Amsterdam continue to research efficient bicycle sharing at railway stations and I am curious to see how bicycle sharing will further develop.

Debóra van der Nat
Delft, November 2018

Executive summary

The combination of cycling and public transport (PT) use has been found to be very successful in the Netherlands. On average, 47% of daily train users cycle to a railway station and this number is expected to grow to until at least 2030. As a result, railway stations suffer from bicycle parking capacity shortages. Large investments are needed to meet the growing demand for bicycle parking capacity, while the expansions take up the limited space around railway stations. To address the ever-growing demand for bicycle parking capacity and to continue the success of the combined use of bicycle and PT, alternative solutions beyond building new bicycle parking facilities are needed.

Bicycle sharing is a promising strategy to tackle bicycle parking capacity shortages at railway stations as it could significantly reduce the number of parked bicycles. A fundamental prerequisite is that a bicycle sharing system (BSS) makes use of the already parked bicycles, which is not the case with the available PT-bicycle system in the Netherlands. Existing literature shows that bicycle sharing between current cyclists has the potential, in theory, to reduce the number of parked bicycles by 22-25% at the central railway stations of the four largest cities in the Netherlands. When bicycles are also shared with travellers currently using other modes 37-50% capacity savings could be achieved. Currently there is a lack of knowledge about bicycle sharing from a user's perspective to make a more realistic estimation of the expected potential. The important factors in bicycle sharing among potential users need to be clarified in order to estimate the potential demand and to progress towards the design of the organisation of an efficient system. Therefore the objective of this study is to investigate the preferences of current bicycle-train users and the demand for bicycle sharing in order to design an efficient bicycle sharing system (BSS).

The knowledge required to meet the objective of this research is gained by answering the following main research question:

"What are the preferences of current cyclists regarding an efficient bicycle sharing system in order to relieve bicycle parking capacity shortages at major Dutch railway stations?"

Conducting a literature study investigated how a bicycle sharing system could contribute to bicycle parking capacity savings at major Dutch railway stations. It highlighted that reversed commuting flows are present at major railway stations. This allows for an efficient BSS which exchanges bicycles between arriving and departing train travellers. For a BSS to function efficiently and to contribute to a reduction in the number of parked bicycles it appeared that several conditions need to be met. First, a high number of travellers using a bicycle as access mode (access cyclists) should be willing to use a shared bicycle, as access cyclists are responsible for the supply of shared bicycles. Second, a high number of travellers should be willing to use a shared bicycle for egress transportation (current and potential egress cyclists). These egress travellers are responsible for the demand of shared bicycles. Current egress cyclists switching to a shared bicycle contribute to the highest capacity savings, as one parked egress bicycle is equivalent to four parked access bicycles. Third, supply and demand of shared bicycles needs to be balanced. This implies that the number of demanded egress bicycles should not exceed the number of access bicycles supplied. This balance prevents for unavailability of shared bicycles, which otherwise would lead to lower bicycle parking capacity savings. The needed balance differs for every railway station as the cycling mode shares vary at the home-end and activity-end. In addition, supply and demand of bicycles fluctuates during the day, week and year.

Subsequently, a literature study into existing and possible bicycle sharing systems and bicycle service initiatives was conducted. This literature study resulted in an overview and characterisation of existing and possible systems, presented in Figure 1. Hybrid sharing is a new proposed system in this thesis and is based on a existing bicycle lease initiatives. This hybrid BSS offers a standardised bicycle for a monthly

subscription fee which is to be shared at railway stations. 2-way station-based systems solely allow for round trips from and to railway stations (open PT systems). The open urban systems allow for single trips within the city and from and to railway stations, where 1-way station-based systems offer shared bicycles which can be parked at assigned racks or parking zones and shared bicycles of free floating systems can be parked almost everywhere in public space.

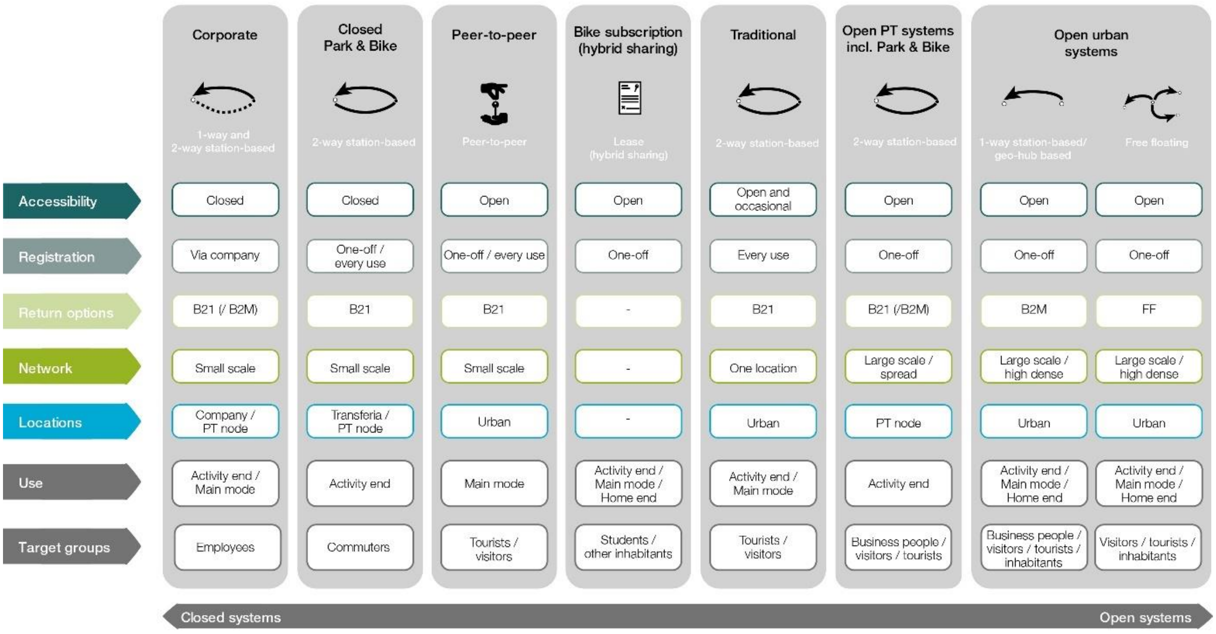

Figure 1: Overview of different bicycle sharing system designs and their most distinctive characteristics. A larger version of this figure can be found in Appendix A.2.

The presented systems were assessed on their suitability to operate as an efficient system, which led to a selection of suitable system designs. These system designs involve the combination of a BSS for access trips (home-end) and a BSS for egress trips (activity-end), in which the systems can be the same at both trip-ends and are serviced by the same bicycles. The assessment resulted in the following promising combinations of existing BSSs and bicycle service initiatives that all make use of standardised bicycles:

Home-end:	*Activity-end:*	*System type:*
Hybrid sharing (lease)	*– 2-way station-based*	*Open PT system*
Hybrid sharing (lease)	*– 1-way station-based*	*Hybrid open urban system*
Hybrid sharing (lease)	*– Free floating*	*Hybrid open urban system*
1-way station-based	*– 1-way station-based*	*Open urban system*
Free floating	*– Free floating*	*Open urban system*

To gain insight into potential user preferences regarding the characteristics (attributes) of the selected systems a stated choice experiment was conducted. The investigated BSS attributes were (1) Accessibility of a shared bicycle at home or at destination (the time in which a shared bicycle can be reached with absolute certainty), (2) Parking convenience (the guaranteed availability of a premium parking place near the platform), (3) Accessibility of a shared bicycle at a railway station, (4) Walking time form shared bicycle parking place to home or destination, and (5) Price. The stated preference (SP) data was collected using an online survey distributed to cyclists at three Amsterdam railway stations during peak hours on average working days and resulted in 961 useful responses. Respondents could choose between using their private bicycle and two shared bicycle alternatives described by the five mentioned BSS attributes. The SP data was analysed with different methods and the results were applied in different ways. The research steps taken, are described below.

Firstly, descriptive statistics were used to draw a picture of the population and to explore respondents trip characteristics. The analysis showed that the respondents are relatively young (median age 33 years) and remarkably high-educated. Moreover, the high number of work-related trips stood out, which is in accordance with literature findings on Dutch bicycle-train users. The income of the respondents is fairly equal to the income of the Dutch population in contrast to what was expected based on literature findings. The majority of the cyclists surveyed travel to or from the railway station four or five times a week. A large part of the egress cyclists pays a charge to use the bicycle parking facility, while only a small fraction of the access cyclists do. The majority of both access and egress cyclists at the three studied railway stations do not experience difficulties finding a bicycle parking place at these railway stations. Overall, it is expected that the sample gives a fair representation of cyclists at major railway stations during peak hours.

Secondly, two multinomial logit (MNL) models were estimated using the stated preference data. One model based on choices of access cyclists and the other model based on choices of egress cyclists, as it was assumed that choice behaviour of these groups differs. The estimated alternative specific constant (ASC) for bicycle sharing revealed a significant base preference for using a private bicycle among access cyclists. This ASC implies that 37% of the access cyclists and 54% of the egress cyclists would opt for use of a shared bicycle with characteristics similar to the use of private bicycles (guaranteed availability, no walking times and free of charge). For both access and egress cyclists, the decision to use a shared bicycle is primarily based on the BSS attribute ‘price’. Price is on average three to four times more important than the second most important attribute ‘accessibility of shared bicycles at the trip starting points’ (home and destination). Furthermore, the results showed that for access cyclists the availability of a guaranteed premium parking place forms an incentive to use a shared bicycle. A premium parking place seems not to be relevant for egress cyclists. Figure 2 gives a relative comparison of the attributes by visualising the average relative importance of the five investigated attributes.

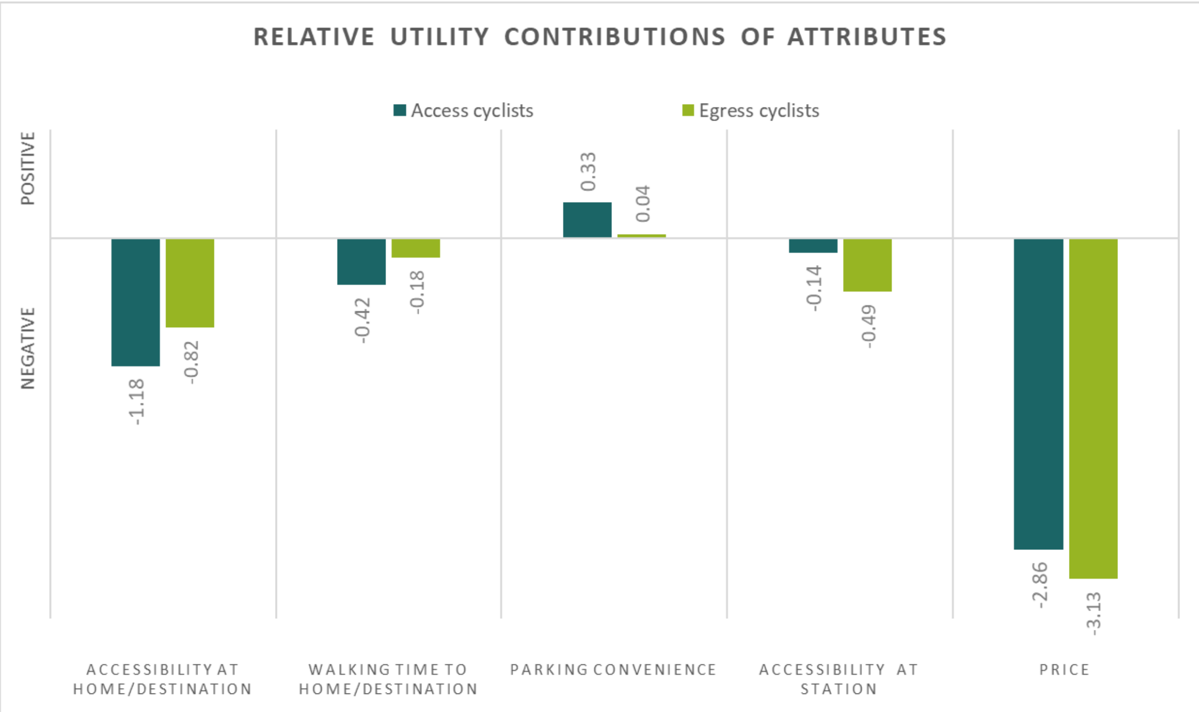

Figure 2: Visualisation of the average relative importance of the investigated attributes

Thirdly, MNL models including personal and trip characteristics as interaction effects were estimated in order to reveal differences in preferences among different groups of respondents. Main findings are that younger cyclists (< 38 years) are more likely to opt for a shared bicycle than older cyclists, which is in accordance with findings in literature on shared bicycle user characteristics. Moreover, it was found that bicycle-train users who pay for bicycle parking are less sensitive to the tariff of shared bicycle use and thus have a higher willingness to pay for shared bicycles. Furthermore, it was found that cyclists having difficulties finding an empty parking place do attach more value to the availability of a premium parking place. Finally, cyclists who make trips of an average cycle distance (between 5 and 15 minutes) were found to be more likely to opt for a shared bicycle.

Fourthly, the choice probabilities for the five different presented bicycle sharing system combinations (with and without a premium parking place) were predicted using the estimated parameters of the base MNL models. The choice probabilities represent the demand for the systems i.e. the part of the population that would be interested in using the systems. It appeared that the demand for the different system set-ups varies widely. The demand is lowest and most heavily varying among access cyclists: when the use of the systems is free of charge, 18-47% of the access cyclists and 41-55% of the egress cyclists are willing to use a shared bicycle, depending on the BSS attributes 'walking time', 'accessibility of shared bicycles' and 'availability of a premium parking place'. However, when the price increases, the demand for the different systems decreases rapidly, as price is a key factor in current cyclists' choices regarding bicycle sharing. The large variety in demand among access cyclists is mainly due to the fact that, in contrast to egress cyclists, access cyclists do attach value to the availability of a premium parking place.

Fifth, the possible reduction in the number of parked bicycles at major Dutch railway stations during work days was estimated. For the estimations the choice probabilities for the different system set-ups based on the collected SP data were used. Figures on bicycle-train use emerging from Microdata of the Dutch National Travel Survey, collected between 2004-2009, were taken as a reference point for the current bicycle parking pressure and travel patterns at railway stations. It was found that when bicycles are only shared between current access and egress cyclists a small but significant reduction in the number of parked bicycles can be achieved: 2-5% for tariffs between 10 and 15 euros per month, 5-9% for tariffs between 5 and 10 euros per month, and 7-15% for tariffs between 0 and 5 euros per month. A capacity reduction of the aforementioned percentages is possible, assuming that the peak in the number of parked bicycles is on work days. When the access bicycles are shared with all potential egress cyclists (current egress cyclists and other travellers making trips with a distance between 1 and 5 km) the bicycle parking capacity savings can be significantly higher: 16-25% at the central stations for the four largest cities and 19-25% at the main stations of other large cities in the Netherlands. A limiting factor in the reduction of bicycle parking pressure, is the demand for shared bicycles being larger than the supply of shared bicycles, leading to the need for a buffer of additional bicycles in order to guarantee availability to users and maintain willingness to use a shared bicycle among travellers. This buffer however, results in increased bicycle parking pressure at peak moments and could therefore even lead to an increase in the needed bicycle parking capacity.

This thesis concludes that a sufficient supply of shared bicycles is of primary importance in the success of the system, as it ensures availability at the railway station, makes a buffer of additional bicycles unnecessary and reduces bicycle parking capacity needs. Therefore it is recommended to offer a BSS that is as inviting as possible for access cyclists. Considering the results of this study, an attractive BSS aimed at access cyclists means, as a starting point, that the tariff should be as low as possible. In addition, it also requires a system with guaranteed availability of bicycles and no walking times, which can be realised with a hybrid sharing (lease) system. Furthermore, it is recommended to offer additional parking convenience as a premium parking place is found to form an incentive for access cyclists to use a shared bicycle. For the recommended 2-way station-based system at the activity-end, a price between 7 and 11 euros per month is recommended. The combination of this system and price ensures that the demand will not exceed the supply and prevents the need for a buffer of additional bicycles, whilst the highest possible capacity savings can be achieved. Since the mentioned tariff could be inconsistent with a lower tariff for the hybrid sharing system, the price-setting and tariff per trip should be considered carefully.

This thesis contributes to the literature on bicycle sharing the Dutch context and contributes to the literature on bicycle parking capacity savings at railway stations as a result of bicycle sharing. The first scientific contribution concerns an efficient BSS being studied from a users' perspective. Hence, this research goes beyond the theory of an efficient BSS as studied by Goeverden & Correia (2018) and allows for more realistic estimations of possible capacity savings. The second scientific contribution concerns bicycle sharing for access transportation at the expense of privately owned bicycles not yet explored in literature. This study provided knowledge in the importance of BSS attributes for using a shared bicycle for both access and egress transportation. Combining user preferences and the demand for bicycle sharing at both trip ends, allows for estimations to be made on what extent parking capacity savings can be achieved. Moreover, a new and unconventional form of bicycle sharing, hybrid sharing (lease), is researched in this thesis.

The results of this study are valuable to the Dutch government as well as other actors involved in developing solutions for the bicycle parking capacity shortages at major Dutch railway stations. This study provides a starting point for further research into the operationalisation of an efficient BSS, its contribution to reduced bicycle parking capacity needs, and the costs and benefits of an efficient BSS at Dutch railway stations. The results of this study may also become relevant for other countries which are now not facing bicycle parking capacity problems, but who may face similar problems in the future if the combined use of bicycle and public transportation increases.

Future research could extend this study by investigating the demand for the most preferable systems among current train travellers who use other modes for access and egress transportation and by investigating the demand among potential train travellers. In that study a distinction between frequent and less frequent train travellers should be made in order to be able to draw conclusions on the price setting (monthly tariff and tariff per trip). Additionally, future research could investigate the implications of fluctuations in supply and demand, and the buffer needed to respond to these fluctuations preferably at individual station level. Both of the aforementioned investigations could contribute to more accurate estimations of the reduction of needed bicycle parking capacity. Moreover, future research could study the cost effectiveness of efficient BSSs. Lastly, a pilot study to test the operationalisation of the system is recommended.

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List of Abbreviations

B21	Back to one
B2M	Back to many
BSS	Bicycle sharing system
FF	Free floating
IIA	Independence of Irrelevant Alternatives
ML	Mixed Logit
MNL	Multinomial Logit
NS	Nederlandse Spoorwegen (Dutch rail operator)
PT	Public Transportation
RUM	Random Utility Maximisation
SC	Stated choice
SP	Stated preference

1. Introduction

Cycling has been an integral part of traffic and transport policy in the Netherlands for decades. This has clearly yielded results as, with a bicycle mode share of 27% for all journeys, the Netherlands has the world's highest rate of bicycle use (Klinkenberg & Bertolini, 2014; Ministerie van Verkeer en Waterstaat & Fietsberaad, 2009; Pucher & Buehler, 2008). In high density urban areas in the Netherlands cycling rates are even higher and continue to increase (Hendriks, 2014; Klinkenberg & Bertolini, 2014).

In particular the combination of cycling and public transport (PT) has been found to be very successful. In the Netherlands 1.2 million people use the train on a daily basis. Around 47% of them, use a bicycle to travel from home to the railway station. At the activity-end, a bicycle is used as a mode of transportation in 12% of all cases (CROW-Fietsberaad, 2014; Hendriks, 2014; Kager, Bertolini, & Te Brömmelstroet, 2016; KiM, 2016b, 2016a). The number of bicycle-PT users is increasing and is expected to grow until at least 2030 (Dijkzeul, Van Schelven, & Kuipéri, 2015). Considering bicycle-PT as one system, an annual growth rate of 5% between 2010 and 2013 is found, while the number of users of other modes showed a decline or only a modest growth (CROW-Fietsberaad, 2014; Hendriks, 2014; Kager et al., 2016; KiM, 2016b, 2016a).

The increased use of bicycles, and especially the intensive use of bicycles in combination with public transportation, has its downsides. As a result, many (mainly larger) railway stations suffer from capacity shortages for bicycle parking and there is need for expansion to meet the growing demand (Dijkzeul et al., 2015). In several Dutch cities, municipalities and other authorities have invested in new parking places at railway stations, to increase capacity. From 2012, 30,000 additional bicycle parking places have been created at the 34 largest train stations in the Netherlands (Dijkzeul et al., 2015). For example, in Utrecht the largest bicycle parking garage in the world opened recently. Despite the 12,500 places that will be completed in 2018, the capacity will not be sufficient to facilitate the demand (Hendriksma, 2017). In most cases the demand for bicycle parking turns out to be higher than expected because of latent bicycle demand (Van Boggelen & Thijssen, 2008; Vos, 2013).

Expansion of bicycle parking facilities is expensive and the costs for building new parking places will only increase as the available space to expand parking places around railway stations is scarce and underground solutions are even more expensive (Dijkzeul et al., 2015; Geerdink, Schooleman, Staffhorst, Doornbos, & Hes, 2010). Between 2012 and 2020, 182.5 million euros are available to provide new parking places at Dutch railway stations. It is expected that, with the available budget, in 2020 there still will be a shortage of 48,000 bicycle parking places and a shortage of around 98,000 bicycle parking places in 2030 (Dijkzeul et al., 2015).

The growing capacity problems not only have its consequences for the Dutch government and organisations like ProRail and NS. Travellers are (already) inconvenienced by long searching times for empty parking places and long walking distances due to more remote parking zones. Moreover, in the future travellers may have to pay for parking their bicycle at a railway station as the large investments needed, in combination with limited budgets, are putting free parking of bicycles under pressure (Dijksma et al., 2016). This is an undesirable situation contradicting the policies driven by the Dutch government that foster improvements in the quality of the total multimodal trip chain and cyclists may opt for other (less sustainable) modes.

It has become clear that solutions other than building new bicycle parking places are necessary to address the ever-growing demand for bicycle parking places and to maintain the quality of bicycle parking at railway stations. The organisations involved, including the Dutch Ministry of Infrastructure and Water Management, NS and ProRail, have started to acknowledge the need for alternative solutions and they have agreed to address the growing problem. This recognition is translated into directions for solutions laid down in a Governance Agreement (Dijksma et al., 2016). Examples of mentioned solutions in this agreement are: more efficient use of the existing bicycle parking capacity by innovative technology, limiting the (free) parking time, smart tariff policy and efficient and accessible bicycle sharing systems.

The proposed solution of efficient and accessible bicycle sharing systems is particularly interesting, as a recent study by Goeverden & Correia (2018) shows that 22-25% of the capacity at central stations in the four largest cities can be reduced when bicycles would be shared among current cyclists. When bicycles would be also shared with travellers currently using other transport modes, 37-50% of the capacity could be reduced. These numbers can be even higher as the analysis is based on data from 2004-2009 and the data ignores some egress cyclists. Moreover, the study assumed a peer-to-peer to system which limited the possible capacity savings.

The existing bicycle sharing system available at Dutch railway stations, the PT-bicycle system (Dutch: OV-fiets), does not make use of the earlier parked bicycles of access cyclists, as the PT-bicycle sharing system offers rental bicycles primarily meant for egress transportation (Van der Meer, 2017). This existing system is, therefore, different from the proposed efficient bicycle system; it does not fully exploit the potential of bicycle sharing in order to reduce bicycle parking pressure and to enlarge the capacity of the PT-bicycle system itself.

It is clear that an efficient and accessible bicycle sharing system in theory has potential to reduce the number of parked bicycle at railway stations. The governmental agreement demonstrates that an efficient bicycle sharing system is already supported by the parties involved in bicycle parking at Dutch railway stations. However, there has not been any further study. The presented capacity savings represent a theoretical maximum. What lacks is knowledge on a user's perspective to make a more accurate estimation of the expected potential, in order to clarify the important factors in bicycle sharing among current cyclists and to progress towards the design of the organisation of an efficient system (Goeverden & Correia, 2018).

The focus of this research is upon the proposed efficient bicycle sharing systems as a measure to reduce the bicycle parking capacity shortages at Dutch railway stations. In this thesis an efficient bicycle sharing system is characterized by usage of the already parked bicycles and the reverse commuting flows at major railway stations in order to save as many parking places as possible. When bicycles that are parked by cyclists arriving at the station from home (in the remaining will be referred to as access cyclists) will be used by arriving train passengers with a bicycle at the railway station (egress cyclists) or arriving train passengers who currently use other modes of transportation (potential egress cyclists), the number of parked bicycles can be decreased and capacity shortages reduced. For more details on the operation of this efficient bicycle sharing system is referred to Chapter 2.

1.2 Research objectives and research questions

The goal of this research is to provide insights in the potential user preferences and demand for bicycle sharing systems among current access and egress cyclists. Doing so, provides recommendations for the design set-up of an efficient bicycle sharing system that contributes to reduced bicycle parking pressure at major Dutch railway stations.

The knowledge required to meet the goal of this research will be gained by answering the following main research question:

> *What are the preferences of current cyclists regarding an efficient bicycle sharing system in order to relieve bicycle parking capacity shortages at major Dutch railway stations?*

More specifically, the following sub research questions need to be addressed:
1. How should a bicycle sharing system be designed in order to contribute to bicycle parking capacity savings at major Dutch railway stations?
2. To what extent do different bicycle sharing system characteristics influence the choice to use a shared bicycle as an access or egress mode among current cyclists?
3. To what extent do different personal and trip characteristics influence preferences in bicycle sharing among current cyclists?
4. What are the implications of efficient bicycle sharing systems preferred by current cyclists on the possible bicycle parking capacity savings at Dutch major railway stations?

1.3 Contribution to science and technology

Worldwide, a lot of work already describes the usage and success factors of BSSs. Most of this work is focused on shared bicycles for inner-city trips and is aimed at increasing cycling rates in cities. This research differs from the existing studies as this thesis is not aimed at increasing cycling rates but aimed at reducing bicycle parking pressure at railway stations and will especially consider access and egress bicycle trips. Urban bicycle sharing systems outside the Netherlands do not serve this purpose, as in most other countries bicycle parking is not an issue of a large extent. Instead of the research abroad that is mainly focused on a shift from other modes to (shared) bicycle use, this research will focus on facilitating the use of shared bicycles at the expense of privately owned bicycles.

Currently, little is known about the extent to which Dutch cyclists are willing to switch to shared bicycles and about the factors influencing the choice of current cyclists between using a privately owned bicycle and a shared bicycle. Only a few figures about the effects of bicycle sharing on the use of private bicycles are available from international studies. These results may not apply to the Dutch situation, as the Netherlands has a unique cycling culture that greatly differs from that in other countries. There is a handful of studies carried out in the Netherlands, however these studies only focus on shared bicycles for egress transportation and do not consider access transportation and the exchange between these two flows, as this research will do. For use of a shared bicycle in access transportation a new and more unconventional type of bicycle sharing, sharing of a leased bicycle (a hybrid form of sharing and owning) will be studied in this thesis.

Goeverden & Correia (2018) studied an efficient bicycle sharing system in the Dutch context, however, their study only focused on the theoretical potential of (peer-to-peer) bicycle sharing. This thesis goes beyond the theory of the system, by examining actual user preferences and trade-offs between availability, walking times, price and parking convenience in order to provide more realistic estimations of possible capacity savings at Dutch major railway stations.

1.4 Research scope

In this thesis bicycle sharing will be studied from the base principal that the system makes use of reversing commuting flows. This means that shared bicycles could be used in both access and egress transportation in order to achieve a reduction in the number of parked bicycles. For this reason, a number of bicycle sharing systems are not a subject of study in this research. Moreover, this study only focuses on bicycle sharing at major (Dutch) railway stations. At major railway stations the problems are most severe but can be made use of the reversing commuting flows.

A bicycle sharing system at railway stations may badly affect bicycle parking pressure at other places in the (inner) city. These consequences will not be part of this study. Also, a peer-to-peer system will not be studied in this research for several reasons, which will be further explained in Chapter 3. Furthermore, business models of BSSs in general and business models of the proposed systems are out of scope of this research.

1.5 Research methodology

In order to answer the research question of this thesis two main research methods are used: a stated choice experiment preceded by a literature study. This section explains why these methods are chosen, considering the research questions of this thesis, and how and at what moment the methods are used.

The first sub research question of this thesis *"How should a bicycle sharing system be designed in order to contribute to bicycle parking capacity savings at major Dutch railway stations?"* is formulated with the aim to provide requirements for an efficient bicycle sharing system. The question is answered by a literature study into the current use of bicycles as access and egress mode, bicycle parking at railway stations and existing or possible bicycle sharing concepts. In addition, existing work into the potential of bicycle sharing for parking savings at railway stations, is reviewed.

The second sub research question *"To what extent do different bicycle sharing system characteristics influence current cyclist's choice to use a shared bicycle as an access or egress mode?"* is answered by conducting a stated choice experiment. Current access and egress cyclists at three Amsterdam railway stations are asked to choose between different shared bicycle alternatives and their private bicycle. An analysis of the stated preference data provides information about the importance of, and relationship between bicycle sharing system characteristics in a cyclists' choice between using a shared or a private bicycle. Moreover, stated preference data provides useful attribute trade-off information and allows for estimating potential demand, later on.

A stated choice experiment offers the possibility to investigate the proposed bicycle sharing system designs despite their new attributes and features that are not present in existing bicycle sharing systems and are currently unknown to the respondents. In addition, a much wider range of attribute levels than currently exists can be covered in the experiment.

The stated choice experiment is preceded by a literature study into the factors that are of influence on cyclists' choices to use a shared bicycle. This is necessary in order to select attributes and attribute levels for the stated choice design.

The third sub research question *"To what extent do different personal and trip characteristics influence preferences in bicycle sharing among current cyclists?"* is derived from the results of the second sub research question and provide insights into how the estimation results differ across various groups of cyclists. A proper way to investigate differences in preferences by different groups of respondents, is by including personal and trip characteristics in the stated choice model that is used to answer sub question two, as is done in this research. The results of the model estimations are compared to findings of the literature study into the possible influencing personal and trip characteristics.

Subsequently, the fourth sub research question *"What are the implications of efficient bicycle sharing systems preferred by current cyclists on the possible bicycle parking capacity savings at Dutch major railway stations?"* will be answered. Using the model estimations derived by answering sub research question three, the choice probabilities for different bicycle sharing system set-ups are estimated. These choice probabilities give an indication of the demand that can be expected. Secondly, based on this potential demand for various bicycle sharing systems, the possible bicycle parking capacity savings at railway station are estimated. For these estimations actual Dutch travellers data is used.

In Figure 3 a total overview of the research methodology in relationship to the sub research questions is presented.

1.6 Thesis outline

In this first chapter the problem has been defined and research questions have been formulated. The next chapter will frame the context and provide insights in the concept and preconditions of an efficient BSS. In Chapter 3 possible BSSs will be studied in order to give insights in promising set-ups of an efficient BSS. Chapter 4 focuses on defining and selecting influencing factors, which form the basis of the design of the stated choice experiment. Chapter 5, is an intermezzo which briefly discusses the theory of stated choice modelling. Subsequently, Chapter 6 elaborates on the design and distribution of the stated preference survey. Chapter 7 will be focused on the results of the estimation of the stated choice models. In Chapter 8 the model estimation results are applied in order to derive the possible bicycle parking capacity savings. Chapter 9, closes this thesis by providing conclusions, discussion and recommendations.

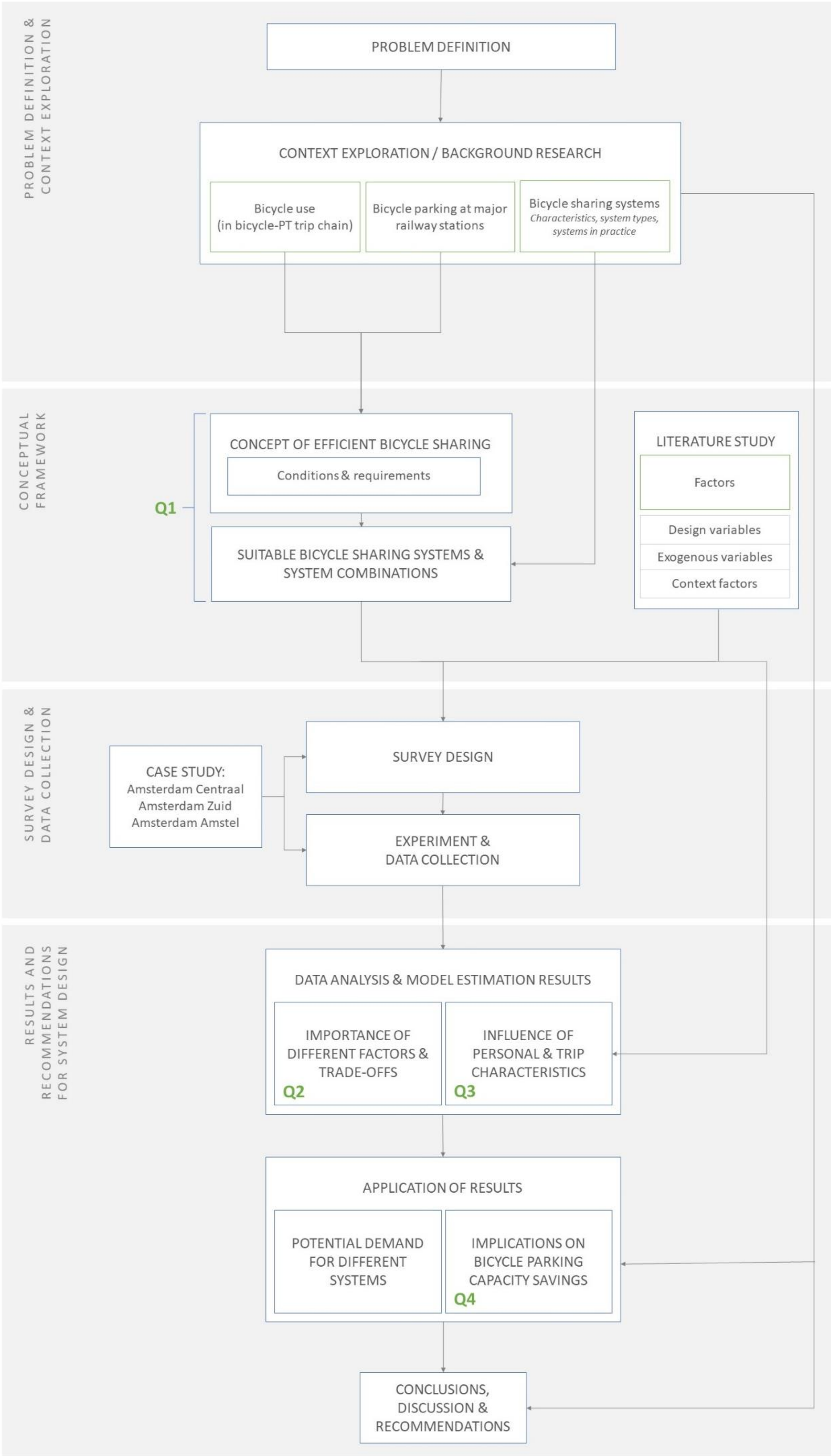

Figure 3: Research methodology

2. The concept of efficient bicycle sharing in the Dutch context

This chapter explores how bicycle sharing can theoretically contribute to relieving bicycle parking pressure at major Dutch railway stations. The aim of this chapter is to provide insights in the concept of efficient bicycle sharing and to derive conditions and requirements for a BSS successful in reducing bicycle parking pressure at railway stations. Analysing the current use of bicycles in access and egress trips, and studying bicycle parking behaviour at Dutch railway stations, will frame the context for bicycle sharing as a possible solution for reducing bicycle parking capacity shortages. Furthermore, this chapter provides insight in the extent to which efficient BSSs can theoretically lead to capacity savings. All in all with the knowledge gained in this chapter, insights are gained into the conditions and requirements that need to be met for a bicycle sharing system in order to operate efficiently. With this knowledge sub research question one can be answered.

Section 2.1 frames the context of an efficient BSS, by studying the (potential) use of the bicycle as a feeder mode in the Netherlands and by studying bicycle parking patterns at Dutch railway stations. Section 2.2 explains the concept of efficient bicycle sharing in the framed context. In Section 2.3 the requirements for a BSS in order to function efficiently are presented. These requirements will be derived by analysing the possible theoretical bicycle parking capacity savings of efficient bicycle sharing. This chapter closes with a conclusion in Section 2.4.

For reasons of consistency, the used definitions are presented below.

Definitions

A bicycle-train trip is defined as a trip having, as its main mode, a train trip, and at least one of the access and egress trips is a bicycle trip.

The bicycle-trip parts can be distinguished in two ways (Hoogendoorn-Lanser & Van Nes, 2005).

- *Access and egress*
  Access: trip part from the origin to the boarding railway station.
  Egress: trip part from the alighting railway station to the destination.

- *Home-end and activity-end*
  Home-end: trip part from / to the railway station near the traveller's home address.
  Activity-end: trip part from / to the railway station near the traveller's activity address.

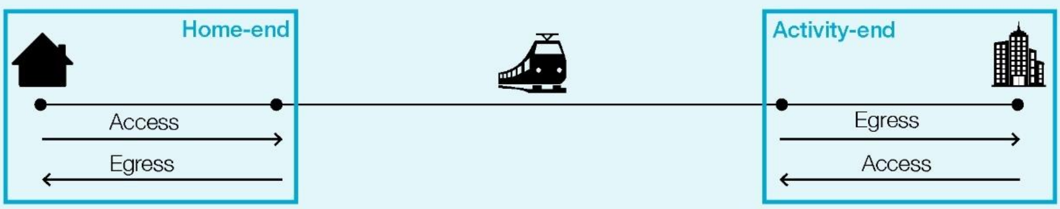

Figure 4: Schematization of a multi-modal train trip

In the remainder of this thesis, access modes or access trips refer to the home-end and egress modes or egress trips to the activity-end, as access to the home-end station and egress from it can be treated as the same (Givoni & Rietveld, 2007).

Travellers who use a bicycle as access mode, will be referred to as ***access cyclists****. Travellers who use a bicycle as egress mode, will be referred to as* ***egress cyclists****.*

2.1 Positioning the Netherlands

This section frames the context for a BSS at Dutch railway stations. First the (potential) use of the bicycle as a feeder mode in the Netherlands will be studied. Subsequently, bicycle parking patterns at Dutch railway stations is a subject of study.

2.1.1 Bicycle as feeder mode

In the Netherlands, the average share of the bicycle as access and egress mode is about 23%. From an international perspective this number is remarkably high (Rietveld, 2000). This high share for the bicycle as feeder mode to railway stations in the Netherlands is mainly due to the fact that the Netherlands can be positioned as a country where cycling is common and with a cycling rate of 27% it is the highest in the world (Klinkenberg & Bertolini, 2014; Ministerie van Verkeer en Waterstaat & Fietsberaad, 2009). In addition, the Netherlands is known for its good public transportation system (Givoni & Rietveld, 2007). The Netherlands has, for example, a dense railway network. On average the distance of residents to the nearest railway station is about 4.5km (Keijer & Rietveld, 2000). For the majority of Dutch inhabitants a railway station is within commonly accepted bicycle distance (5km) or potential bicycle distance (7.5km) (Kager et al., 2016). In the Randstad (the economic core area of the Netherlands) 95% of the residents live within 5km distance from a railway station (Stedenbaan, 2014).

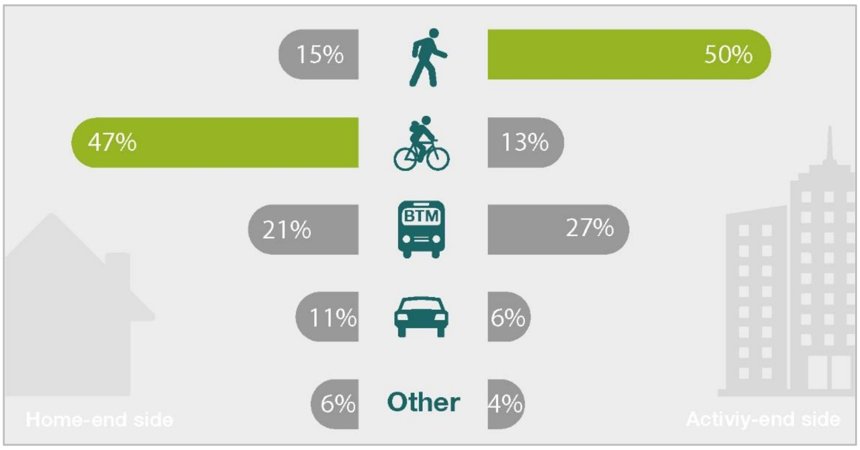

Figure 5: Average modal choice at the home-end and activity-end in the Netherlands (KiM, 2014)

Access mode (home-end)

Around 47% of the 1.2 million daily train users in the Netherlands cycles from home to a railway station (KiM, 2014). This share is followed by public transportation and walking as an access mode (see Figure 5). Most of the access cyclists are frequent train travellers (Shelat, Huisman, & Van Oort, 2017). The share of bicycle as access mode increases as the frequency of train use increases. In other words, the more train trips a week, the higher the chances for using a bicycle as access mode (Givoni & Rietveld, 2007). An empirical analysis of actual Dutch PT-users showed that most access trips are made multiple times in a week and in most cases on weekdays during rush hours (Shelat et al., 2017).

Egress mode (activity-end)

In egress transportation bicycles are less used as means of transportation. Around 13% of the train travellers uses a bicycle as egress mode (KiM, 2014). This difference in bicycle use at the home-end and at the activity-end has various reasons. First, it can be explained by the asymmetry in the availability and use of bicycles (Rietveld, 2000). Where most people do have a privately owned bicycle available at the home-end, at the activity-end most people do not. Factors keeping people from having a second bicycle are the purchase and maintenance costs and the risk of theft (Maat & Louw, 2012).

A significant amount of travellers making the same train trip frequently, though, do have a bicycle available at their station of arrival. Exact figures on the numbers of ‘second’ bicycles parked at Dutch railway stations are lacking. For more infrequent activities where travellers do not have a second bicycle available, rental bicycles may be used (Martens, 2007). For these trips a successful large-scale flexible bicycle rental (PT-bicycle) has been introduced at Dutch railway stations. In 2015 14% of all egress cyclists was using a PT-bicycle, where in 2001 this was only 1% (Goeverden & Correia, 2018). How the share of egress cyclists is divided in users of other shared and rental bicycles and users of privately owned (second) bicycles at railway stations, is unknown. Another reason for the low share of the bicycle as egress mode is that most activity destinations are located near railway stations. Almost 40% of all destinations are located within 1.5 km from a railway station (Rietveld, 2000). For this distance walking is a good alternative for many travellers.

Spatial and temporal variation in daily cycling demand

The presented figures about bicycle use in the bicycle-train trip are average rates for the Netherlands, and vary among different municipalities and different railway stations in the Netherlands. In most major Dutch cities the bicycle share in access transportation is 55 percent, also in cities with the largest bicycle parking shortages at railway stations (Amsterdam, Utrecht and Eindhoven).

The daily bicycle demand is varies over time. Throughout the year, by day of the week and by school holiday a different amount of people is using the bicycle to travel to and from railway stations. Moreover, weather has an impact on the day-to-day variations in bicycle use. Air temperature, precipitation, hours of sunshine and wind speeds are found to be most relevant explaining variables (Thomas, Jaarsma, & Tutert, 2013).

2.1.2 Bicycle parking patterns at railway stations

The Netherlands counts more than 400 railway stations, where in total 430,000 bicycle parking places (of which 120,000 guarded parking places) are available (Nederlandse Spoorwegen, 2017). In use of the bicycle parking places at major Dutch railway stations, typical parking patterns can be recognized. Insight in these patterns will provide understanding of how the current use of bicycle parking suits an efficient bicycle sharing system.

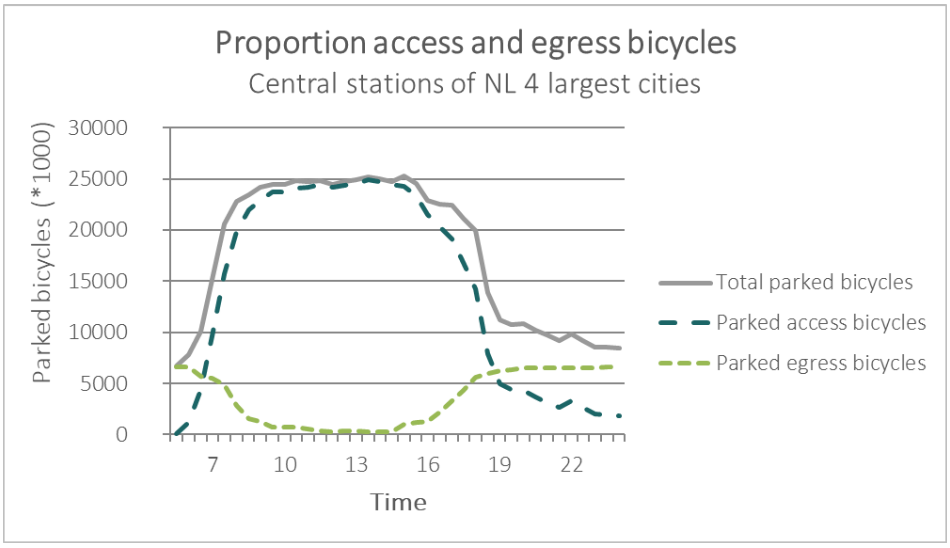

Figure 6: Bicycle pressure during on an average workday at the central stations of the Dutch four largest cities (based on NTS data)

In general, in the morning most access cyclists park their bicycles (access bicycles). In the afternoon or at the beginning of the evening these bicycles are picked up in order to return home (Goeverden & Correia, 2018; KiM, 2018; Van Boggelen & Thijssen, 2008). Egress cyclists travel in the opposite direction. Access cyclists generally arrive earlier at the station (at the beginning of the morning during rush hour) than egress cyclists leave (at the end of the morning rush hour). In the evening this image is reversed (KiM, 2018). Figure 6 shows the described patterns on an average workday at the central stations of the Dutch four largest cities based on NTS Data. It must be noted that the number of parked egress bicycles during the day is an underestimation because of limitations of the data (see Section 8.2).

In Figure 7 the actual bicycle parking pressure at the individual station level is presented. The figure concerns bicycle parking facilities at four major Dutch railway stations throughout a regular workday and confirms the earlier described patterns. Between 6.30 and 8.30 am the number of parked bicycles rises considerably. At 7.30 am the capacity of unguarded bicycle facilities at most stations has been exceeded. The number of outflowing bicycles (egress cyclists) is considerably lower than the inflow of bicycles, as could be expected from the mode shares at the home-end and activity-end. At the beginning of the afternoon the number of parked bicycles increases slightly by travellers who start their train trip in the afternoon. The highest peak in bicycle parking pressure is therefore between 12.30 and 13.30 pm (Van Boggelen & Thijssen, 2008).

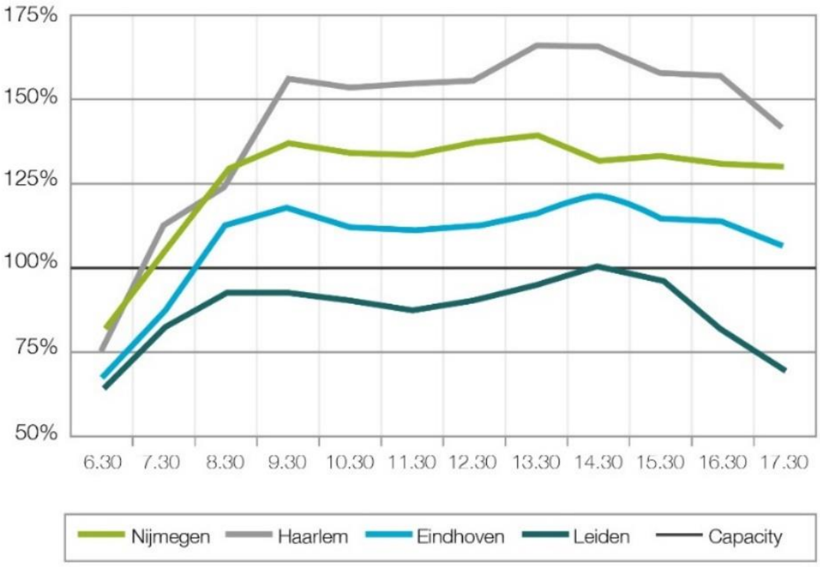

Figure 7: Bicycle parking pressure at unguarded bicycle parking facilities at four major Dutch railway stations on a regular workday (Fietsberaad, 2008)

The figure also shows that at 6.30 am already 60% to 80% of the bicycle parking capacity is used. These bicycles are mainly used for egress transportation. Bicycles are parked for one or more nights by, for example, commuters and students. (Goeverden & Correia, 2018; KiM, 2018; Van Boggelen & Thijssen, 2008). In total those egress bicycles (or also called 'second bicycles') account for at least 45% of the total bicycle pressure at all Dutch railway stations (KiM, 2018). In case of bicycle capacity shortages, one new traveller who places a second bicycle at a station, generates an equivalent parking pressure of on average four parked access bicycles (KiM, 2018).

2.2 The concept of efficient bicycle sharing

In Section 2.1 knowledge has been gathered on use of bicycles as access and egress mode, bicycle parking behaviour and its implications for bicycle parking pressure at railway stations during the day. It appears that certain patterns in bicycle parking behaviour exist. The pattern of reversed commuting flows can be used in order to relieve bicycle parking pressure and is an integral part of an efficient BSS. In this section the concept of efficient bicycle sharing will be explained by discussing the operation and target groups of an efficient BSS.

As already mentioned in the introduction of this thesis, an efficient BSS makes use of the reversed commuting flows of access and egress cyclists. This concept is graphically described in Figure 8 and Figure 9. Figure 8 gives a schematic overview of a bicycle trip of an access cyclist and a bicycle trip of an egress cyclist. In the current situation, bicycles are not shared between these types of cyclists. It shows that a person cycles from home to the railway station. Subsequently, this person's bicycle will be parked at the railway station and will not be used for a certain time. At the same time another traveller arrives at the railway station and uses a private or rental bicycle to travel from the railway station to their destination. This leads to a situation where, at peak moments, both the bicycles of access cyclists and the bicycles of egress cyclists are parked at the railway station.

Figure 9 shows the operation of an efficient BSS, a situation in which bicycles are shared between access and egress cyclists. A person cycles from home with a shared bicycle. At the railway station this bicycle is available to an arriving train passenger, for example for a trip to a work or study location. When access cyclist return at the station for their bicycle trip to home, a shared bicycle is available again, as most egress cyclists already returned at the railway station and a number of additional shared bicycles is provided.

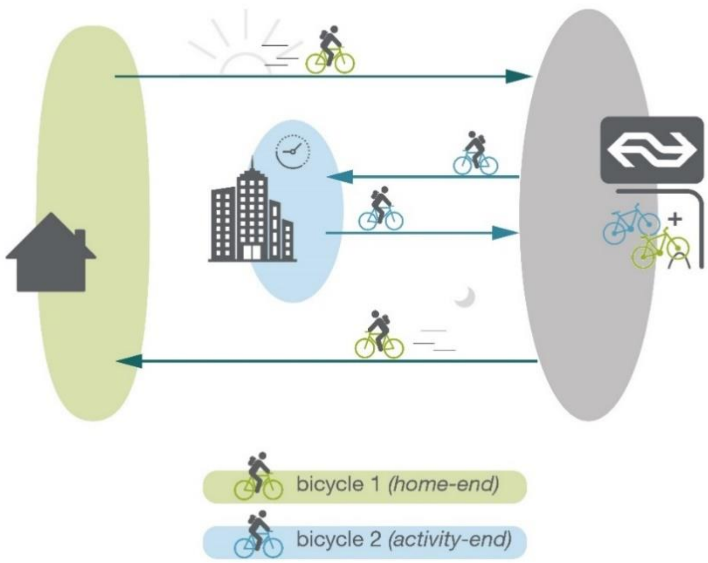

Figure 9: Schematic overview of the average bicycle trip to and from a railway station when bicycles are not shared

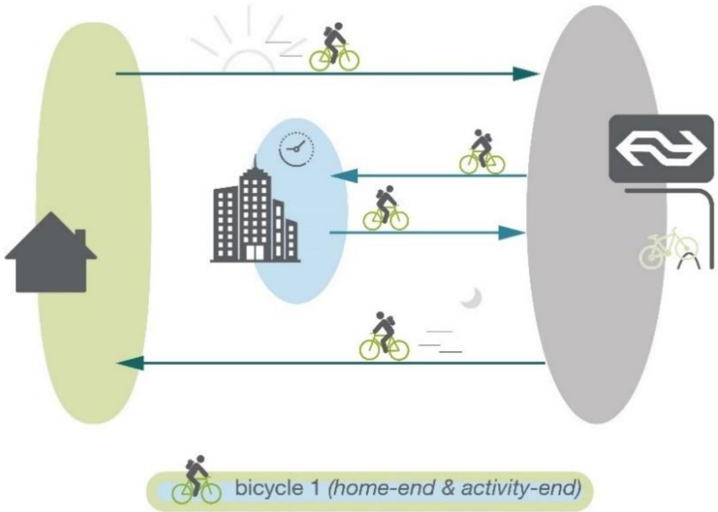

Figure 8: Schematic overview of the average bicycle trip to and from a railway station when bicycles are shared between access and egress cyclists

Four different types of (potential) travellers could participate in this efficient BSS:

- Current access cyclists
  Persons using a bicycle to travel from or to a railway station at the home-end.
- Potential access cyclists (new access cyclists)
  Persons currently using other modes to travel from or to a railway station at the home-end.
- Current egress cyclists
  Persons using a bicycle to travel from or to a railway station at the activity-end.
- Potential egress cyclists (new egress cyclists)
  Persons currently using other modes to travel from or to a railway station at the home-end.

The first two categories of travellers facilitate the supply of bicycles. These access bicycles can subsequently be used by current and potential egress cyclists. The access cyclists can be classified as bicycle suppliers and egress cyclists as demanders of bicycles.

2.3 Requirements for achieving bicycle parking capacity savings

The participation of the different groups of travellers distinguished in Section 2.3 determine the potential bicycle parking capacity savings that can be achieved eventually. Additionally, other factors regarding the system are responsible for achieving capacity savings. All in all, this section will provide insights in the conditions to be met in order to achieve certain bicycle parking capacity savings with the implementation of an efficient bicycle sharing system.

Bicycles could be shared between current access cyclists and current egress cyclists. In this case, both a bicycle parking place occupied by a bicycle of an access cyclist and a bicycle parking place occupied by the bicycle of an egress cyclist can be saved. This will result in the highest reduction of bicycle parking pressure as bicycles used by egress cyclists are in general parked during the nights and weekends and only leave the bicycle parking facility occasionally, for example, on some work days during the day. Therefore, one access bicycle being used by an egress cyclist who gives up its' own bicycle will not only save one bicycle parking place during the day, but will also remove a bicycle which is responsible for an equivalent parking pressure of on average four parked access bicycles (KiM, 2018).

When additional egress travellers who are currently using other modes of transportation (potential egress cyclists) could also use a supplied access bicycle and are willing to switch to using a shared bicycle, possible capacity savings could be even higher. The requirement that sufficient access bicycles are supplied must be met. In this case one bicycle parking place, particularly during the day, could be saved in comparison with no sharing.

Hence, making access cyclists switch to a shared bicycle is always useful, as it creates a supply of bicycles available for sharing. It will not in all cases be helpful in relieving bicycle parking pressure. When all the supplied access bicycles are used by egress cyclists (current or new cyclists), availability of shared bicycles can no longer be guaranteed. This creates the need for a buffer of additional bicycles.

It is also possible that an access traveller currently using another mode of transportation will switch to use of a shared bicycle. This might be beneficial when the demand among egress travellers is higher than the supply of bicycles by current access cyclists. Otherwise, the supply of bicycles by new access cyclists will only lead to additional parked bicycles, which is, solely from the viewpoint of bicycle parking capacity, not desired.

Goeverden & Correia (2018) studied the extent to which different types of travellers switching to shared bicycle use will result in a reduction in the number of parked bicycles on work days. Based on data of the Dutch National Travel Survey, the potential, i.e. the decrease of the daily peak in bicycle parking as a result of sharing (when every bicycle-train user uses a shared bicycle), was estimated. Calculations were made for several types of railway stations. Table 1 provides an overview of the potential capacity reductions at different types of railway stations for systems with different buffer times throughout the day. A buffer time is the time frame a bicycle should be parked at the railway station before or after sharing in order to ensure availability of bicycles.

The results of their study show that significant bicycle parking capacity savings can be achieved with bicycle sharing. For example bicycle sharing between current cyclists can reduce the needed parking capacity at the central stations of the four largest cities by 22-25% (no buffer times). Longer buffer times, however, decrease the potential bicycle parking capacity savings significantly. When buffer times increase to 0,5 hour the capacity savings decrease to 14-21% and when buffer times are one hour the savings decrease to 6-10%. When bicycles are also shared with potential egress the bicycle parking capacity at the central stations of the four largest cities can be reduced by 40-47%, decreasing to savings of 11-15% in case of buffer times of one hour.

Table 1: Potential capacity reduction for different buffer times (Goeverden & Correia, 2018)

	No buffer times	No buffer time before use, 0.5 hour buffer time after use	Buffer times 0.5 hour	Buffer times 1 hour
Whole Netherlands				
Sharing between current cyclists	20-20%	19-20%	17-19%	12-13%
Sharing between current and potential cyclists	46-51%	43-46%	34-37%	23-25%
Central stations of the four largest cities				
Sharing between current cyclists	22-25%	19-24%	14-21%	6-10%
Sharing between current and potential cyclists	40-47%	35-39%	25-34%	11-15%
Central stations of other large cities				
Sharing between current cyclists	19-29%	15-26%	13-22%	8-16%
Sharing between current and potential cyclists	37-50%	30-43%	24-35%	15-23%

It must be noted that the presented numbers represent a theoretical maximum and are an overestimation of the actual possible capacity savings, since it was assumed that all cyclists and potential cyclists participate in the system. The presented capacity savings are an underestimation of the theoretical maximum, as the study focused on a peer-to-peer sharing system (a system where personal bicycles are shared), where bicycles have to be returned at the railway stations on time. This requirement limits the sharing possibilities. Furthermore, a part of the egress cyclists is not included in the estimations because of limitations in the data.

2.4 Conclusion

This chapter framed the context for shared bicycles as feeder mode and draw up requirements for an efficient BSS at railway stations. It was found that at Dutch major railway stations reversed commuting flows are present. In general, access cyclists arrive a little earlier at railway stations than egress travellers do, which facilitates an efficient BSS. Bicycles of arriving and departing train travellers could be exchanged. The parked bicycles of access cyclists could be used by current egress cyclists or potential egress cyclists (egress travellers currently using other modes), which releases bicycle parking space during the day.

In theory, efficient bicycle sharing can significantly reduce bicycle parking pressure at major Dutch railway stations and can contribute to reduced bicycle parking shortages. It is found that bicycle parking capacity savings of 22-25% can be achieved at the central railway stations of the four largest cities in the Netherlands when bicycles are shared between current cyclists. When bicycles are also shared with travellers currently using other modes, 37-50% bicycle parking capacity savings could be achieved.

In order to contribute to a reduction in the number of parked bicycles different requirements need to be met: (1) a significant number of access cyclists must be willing to use a shared bicycle, (2) a significant number of egress travellers must be willing to participate in the BSS and (3) buffer times for the operation of the BSS must be limited. The largest bicycle parking capacity savings can be achieved when as many of the parked bicycles of access cyclists as possible are available to current cyclists and other travellers. A system without buffer times will lead to the highest bicycle parking capacity savings. As current egress bicycles are responsible for an equivalent parking pressure of, on average, four parked access bicycles, it seems most beneficial when current egress cyclists switch to a shared bicycle.

Cycling mode shares vary at both the home-end and the activity-end. Additionally, the shares differ for various railway stations and fluctuate during the day and year. This will have consequences for the balance between the supply and demand of shared bicycles in the efficient BSS.

3. Promising bicycle sharing systems

Knowledge has been gathered on the requirements for an efficient bicycle sharing system which is able to contribute to a reduced bicycle parking pressure in the Dutch context. Such a system can be realised with different possible types of BSSs. In the Netherlands different BSSs have become available over the years and also new bicycle service initiatives are introduced. However, not all available and possible types of systems result in a reduction in bicycle parking pressure and can be called efficient. This has in particular to do with the combination of systems that is available for cyclists at the home-end and for cyclists at the activity-end. This chapter investigates what type of possible systems and system combinations are suitable and promising for an efficient BSS. This knowledge provides insights in how an efficient BSS at railway stations could be set up and what types of systems should be investigated in the remainder of this study.

First the existing and possible BSSs are studied. An overview of the studied systems and their characteristics is presented Section 3.1. Subsequently, in Section 3.2 the systems are assessed on their suitability for an efficient system and promising system combinations (home-end and activity-end) are selected. Section 3.3 closes with a conclusion.

The box below presents a definition of a BSS according to literature. The investigated systems in this chapter do not strictly adhere to this definition in order to provide a broader view of all bicycle sharing systems and bicycle service initiatives.

Bicycle sharing system (BSS) definition:
In short, according to (APPM & The New Drive, 2017; S. A. Shaheen, Guzman, & Zhang, 2010) a BSS offers bicycles for *short-term* rental at a *low cost* in a *publicly accessible* network of bicycles. Shared bicycles are *easily accessible*, easy to use and form part of the transport system, in addition to the train, bus, car and own bike. After one *registration* a user is able to use bicycles at multiple locations and at different times. In principle no one-to-one relationship between user and bicycle exists and bicycle stations are unmanned. This implies that reservation, pick-up and return of bicycles are *self-serviced*.

Bicycle purchase and maintenance costs, as well as storage and parking responsibilities are typically covered by bicycle sharing programs (S. A. Shaheen et al., 2010).

CROW-Fietsberaad (APPM & The New Drive, 2017) extend the definition by stating that BSSs are designed from the philosophy to optimize use of shared bicycles, manifesting by hours of accessibility, user-friendliness, pick-up and return points and pricing.

3.1 Existing bicycle sharing systems & bicycle service initiatives

In more and more cities worldwide, BSSs have become available. Also in the Netherlands different systems have been introduced over the years. In 1967 the first variant of a bicycle sharing system, the so-called 'Wittefietsenplan', was introduced in the city of Amsterdam. Nowadays different types of systems can be found in the Netherlands and abroad.

One of the largest and most successful bicycle sharing systems in the Netherlands at the moment is the NS PT-bicycle (Dutch: OV-fiets). This *open PT system* mainly focuses on transportation for the first and last mile of travel at the activity-end. At 300 railway stations in the Netherlands a total of almost 15,000 bicycles is available to all travellers with a PT-card. At the moment the PT-bicycle system cannot be defined as an efficient BSS as this system does not make use of the already parked access bicycles but adds bicycles to the total number of parked bicycles. In 2008 a pilot study was undertaken in which PT-bicycles could be taken home by frequent train travellers, called OV-fiets@home. This pilot was not particularly aimed at reducing bicycle parking pressure at railway stations, but aimed at increasing the stock of PT-bicycles. Users had to bring the bicycle to the railway station at almost all workdays. Because of these complex user conditions the pilot failed (Nederlandse Spoorwegen, 2013).

On a smaller scale c*orporate systems* and *closed park & bike systems*, which also serve as last mile solutions at the activity-end, can be found at PT nodes or large car parking facilities. These systems differ from the open PT-bicycle system, as use is restricted to a particular group of users, for example employees of one or more companies in a certain area.

Also within cities it has become possible to make use of shared bicycles. Different forms of *open urban sharing systems* with a high density network can be found in several cities. The first variants of *open urban systems* are station-based systems with physical docking stations. The entry of GPS allowed for more flexible variants of open urban BSSs without physical bicycle stations. Docking stations are replaced by geo-fenced parking places without physical bicycle racks. So called *free floating systems* even no longer define bicycle parking places. The bicycles can be parked anywhere on the street and can be easily found by users via an online application.

With *peer-to-peer* sharing it has also become possible to make use of bicycles owned by individuals. Via an online platform or smartphone application private bicycles are offered for use by another individual for a certain compensation. The keys can be handed personally or the bicycle can be opened with a 'smart lock'. When a smart lock is used, this form of bicycle sharing is very similar to the free floating bicycle system, as the bicycle can be left everywhere at every moment (Van Zessen, 2017).

Despite the mentioned innovative sharing systems, more *traditional rental bicycles* mainly aimed at single-use by tourists, are also still on offer. This system can be hardly called a sharing system, as users have to register for every use and usually have to return the bicycle at the same location.

Finally, another recently introduced concept in the field of cycling must be mentioned. In 2014 a company (Swapfiets) started with *bicycle lease* among students in the Netherlands. Nowadays this company is operating on a large scale and is also focused on other target groups. Already 54,000 bicycles in 16 Dutch and two Belgian major cities are owned by Swapfiets (Blom, 2018). Recently also other bicycle lease companies have started, e.g. Instabike and Van Moof+. Customers pay a monthly fee covering the rental and maintenance costs. In return, they receive full service when the bicycle has technical problems or the bicycle is 'swapped' for another bicycle. At the moment customers do not have to pay a deposit and can cancel their subscription monthly.

The concept of bicycle lease cannot be called a sharing system as a one-to-one relationship between a bicycle and user does exist. However, this bicycle service initiative could be easily transformed into a bicycle sharing system in the future. Users with a subscription use the lease bicycle at home in the same way as they would use their private (lease) bicycle. When the bicycle is parked at a railway station the bicycle becomes a shared bicycle which will be available to other travellers. Since lease bicycles are standardized bicycles, exchange is possible. In this thesis this form of bicycle sharing is proposed as a hybrid BSS.

Figure 10: Impression of the mentioned BSSs and bicycle service initiative. From top left to bottom right: PT-bicycles by Fietsen123 (2016), station-based system by Gobike (2016), free floating system by Edwardx (2017), traditional bicycle rental by Bimbimbikes (n.d.), peer-to-peer sharing with smart lock by Voets (2013), bicycle lease by Swapfiets (n.d.).

3.2 Selection of suitable systems and promising system combinations

3.2.1 System characterisation

From Section 3.1 has become clear that a great variety of possible BSSs exists. The available BSSs and the proposed BSS can be distinguished by five main characteristics: accessibility, registration, return options, network and locations (APPM & The New Drive, 2017). An extensive description of these aspects can be found in Appendix A. Besides these five main characteristics, the use (e.g. for egress transportation or as main mode) and target groups differs among the system types, which is basically a result of the other system characteristics.

Figure 11 provides an overview of the different systems types and a description of their characteristics is given. The system characterisation is based on a study by CROW-Fietsberaad (APPM & The New Drive, 2017) and is extended with additional BSSs and bicycle service initiatives. In Appendix A a larger version of Figure 11 can be found. Different types of station-based systems are distinguished in the figure. 2-way station-based systems require a round trip. 1-way station-based systems allow for single trips.

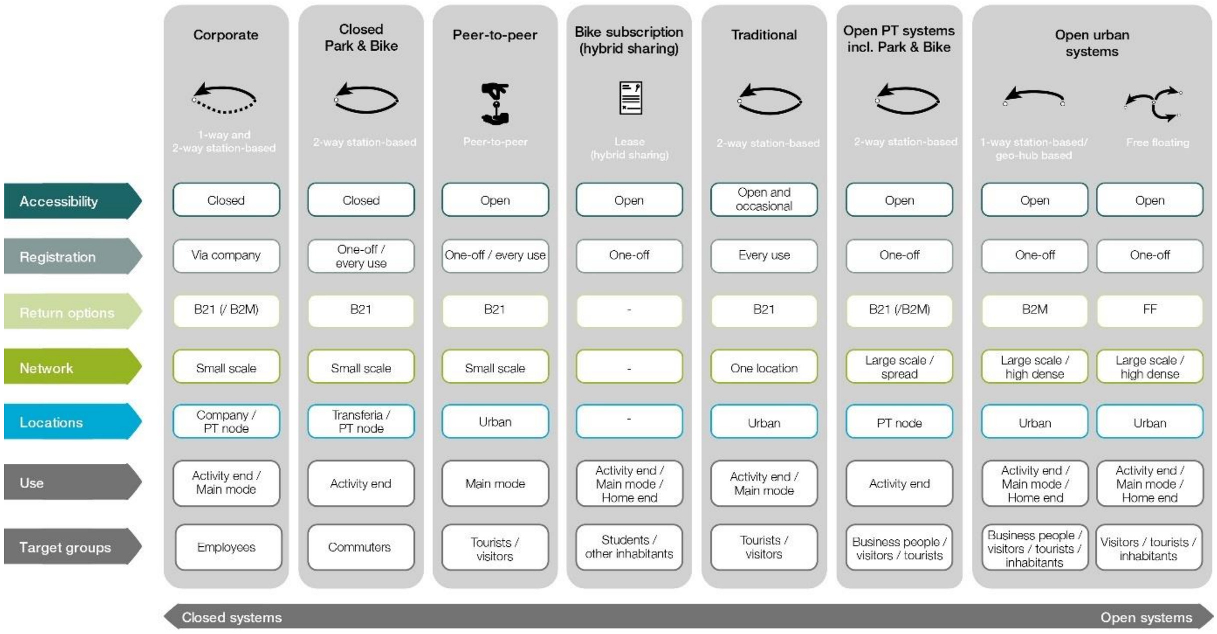

Figure 11: Overview of different bicycle sharing system designs and their most distinctive characteristics. A larger version of this figure can be found in Appendix A.2.

3.2.2 Suitability assessment

Not all of the systems presented in Figure 11 are suitable for an efficient bicycle sharing system at railway stations. In order to select the suitable systems, the different proposed systems will be systematically assessed by considering the four of the five main characteristics. All systems are assessed considering the system is implemented at railway station.

Accessibility

Firstly, it is important to understand that the larger the number of travellers who can participate in the system, the more successful the system can be in relieving bicycle parking pressure (see Section 2.4). For this reason, it is most interesting to focus on frequent users of a bicycle parking facility, i.e. daily commuters like workers and students. A suitable system must therefore be accessible for all users despite the company or educational institution people are associated with. This makes that corporate systems and closed Park & Bike systems are precluded as a suitable system.

Registration

Moreover, it is assumed that frequent travellers do not want to spend time and effort to register before every use. Traditional bicycle rental systems ask for registration at every use. This also applies to some variants of closed Park & Bike systems and peer-to-peer system were keys are handed personally. A traditional bicycle rental system, therefore, is assessed as unsuitable.

Return options

There are no requirements on the return options of the BSS in order to function efficiently, however inflexible return options can influence the contribution to bicycle parking capacity savings. A peer-to-peer system can contribute to capacity savings, however those are limited because of the buffer times needed (Goeverden & Correia, 2018). In addition, peer-to-peer bicycles must be returned within specific time span, which limits a user's flexibility. It is therefore assumed that a peer-to-peer system will not offer the service desired and expected by users, as flexibility is one of the success factors and most appreciated aspects of cycling. Peer-to-peer systems are for these reasons eliminated as an appropriate system.

Network

The desired scale of the network of the efficient BSS is depending on the type of use. Users at the home-end will prefer a large scale and dense network as this offers limited walking time and higher reliability/availability, while for transportation at the activity-end a small scale network is sufficient as long as the bicycles can be picked-up and returned at the railway station.

Conclusion

All in all, open urban systems (1-way stations-based and free floating), an open PT systems (2-way station-based) and bicycle lease (hybrid sharing) are considered as suitable systems.

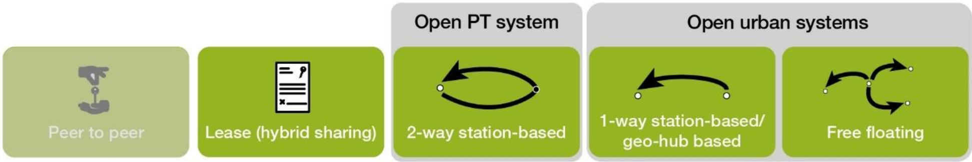

Figure 12: Overview of selected suitable systems

3.2.3 Promising system combinations

The design of the efficient BSS can be described as the combination of one of the aforementioned systems at the home-end (access trips) and one of these systems at the activity end (egress trips), in which the system can be the same at both sides. Not all combinations of the systems presented in Figure 10 are beneficial in reducing bicycle parking capacity savings. Therefore a number of promising system combinations are selected. The figure below provides a graphical overview of the found promising combinations of bicycle sharing at the home-end and at the activity-end (blues lines). For the sake of clarity, these combinations do not specifically represent an example of an individual's trip combination of access and egress transportation.

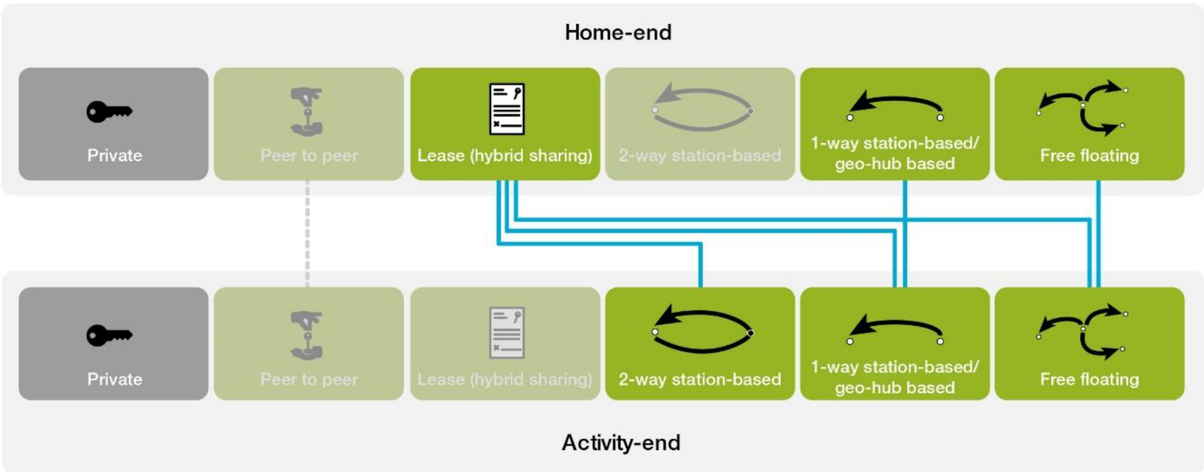

Figure 13: Promising combinations of bicycle sharing at the home-end and at the activity-end (blue lines)

Lease (hybrid bicycle sharing) at the home-end is selected as a possible and promising system and can be combined with three different systems (2-way station-based, 1-way station-based and free floating) at the activity-end in order to reduce the number of parked bicycles. A combination between bicycle lease and 1-way station-based bicycles, will however result in a situation where access cyclists also have 1-way station-based shared bicycles available to travel to the railway stations.

Combinations with bicycle lease at the activity-end are not considered a these combinations will not make sense. Leasing a bicycle for trips between a railway station and a destination implies basically the same as owning a second private bicycle at a railway station and will not contribute to a reduction in the number of parked bicycles. Only when leased bicycles are equipped with a time lock, a combination with bicycle lease at the activity-end will be effective. In that case, bicycle lease at the activity-end will offer the same service as the other bicycle sharing systems with an option to reserve a bicycle. Bicycle lease at the activity-end is therefore not considered anymore.

A 2-way station-based bicycle sharing at the home-end implies that a shared bicycle is used to travel from a bicycle station near home to a railway station. Subsequently, at the railway station the bicycle is still held by the original user and not shared with other travellers. 2-way station-based bicycle sharing at the home-end therefore does not make any sense in reducing the bicycle parking pressure at railway stations by means of bicycle sharing and is not further studied.

At the activity-end a 2-way station-based is considered a suitable system. This is similar to the already existing PT-bicycle system and can, as earlier mentioned, be combined with bicycle subscription (lease) at the home-end. Combinations with other systems at the home-end are not considered as suitable as it is illogical to combine a 2-way station-based bicycle sharing for egress cyclists with other open urban systems which allow for one-way trips.

A 1-way station-based is a suitable and effective solution in reducing bicycle parking pressure at the home-end as well as at the activity-end. A combination between 1-way station-based at the home-end and 2-way station-based system or free floating system at the activity-end is confusing and illogical, because of the different return and parking policies. There should be no distinction between access cyclists and egress cyclists in the places where a bicycle could be picked up and returned. In combination with free floating it is likely that people will not place the bicycle in a station or in a parking zone, as it is allowed to place the bicycle everywhere. For this reason, only a combination of 1-way station-based at both trip ends is selected.

A free floating system at both the home-end and at the activity-end is similar to an open urban BSS. As mentioned, a free floating system can be combined with bicycle subscription at the home-end. In that case it becomes a 'hybrid open system' where access cyclists have two options for using a shared bicycle as access transportation.

All in all, five combinations can defined as promising in reducing the bicycle parking pressure, of which two are fully open urban systems, two hybrid open urban systems (flexible sharing) and one open PT system similar to the existing PT-bicycle system however combined with hybrid shared (bicycle subscription/lease) at the home-end (see Figure 13).

3.3 Conclusion

By literature study was found that a large variety of bicycle sharing systems have become available over the years: corporate systems, closed Park & Bike systems, peer-to-peer systems, bicycle lease (hybrid sharing), traditional bicycle rental, open PT systems, open urban systems (free floating and station-based). In this thesis, a possible new type of BSS is proposed: a hybrid bicycle sharing system. This form of bicycle sharing is a combination of bicycle lease and bicycle sharing at railway stations.

Literature study also found that the different BSSs can be distinguished on five main aspects: accessibility, registration, return options, network and locations. How and to what extent these five aspects will and need to relate to a BSS aimed at relieving bicycle parking pressure at railway stations is assessed. This resulted in a selection of suitable systems, consisting of open urban systems (1-way stations-based and free floating), an open PT system (2-way station-based) and bicycle lease (hybrid sharing).

Subsequently is investigated how the selected systems can be combined at the home-end and at the activity-end in order to realise a system that is able to contribute to relieved bicycle capacity problems at railway stations. This has led to five promising system combinations:

Home-end – Activity-end	
▪ Lease (hybrid sharing) – 2-way station-based	Open PT system
▪ Lease (hybrid sharing) – 1-way station-based	Hybrid open urban system
▪ Lease (hybrid sharing) – Free floating	Hybrid open urban system
▪ 1-way station-based – 1-way station-based	Open urban system
▪ Free floating – Free floating	Open urban system

4. Factors influencing shared bicycle use

One of the objectives of this study is to get insight in the extent to which different personal characteristics, trip characteristics and bicycle sharing system attributes impact the demand for shared bicycles in access and egress transportation by current cyclists. By conducting a literature study this chapter explores the factors that have a potential impact on use of shared bicycles. The obtained factors are assessed on different criteria in order to make a smaller selection of factors for further investigation in the remainder of this study.

In Section 4.1 the findings of the literature study will be discussed and are turned into a list of all possible influencing factors. In Section 4.2 the obtained factors will be assessed. This chapter closes with a summary in Section 4.3.

4.1 Literature study into influencing factors

A literature study into the factors that influence the use of shared bicycles is conducted. This study is guided and scoped by the following questions:

- *Which factors (design variables, context factors and exogenous factors) influence the use of shared bicycles?*
- *What is the importance of these factors according to existing studies?*

This research solely focuses on choices of current cyclists. Therefore the literature study is limited to factors that will influence the choice of current cyclists in use of a shared bicycle. For example, availability of bicycle infrastructure will change the attractiveness of shared bicycle use. However, this factor will not influence the choice of current cyclists to use a shared bicycle instead of their own bicycle. In addition, factors that will influence the choice for shared bicycle use by decreasing the attractiveness of the use of private bicycles or other modes (push policies), will not be studied.

4.1.1 Findings of the literature study into influencing factors

In total ten scientific works are reviewed. Seven studies are evaluating existing BSSs based on stated preference data or actual user data. Three studies are based on stated preference data of actual users in Europe (The Netherlands, Belgium and Greece). Appendix C provides an overview of the works studied and the main findings. Below the findings will be shortly discussed.

Of the BSS characteristics studied, travel cost, travel time and travel comfort have be found to be the most important attributes (in descending order). From several revealed preference studies (Bachand-Marleau, Lee, & El-Geneidy, 2012; Fishman, Washington, Haworth, & Mazzei, 2014; Fishman, Washington, Haworth, & Watson, 2014; Médard de Chardon, Caruso, & Thomas, 2017) the proximity (and density) of shared bicycle stations, which will indirectly influence user's travel time and travel comfort, has been found to be most important for users. From the stated preference studies (Altaf, 2017; H Heijningen, 2016; Yannis, Papantoniou, Papadimitriou, & Tsolaki, 2015) travel cost has been found to the main influencing attribute. In addition travel time and travel comfort (the type of bicycle) are found to be of high importance. It must be noted that not all characteristics of BSSs have been studied. For example, the availability of bicycles as attribute was lacking.

The influence of personal characteristics on shared bicycle use is investigated in several studies. It appears that shared bicycle users are more likely to be young (Susan A. Shaheen, Martin, & Chan, 2012; Yannis et al., 2015), male (Murphy & Usher, 2015; HMC Van Heijningen, 2016; Yannis et al., 2015), have a high income (Fishman, Washington, Haworth, & Watson, 2014; Murphy & Usher, 2015) and/or are highly educated (Altaf, 2017; Susan A. Shaheen et al., 2012). A comparison between regular cyclists and shared bicycle users in Washington showed however that users of BSSs are more likely to be women and tend to have lower incomes. How different personal characteristics are influencing the preference for certain BSS attributes is unknown.

In a stated preference study of Altaf (2017) among potential users in Belgium, trip purpose is found to be of no influence on the use of shared bicycles. In revealed preference studies (S. A. Shaheen et al., 2010) the found trip purposes varied, but most are school and work-related. Van Heijningen (2016) found that trip distance is influencing the preference for bicycle type (electric versus traditional).

4.1.2 Limitations on the applicability of the findings

The literature study on the factors influencing the use of shared bicycles and their importance, cannot be directly applied to this study context and the Dutch situation. The applicability of the literature study is limited by the fact that:

- Most (revealed preference) studies concern BSSs in contexts that greatly differ from the Netherlands. For example, cultural difference and differences in (cycle) infrastructure, will affect the influence of factors found in the studies.
- There are no studies found that focus on shared bicycle users with a private bicycle or regular cyclists switching to shared bicycle use. This is quite logical considering that most BSSs are aimed at increasing cycling rates and mainly the switch from other modes to cycling is subject of study. For regular cyclists the factors and the extent to which certain factor influence the choice to make use of a shared bicycle will differ from users of other modes.
- Most studies focus on investigating the factors influencing the use of station-based shared bicycles. These systems were and still are prevailing in many large cities worldwide. Nowadays, however, new generations of BSSs have made their appearance. (Revealed) preference studies among users of these new types of BSSs (e.g. free-floating bicycle users) are lacking. Information on certain factors and attributes as, for example, ‘availability of bicycles’ is therefore limited.

The mentioned limitations require the list of influencing factors derived from literature to be complemented. By a brain storm session with two experts on bicycle sharing, the list of factors influencing shared bicycle use derived from literature, is expanded by other factors that could influence the choice of current cyclists to use a shared bicycle. In Appendix C an overview of all possible factors is provided.

4.2 Selection of factors

A selection is made from the large number of possible influencing factors presented in Appendix D, for several reasons. At first, the influence of not all factors can be measured with a questionnaire and a stated choice experiment. In addition, not all factors will be equally important to cyclists. Moreover, not all factors can be managed by the operator of a BSS or by the government, which make it not useful to derive to derive information on these factors. At last, surveys are limited in the number of questions, as respondents are not willing to spend much time on filling in the survey and will be exhausted after a certain time span, which will compromise the credibility of the results.

For these reasons this study is limited to a number of influencing factors. To make a selection, factors are assessed on the following three criteria:

- Expected influence on mode choice between shared bicycle and private bicycle use
- Measurability with a stated choice experiment and questionnaire
- Manageability by government or BSS operator

Appendix C presents the assessment of the obtained factors on the aforementioned criteria. All factors which are measurable, manageable and have an average to high influence on bicycle mode choice are selected.

Personal characteristics

From the obtained influencing personal characteristics a large number are eliminated for further investigation because the characteristics are not manageable by a BSS operator or the government. Only 'available travel allowances' and 'familiarity with shared & leased bicycles' are manageable, measureable and expected to be of high influence. Some additional factors are included in the final selection for further investigation. For example gender, age, education and activity (job status) provide useful information on the composition of the respondent group and potential target groups for a BSS.

Trip characteristics

None of the trip characteristics is manageable by a BSS operator or the government. Nevertheless all of the possible influencing factors are included in the final selection, as these factors provide information about the applicability of the study results to other locations.

Bicycle facility characteristics

Securing method, payment method and construction type are not selected for further investigation as the expected influence is too low.

Bicycle sharing system characteristics (BSS attributes)

The criteria 'expected influence on shared bicycle use' and the 'measurability with a survey and stated choice experiment' mainly determined the selected BSS attributes. The BSS attributes selected for further investigation are: price, walking time/walking distance, parking convenience, bicycle availability.

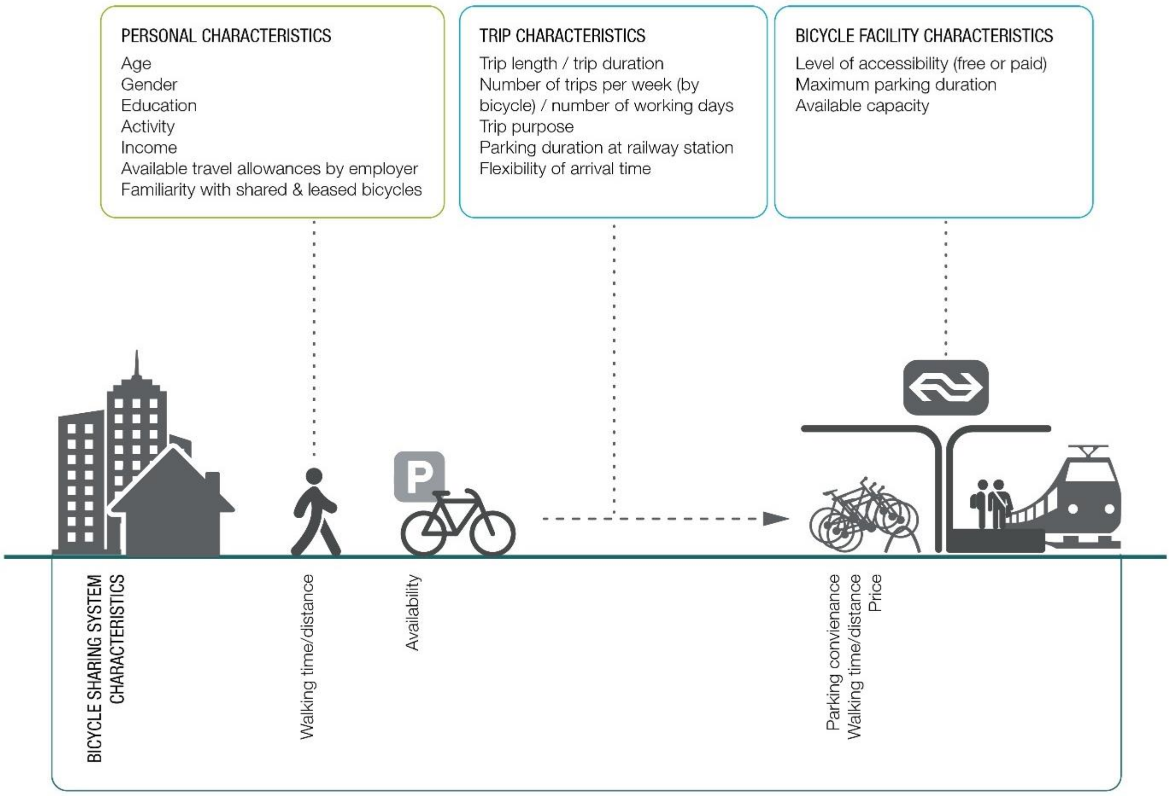

Figure 14: Final list of selected factor for further study, classified by variable type

4.3 Conclusion

This chapter explored what factors could influence the use of shared bicycles by current cyclists for their trip to or from a railway station. A literature study provided knowledge on these influencing factors. Where literature is lacking, the list of possible influencing factors is extended. At the end, all possible influencing factors are assessed on several criteria to derive a smaller number of factors to include in the survey. These factors can be characterized as BSS attributes, personal characteristics, trip characteristics and bicycle facility characteristics. The final list of selected factors for further study is presented in Figure 14.

5. Discrete choice modelling

Before heading to the design of the stated choice experiment on the selected factors in Chapter 6 and subsequently estimating choice models in Chapter 8, the method of discrete choice modelling is discussed.

In short, it can be stated that discrete choice modelling is a method used to infer people's preferences and the trade-offs they make by observing their choices. With the observed choices, discrete choice models can be estimated to determine the relative influence of different attributes in peoples choices. Ultimately, discrete choice models enable to predict the probabilities of choices of a group of individuals and give insights in how the studied attributes of an alternative are valued differently among different groups of people.

In this chapter, the theoretical aspects of discrete choice modelling are topic of discussion. First, in Section 5.1 the framework of discrete choice models and general assumptions are provided and are linked to this study. Also, the theoretical basis of discrete choice models, random utility theory, is introduced. The formulation of this theory in the Multinomial Logit choice Model (MNL) is discussed in Section 5.2. This section also explains why this model is applied in this thesis and discusses the limitations of the used model.

For a full background on the theory is referred to Ben-Akiva & Bierlaire (1999) and Train (2009).

5.1 Discrete choice modelling framework

5.1.1 General framework and assumptions

According to Ben-Akiva & Bierlaire (1999), discrete choice modelling can be presented by a framework formed by four general assumptions about decision makers, alternatives, attributes and the decision rule. Below, these four terms will be further explained.

- Decision maker
  An entity that makes choices or takes a decision. In this study referred to as a current cyclist.
- Alternatives
  The choice options which are available to the decision-maker. In this study two shared bicycle alternatives and a base alternative.
- Attributes
  The variables describing the different alternatives and taken into account by a decision maker when choosing between alternatives. The attributes used in this study are explained in Section 6.4.
- Decision rule
  Description of the process used by the decision maker to make a choice between alternatives.

In short, it can be stated that a decision maker makes a choice between different alternatives described by a number of attributes, using a certain decision rule. Most used discrete choice models are based on the utility maximisation decision rule. This decision rule assumes that decision makers make choices in order to maximise their utility. To each alternative in the choice set decision makers attach a certain value (utility), of which the alternative with the highest utility will be chosen. Discrete choice models based on this decision rule are named Random Utility Maximisation-models (RUM-models).

5.1.2 Random Utility Maximisation

As discussed, the core of random utility maximisation models is an individual selecting the alternative with the highest utility. Implicitly or explicitly the different alternatives in the choice set are compared by the decision maker. The decision rule based on RUM is described by the following formula:

$$V_i = \sum_m \beta_m * x_{im}$$

Where:
V_i *denotes the observed utility of associated with a considered alternative* i
β_m *denotes the decision weight associated with attribute* x_m
x_{im} *denotes the value associated with attribute* x_m *for the considered alternative* i

A decision maker's utility of an alternative can be described as the total of the multiplications of the, by decision maker's assigned, importance of attributes (the decision weights, β_m) with the corresponding attribute levels for the considered alternative (x_{im}). The decision weights represent the sensitivity of decision makers to the specific attributes (m).

In the presented equation it is assumed that decision makers make fully rational decisions and their choice behaviour can be fully described by observed factors. However, different forms of randomness in decision makers choices exist: e.g. randomness due to unobserved attributes, unobserved taste variation and measurement errors or imperfect information. To compensate for the of uncertainty due to the lack of information, a random error term is included in the equation, leading to the following utility function known as the linear additive random utility function:

$$U_i = V_i + \varepsilon_i = \sum_m \beta_m * x_{im} + \varepsilon_i$$

Where:
U_i *= the random (or total) utility associated with a considered alternative* i
ε_i *= the observed utility associated with a considered alternative* i *(part worth utility)*
V_i *= the observed utility associated with a considered alternative* i *(part worth utility)*
β_m *= the estimable parameter associated with attribute* x_m
x_{im} *= the value associated with attribute* x_m *for the considered alternative* i

The non-deterministic non-observable part of the utility function is denoted with ε_i and is assumed to follow assumed probability distribution (Ben-Akiva & Lerman, 1985).

5.2 Multinomial logit choice model

Different models have been proposed in order to estimate the attributes' model parameters and predict choices. Most applied models are Multinomial Logit (MNL) and Mixed Logit (ML). In this research an MNL model is used. The main reason for using this model is that it is a simple and efficient model to provide first insights in choice behaviour, which is aimed for in this study. Besides, the time to carry out this study is limited. The MNL model has some limitations as will be explained in this section. Where possible it is tried to accommodate for these limitations.

5.2.1 Multinomial logit model structure

The MNL model is a well-known and widely-used discrete choice model. The popularity is mainly due to the simple mathematical structure of the methods and the short calculation times for this reason. The model uses a closed formula to calculate choice probabilities and is characterized by its assumptions regarding the unobserved part of the utility function, the error term. MNL models assume that the error terms are independently and identically distributed (i.i.d.). In other words, the unobserved utility parts of the alternatives are considered to be uncorrelated over the different alternatives and will determine the utility of the alternatives to the same extent. The closed formula of MNL model is has the following form:

$$P_n(i) = \frac{e^{V_{in}}}{\sum_{j \in c_n} e^{V_{jn}}}$$

Where:
$P_n(i)$ *denotes the probability of a decision maker* (n) *choosing alternative* i
V_{in} *denotes the observed utility associated with a considered alternative* i *by decision maker* (n)
c_n *denotes the choice set of decision maker* (n)*, where:*
$\quad$ $_j$ *is an element of choice set* c_n
e *is the base of the natural logarithm (±2,72)*

5.2.2 Limitations of the MNL model

The main limitations of the MNL model are:

- The Independence of Irrelevant Alternatives or IIA;
- Ignorance of panel effects;
- Inability to capture random taste variation.

A result from the i.i.d. assumption on the error term is the Independence of Irrelevant Alternatives (IIA). This implies that in an MNL model the probability of a choice between two alternatives is not depending on the presence of a third alternative. This is of influence when both alternatives have strong related characteristics with each other and it would be expected that these two alternatives would compete much stronger with each other than with the other attribute. This leads to misplaced and inappropriate choice probabilities as a result.

In addition, the MNL model is not able capture panel effects as it does not take into account correlations between choices made by the same individual over time. As a result every observed choice is considered as independent choice and is considered to contain an equal amount of information. This may lead to an overestimation of t-values and an overestimation of the significance of the parameters therewith.

Furthermore, the MNL model is only able to represent systematic taste variation and cannot capture random taste variation. This means that the MNL model assumes the same tastes for all decision makers. As a result the MNL model cannot differentiate in tastes linked to unobserved attributes.

In this study the IIA would not form an issue as for both unlabelled alternatives and a base alternative (see Section 6.4) nests of alternatives are not relevant. For the assumed homogeneity in preferences by the MNL model will be compensated by estimating MNL models including interaction effects between the attributes and personal and trip characteristics. In this way heterogeneity in preferences between different groups of respondents can be revealed. By estimating an ML model panel effects could be taken into account. However, as explained the model estimation are not extend to this more advanced model because of limitation in time. The ignorance of panel effect will therefore remain the main limitation of the application of the chosen choice model in this study.

6. Design & distribution of the stated preference survey

In Chapter 4 knowledge has been gathered on the factors influencing the choice between using a shared bicycle and a private bicycle for trips from and towards railway stations. A number of different personal characteristics, trip characteristics, bicycle facility characteristics and BSS attributes are selected for further investigation. This chapter focuses on the design and distribution of a survey, consisting of a questionnaire and a stated choice experiment, based on the selected factors in Chapter 4. The result of the survey will provide information on the importance of, and relationship between, the factors influencing a travellers' choice between using a shared or a private bicycle.

This chapter will deal with the full process of data collection: from designing the stated choice experiment and questionnaire, to the start of the analysis by data cleaning and coding. In addition this chapter will provide insights in the sample characteristics and will discuss the representativeness of the sample.

Section 6.1 will discuss the chosen respondent group and will describe the method of data collection. In Section 6.2 the case study locations will be briefly analysed. Section 6.3 will discuss the survey set-up prior to start on elaborating the experimental design of the stated choice experiment in Section 6.4. Subsequently, Section 6.5 discusses the process of designing the other survey questions and an overview of the final survey will be given. In Section 6.6 is explained how the data is prepared in order to execute data analyses. Section 6.7 gives insight in the characteristics of the respondents by a descriptive analysis of the collected survey data. This chapter closes with a conclusionin Section 6.8.

6.1 Data collection

6.1.1 Respondent group

In Section 2.3 the target groups of an efficient BSS are investigated. It is found that different types of (potential) travellers could participate in an efficient BSS: current access cyclists, potential access cyclists, current egress cyclists and potential egress cyclists.

Current access cyclists appeared to have an important role in the success of an efficient BSS. This group of current travellers is responsible for the supply of shared bicycles, hence the bicycles can be used by egress travellers, and bicycle parking pressure can be reduced. Currently, it is unknown to which extent current access cyclists are willing to use a shared bicycle instead of a private bicycle for access trips and what their preferences are regarding shared bicycle systems. Therefore, it is important to gather information on the preferences of current access cyclists.

Current and potential egress cyclists play an equally important role, since these groups of bicycle demanders are responsible for the actual realisation of capacity savings by taking the bicycle out of the bicycle parking facilities at railway stations to their destination. In particular, current egress cyclists, of whom it is assumed a private bicycle is used for egress transportation, can contribute to relatively large capacity savings for each bicycle supplied by access cyclists. One egress cyclist switching to a shared bicycle can contribute to a reduced parking pressure of on average four parked access bicycles (see Section 2.2). Moreover, little is known about the preferences of current egress cyclists for using a shared bicycle. For these reasons it is desired to gather information among this group.

Additionally, access and egress travellers currently using other modes of transportation are potential shared bicycles users and may contribute to additional bicycle parking capacity savings. When these types of travellers would be approached, the number of needed respondents will rise considerably in order to obtain sufficient information on the preferences of current cyclists. Current cyclists only cover a limited part of all travellers. Moreover, results of other studies focused on the preferences of potential egress cyclists are available. Therefore, it is chosen to limit the respondent group to only current cyclists.

Moreover, it is found that an efficient BSS particularly aimed at commuters may be most beneficial in reducing bicycle parking pressure (see Chapter 2). Commuting access cyclists travelling during the morning peak, usually park their bicycle during the whole workday and can therefore supply a shared bicycle for a long time during the day. Egress cyclists arriving in the morning peak may use this bicycle until they return (early) during the evening peak hour. For this reason this study is in particularly aimed at current cyclists that are parking and taking their bicycle during the morning and evening peak hours.

A consequence of the choice to limit the respondent group to current cyclists is, that solely on the basis of the results of this study, no insights in the total demand which can be expected for a new BSS can be gained. The preferences of potential access and egress cyclists (during the day) are not studied, and the demand among these groups will be unknown. This implies that, based on the results of this study, it is not possible to estimate the possible bicycle parking capacity savings as a result of bicycle sharing. However, based on the results of other studies an indication can be given.

Furthermore, it is expected that the chosen respondent group may provide the most reliable results, as current cyclists already have experience with the circumstances around bicycle parking facilities and perhaps also have experience with using a shared bicycle. Therefore it is assumed these people have a good understanding of their preferences regarding cycling and bicycle parking.

6.1.2 Data collection method

In 2012 Maat & Molin (2015) investigated bicycle parking at the central railway station of the city of Delft, the Netherlands. In order to collect data for this research project, cyclists were directly approached at the bicycle parking places of the railway station. By handing out flyers cyclists were invited to participate in an online survey and a prize was raffled among the respondent in order to increase the response rate. This method have appeared to be successful in recruiting the targeted respondent group. Therefore, a similar data collection method is applied in this research.

By handing out flyers at three Amsterdam railway stations (Amsterdam Amstel station, Amsterdam Central station and Amsterdam Zuid station) cyclists were invited to participate in the online survey. On the flyers a link and a QR code to an online survey could be found (see Appendix F.3. for the flyer). The weblink enabled respondents to fill in the survey on a suitable moment, for example during their train trip. Among the respondents that completed the survey, gift cheques of 25, 50 and 100 euros, with a total of 250 euros, were raffled.

Figure 15: Data collection: handing out flyers to cyclists at railway stations

Data is collected in the period between 10 April 2018 and 3 May 2018. On six workdays during the morning and evening peak, (7:00-9:30 AM and 16:00-18:30 PM), three to five people distributed survey invitations to users of bicycle parking facilities at the three mentioned railway stations. At each of the three railway stations data is collected on in total two workdays. In the morning peak most flyers were distributed, as a large number of travellers passing by in the afternoon, already received a flyer in the morning. The distributors of the flyers were mainly located on walking routes from the platform to the bicycle racks or at the entrances and exits of the parking facilities. Not all cyclists could be reached and also some non-cyclists received a flyer. At bicycle parking facilities with a clear entrance, the invitations were accepted more easily. In total around 8,300 flyers were distributed.

6.2 Case study locations

This section will provide background information on the three selected Amsterdam railway stations, by studying the three locations on bicycle parking.

Figure 16: The three studied Amsterdam railway stations on the map

6.2.1 Study location 1: Amsterdam Centraal

Amsterdam Centraal is a railway station with the highest number travellers in the Netherlands. On an average work day almost 185,000 train passengers are arriving and departing (Nederlandse Spoorwegen, 2018). At several locations around the station building bicycle parking places are provided. The places are varying from unroofed, unguarded and free, to roofed, guarded and paid. In total 12,800 bicycle parking place can be found at Amsterdam Centraal. The invitations for the survey are mainly distributed at the west and north side of the railway station.

Table 2: Details on bicycle parking at Amsterdam Central railway station

Bicycle parking facility	Parking places	Parking pressure	User charge	Maximum parking duration	Security	Studied location
Fietsflat	2,270	N/A	Free	14 days	Unguarded	✓
West	800	N/A	Paid	14 days	Guarded	✓
IJzijde-west	1,300	N/A	Paid	14 days	Guarded	✓
Fietsplatform	2,300	N/A	Free	14 days	Unguarded	✓
Fietspont	400	N/A	Free	14 days	Unguarded	-
Oost	1,700	N/A	Paid	14 days	Guarded	-
Stationsplein ground level	4,300	N/A	Free	14 days	Unguarded	-
	12,800					

N/A: not available

6.2.3 Study location 2: Amsterdam Zuid

Amsterdam Zuid is a railway and metro station, located near the Zuidas international business district and important educational institutions on the one side, and near a number of densely populated neighbourhoods one the other side. The number of passengers arriving and departing from this station is growing rapidly, with almost 55,000 daily train passengers in 2017 (Nederlandse Spoorwegen, 2018). At the moment of surveying, two large underground bicycle parking facilities could be found at this railway station. At both facilities short parking (<24 hours) is free of charge. The parking pressure at both locations varies widely. This is due to the more favourable location of the 'Zuidpleinstalling' and the high number of available parking places in the new 'Mahlerpleinstalling'.

Table 3: Details on bicycle parking at Amsterdam Zuid railway station

Bicycle parking facility	Parking places	Parking pressure	User charge	Maximum parking duration	Security	Studied location
Zuidpleinstalling	2,650	>100%	Free (24h)	28 days	Guarded	✓
Mahlerplein	3,000	>35%	Free (24h)	28 days	Guarded	✓
	5,650					

6.2.4: Study location 3: Amsterdam Amstel

Amsterdam Amstel station is the smallest of the three study locations. On an average workday almost 32,000 arriving and departing passengers can be counted (Nederlandse Spoorwegen, 2018). Bicycles can be parked outside or in the underground facility. At the moment of writing, the underground bicycle facility is under construction in order to extend the bicycle parking capacity.

Table 4: Details on bicycle parking at Amsterdam Amstel railway station

Bicycle parking facility	Parking places	Parking pressure	User charge	Maximum parking duration	Security	Studied location
Basement	1,500	N/A	Free (24h)	28 days	Guarded	✓
Outside	2,000	>100%	Free	28 days	Unguarded	✓
	3,500					

N/A: not available

6.3 Survey set-up

The survey is made up of three different parts (see Figure 17). The first part includes questions on cycling and bicycle parking behaviour. This provides information about respondent's trip characteristics and some personal characteristics. The next part of the survey is the stated choice experiment and the last part of the survey includes questions about the respondent's socio-demographic situation.

The part with the stated choice experiment consists of two experiments. One is designed for access cyclists and deals with trips from home to the railway station and vice versa. The other experiment is designed for egress cyclists, covering bicycle mode choices in egress transportation. The alternatives and attributes are in principle similar for both experiments, although the attributes names and descriptions of two attributes slightly differed, which made the experiments more understandable for the respondents and prevented misinterpretation. Every individual respondent participated in only one of the two experiments.

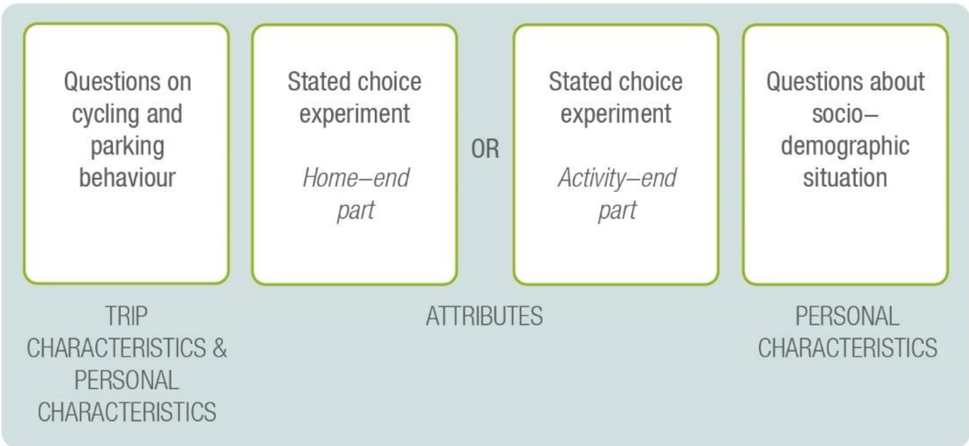

Figure 17: Schematization of survey design

6.4 Experimental design

This section will describe the process of constructing the experimental design and will discuss the considerations made during this process. First, alternatives, attributes and attribute levels will be determined. Subsequently, the final choice sets will be constructed.

6.4.1 Model specification

Alternatives

In a stated choice experiment, respondents (decision makers) are asked to make a choice between different alternatives, described by a number of attributes, in order to obtain information about their preferences. In this study current cyclists are asked to choose between different types of shared bicycles described by different attributes and varying attribute values among the choice sets.

This stated preference study is aimed at gathering information on choices of current cyclists between using a private bicycle or a shared bicycle for access or egress trips. Therefore the choice alternatives in this stated choice experiment consist of different bicycle sharing system designs and a base alternative: use of a cyclists' private bicycle. When respondents are asked to make a choice between the different shared bicycle alternative and the base alternative, it is possible that the parameters of the bicycle sharing alternatives cannot be estimated, as a result of too many respondents opting for the base alternative. For this reason respondents are asked to choose between the shared bicycle alternatives first. Subsequently, the respondents will choose between the shared bicycle alternatives and the base alternative. In this way, insights in user preferences and trade-offs for the shared bicycle alternatives can be gained, even when only a small number of respondents will opt for the shared bicycle.

The number of shared bicycle alternative is limited to two, in order to minimise complexity. The choice sets in this stated choice experiment exist of two unlabelled alternatives (shared bicycle 1 and shared bicycle 2). This means that the names of both alternatives do not represent a characteristic. The main reason for using unlabelled alternatives is that it allows for obtaining information on the importance of the attributes without further specification of the system. This makes it possible to test scenarios representing bicycle sharing systems which are not existing at the moment. A fundamental prerequisite in this case is that the attributes represent the most important attributes which make up the different systems. In addition an experiment with unlabelled alternatives will lead to a design which needs a smaller number of choice sets to derive the same amount of information.

Attributes

Both shared bicycle alternatives will be described by a set of attributes with different attribute values. The base alternative (use of a private bicycle) is not described by any attributes. This stated choice experiment consists of two unlabelled alternatives with generic attributes, which implies that all attributes are present in both alternatives and having the same attribute values for both alternatives.

In Chapter 4, six BSS attributes were selected for further investigation. It is assumed that the different promising BSSs, selected in Section 3.2, can be fully described by the six selected attributes, which will allow for estimations of the demand for the different promising BSSs in the remainder of this study. In addition, a full description of the alternatives is needed in order to provide the respondents sufficient information to make a choice.

For better understanding, two of the six selected attributes are merged into one. The attributes walking time to a shared bicycle from home or destination and the availability of a shared bicycle at home or destination (the chance to find a bicycle in a certain time span) are merged into 'accessibility of a shared bicycle'. This attribute describes the time needed to walk to a shared bicycle in most of the cases and the maximum walking time (in case the bicycle was not available in the time needed most of the cases).

Below a definition of the five final attributes is given:

- Accessibility of a shared bicycle at home / at destination

  The time in which a shared bicycle can be reached with absolute certainty.
- Walking time from shared bicycle parking place to home / to destination

  The time needed to walk from the place were shared bicycles can be parked (e.g. at a bicycle station on certain distance or just everywhere in public space) to home or destination.
- Parking convenience (premium parking place)

  Parking convenience is defined by the availability or unavailability of a guaranteed premium parking places near the platform. With the guaranteed availability of a premium parking place walking times from bicycle parking place to platform will be shortened and the time needed in order to find an unoccupied parking place is reduced. When premium parking place are not offered, cyclists must search for an empty bicycle parking place by themselves.
- Accessibility of a shared bicycle at railway station

  The time in which a shared bicycle can be reached with absolute certainty.
- Price

  The costs of using a shared bicycle.

Attribute levels and ranges

The five selected attributes are further specified in a number of levels and these attribute levels are quantified. In this study it is desired to test for non-linear effects of the attribute 'walking time from shared bicycle parking place to home/destination' and for the attribute 'price'. In order to test for non-linear effects, the application of more than three levels for an attribute is required. Moreover, it is desired to achieve attribute level balance in the chosen orthogonal design, as far as possible. This will be further discussed in Section 6.4.2. These prerequisites resulted in four attributes being varied in four levels and one attribute being varied in two levels. Table 5 provides an overview of all included attributes and chosen levels.

Table 5: Alternatives and attribute levels for the unlabelled SC experiment

ATTRIBUTES	ALTERNATIVES Shared bicycle 1	 Shared bicycle 2	BASE ALTERNATIVE
Accessibility at home / at destination	Guaranteed at front door Always in 2 mins Mostly in 2 mins, always in 4 mins Mostly in 2 mins, always in 6 mins	Guaranteed at front door Always in 2 mins Mostly in 2 mins, always in 4 mins Mostly in 2 mins, always in 6 mins	Privately owned bicycle
Walking time to home / to destination	0 mins 1 mins 2 mins 3 mins	0 mins 1 mins 2 mins 3 mins	
Parking convenience	Self search for parking place Premium parking place near platform	Self search for parking place Premium parking place near platform	
Accessibility at railway station	Guaranteed: Direct available for use High: Always in 2 mins Medium: Mostly in 2 mins, always in 4 mins Low: Mostly in 2 mins, always in 6 mins	Guaranteed: Direct available for use High: Always in 2 mins Medium: Mostly in 2 mins, always in 4 mins Low: Mostly in 2 mins, always in 6 mins	
Price	Free of charge 6 €/month (0.30 €/single trip) 12 €/month (0.60 €/single trip) 18 €/month (0.90 €/single trip)	Free of charge 6 €/month (0.30 €/single trip) 12 €/month (0.60 €/single trip) 18 €/month (0.90 €/single trip)	

Below the quantification of the attributes and the chosen levels will be discussed.

Accessibility at home / at destination

This attribute is varied in four levels with a nominal scale and varies between guaranteed at front door (i.e. always direct available and 0 minutes walking time) and 'mostly in 2 minutes, always in 6 minutes'.

Walking time from bicycle parking place to home / to destination

This attribute is varied in four levels varying from 0 minutes (the bicycle can be parked everywhere) to 3 minutes (the bicycle must be parked in a bicycle station on approximately 3 minutes walking distance).

Parking convenience

This attribute is varied in two levels: offering a guaranteed premium parking place near the platform or the old situation where cyclists search for a bicycle parking place by themselves (no guaranteed premium parking place near the platform).

Accessibility at railway station

This attribute has the same attribute levels as 'accessibility at home / at destination/. The attribute level of 0 minutes (guaranteed at front door) is replaced by 'direct available for use'.

Price

Price ranges are constructed based on actual prices of existing BSSs in the Netherlands (Appendix A.3 provides an overview of the analysis). This attribute is varied in four levels. The lower limit of €0.30 per single trip (30 min) is around half of the lowest actual tariff. It is assumed that the cost can be reduced when the systems grow. Besides, it is useful to gain information on the demand for a BSS with a very low tariff, in case a BSS may be subsidised and because it is more accurate to interpolate than to extrapolate. The upper limit of €0.80 per trip represents a price around the average of current tariffs (January 2018).

Since most BSSs offer different price for different time spans, the prices are converted to a day and a monthly tariff. The ratios between the trip, day and monthly tariffs are equal for all attribute levels. Also for this attribute more than three levels are chosen in order to be able to test for non-linear effects.

6.4.2 Generation of the experimental design

With the attributes and attribute levels defined in the previous section, an experimental design is created. In an experimental design, choice sets are constructed by combining different attribute levels of an attribute into a set of alternatives. It is of high importance to vary the different levels of the design throughout the experiment in a correct way, in order to produce the best data to estimate the independent contribution of the different attributes in the respondents' choices. The chosen experimental design will therewith also impact the significance of the estimated effects.

Basically two types of experimental designs are distinguished: orthogonal designs and efficient designs. Orthogonal designs minimize the correlations between attributes and allow for estimating all main effects, i.e. each attribute can be evaluated independently of all the other attributes (Molin, 2017b). Two-way interaction effects (interaction between attributes) however, cannot be estimated with this design. Efficient designs maximize the information from each choice situation and therewith minimize the standard errors of the parameter estimates (Molin, 2017a). A general belief is therefore that efficient designs are able to outperform orthogonal designs.

It was not assumed that high standard errors would a be problem in this study, since a large number of respondents was expected. Moreover, no priors were available and a pilot study should be carried out in order to find priors. When the found priors are not accurate, the benefits of the efficient design will be cancelled out and the quality of the final parameter estimates will be affected. Therefore an efficient design would not necessarily be beneficial in this case. High correlations between attributes were of higher concern in this study, as these should be low in order to be able to estimate all main effects. Based on these considerations it is chosen to use an orthogonal design.

An orthogonal design can be generated in different ways. Important considerations are the number of choice sets needed and small correlations between attributes. A full factorial design guarantees no correlations between attributes and allows for estimating all main and interaction effects (ChoiceMetrics, 2018). However, a large number of choice sets would be needed, as the full factorial design consists of all possible choice combinations. This can be calculated by the formula L^A (number of attribute levels$^{\wedge \text{ number of attributes}}$) (Molin, 2017b). In this case 512 ($=4^4*2^1$) choice sets would be needed. This large number of choice sets will result in an elaborate survey which will exhaust respondents.

Use of a fractional factorial design solved this issue, as it limits the number of choice sets and, in addition, still ensures the absence of correlations between attributes. Basic plans are published fractional factorial designs constructed by mathematicians. When these plans are applied in a correct way, not any pair of attributes within the alternative will be correlated and the design is assured to be orthogonal (Molin, 2017c). A drawback of designs based on basic plans is that they only allow for estimating main-effects, i.e. interaction effects cannot be estimated. In this study however it is not necessary to estimate interaction effects, but they might play a role. Therefore a fold-over of the basic plan is added to the design. This doubles the number of choice sets needed, but will assure that all main effects are uncorrelated with all two-way interaction effects.

A basic plan suitable for the number of attributes and levels defined in this study, is basic plan 3 (when sequential construction is applied). A fold-over design of this basic plan resulted in a design with 32 rows (32 choice sets). Sequential construction leaded to correlations between alternatives, however this is not a problem as this experiment consists of only generic attributes and the same attributes appear twice in the choice sets (Molin, 2017b). Simultaneous construction would have led to a very high number of choice situations.

In Appendix F.1 is shown how the attributes and levels defined in this study are assigned to the different columns of the basic plan. The choice sets are constructed by random drawing. During the drawing process dominant alternatives popped-up. This means that in some choice sets one of the alternatives would be clearly more preferred over the other, which make that respondents' choices will not provide much information (ChoiceMetrics, 2018). The dominant alternatives are countered by (1) manually changing the order in which attributes are assigned to the columns of the basic plan and by (2) manually swapping the, by random drawing, constructed alternatives within the same block, while still orthogonality is preserved. This operation was executed until dominance was cancelled out.

One of the columns of the basic plan is used for blocking. By blocking, the number of choice sets is reduced to eight choice sets per respondent (four blocks). The final choice combinations can be found in Appendix F. These choice combinations are randomly assigned to different respondents in the online survey.

6.5 Final survey design

As explained in Section 6.1 Data collection the survey consisted of three parts:

- questions about respondents' trip and parking characteristics;
- the stated choice questions;
- questions about respondents' socio-demographic situation.

In Appendix F.3 the final presented web survey can be found and is briefly discussed below.

First respondents are presented a short introduction about the subject, the average time that will be needed to fill in the survey (10 minutes), prizes that are raffled among respondents and the use of their personal data. It is not explained to respondents how a bicycle sharing system can result in reduced parking pressure.

Subsequently, respondents are questioned about their most recent bicycle trip from or to the railway station. This way, respondent's trip characteristics are derived. It also ensures that respondents can be sent to the right stated choice questions (bicycle sharing for access or egress transportation) later on. In addition, some questions about respondents' bicycle parking behaviour and about their familiarity with using different types of shared bicycles follow.

These questions are followed by a short introduction into bicycle sharing, an introduction into the stated choice experiment and an explanation of the attributes in the stated choice experiment. After reading this information respondents are presented one of the total of eight choice situations at a time. Cyclists who use their bicycle to travel from home to one of the three studied Amsterdam railway stations, were presented one of the four blocks of the stated choice questions designed for access cyclists. Cyclists who used their bicycle to travel from one of the three studied Amsterdam railway stations to their destination were presented one of the four blocks of stated choice questions designed for egress cyclists.

In addition to the stated choice questions, respondents are asked a few questions about their preferences for bicycle sharing. The survey closes with questions about respondents personal situation (age, gender, income etcetera). All respondents should have been able to find an answer that fits their situation, by including the option 'other'.

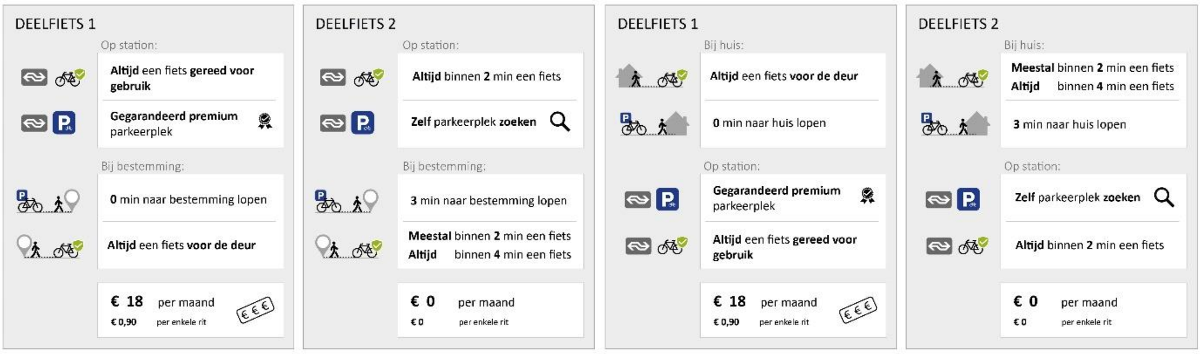

Figure 18: Examples of two choice sets (left: choice set for egress cyclists, right: choice set for access cyclists).

The survey is constructed in SurveyGizmo. This online survey program allowed for assigning one of the blocks of stated choice questions to a respondent, whilst all blocks of questions are presented to an equivalent number of respondents. A mobile and web version is made, as it was expected that a large number of people would open the survey on their phone. Timers were implemented to get insight in the time needed to read explanations and to answer questions. This allowed for exclusion of respondents who did not seriously complete the survey.

6.6 Data preparation

The survey is completed by 1061 respondents in total. Before analysing the data, the data is cleaned and prepared. In this section, the considerations that have been taken into account and the choices made in these processes, will be discussed.

6.6.1 Data cleaning

For several reasons some respondents were excluded from the survey in advance or their answers were excluded from the data for the model estimation.

- A first requirement for the respondents was to make use of the bicycle parking facilities at one of the three Amsterdam railway stations. 30 out of 1061 respondents did not fulfil this requirement as they were no bicycle users. After the start of the survey they received a message not to be in the target group for this research.
- The data of seven respondents was excluded as they were not cycling from or to one of the three selected Amsterdam railway stations.
- Four respondents indicated in the comment section that they, for some reason, did not take a look at the pictures in the choice tasks or could not see (a part of) the pictures, probably due to a bad internet connection. (It must be noted that it cannot be guaranteed that all other respondents have seen the images in the choice sets. However, a quick analysis of the minimum completion time of the choice tasks showed no reason to exclude respondents).
- Three respondents had completed the survey by answering all 4 blocks of 8 choice situations or completed none of the required choice tasks for an unknown reason. These respondents were also excluded from the estimation of the model.
- At last 55 users of PT-bicycles were not included in the model estimations. PT-bicycle users are already using a form of a shared bicycle. A choice between the shared bicycle alternatives and a private bicycle will therefore not make sense in order to estimate the demand for shared bicycles.

In total 961 useful survey responses with eight completed choice tasks remain, providing 7688 (961 respondents $\times$ 8 choices) observations for the estimation of the models. 66.8 percent of these observations concern access cyclists (679 respondents). The other part (337 respondents) concern egress cyclists. For both groups a different choice model is estimated.

The median time needed to complete the survey is 11 minutes. To complete the choice tasks, on average 6.7 minutes were needed, with a median time of 4.2 minutes. All choice tasks contained a choice between two shared bicycles and in additional question one had to choose between the chosen shared bicycle and their private bicycle. The minimum time used to complete the choice tasks and the time to complete the questionnaire gave no grounds to exclude any respondents from the data.

6.6.2 Applied variable coding schemes

The respondents' answers of the stated choice questions of the survey will be analysed in Chapter 7, by estimating three different MNL models. A base MNL model without interaction variables, an MNL model including personal characteristics and an MNL model including trip characteristics will be estimated.

In all three models, the attributes of the shared bicycle alternatives are coded. The attributes 'accessibility at home / destination', 'accessibility at railway station' and 'parking convenience' have categorical attribute values, which makes coding required in order to be able to estimate the model. This also counts for some interaction variables: the non-continuous interaction variables need to be coded in order to be able to estimate a parameter for every segment in the category.

Different types of coding schemes could be applied and will have different implications for the interpretation of the estimated parameters. The chosen coding schemes for both variable types will be discussed from now on.

Attribute coding schemes

It is desired that the coding of attributes contributes to convenient interpretation of parameter estimations and interpretation alternative specific constant. Therefore, in this study is chosen to apply dummy coding to the attributes with categorical attribute levels. This type of coding allows for more easy interpretation of the estimation results, as the parameters for dummy variables indicate a utility difference with the reference level. The reference levels of all coded attributes represent values that are assumed as most attractive and are almost similar to the characteristics of a private bicycle (e.g. always direct available, no walking times, no charge). This makes that the alternative specific constant (ASC) will represent the utility of a shared bicycle similar to using a private bicycle.

The dummy coding scheme consists of L-1 indicator variables, in case an attribute has L variables. This type of coding uses only zeros and ones, where a reference level has a value of zero for all indicator variables. For the reference levels no parameters will be estimated and these levels will have utility of zero. In Table 6 a general example of the dummy coding scheme is given. The final coding schemes for all attributes are presented in Table 7.

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Table 6: General dummy coding scheme for an attribute with four levels

Levels	Variable 1	Variable 2	Variable 3
Level 3	1	0	0
Level 2	0	1	0
Level 1	0	0	1
Reference level	0	0	0

Table 7: Applied (dummy) coding schemes

Accessibility at home / at destination	AHD1	AHD2	AHD3	Walking time	WALK1
Mostly in 2 mins, always in 6 mins	1	0	0	3 mins	3
Mostly in 2 mins, always in 4 mins	0	1	0	2 mins	2
Always in 2 mins	0	0	1	1 mins	1
Guaranteed at front door	0	0	0	0 mins	0

Accessibility at station / Accessibility at destination	AS1	AS2	AS3	Price	PRICE1
Mostly in 2 mins, always in 4 mins	1	0	0	18 €/month	18
Mostly in 2 mins, always in 6 mins	0	1	0	12 €/month	12
Always in 2 mins	0	0	1	6 €/month	6
Guaranteed in front of the door	0	0	0	free of charge	0

Parking convenience	PARK1
Self search for parking place	1
Premium parking place near platform	0

Personal and trip characteristics coding schemes

In this study effect coding is applied to personal and trip characteristics. Effect coding makes interpretation of the parameter estimate for the interaction variable more convenient, as the parameter estimate represents the difference in utility compared with the average of all segments in the category. This is useful since the estimated parameters for the interaction variable will give information on the utility difference with respect to the average of all respondents. When dummy coding would be applied, every parameter estimate for a different segment would represent a difference in utility compared with the segment chosen as reference level.

Effect coding uses zeros, ones and minus ones to code the different segments, where one segment of the interaction variable is coded with only minus ones. In Table 8 an example of the used effect coding scheme is given. Table 9 presents the final coding schemes for all attributes.

Table 8: General effects coding scheme for an interaction variable segmented into three groups

Levels	Variable 1	Variable 2
Group 2	1	0
Group 1	0	1
Reference group	-1	-1

Table 9: Effect coding scheme for the included personal characteristics with categorical levels

Segments	Applied effect coding		
Gender	GENDER		
Male	1		
Female	-1		
Income	INCOME1	INCOME2	INCOME3
> €60.000	1	0	0
€40,000 - €60,000	0	1	0
€20,000 - €40,000	0	0	1
< €20,000	-1	-1	-1
Job status	JOB1	JOB2	
Student	1	0	
Part time working	0	1	
Full time working	-1	-1	
Familiarity with bicycle sharing	FAM		
Familiar with PT-bicycle (regular or occasional user)	1		
Unfamiliar with PT-bicycle	-1		

Table 10: Effect coding scheme for the included trip characteristics with categorical levels

Segments	Applied effect coding		
Railway station	STATION1	STATION2	
Amsterdam Amstel	1	0	
Amsterdam Centraal	0	1	
Amsterdam Zuid	-1	-1	
Paid parking	PAID		
Paid parking (paid by cyclists themselves)	1		
Unpaid parking (not paid by cyclists themselves)	-1		
Experienced bicycle parking difficulties	PARKPRES		
Always or often	1		
Occasionally or never	-1		
Trip duration	TRIPDUR1	TRIPDUR2	TRIPDUR3
≥ 16 min	1	0	0
11 - 15 min	0	1	0
6 - 10 min	0	0	1
1 - 5 min	-1	-1	-1
Flexibility of arrival time at home / destination	FLEXHD1	FLEXHD2	
Not flexible	1	0	
Bit flexible	0	1	
Very flexible	-1	-1	
Flexibility of arrival time at station	FLEXST1	FLEXST2	
Not flexible	1	0	
Bit flexible	0	1	
Very flexible	-1	-1	
Bicycle reimbursement	BICREIMB1	BICREIMB2	BICREIMB1
Full reimbursement	1	0	1
Partial reimbursement	0	1	0
No reimbursement	-1	-1	-1

6.7 Descriptive analysis of the sample

In total around 8300 invitation flyers were distributed among bicycle parking facility users and several other travellers at three Amsterdam railway stations. From the persons that received an invitation flyer 1061 persons completed the survey, which gives a response rate of around 12.2%. The respondents used different devices to fill in the online survey. The majority used a mobile phone (50.9%), followed by use of a laptop or desktop (45.4%). A few respondents used a tablet (3.7%).

6.7.1 Exploration of respondents' answers

In the last part of the survey, respondent's personal characteristics were obtained. In Appendix G.1 the frequency distributions of respondents personal and trip characteristics are presented. The different tables provide figures on the total of all respondents, on the respondents divided by access and egress cyclists, and for the respondents divided by the three different railway stations.

Personal characteristics

The sample has almost equal shares of the genders. The respondents in the sample are relatively young and remarkably high-educated. The average age is 38 years (the median age is 33 years). On average 55.3% of the respondents completed a Masters Degree. On average 72.4% of all respondents has a full time job, 18.2% is working part time and 7.4% is a student. The median income is 35,000 euros.

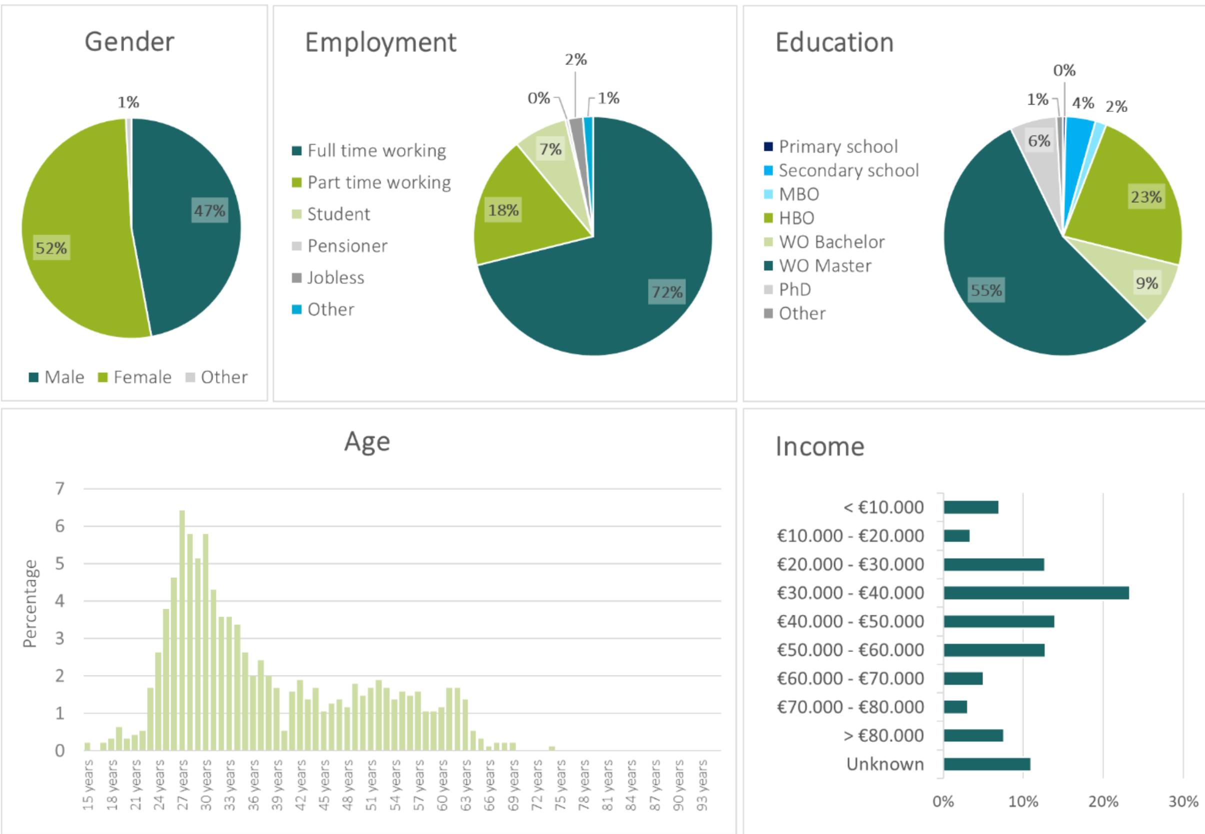

Figure 19: Graphical overview of respondents' personal characteristics

Trip and bicycle parking characteristics

For most respondents Amsterdam Zuid was the departure or arrival station (42.1%). At the railway stations Amsterdam Amstel and Amsterdam Centraal, 25.4% and 32.5% of the respondents were recruited, respectively. Almost all respondents' trips were work or business related (91.6%). The average duration of an access trip is 12 minutes (median time 10 minutes). An egress trip takes respondents on average 13 minutes (median time 12 minutes). The majority of the respondents makes their trip to or from the railway station 4 or 5 times a week.

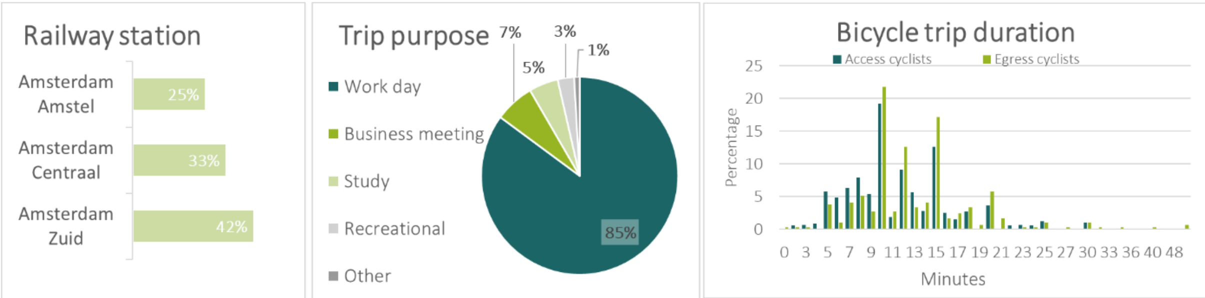

Figure 20: Graphical overview of respondents trip characteristics

Regarding bicycle parking, significant differences between access and egress cyclists are found. A large part of the egress cyclists paid charge for using the bicycle parking facility (42.0%), while only a small fraction of the access cyclists did. This has probably to do with the fact that egress cyclists clearly park their bicycles for a longer time than access cyclists do (see Figure 21) and bicycle parking longer than 24 hours is being charged at most studied railway stations (see Section 6.2). In total 21.4% of the respondents has paid for using the bicycle parking facility at the railway station. The experienced bicycle pressure, in terms of difficulty with finding an empty bicycle parking place, does not significantly differ between access and egress cyclists. The majority of both groups does not experience difficulties finding bicycle parking place at one of the three Amsterdam railway stations.

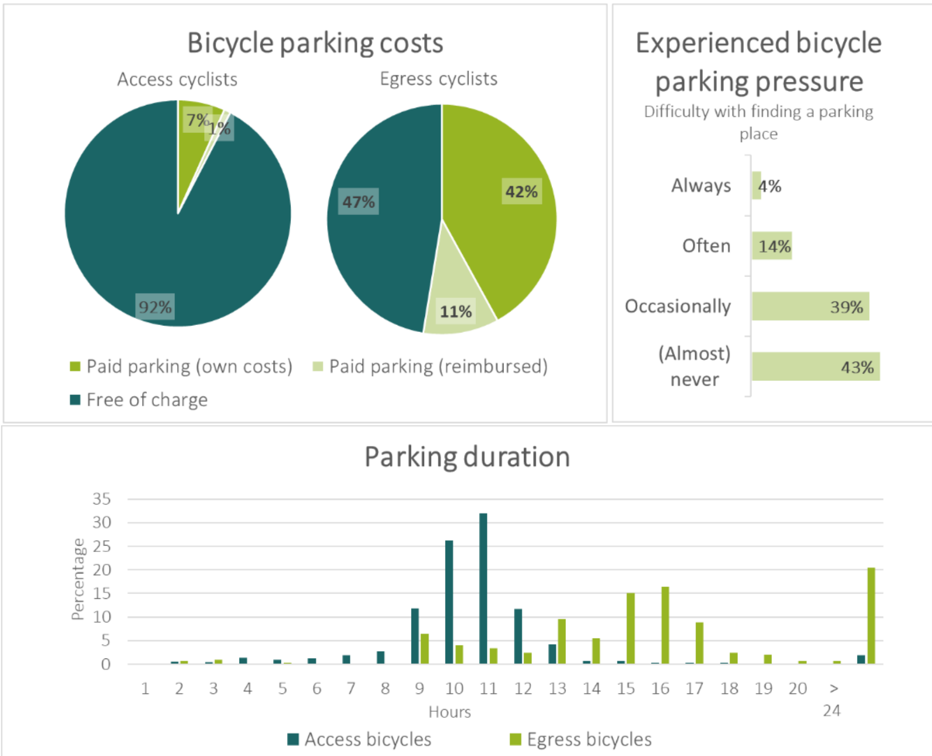

Figure 21: Graphical overview of respondents bicycle parking characteristics

6.7.2 Representativeness of the sample

Overall it is assumed that the respondent sample gives a fair representation of the population (current cyclists at major railway stations), as the respondents were directly approached at bicycle parking facilities at railway stations. Nevertheless this method of data collection still does not guarantee a representative sample. It is, however, difficult to check to which extent the sample is representative for the population. Detailed information on the characteristics of cyclists at the three studied Amsterdam railway stations during peak hours is lacking, which makes a comparison of the socio-demographic characteristics of the sample with figures of the population hard. Based on general findings in literature on (Dutch) bicycle-train users and by comparing the sample with the Amsterdam population, it is tried to provide insights in the representativeness of the sample. Supportive figures are provided in Appendix G.1.

First, the high proportion of commuting trips stand out. This is in accordance with Martens (2007) and (Van Boggelen & Thijssen, 2008) who found that the combination bicycle-train is mainly used for commuting purposes. The Dutch national mobility (KiM) (2014) found that six out of seven bicycle-train trips have a work or an educational purpose. In this study, the number of only work-related trips is even higher (9 out of 10). This is probably due to the fact that the invitations flyers for the survey where distributed during the morning and evening peak hours, when most commuters with a full time job park and pick up their bicycle.

The number of trips with an educational purpose, however, is significantly lower than would be expected based on findings in literature. Shelat at al. (2017) found that, on average, 32% of all Dutch bicycle-train users are university students (which however not directly implies that of trips have an educational purpose). In this study, only 7% the respondents are students and in total 5% of the trips had an educational purpose. The number of students, and presumably also the number of educational trips, is possible an underrepresentation of the total population. This low number of students and educational trips may also relates to the distribution of the survey during the morning and evening peak hours. Students are more flexible in their arrival and departure times and may travel after and before the peak hours. In addition, the presence of study locations within acceptable walking distance and available PT-connections may have influenced the low number of students and educational trips among the respondents.

Furthermore, the small share of less-educated travellers and high share of more-educated travellers is remarkable. More than 60% of the respondents has at least a Masters Degree, while only 2% of the respondents has completed Secondary vocational education (Dutch: MBO). Compared with the Amsterdam population, these percentages are around 30% and 21% respectively (Gemeente Amsterdam, 2017) (see Appendix G.1). The high share of highly-educated people is in accordance with findings of Heinen & Bothe (2014) and Shelat et al. (2017). According to these studies, it can be explained by the fact that the group of less-educated travellers typically makes commuting trips of shorter distances. More-educated travellers are more likely to travel longer distances as jobs requiring higher education are more specialized and found at fewer locations.

It is difficult to compare the average income of the respondents with the income of the Amsterdam and total Dutch population, as respondents could opt for different income categories. Assuming that all respondents in the highest income category (>80,000 euro) earn 80,000 euros and the respondents in the other income categories earn the middle value of that category, the average income is equal to the mean income of 35,000 euros. Compared with the Amsterdam population the incomes of the respondents are relatively high (see Appendix G.1). The incomes of the total Dutch population and the incomes of the respondents are fairly equal. Based on the work of Shelat et al. (2017) would be expected that respondents had a higher income, as bicycle-train users are found to often have a higher income than the average population.

Overall slightly more women than men participated in the survey. The ratio between males and females differed however for each studied railway station. From research by Heinen & Bohte (2014) among Dutch PT-commuters could be expected that the bicycle-train share of males would be larger than the share of females. In contrast, research by Shelat et al. (2017) found that Dutch bicycle-train users are equally represented by males and females. Therefore the almost equal proportion of male and female respondents gave no grounds to assume that the sample is an unrealistic representation of the population.

Compared with the age of the inhabitants of the city of Amsterdam, the group with an age between 25 and 34, is relatively large (see Appendix G.1). This cannot be declared by existing research. According to Heinen and Bothe (2014) bicycle, bicycle-train users are slightly younger than other commuters, but age does not differ much between all travellers. A plausible explanation for the high number of young and middle-aged respondents, is that this group is more interested in the topic and in participating in an online survey.

All in all is concluded that the number of work related trips may be overrepresented for the total number of current cyclists during the day. The number of younger cyclists may also be overrepresented. The number of students of students might be underrepresented compared with findings in literature. The higher incomes and the small proportion of less-educated people is in accordance with findings in literature. Overall it is expected that the sample gives a fair representation of all cyclists at railway stations during the whole day.

6.8 Conclusion

This chapter described the process of designing the stated preference survey and collecting and preparing the data for the analysis. The survey is aimed at current cyclists at railway stations and is be distributed among users of bicycle parking facilities at three railway stations in Amsterdam during peak hours. Next to questions about socio-demographic characteristics and trip characteristics the survey consisted of 8 stated choice questions. Which stated choice questions a respondent received, depended on whether the respondent used a bicycle as access or egress mode to the studied railway stations.

In the stated choice questions, respondents could opt for two different shared bicycle alternatives, and in an additional question they could also opt for a base alternative: using their private bicycle. This ensured that parameters for bicycle sharing attributes could be estimated in case too many respondents would opt for the base alternative.

The shared bicycles are described by five attributes:

- Accessibility of a shared bicycle at home / at destination
- Walking time from shared bicycle parking place to home / to destination
- Parking convenience
- Accessibility of a shared bicycle at railway station
- Price

Based on these attributes and the defined attribute levels the choice sets are constructed. An orthogonal design, based on a basic plan is used as this design could minimize correlations (it was not expected that high standards errors would be an issue) and this design could limit the number of choice sets needed. A fold-over of the design is used, as it was expected that interaction effects might play a role, and a fold-over assure that all main effects are uncorrelated with all two-way interaction effects. All in all, this resulted in a design with 32 choice sets, which are blocked to 8 choice sets per respondent.

The online survey resulted in 961 useful survey responses of which 66.8 percent of these observations concern access cyclists (679 respondents).

Compared with findings in literature the number of work-related trips among the respondents' trips seems to be relatively high, although a high share is not unusual. The number of students is found to be relatively low. In addition, the respondent sample is highly-educated and remarkably young . Overall it is assumed that the sample give a fair representation of all cyclists at railway stations during the whole day.

7. Data analysis & model estimation

In this chapter the data analysis and model estimates will be described. The estimation of two MNL models (see Chapter 5) will provide insights in the extent to which the different studied BSS attributes, selected in Chapter 4, influence the choice of current cyclists to use a shared bicycle as an access or egress mode. By estimating MNL models including personal and trip characteristics as interaction variables is investigated to what extent the preferences vary among different groups of respondents with different trip or personal characteristics.

First, Section 7.1 describes the model and model estimation results of a base MNL model. Section 7.2 describes the model and model estimation results of an MNL model including the personal and trip characteristics as interaction variables. This chapter closes with a summary in Section 7.3. In Chapter 8 will further elaborated on the interpretation and applications of the results of the models presented in this chapter.

7.1 Base MNL Model estimation

Chapter 5 discussed the theory of discrete choice modelling and MNL models. This section describes the estimation of a base MNL model using the free open source software Biogeme.

Two MNL models are estimated: one based on the choices of access cyclists and the other based on the choices of egress cyclists. It is chosen to estimate the parameters of the attributes of both stated choice experiments separately, as it was assumed that choice behaviour of access cyclists will differ from that of egress cyclists. In addition, the individual parameters estimates are needed in order to give an estimation the potential demand for shared bicycles among both groups of cyclists (see Chapter 8). As a consequence, however, the estimations results of both models cannot be directly compared, because the error components of the models may differ. The parameters should therefore be interpreted individually and without comparison between both models.

7.1.1 MNL Model description

Applying the random utility maximisation theory to the shared bicycle mode choice problem results in the following utility function:

$$U_{SharedBicycle} = ASC + \beta_{ahd} * AHD + \beta_{walk} * WALK + \beta_{park} * PARK + \beta_{as} * AS + \beta_{price} * PRICE + \varepsilon$$

Where:

$U_{SharedBicycle}$	*= utility of the shared bicycle alternative (compared to the private bicycle alternative)*
ASC	*= alternative specific constant (for both shared bicycle alternatives)*
β_{ahd}	*= generic parameter for the variable 'accessibility at home or at destination' (AHD)*
β_{walk}	*= generic parameter for the variable 'walking time from bicycle parking place to home or destination' (WALK)*
β_{park}	*= generic parameter for the variable 'parking convenience at railway station' (PARK)*
β_{as}	*= generic parameter for the variable 'accessibility at railway station' (AS)*
β_{price}	*= generic parameter for the variable 'price' (PRICE)*
ε	*= random error component*

The utility of both shared bicycle alternatives is calculated using this equation. The base alternative (use of private bicycle) has in all cases a utility of zero. In Appendix G.3 the full model specification used to run the model in Biogeme, is included. The applied dummy coding scheme is presented in Section 6.6.

7.1.2 Estimation results

The specified model as discussed in the previous section is estimated. In Table 12 and Table 13 the results of the model estimations for access cyclists and egress cyclists are presented.

Table 11: Model estimation statistics

	Model 1: Access cyclists	Model 2: Egress cyclists
Number of estimated parameters	10	10
Number of observations	5344	2344
Null log-likelihood	-5870.984	-2575.147
Final log-likelihood	-2992.869	-1599.133
Likelihood ratio test	5756.229	1952.029
Rho-square	0.490	0.379
Adjusted rho-square	0.489	0.375

Table 12: Utility contributions of attribute levels, std errors, t-values & p-values in the model for access transportation (MNL model)

Access cyclists (N = 5344 choices)

		Part worth utility	Std error	t-test	p-value
ASC shared bicycle		-0.512	0.124	-4.12	0.00
Accessibility at home	*Guaranteed*	0.000	-	-	-
	High	-0.414	0.104	-3.97	0.00
	Medium	-0.564	0.093	-6.05	0.00
	Low	-1.180	0.121	-9.81	0.00
Walking time to home		-0.141	0.031	-4.52	0.00
Parking convenience	*Premium parking*	0.329	0.071	4.63	0.00
	No premium parking	0.000	-	-	-
Accessibility at station	*Guaranteed*	0.000	-	-	-
	High	0.230	0.112	2.06	0.04
	Medium	-0.135	0.123	-1.10	0.27
	Low	-0.114	0.107	-1.07	0.28
Price		-0.512	0.124	-4.12	0.00

An absolute p-value smaller than 0.05 is considered as statistically significant.

Table 13: Utility contributions of attribute levels, std errors, t-values & p-values in the model for egress transportation (MNL model)

Egress cyclists (N = 2344 choices)

		Part worth utility	Std error	t-test	p-value
ASC shared bicycle		0.179	0.164	1.09	0.28
Accessibility at destination	*Guaranteed*	0.000	-	-	-
	High	-0.237	0.139	-1.70	0.09
	Medium	-0.359	0.122	-2.95	0.00
	Low	-0.822	0.152	-5.41	0.00
Walking time to destination		-0.059	0.040	-1.46	0.15
Parking convenience	*Premium parking*	0.036	0.091	0.40	0.69
	No premium parking	0.000	-	-	-
Accessibility at station	*Guaranteed*	0.000	-	-	-
	High	-0.053	0.144	-0.36	0.72
	Medium	-0.272	0.153	-1.78	0.07
	Low	-0.488	0.138	-3.54	0.00
Price		-0.174	0.008	-20.69	0.00

An absolute p-value smaller than 0.05 is considered as statistically significant.

Not all parameters are found to be significant on a 95% confidence interval (p-value < 0.05); (t-value >1.96). When a parameter is not significant it is not possible to generalize the results for the population. In this study, however, the sample is relatively large what resulted in small standard errors. When a sample is large, which implies small standard errors, the found parameters will approach the parameters for the true population, under the assumption that the sample is representative for the population.

Despite of the small standard errors, the t-values of for example the attributes 'walking time to destination', 'parking convenience' and 'accessibility at the station' in the model for egress cyclists are too small to become significant. The insignificance of the parameters is in this case merely due to the very small parameter estimates found. The parameters will have a value close to zero. This, however, does not directly imply that these attributes are not relevant in cyclist's choices for a shared bicycle. It is possible that preferences of different (types of) cyclists may vary and cancel each other out, which resulted in an average value around zero. These differences can be revealed by estimating models for different segments of respondents, which will done in Section 7.2 or by estimating an ML model as discussed in Chapter 5.

A positive parameter estimate indicates that utility will increase if the attribute level increases. A negative estimate indicates a decrease in utility if the attribute level increases. Except for the level 'high accessibility at the station' in the access cyclists model, all parameters have a logical sign. It was expected that 'parking convenience' would have a positive parameter estimate as a guaranteed premium parking place will save cyclists time and stress compared to searching for a bicycle parking place by the people themselves and would increase utility. Furthermore, it was expected that a reduced accessibility, longer walking times and a higher price would all have a negative influence on the choice for a shared bicycle. The level 'high accessibility at the station' however, has a positive sign. This irregularity is probably due to the naming of the chosen attribute levels and the interpretation of these levels by the respondents. Possibly a walking time of two minutes is not experienced negatively compared with 'directly available for use' or direct availability is interpreted as having a certain walking distance longer than two minutes.

The found parameter estimates are relative values. To interpret the parameter estimates, the values have to be compared with parameter estimates of all other attribute in the same model. Figure 22Figure 22 provides a relative comparison of the attributes by visualising the average relative importance of the investigated attributes. The percentages represent the relative importance of the attribute in a cyclist's choice to use a shared bicycle and are derived by calculating the share of the attribute in the total utility that can derived, i.e. the absolute highest utility range minus the lowest utility range (where the utility range is calculated by: β*attribute value).

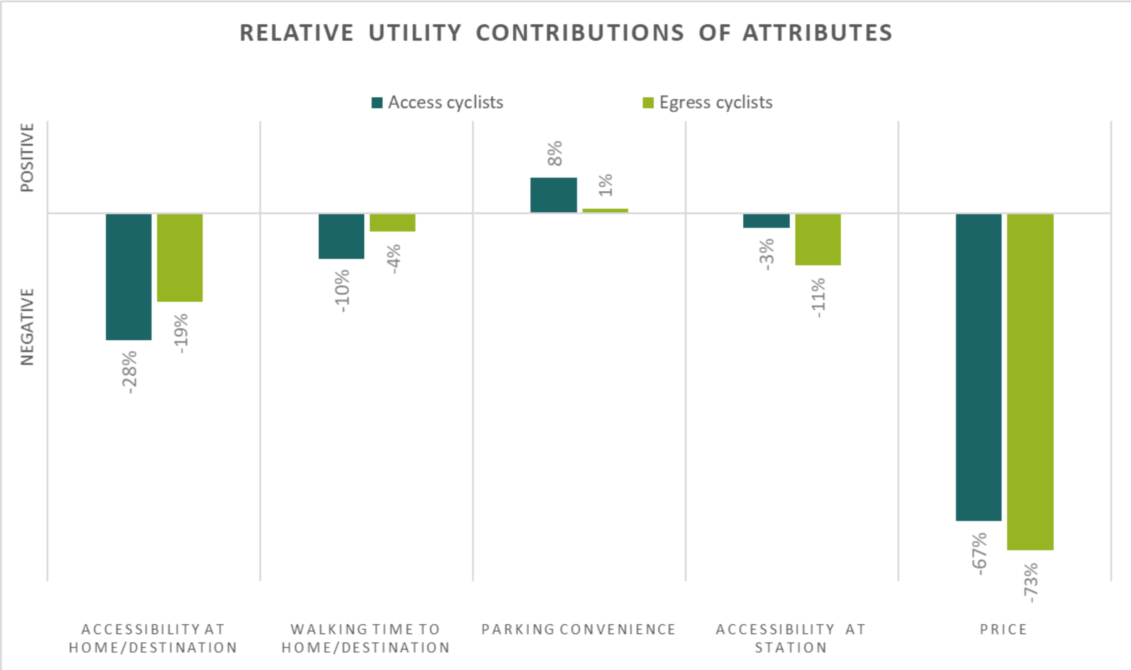

Figure 22: visualisation of the average relative importance of the investigated attributes

The figure shows that on average, the attribute price is of large importance, and key factor in both access and egress cyclists' choices to use a shared bicycle. This is followed by the accessibility at home or at destination as second most important attribute. Subsequently, the order of relative importance of the attributes, differs between access and egress cyclists. For access cyclists the order is as following: walking time from bicycle parking place to home, parking convenience and, lastly, accessibility at the railway station. For egress cyclists the third important to least important attributes are accessibility at the railway station, walking time from bicycle parking place to destination and parking convenience.

From now on the individual parameter estimates of both MNL models will be discussed.

The estimated constant

In the model a constant is estimated for the shared bicycle alternatives. This constant represents the utility of all attributes associated with bicycle sharing, which are however not varied in the experiment. Since only utility differences can be estimated, the constant also represents the utility with respect to the chosen reference levels. In this study the attributes are dummy coded in such a way that all chosen reference levels represent attribute levels similar to use of a private bicycle for access and egress trips.

For access cyclists this implies:

- a bicycle guaranteed at the front door;
- 0 minutes walking time to home;
- search for a parking place at the railway station by someone himself;
- a bicycle direct available at railway station and
- use is free of charge.

For egress cyclists this implies:

- a bicycle direct available at the railway station;
- 0 minutes walking time to the destination;
- search for a parking place at the railway station by someone himself;
- a bicycle guaranteed available at the front door of destination and
- use is free of charge.

Therefore the constant represents the utility of the bicycle sharing alternatives in comparison to use of the private bicycle. When the constant shows a positive utility, it reveals an average base preference among the respondents for use of a shared bicycle. When the constant shows a negative utility it reveals an average base preference for use of the private bicycle.

The estimate of the constant for using a shared bicycle reveals a significant base preference for using a private bicycle for access cyclists. As expected, the alternative specific constant for bicycle sharing has a negative sign, which means that using a private bicycle is preferred if all attributes of a shared bicycle have reference levels. The constant for the shared bicycle alternative for access cyclists has a value of -0.512. This denotes that the utility of a shared bicycle with characteristics similar to a private bicycle is valued 0.512 utils lower than a private bicycle. For egress cyclists the constant has a value of 0.179, although it should be noted that this value is not statistically significant. The positive constant means that use of a shared bicycle with characteristics similar to a private bicycle is valued higher than use of a private bicycle.

Accessibility: Accessibility at home (access cyclists) & Accessibility at destination (egress cyclists)

The attribute accessibility is varied in four levels:

- Guaranteed available at front door (guaranteed accessibility - reference level);
- Always in 2 minutes available (high accessibility);
- Mostly in 2 minutes available, always in 4 minutes available (medium accessibility);
- Mostly in 4 minutes available, always in 6 minutes available (low accessibility)

As expected, the attributes of accessibility have a negative sign, which indicate that utility will decrease if accessibility is decreased. A comparison of the relative importance of the all attributes of this study shows that among access cyclists the attribute ‘accessibility at home’ and among egress cyclists ‘accessibility at destination’ are found to be the most important attributes after price.

The absolute difference in utility between ‘high accessibility and ‘medium accessibility is smaller than the utility difference between ‘medium accessibility’ and ‘low accessibility’. This implies that the utility of this attribute will decrease exponentially with a decreasing accessibility. This is graphically showed in Figure 23.

In comparison with the accessibility of shared bicycles at the railway station, the accessibility at home and accessibility at the destination are, for both access and egress cyclists, more important. This could be explained by the fact that a traveller’s house and destination (e.g. workplace) are trip starting points, while a railway station is never the start of a first-mile bicycle trip but always the start of the last mile of a trip. When one is travelling from home or a destination towards a railway station one often wants to arrive on time to catch a train and cannot afford time loss because of a lack of accessibility of bicycles.

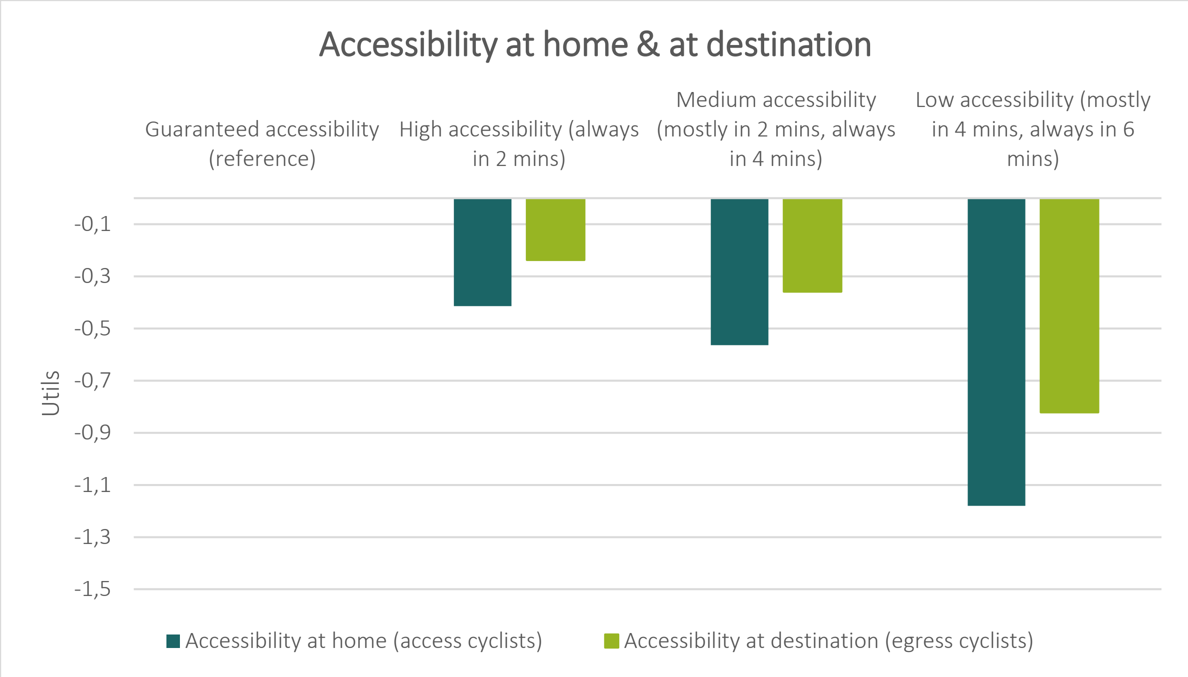

Figure 23: Part worth utilities of 'accessibility at home' for access cyclists and 'accessibility at destination' for egress cyclists visualised.

Walking time: Walking time from bicycle parking place to home (access cyclists) & Walking time from bicycle parking place to destination (egress cyclists)

This attribute represents the time needed by an access cyclist to walk from the nearest place where a shared bicycle can be parked to home. For egress cyclists it represents the time needed to walk from the nearest shared bicycle parking place to their destination. The attribute is varied in the levels: 0 minutes, 1 minute, 2 minutes and 3 minutes. Since this attribute is a continuous variable, the attribute levels are not coded in the estimation of the model (see Section 6.6).

It was expected that the attribute walking time would show a non-linear relationship with utility, based on findings of Maat & Molin (2015). A test for non-linearity of this attribute showed, however, that the non-linear parameters for walking time are not statistically significant. This indicates that, based on the respondent data of this study, the relationship between walking time and utility is linear.

The parameter estimate for ‘walking time to home’ is -0.141. This indicates that when for access cyclists the walking time from bicycle parking place to home will increase with 1 minute, utility will decrease with 0.141 utils. The parameter estimate for ‘walking time to destination’ is -0.0588. This parameter estimate has not become significant on a 95% confidence interval. Because of the very low parameter estimate and the very low standard error it can be concluded that the studied variation in walking time from bicycle parking place to destination (0 to 3 minutes), is not found to be relevant in the average egress cyclist’s choice to use a shared bicycle.

A possible explanation for the insignificant parameters for the studied variation of walking times, is that walking times from bicycle parking places to traveller’s destinations (e.g. offices, universities, museums, shopping malls) are often already a few minutes, as not all bicycles can be parked in front of the door. A three-minute walk from a shared bicycle parking place to a destination will be less experienced as a decrease in utility when the walking time for parking a private bicycle is already two minutes.

Access cyclists are, however, often used to park their bicycle close to home or even in a bicycle shed at home, which makes the difference between walking times for a shared bicycle longer than when a private bicycle would be used.

Parking convenience

This attributes implies the availability of a premium bicycle parking place near the platform which facilitates easy parking. The attribute parking convenience is varied in two levels:

- A guaranteed premium parking place near the platform;
- Search for a parking place by the cyclists themselves (represents the current situation and reference level).

The parameter estimates show that access cyclists attach significant importance to the availability of a premium parking place. In case a premium parking place is offered, utility of bicycle sharing increases with 0.329 utils. Offering a premium parking place to egress cyclists almost has no difference on the utility of bicycle sharing among egress cyclists. A premium parking place will increase utility with only 0.0364 utils. This value however, is not significant on a 95% confidence interval, but has a very low standard error. Therefore a premium parking place can be considered as not relevant in the average choice of egress (which not excludes that the relevance of this attribute varies between different cyclists) and can therefore be considered to be close to zero.

Accessibility at railway station

The attribute 'accessibility at railway station' represents the accessibility of shared bicycles at the railway station after arrival by train. This attribute is varied in four levels, similar to the attributes 'accessibility at home' and 'accessibility at destination':

- Direct available for use (guaranteed accessibility - reference level);
- Always in 2 minutes available (high accessibility);
- Mostly in 2 minutes available, always in 4 minutes available (medium accessibility);
- Mostly in 4 minutes available, always in 6 minutes available (low accessibility).

In the model for access cyclists the parameter estimates for this attribute show a number of peculiarities. At first should be noted that not all parameters are significant on a 95% confidence interval. As earlier mentioned, the signs for some estimates are illogical and a decrease in attribute values shows varying effects on utility. For example, a decrease in accessibility from 'guaranteed accessibility' to 'high accessibility' show an increase in utility. In addition, 'low accessibility' is valued higher than a 'medium accessibility'. The results of these parameter estimates should therefore be interpreted with care. All in all can be stated that on average the attribute 'accessibility at railway station' is, for both access and egress cyclists, not of large importance in cyclist's choice for bicycle sharing, compared with the other investigated attributes.

From the model including choices of egress cyclists, the parameter estimates for this attribute show more plausible results. The effect of a lower accessibility from 'guaranteed accessibility to 'high accessibility' is nihil, which implies that a walking time of two minutes is on average not of importance for egress cyclists. For a lower accessibility the utility decreases exponentially, with a utility decrease of 0.488 utils for the lowest accessibility level. This is graphically showed in Figure 24. The accessibility of shared bicycles at the railway station is for egress cyclists half as important as the accessibility at the destination.

Figure 24: Part worth utilities of 'accessibility at railway station' for access and egress cyclists visualised.

Price

The price for using a shared bicycle is varied in different levels. The tariffs are: €0 per month (or €0 per single trip), €6 per month (or €0.30 per single trip), €12 per month (or €0.60 per single trip) and €18 per month (or €0.90 per single trip).

It was expected that the attribute price would show a non-linear relationship with utility. Therefore, this attribute is tested for non-linearity. The non-linear parameters however are not statistically significant, which indicate that, based on the respondent data, the relationship between price and utility is linear.

Compared with all other attributes price is both for access and egress cyclists most important in the choice for using a shared bicycle. In the model for access cyclists the parameter estimate for price is -0.159. This indicates that if price will increase with one euro per month (or 5 eurocent per single trip), utility will decrease with 0.159 utils. The parameter estimate of the attributes price is -0.174 in the model for access cyclists. It can, however, not be concluded that egress cyclists are slightly more sensitive towards an increase or a decrease in price, as the parameter estimates of both models cannot be directly compared, as discussed at the start of this section.

7.1.3 Overview of estimation results

The base MNL models give plausible results which are explainable and have expected signs except for some minor peculiarities. The main findings will be discussed below:

Main findings:

- Among access cyclists there is a negative base preference for using a shared bicycle, which indicates that use of a private bicycle is preferred over use of shared bicycle with the same characteristics as a private bicycle. Among egress cyclists there is a positive base preference for bicycle sharing, however not statistically significant on a 95% confidence interval.
- Price is the most important attribute in both access and egress cyclists' choices for using a shared bicycle.
- Accessibility at the trip starting points (home and destination) are most important after the attribute price. Price is, on average, three to four times more important.

- Access cyclists do attach some value to having a guaranteed premium parking place available. For egress cyclists the availability of a premium parking place is, on average, not relevant.

All in all this means that access cyclists are less likely to opt for bicycle sharing and prefer to use their private bicycle. A premium parking place could make this group more likely to use a shared bicycle. Egress cyclists are in principle more likely to opt for a shared bicycle, the availability of a premium parking place offers for this group no incentive.

7.2 MNL model estimations with personal and trip characteristics as interaction variables

In the MNL model described in Section 7.1, preferences for different shared bicycle system attributes among current access and egress cyclists were estimated. In the used model, interaction effects between choices made by the same individuals and groups of people (e.g. high income) were ignored, as the MNL model assumed homogeneity in preferences. Different individuals or groups of individuals, however, might have different preferences. By including cyclists' personal and trip characteristics as interaction variables in the MNL model, heterogeneity is taken into account. This allowed for estimating the influences of the earlier specified personal and trip characteristics (see Chapter 4) on the tastes for different BSS attributes and can reveal differences in preferences among different segments of respondents when an attribute was found to have a value close to zero.

In this section, an MNL model including personal characteristics as interaction variables and an MNL model including trip characteristics will be discussed and an interpretation of the significant and striking effects will be given. The personal and trip characteristics of the cyclists were derived from the general questions in the survey. Not all investigated personal and trip characteristics could be included in the model, as for some characteristics insufficient variation was present to make segments consisting of a sufficient number of respondents with the same characteristics. For example, for the variables 'trip purpose' and 'education' could not be estimated.

7.2.1 MNL model description

The personal characteristics and trip characteristics are researched and incorporated in the MNL model sequentially.

In the equation below the utility function of the MNL model with gender incorporated as interaction variable, is given. With the model the effects of each characteristic on the alternative specific constant as well as the alternative specific parameters is estimated.

$$
\begin{aligned}
U_{SharedBicycle} = {} & ASC + \beta_{gender} * GENDER + \beta_{avhd1} * AVHD1 + \beta_{avhd2} * AVHD2 + \beta_{avhd3} \\
& * AVHD3 + \beta_{walk} * WALK + \beta_{park} * PARK + \beta_{avs1} * AVS1 + \beta_{avs2} * AVS2 \\
& + \beta_{avs3} * AVS3 + \beta_{price} * PRICE + \beta_{gender\_avhd1} * AVHD1 * GENDER \\
& + \beta_{gender\_avhd2} * AVHD2 * GENDER + \beta_{gender\_avhd3} * AVHD3 * GENDER \\
& + \beta_{gender\_walk} * WALK * GENDER + \beta_{gender\_park} * PARK * GENDER \\
& + \beta_{gender\_avs1} * AVS1 * GENDER + \beta_{gender\_avs2} * AVS2 * GENDER \\
& + \beta_{gender\_avs3} * AVS3 * GENDER + \beta_{gender\_price} * PRICE * GENDER + \varepsilon
\end{aligned}
$$

In Appendix G.3 the full model specification used to run the model with interaction variables in Biogeme, is included. The schemes applied to code the interaction variables are discussed in Section 6.6.

7.2.2 Estimation and interpretation of results of the MNL model including personal characteristics

A total overview of all interaction effects between personal characteristics and the BSS attributes is presented in Appendix G.4. The parameter estimations for the interaction variables indicate the change in main parameter of a certain attribute for respondents within that category. The interaction effect of the personal characteristic 'familiarity with bicycle sharing' with the alternative specific constant for bicycle sharing is for example 0.221. The positive parameter estimate indicates that respondents who have experience with the use of a shared bicycle have a higher base preference than the average respondent. The main parameter estimate for the alternative specific constant is -0.515. The alternative specific constant for respondents familiar with bicycle sharing is -0.515 + 0.221 = -0.294. Another example is the interaction effect of 'income (€20,000-€40,000)' with the attribute price. The negative parameter estimate on the already negative main parameter indicates a higher sensitivity for price by respondents with an income between €20,000-€40,000.

Most of the estimated interaction effects between the personal characteristics and the attributes are not significant on a 95% confidence interval. In Table 14 the relevant and significant interaction effects between personal characteristics and bicycle sharing system attributes are listed. In some cases an interaction effect is statistically significant but the parameter estimate of the main effect is not. This means that the parameter estimate for an attribute can be assumed to be zero over the total population. The significant parameters for the interaction effects reveals the difference in preferences between the different groups.

Table 14: Relevant and significant interaction effect between personal characteristics and bicycle sharing system attributes. Significant values are coloured red. Parameter estimates for reference levels in italics (no information on statistical significance available).

Personal characteristics Segments	Attributes			
ACCESS CYCLISTS				
Familiarity with bicycle sharing	**Price**			
Main parameter	-0.150*			
Familiar with PT-bicycle (regular or occasional user)	-0.021*			
Unfamiliar with PT-bicycle	*0.021*			
EGRESS CYCLISTS				
Age	**Ascsb**	**Ah2**	**Price**	
Main parameter	0.136	-0.328*	-0.182*	
Age continuous	-0.405*	0.336*	0.002*	
Income	**Ad3**	**As1**	**As3**	**Price**
Main parameter	-0.221	-0.355	0.342	-0.208*
> €60,000	0.042	-0.367	0.156	0.046*
€40,000 - €60,000	-0.146	-1.360*	-0.842*	-0.045
€20,000 - €40,000	0.122*	0.192	-0.581	0.055*
< €20,000	*-0.018*	*1.535*	*1.267*	*-0.056*
Familiarity	**Ascsb**	**Ad2**	**Walk**	
Main parameter	0.0436	-0.262	-0.056*	
Familiar with PT-bicycle (regular or occasional user)	0.439*	-0.277*	-0.036*	
Unfamiliar with PT-bicycle	*-0.439*	*0.277*	*0.036*	

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

For the personal characteristics gender and job status no significant influence on the preference the investigated BSS attributes or the alternative specific constant have been found. Also for access cyclists the attribute age has no significant influence on the preference for the different BSS attributes. However egress cyclists aged above the average age of the population (38 years) have a lower (more negative) base preference for using a shared bicycle in egress transportation. Younger egress cyclists have a higher (or more positive) base preference for using a shared bicycle as egress mode and will be more likely to opt for a shared bicycle. This finding is in accordance with Shaheen et al. (2012) and Murphy & Usher (2015) that found that shared bicycle users are often relatively young (< 34 years). In addition, it is found that higher aged egress cyclists are less sensitive for a reduced accessibility of shared bicycles at their destination (only the level 'mostly in 2 minutes, always in 4 minutes' has become significant on a 95% confidence level). This interaction effect cannot be explained.

Between income and the sensitivity for price statistic significant relationships are found, however the differences in signs of these interaction effects between access and egress cyclists are remarkable. For both access and egress cyclists the main parameter estimates are negative. The parameter estimates of the interaction variables have varying signs over the different segments with rising incomes, where the estimates of the access and egress model are found to have opposite signs. Access cyclists with an income between €20,000 and €40,000 are found to be slightly more sensitive for price. Egress cyclists with an income in this segment and an income higher than €60,000 are found to be less sensitive for price. Access cyclists earning €40,000 to €60,000 per year are found to be more sensitive for accessibility of shared bicycles at the railway station. These varying effects could not be explained. Based on a studies by Fishman et al. (2014) and Murphy & Usher (2015) would be expected that respondents with a high or middle income would be more likely to be a shared bicycle user.

Also for 'familiarity with bicycle sharing' significant interaction effects are found, but no plausible explanation for these effects can be given. Access cyclists who use a PT-bicycle regularly or occasionally are found to be a bit more sensitive for price. Egress cyclists are found to be more sensitive for a reduced accessibility of shared bicycles at their destination.

7.2.3 Estimation and interpretation of results of the MNL model including trip characteristics

A total overview of all interaction effects between trip characteristics and the BSS attributes is presented in Appendix G.4. In this section the relevant and significant interaction effects with trip characteristics will be discussed sequentially.

It is found that access cyclists who pay a fee for bicycle parking at the railway station are less sensitive for the users tariff of shared bicycles. This can be declared by the fact that for this group the difference in price between using a shared bicycle and using a private bicycle in combination with paid parking is smaller, because of the already paid fee for parking.

Access cyclists having difficulties finding a bicycle parking place at railway stations, clearly have a lower base preference for using a shared bicycle. An explanation of this interaction effect, could be that these cyclists think of shared bicycles as additional bicycles which will only result in more bicycle parking pressure. It must be noted, that in the survey is not explained that shared bicycle might result in a lower bicycle parking pressure. In addition, access cyclists experiencing high bicycle parking pressure are more sensitive for a premium parking place and less sensitive for price (both statistically significant).

Table 15: Relevant and significant interaction effects between trip characteristics and bicycle sharing system attributes. Significant values are coloured red. Parameter estimates for reference levels are showed in italics (no information on statistical significance available).

Personal characteristics Segments	Attributes		
ACCESS CYCLISTS			
Paid parking	**Price**		
Main parameter	-0.125*		
Paid parking (paid by cyclists themselves)	0.042*		
Unpaid parking (not paid by cyclists themselves)	*-0.042*		
Experience bicycle parking pressure	**Ascsb**	**Park**	**Price**
Main parameter	-0.571*	0.434*	-0.141*
Always or often	-0.302*	0.179*	0.036*
Occasionally or never	*0.302*	*-0.179*	*-0.036*
Trip duration	**Ascsb**	**As1**	**Price**
Main parameter	-0.500*	-0.120	-0.161*
≥ 16 min	-0.561	-0.019	0.034*
11 - 15 min	0.551*	-0.439*	-0.010
6 - 10 min	-0.064	0.251	0.008
1 - 5 min	*0.074*	*0.207*	*-0.032*
Flexibility of arrival time at home	**Ascsb**		
Main parameter	-0.461*		
Not flexible	-0.777*		
Bit flexible	0.086		
Very flexible	*0.691*		
Flexibility of arrival time at station	**Ah1**		
Main parameter	-0.995*		
Not flexible	-0.454*		
Bit flexible	0.148		
Very flexible	*0.306*		
EGRESS CYCLISTS			
Experience bicycle parking pressure	**Price**		
Main parameter	-0.165*		
Always or often	0.029*		
Occasionally or never	*-0.029*		
Trip duration	**Ascsb**	**As2**	
Main parameter	-0.208*	-0.208*	
≥ 16 min	-0.595	-0.595	
11 - 15 min	0.640	0.640	
6 - 10 min	0.724*	0.724*	
1 - 5 min	*-0.769*	*-0.769*	

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

Additionally the results highlight that for access trips of average distance (around 11-15 minutes cycle time) the negative base preference for using a shared bicycle seems to disappear. Cyclists make longer trips (> 16 minutes have a much larger negative base preference for using a shared bicycle as access mode (p-value =0.05) and may be less likely to opt for a shared bicycle. Possibly a shared bicycle is seen as less comfortable compared with a private bicycle on this distance.

Also in egress transportation these relationships can be found. Egress cyclists making short bicycle trips (1-5 minutes) have a more negative base preference for using a shared bicycle as egress mode. Short to average trips (6-10 minutes) have a significant larger and positive base preference. Also for trips between 11 to 15 minutes this base preference is more positive and for trips of 16 minutes and longer the base preference is much more negative again, however both are not statistically significant on 95% confidence interval.

Access cyclists making trips between 11 to 15 minutes are found to be more sensitive for the accessibility of shared bicycles at the railway station (only the highest level of accessibility is significant). It was expected that a longer trip duration would influence the importance of the accessibility of shared bicycle at the railway station negatively, as it would be less easy for these travellers to reach home by using other modes. This effect has however not been found.

In the model for egress cyclists also significant interaction effects between trip duration and accessibility of shared bicycles at the railway station have been found. Egress cyclists with a nearby destination (1 to 5 minutes cycling distance), are found to be less sensitive for the accessibility of shared bicycles at the railway station. This finding can be declared by the fact that for this group walking could be an alternative mode when no shared bicycles are available.

Access cyclists making more trips per week, appear to be less sensitive for a lower accessibility of bicycles at the railway station (p-values of all levels varying between 0.01 and 0.06). This contradicts to the expectation that people travelling more often would like to be more certain of having a shared bicycle available to travel home. On the egress side cyclists the assumption seems to hold, as cyclists travelling to a railway station more frequently, are more sensitive for the accessibility of shared bicycles at their destination.

Regarding flexibility of arrival time it is found that access cyclists' flexibility in arrival time at the railway station is found to be a factor influencing the sensitivity for the accessibility of shared bicycles at home. The less flexible cyclists are in their arrival time at the railway station, the more important the accessibility of shared bicycles at the home-end is found to be (not for all attribute levels significant on a 95% confidence level). This is consistent with the assumptions that cyclists who need to be on time attach more value to a certain availability within a certain time. In the results of the model concerning egress cyclists no significant interaction effects with flexibility of arrival time have been found.

Furthermore, it is found that access cyclists receiving a partial bicycle reimbursement are less sensitive for price. In egress transportation receiving a partial reimbursement leads to a higher sensitivity for price. Striking is that egress cyclists receiving a full reimbursement have a lower (negative) base preference for bicycle sharing, while egress cyclists receiving a partial reimbursement have a significantly higher (positive) base preference for using a shared bicycle. It is however possible that respondents assumed that a shared bicycle will not be part of their reimbursement. This interaction effect should be further investigated as it is assumed that this characteristics will have an influence on the sensitivity for price.

Between cyclists at the three different studied railway stations no significant interaction effects on BSS attributes are found.

7.2.4 Overview of estimation results

The MNL models including interaction effects with personal and trip characteristics show a number of significant interactions between these characteristics and BSS characteristics. A number of the effects can however not be explained. The main findings will be discussed below:

Main findings:

- Younger cyclists (<38 years) are more likely to opt for shared bicycle use.
- Paid facility users are less sensitive to cost of shared bicycle use.
- Access cyclists who experience bicycle parking pressure are more sensitive to parking convenience (availability of a premium parking place).
- Cyclists making trips between 5 and 15 minutes are more likely to become a shared bicycle user.
- Gender and job status do not have a significant influence on shared bicycle use by current cyclists.
- Income and familiarity with shared bicycle use have a significant influence on the probability to use a shared bicycle, however these effects could not be explained.

7.3 Conclusion

For the choices of access cyclists and egress cyclists two separate MNL models are estimated, as it was assumed that choice behaviour of access cyclists will differ from that of egress cyclists. The estimations of the base MNL models give plausible results which are explainable and have expected signs except for some minor peculiarities.

It was found that access cyclists on average prefer to use their private bicycle over the use of a shared bicycle with the same characteristics as a private bicycle. Egress cyclists are in principle more likely to opt for a shared bicycle, because of a positive alternative specific constant for bicycle sharing, however this constant is not significant on a 95% confidence interval. Furthermore, it is found that for both access cyclists and egress cyclists price is a key factor in their choice to use a shared bicycle. After price, accessibility at the trip starting points (home or destination) are most important. Price is however, on average, still more than three to four times more important. Extra parking convenience by means of a premium parking place is for access cyclists an incentive to use a shared bicycle.

In contrast with what would be expected, the attribute 'walking time from bicycle parking place to home or destination' and the attribute 'price' are found to have a linear effect with utility. For the first mentioned attribute this can be declared by the small range in attribute levels investigated. For the attribute price this finding cannot be declared.

By including personal and trip characteristics as interaction variables in the model, a number of relevant and significant interaction effects between trip and personal characteristics and BSS attributes are found. Main findings are that younger cyclists (< 38 years) are more likely to choose a shared bicycle than older cyclists which is in accordance with existing literature on the characteristics of shared bicycle users. Furthermore, it appeared that bicycle-train users who pay for bicycle parking are less sensitive for the cost of shared bicycle use. In addition, it is found that access cyclists having difficulties finding an empty parking spot attach more value to the availability of a premium parking place. Lastly, the results show that cyclists making trips of an average cycle distance (between 5 and 15 minutes) are more likely to choose a shared bicycle.

The tested interaction effects 'gender' and 'job status' have not proved to be significant. Also between cyclists at the three different railway stations no significant interaction effects on BSS attributes are found. Some significant interaction effects as for example income 'income' and 'familiarity with bicycle sharing' could not be explained. Into the influence of a bicycle reimbursement on the sensitivity for price additional research is needed.

8. Model application

In Chapter 7 MNL models were estimated using the collected SP data. These estimations resulted in insights in the preferences of current cyclists regarding different BSS characteristics. In this chapter these results will lbe translated into the demand that can be expected for different bicycle sharing system set-ups based on the investigated system attributes. With the estimated potential demand for bicycle sharing, the possible bicycle parking capacity savings that can be achieved as a result of bicycle sharing will be estimated using actual Dutch travellers data.

First, in Section 8.1 will be calculated what demand for different promising bicycle sharing systems can be expected among current cyclists. Subsequently in Section 8.2 will be estimated to what possible bicycle parking capacity savings the availability of these systems will lead at different railway stations and will be discussed what this implies for the design of the system set-up. This chapter closes with a conclusion in Section 8.3.

8.1 Prediction of demand

In this section the findings presented in Chapter 7 will be translated into the potential demand for bicycle sharing from and towards railway stations. For different bicycle sharing system design setups will be calculated what part of the population would be interested in using the system based on their choices made in the SP survey. This will provide insights in the quality that should be offered (in terms of for example availability and walking times) in order to meet up the same demand at varying prices.

First, the different bicycles sharing system designs selected in Chapter 3 will be translated into scenarios by defining and describing the used attribute values. Subsequently the model to calculate the choice distribution will be presented. Then, the choice probabilities will be calculated and the differences in the demand for the different bicycle sharing system setups will be discussed. Finally, an overview of conclusions will be presented which will provide a starting point for further recommendations.

8.1.1 Scenarios: bicycle sharing design setups

The different bicycle sharing system design setups based on different bicycle sharing systems and bicycle service initiatives analysed Chapter 3. From the analysis six different promising and suitable bicycle sharing systems emerged:

Home-end
- Hybrid sharing (lease)
- 1-way station-based
- Free floating

Activity-end
- 2-way station-based
- 1-way station-based
- Free floating

Section 3.2 discussed the characteristics of these bicycle sharing systems. In order to use the systems as a basis for scenarios, the system characteristics are related to matching attribute values. Most distinctive attributes of the systems are 'accessibility at home' or 'accessibility at destination' and 'walking time to home'. Regarding this two attributes it is assumed that:

- Leased bicycles (hybrid sharing) are always direct available at home;
- Leased bicycles (hybrid sharing) can always be parked at home (0 minutes walking distance);
- A free floating bicycle can always be accessed within 2 minutes walking;
- A free floating bicycle can always be parked in front of the door at home or at a destination;
- Bicycle stations of the station based systems are placed in such a way that the distance between stations is 300 meters (commonly recommended distance according to Médard de Chardon et al. (2017)) resulting in an average walking distance of 3 minutes;
- A bicycle station with available shared bicycles can always be found within 4 minutes walking distance and is mostly found within 2 minutes walking distance.

Table 16 and Table 17 describe the scenarios and associated attribute values. The attributes 'parking convenience' (availability of a premium parking place) and 'accessibility at the railway station' are not specific to the different systems and values may vary. In order to give a clear view on the influence of most distinctive attributes of the different system setups the attribute 'accessibility at the railway station' is not varied across the different scenarios. For convenience, in all scenarios is assumed that shared bicycles are directly available at railway stations. The influence of parking convenience is investigated by additional scenarios including a premium parking place.

User tariffs for the different systems may vary. As price is found to be a key factor in current cyclist's preferences for bicycle sharing, the demand for all system setups is calculated for user tariffs between 0 euro and 18 euro per month.

Table 16: Attribute values of the different tested bicycle sharing design setups at the home-end

Scenario	Accessibility at home	Parking convenience at railway station	Accessibility at railway station	Walking time to home
Hybrid sharing premium (lease)	Guaranteed at front door	Premium parking place	Direct available for use	0 mins
Hybrid sharing (lease)	Guaranteed at front door	No premium parking place	Direct available for use	0 mins
1-way station-based premium	Mostly in 2 mins, always in 4 mins	Premium parking place	Direct available for use	3 mins
1-way station-based	Mostly in 2 mins, always in 4 mins	No premium parking place	Direct available for use	3 mins
Free floating premium	Always in 2 mins	Premium parking place	Direct available for use	0 mins
Free floating	Always in 2 mins	No premium parking place	Direct available for use	0 mins

Table 17: Attribute values of the different tested bicycle sharing design setups at the activity-end

Scenario	Accessibility at destination	Parking convenience at railway station	Accessibility at railway station	Walking time to destinat ion
2-way station-based premium	Guaranteed at front door	Premium parking place	Direct available for use	0 mins
2-way station-based	Guaranteed at front door	No premium parking place	Direct available for use	0 mins
1-way station-based premium	Mostly in 2 mins, always in 4 mins	Premium parking place	Direct available for use	3 mins
1-way station-based	Mostly in 2 mins, always in 4 mins	No premium parking place	Direct available for use	3 mins
Free floating premium	Always in 2 mins	Premium parking place	Direct available for use	0 mins
Free floating	Always in 2 mins	No premium parking place	Direct available for use	0 mins

8.1.2 Choice probability calculations

The probability that a current cyclist will choose for one of the shared bicycle alternatives, presented in Table 16 and Table 17 or the base alternative (private bicycle), can be predicted by using the logit choice probability function presented in Section 5.2. This function is as following:

$$P_n(i) = \frac{e^{V_{in}}}{\sum_{j \in c_n} e^{V_{jn}}}$$

As an example, the utility and the choice probability for the 'hybrid sharing premium (lease)' scenario without users charge is calculated below. The utility of the base alternative is in all cases equal to zero.

$$U_{sharedbicycle} = ASC + \beta_{avhd} * AVHD + \beta_{walk} * WALK + \beta_{park} * PARK + \beta_{avs} * AVS + \beta_{price} * PRICE + \varepsilon$$

$$U_{sharedbicycle} = -0.512 + 0 - 0.141 * 0 + 0.329 * 1 + 0 - 0.159 * 0 = -0.183$$

$$U_{privatebicycle} = 0$$

This leads to the following calculation:

$$P_{n\ sharedbicycle} = \frac{e^{U_{sharedbicycle}}}{e^{(U_{sharedbicycle})} + e^{(U_{privatebicycle})}} = \frac{e^{-0.183}}{e^{(-0.183)} + 1} = 45\%$$

This means that, when for example current cyclists could opt for a bicycle sharing similar to the setup of a 'lease premium' system, 45% of these cyclists would choose for the shared bicycle alternative. The other 55% would remain using their private bicycle.

8.1.3 Bicycle sharing system demand

With the presented formula, the potential demand among both current access and egress cyclists regarding all different promising bicycle sharing systems, presented in Table 16 and Table 17, are calculated. The calculations are based on the model described in Section 7.1. This model concerns a base MNL model without the implementation of interaction variables on trip and personal characteristics. Note that, in the calculations it is assumed that all interested cyclists make use of the same system, i.e. that different BSSs do not exist in parallel.

The calculated demand cannot be interpreted as real market shares as it is based on stated preference data. It must be noted that the figures, therefore, do not indicate the potential of a certain design set up. The figures show the differences in attractiveness for several design setups and it shows under what conditions the different tested systems meet the same demand.

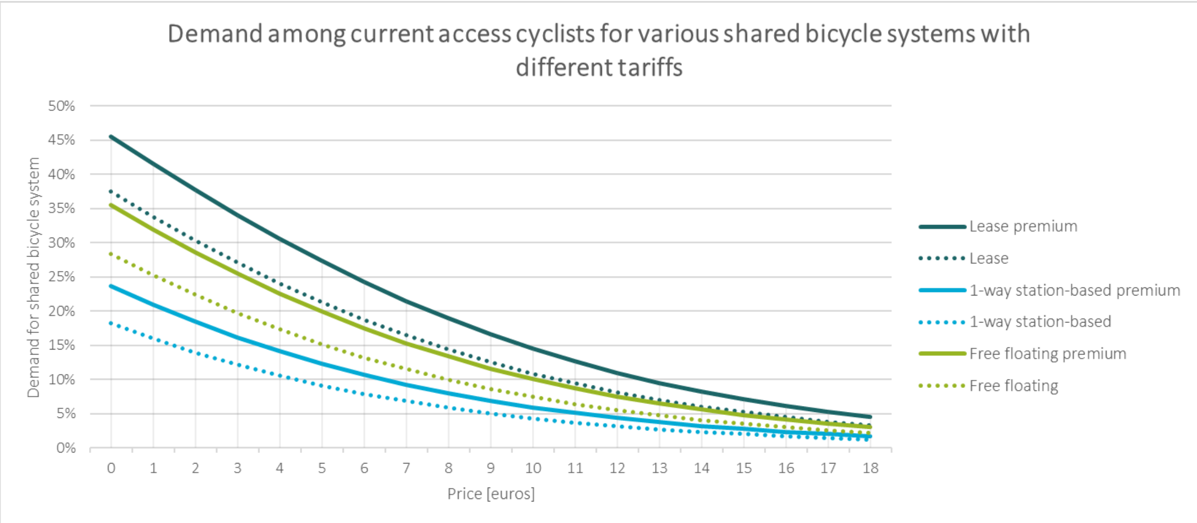

Figure 25: Demand among current access cyclists for various shared bicycle systems with different tariffs

Figure 25 presents the demand among access cyclists for the different promising bicycle sharing systems with different tariffs between 0 euro and 18 euro and with and without a premium parking place. The figure shows that a significant demand among access cyclists exist, however, the demand decreases rapidly as price increases. This is as expected as price is found to be key factor in current cyclists choices regarding bicycle sharing. In descending order (from highest to lowest demand at the price), the systems can be ranked as following:

- hybrid sharing premium (lease),
- hybrid sharing (lease),
- 1-way station-based premium,
- 1-way station-based,
- free floating premium, and
- free floating.

Hybrid sharing with premium parking seems to be the most attractive option, after all, this system offers users a high availability at home and short walking times.

The maximum proportion of cyclists interested in using a shared bicycle for access transportation is 45% and can be achieved with a hybrid sharing premium system, on condition that use of the system is free of charge. This system se-up implies that use of a shared bicycle is similar to use of a private bicycle in combination with a premium parking place at the railway station. When use of this system will cost 15 euros a month (the current price for a bicycle lease subscription), 7% of the access cyclists is interested. If the price would be decreased to 10 euros, 15% is interested in using a lease bicycle with a premium parking place. The absence of a premium parking place will lower the demand with 5% at a price of 10 euros.

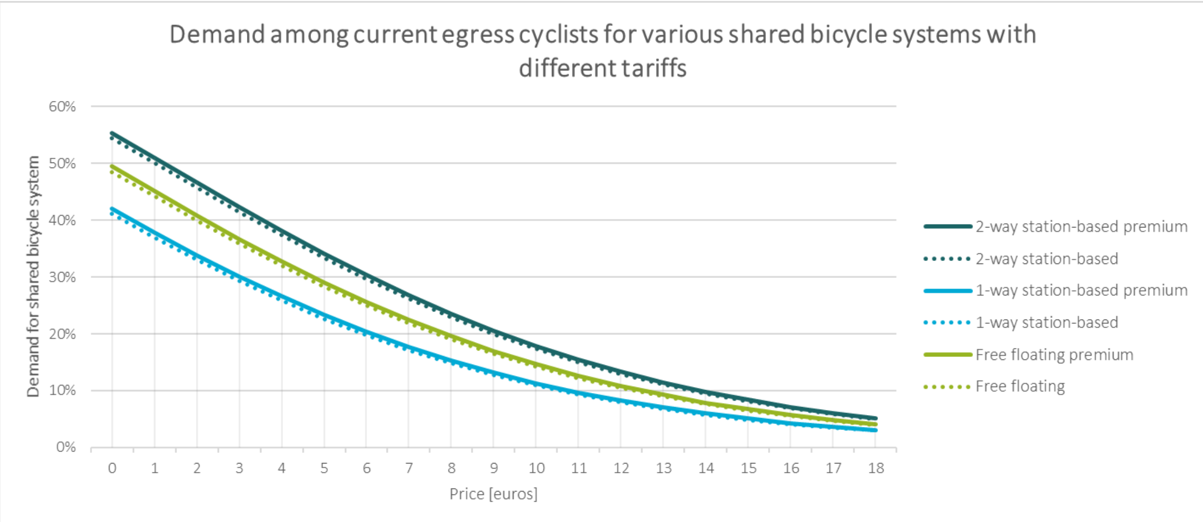

Figure 26: Demand among current egress cyclists for various shared bicycle systems with different tariffs

Figure 26 shows the demand for the proposed systems among egress cyclists. In principle the figure gives the same picture, although the demand curves are slightly higher. Also the difference in demand between a system offering a premium parking place and the same system without premium parking place has faded since egress cyclists do not attach much value to the presence of a premium parking place.

The maximum proportion of egress cyclists who is willing to use a shared bicycle is slightly higher than the proportion of access cyclists. This can be mainly explained by the fact that egress cyclists have a larger (positive) base preference for bicycle sharing. The maximum proportion of egress cyclists who are willing to use a shared bicycle instead of their private bicycle is 55% (when the bicycle characteristics are similar to a 2-way station-based system (e.g. a PT-bicycle) in combination with a premium parking place and use of the shared bicycle would be free of charge).

All in all can be concluded that the demand for the different investigated BSS systems among current cyclists is, mainly for using a shared bicycle as access mode, highly dependent on the design of the system. Hybrid sharing (lease) seems to be the most promising system to facilitate shared bicycle use among access cyclists in order to create a relatively high supply of bicycles to be used by egress travellers, as this system ensures the highest demand. The availability of a premium parking places will increase the demand for shared bicycles as access mode significantly.

8.2 Implications for possible bicycle parking capacity savings

In Section 8.1 the potential demand among access and egress cyclists for different bicycle sharing system set-ups is determined. In this section these findings will be used to estimate the impact on possible bicycle parking capacity savings.

As explained in Chapter 2, the possible bicycle parking savings are primarily depending on the number of access cyclists supplying a shared bicycle and the number of egress cyclists demanding a shared bicycle. Therefore, first the number of interested shared bicycle users at home-end and at the activity-end are derived from the proportions of access and egress cyclists who are willing to use a shared bicycle, determined in Section 8.1. Data of the Dutch Travel Survey is used in order to estimate possible bicycle parking savings as a result of the different (combinations of) BSS systems. Actual travel data is needed as bicycle shares at the home-end and the activity-end differ. On average around 47% of all train travellers in the Netherlands use a bicycle as access mode, while only 13% of the train travellers use a bicycle as egress mode (KiM, 2014). These figures may vary between different (types of) railway stations and may even vary during different times of the day and week. This variations in demand and supply make it difficult to estimate average possible bicycle parking capacity at major Dutch railway stations, based on simple assumptions.

From the analysis in Chapter 3 appeared that not all combinations of bicycle sharing systems, made-up of the investigated systems in Section 8.1, are able to contribute to a reduction of parked bicycles. Different types of existing BSSs and a new type of bicycle sharing (hybrid sharing) are considered as suitable efficient BSSs. The following BSS combinations are found to be promising in relieving bicycle parking pressure at railway stations and will therefore be investigated in this section:

Home-end:	*Activity-end:*	*System type:*
▪ Hybrid sharing (lease)	– 2-way station-based	Open PT system
▪ Hybrid sharing (lease)	– 1-way station-based	Hybrid open urban system
▪ Hybrid sharing (lease)	– Free floating	Hybrid open urban system
▪ 1-way station-based	– 1-way station-based	Open urban system
▪ Free floating	– Free floating	Open urban system

It is considered that all interested access cyclists will use the home-end system and all interested egress cyclists will use the activity-end system.

As price is found to be a key factor in the demand for bicycle sharing, the possible bicycle parking capacity savings are estimated for the different system combinations with varying tariffs. For both open urban systems (1-way station-based and free floating) the use of shared bicycles is the same for access and egress cyclists. For this reason, the same tariff will hold, regardless if the bicycle is used for an access or egress trip. Capacity savings for the two systems are estimated when with tariffs between 0 and 18 euro per month (0 to 0.90 euros per single trip). For the systems combining hybrid sharing (lease) at the home-end with other system set-ups at the activity-end, it is reasonable that tariffs for hybrid sharing (lease) may be different from the other systems. Therefore hybrid sharing is investigated for three different fixed tariffs (5, 10 and 15 euros per month) combined with systems with tariffs ranging between 0 and 18 euros per month (0 to 0.90 euros per single trip).

The estimations of bicycle parking capacity savings for the different system combinations in this section are based on systems described in Table 16 and Table 17. The investigated systems include the availability of a premium parking place.

8.2.1 Data

Microdata of the Dutch National Travel Survey is used as a basis for the estimations. This data includes information on travellers and their households, characteristics of their trips and trip legs. The data also includes detailed information on the access and egress trips of individuals towards specified railway stations on workdays, Saturdays and Sundays. Part of the data are the times at which travellers using different modes depart and arrive at railway stations. From this information on the arrival and departure times the parking duration of access bicycles and egress bicycles can be deduced. In addition, the data provides information on the times on which potential egress cyclists (travellers using other modes) may use a shared bicycle.

The used data is collected in the period from 2004 to 2009. More recent data of the period from 2010 to 2015 is available and also includes station information, however the sample of this data is too small to make accurate estimations of possible capacity savings. The used data includes almost 1,000,000 observed trips from which 16,000 trips by train. In total 1961 access cyclists and 370 egress cyclists are sampled. The number of observations for individual railway stations are significantly lower and cannot be used to make an accurate estimation of parking capacity savings. Therefore data of different types of railway stations is combined. Data of the central stations of the four largest Dutch cities is combined and the data of the central stations in other large Dutch cities is combined. A list of the combined railway stations and the number of samplers can be found in Appendix H.1. Combining the data implies that several stations are considered as one station in the analysis. This means that parked bicycles at all combined stations can be used by egress travellers at all those combined stations. This assumption is unrealistic, and may lead to an overestimation of the capacity savings when the distribution of parking and employment periods of travellers at the combined stations differ.

On the other hand use of this data may for several reasons lead to an underestimation of the possible bicycle parking capacity savings. First, the data represents projected numbers of arrivals and departures of cyclists at only one workday. This means that the data does not provide information on the number of parked egress bicycles that remain unused for several days during the week. When this type of travellers switch to use of shared bicycles, capacity savings will increase since their bicycles are parked during a large number of days and nights. These bicycles are responsible for bicycle pressure of on average four access bicycles (KiM, 2018). This implies that the estimations ignore capacity savings due to a part of the current egress cyclists switching to a shared bicycle. Secondly, use of the data will lead to an underestimation of the possible capacity savings as the data is collected between 2004-2009 and is relatively old. In the meantime the number of bicycle-train users has increased, mainly for access transportation (KiM, 2016b, 2016a). This growth will increase the possible reduction of bicycle parking capacity savings at railway stations.

All in all it is assumed that the data can be used to give a realistic indication of the order of magnitude of capacity savings that can be achieved by the availability of different bicycle sharing systems.

8.2.2 Method

Based on the Dutch National Travel Survey data and the choice probabilities for different systems calculated in Section 8.1, the possible capacity savings are estimated. The estimations concern capacity savings at the central stations of the four largest Dutch cities and at central stations in other major Dutch cities at workdays. In this study is assumed that the peak in the number of parked bicycle is during an average workday. Several steps are carried out in order to derive the extent to which bicycle parking capacity can be saved, which will be discussed below.

First, the number of parked bicycles over time blocks of 30 minutes during the day are estimated. The numbers are derived from the arrival and departure times of current cyclists. It is assumed that a bicycle used for access transportation is parked at the station in the period between the moment a current cyclist boards a train and the moment that this cyclist returns at its original departure station. The number of parked egress bicycles during the day is calculated assuming that all egress cyclists own bicycle which is parked at the railway station. Their employment period is the period the bicycle is not parked.

Subsequently, the number of access bicycles that are available for sharing (supplied bicycles) and the number of shared bicycles demanded by current egress cyclists and potential egress cyclists during blocks of half an hour are calculated. This calculation is performed by projecting the choice probabilities for the different systems with different tariffs, derived in Section 8.1, on the total number of supplied and demanded bicycles. Next, the number of actual shared bicycles during a certain period is calculated, given that the number of bicycles demanded by egress travellers cannot be larger than the number of bicycles supplied by access cyclists at that moment. It is assumed that a shared bicycle used by a current egress cyclists will result in a removed access bicycle during the egress cyclists' employment period and a removed egress bicycle during the rest of the day. A shared bicycle used by a new egress cyclists results in a removed access bicycle during the egress travellers' employment period.

When the number of shared bicycles used during the day is known, the extent to which the peak in the number of parked bicycles can be reduced, is estimated. This reduction in the peak of parked bicycles represents the extent to which bicycle parking capacity can be saved, assuming that the peak in the number of parked bicycles is on work days. The estimations show that the supply of bicycles is not in all cases sufficient in order to provide sufficient demand. For this reason, capacity savings are estimated including the needed buffer of additional shared bicycles in order to provide sufficient shared bicycles to interested shared bicycle users.

Additionally, possible bicycle parking capacity savings when bicycles are shared between access cyclists and potential egress cyclists are estimated. Assumptions are made on the potential egress cyclists who are willing to use a shared bicycle. Firstly, it is assumed that, from all travellers currently using other egress modes, only travellers making trips with a distance between 1 and 5 kilometres can be considered as potential egress cyclists. Secondly, assumptions are made on the proportion of egress cyclists who are willing to use a certain type of shared bicycle for a certain price. As an upper limit, it is assumed that the proportion of those egress travellers is the same as the proportion of current egress cyclists willing to use a shared bicycle. This assumption seems realistic based on earlier carried out stated preference studies regarding shared bicycle use in the Dutch context of Van Heijningen (2016), who studied preferences for shared bicycles of commuters and Steegman (2016) who carried out a study among students. However, direct implementation of their results is difficult as estimated parameters should be interpreted relatively and choice probabilities are calculated for slightly different scenarios. Moreover, this study covers a wider range of tariffs. Therefore, also a lower limit of potential demand among potential egress cyclists is investigated to provide a more extensive and realistic overview of possible savings. For the calculations of the lower limit of capacity savings it is assumed that when a certain proportion of current egress cyclists is interested in using a shared bicycle, half of that proportion of potential egress cyclists is willing to use a shared bicycle. When, for example, half of the current egress cyclists is willing to use a particular shared bicycle system, it is assumed that a fourth of the other egress travellers will.

It is assumed that all egress cyclists use a privately owned (second) bicycle at the railway station. Use of PT-bicycles among egress cyclists is ignored, as the system had a marginal share between 2004 and 2009. In addition, no restrictions are applied for egress cyclists to return their shared bicycle within a certain time, as would be required when bicycles are shared peer-to-peer. Egress travellers may take a bicycle, although they cannot return the bicycle before access cyclists return at the railway station in order to use the same bicycle to travel home. After all, all bicycles are standardised and there is no one-to-one relationship between user and bicycle.

8.2.3 Results

The possible bicycle parking capacity savings as result of the availability of different bicycles sharing systems are estimated for the combined central stations of the Dutch four largest cities (Amsterdam Central station, Utrecht Central station, The Hague central station and Rotterdam Central station) and for the combined central stations of other large Dutch cities (listed in Appendix H.1) For these two combinations of railway stations types, different estimations of bicycle parking savings are made:

(1) In case bicycles are only shared between current cyclists. These estimations show to what extent the demand among current egress cyclists can be facilitated with the supply of access bicycles.

(2) In case bicycles are shared between current access cyclists and potential egress cyclists (current cyclists and other egress travellers with trips between 1 and 5 km). This provides insights in the extent to which the supply by access cyclists can meet the possible demand. The unavailability of bicycles due to a mismatch between supply and demand is ignored.
   a. Upper limit: assuming that among other egress travellers the same demand can be expected as among current egress cyclists.
   b. Lower limit: in case bicycles are also shared between current access cyclists and potential cyclists, however the demand among other egress travellers is halved.

(3) In case bicycles are shared between current access cyclists and potential egress cyclists, compensating for the buffer of additional bicycles needed in order to catch up the demand
   a. Upper limit, the assumptions of 2a hold.
   b. Lower limit, the assumptions of 2b hold.

This section primarily presents graphical presentations of the results for the four largest cities. The differences in estimation results with the central stations at other large Dutch cities will be discussed. In Appendix H provides a total overview of the estimated bicycle paring capacity savings. As earlier mentioned, the tariffs for the hybrid sharing system are fixed at tariffs of 5, 10 and 15 euros, while the other investigated systems at the home-end and activity-end have tariffs between 0 and 18 euros.

Sharing between current cyclists

When bicycles are only shared between current cyclists, the possible capacity savings of the different systems with different tariffs vary widely. When for example the systems have tariffs similar to the current tariffs, capacity savings between 1-8% can be achieved at the central stations in the four largest cities. When all systems have tariffs between 5 and 10 euros per month, capacity savings between 3-9% are feasible. When the bicycles are free of charge, savings between 9-15% can be achieved. The capacity savings in case of sharing between current cyclists are slightly higher at the central stations in other large Dutch cities than at the four largest cities. However, when tariffs increase, the differences fade.

Figure 27 shows that not all interested egress cyclists can be facilitated. When the curve turns into a straight line, the demand for that particular system combination with a certain tariff becomes larger than the supply of shared bicycles. Since the supply is not sufficient, the capacity savings stuck at the same level. For example, in the four largest cities, the hybrid sharing systems with subscription tariffs between 10 and 18 euros will encounter this problem when the systems at the activity-end have a tariff of 7 euros or lower. In practice, this situation will lead to an unavailability of shared bicycles. This may result in egress cyclists not willing to switch to use of a shared bicycle and will keep their private bicycle. It cannot be guaranteed that the access cyclists who used a shared bicycle for their access trip, will find a bicycle for the return trip to home when they arrive at the railway station again later on the day. All in all, this will lead to a lower supply and demand, which will subsequently lower the capacity savings.

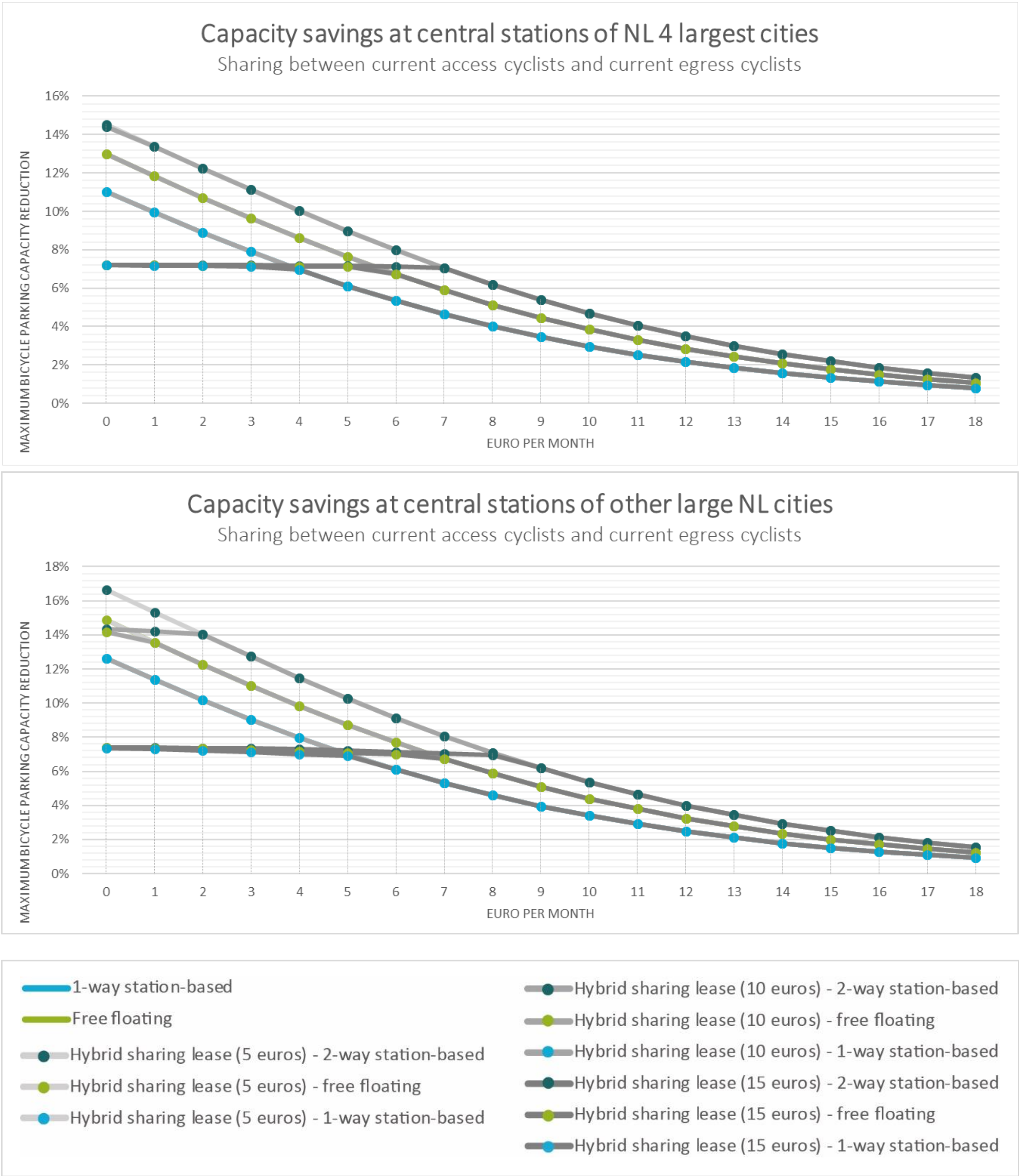

Figure 27: Possible capacity savings at the central stations of the four largest Dutch cities and the central stations of other large cities in the Netherlands when bicycles are shared between current access and egress cyclists

Sharing between current access cyclists and potential egress cyclists

In case bicycles are shared between current and potential cyclists the possible bicycle parking capacity savings increase rapidly. When the systems have tariffs similar to the current tariffs, 7-19% capacity savings could be achieved, depending on the system set-up. When tariffs are lowered to monthly prices between 5 and 10 euros, the capacity savings will increase to values between 7-26%. Also in case of sharing between current and potential cyclists, the capacity savings are slightly lower at central stations of the four largest cities than for the central station at other large Dutch cities.

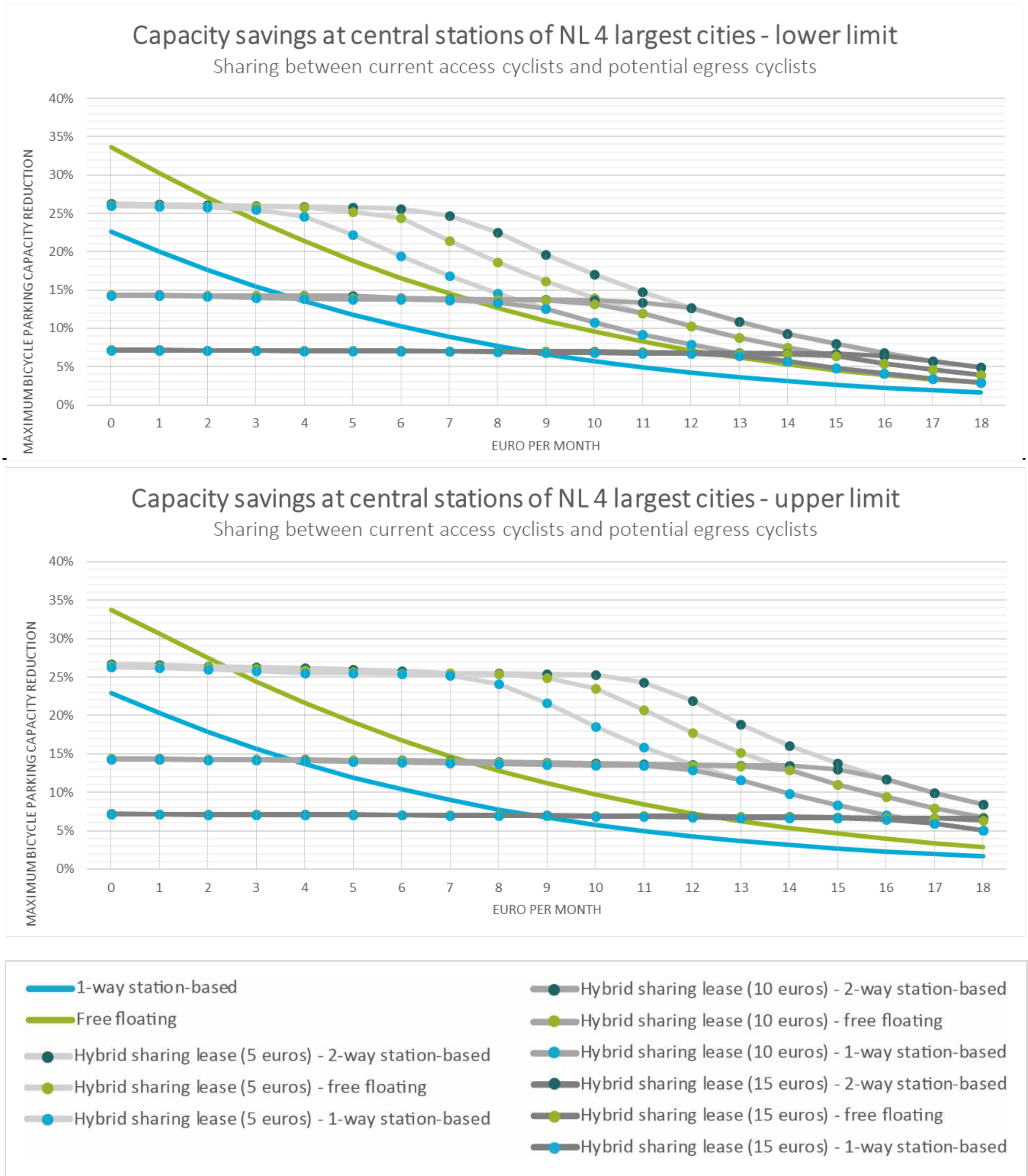

Figure 28: Possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (not compensated for need buffer of shared bicycles)

The large differences in capacity savings between the systems with similar tariffs are mainly due to the mismatch in supply and demand of shared bicycles. The capacity savings remain limited when the supply of access bicycles is insufficient to catch up the demand by (potential) egress cyclists. In principle this situation of insufficient supply applies to all investigated systems and tariffs, except for some combinations of hybrid sharing. When for example hybrid sharing with a fixed tariff is combined with another bicycle sharing system having a higher tariff than the bicycle subscription, bicycle sharing has become less attractive to egress cyclists and the supply can meet the lowered demand. In practice, a higher monthly tariff than the bicycle subscription will result in egress cyclists taking a hybrid sharing bicycle subscription instead of the subscription for the other systems (1-way or 2-way station-based or free floating).

At the central stations of other large Dutch cities the possible savings that can be achieved are slightly higher (see Appendix H.3). However, for the same tariffs the savings are lower at the other stations. This is due to a lower relative total demand in comparison with the supply. Therefore, the demand can be still facilitated when the tariffs for the system are lower in comparison with the four largest stations.

Sharing between current access cyclists and potential egress cyclists including buffer

This subsection discusses the possible bicycle parking capacity savings when a buffer of additional bicycles is supplied. This buffer equals the supply and demand for shared bicycles and provides a shared bicycle to all interested shared bicycle users. The actual buffer probably needs to be slightly higher than expected based on the estimations, as demand and supply are fluctuating over the day, week and year (see Chapter 2). These fluctuations are not fully covered by the travel data, which results in a possible under estimation of the needed buffer and a possible overestimation of the potential capacity savings. Despite, the estimations that will be discussed give an indication of how the buffer will influence the possible capacity savings.

Figure 30 presents the possible bicycle parking capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current and potential cyclists. The buffer of additional bicycles is included in the estimations. Overall, the needed buffer leads to a rise in the number of parked bicycles, hence a decrease in possible capacity savings. Figure 29 illustrates the consequences of a buffer for the possible capacity savings by providing an example of the development of the bicycle parking pressure during an average work day. Mainly during the night and at the morning and evening peak hours bicycle parking pressure is increased compared to a situation of bicycle sharing without additional buffer of parked bicycles. All system combinations were a buffer is needed, show the same development of bicycle parking pressure, however to a different extent.

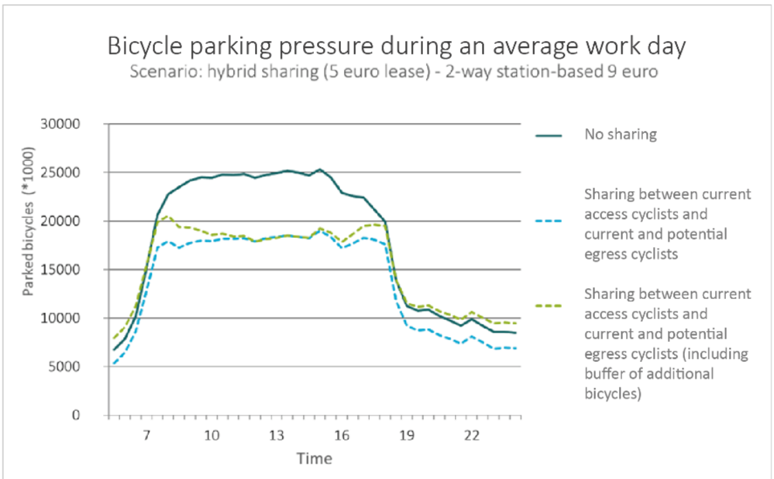

Figure 29: Bicycle parking pressure during in average workday when bicycles are shared between access cyclists and potential egress cyclists

As a result of the buffer of additional bicycles, the total possible bicycle parking capacity savings decrease (see Figure 30). For some system set-ups the needed buffer rises to considerable amount of additional parked bicycles, which even results in a growth of the number of parked bicycles. The maximum possible capacity savings that still can be achieved are 16-24% at the central stations of the four largest Dutch cities and 19-25% at the central stations of other large Dutch cities. The systems with a hybrid sharing subscription of 5 euro seem to be most promising, as these systems create a large supply which limits the needed buffer. The systems without hybrid sharing may also result in significant capacity savings, however, primarily when the tariffs are very low.

For the central stations of other large Dutch cities the capacity savings are in general slightly higher in case a buffer is included (see Appendix H.3). When the demand is larger than the supply, the capacity saving still remain positive.

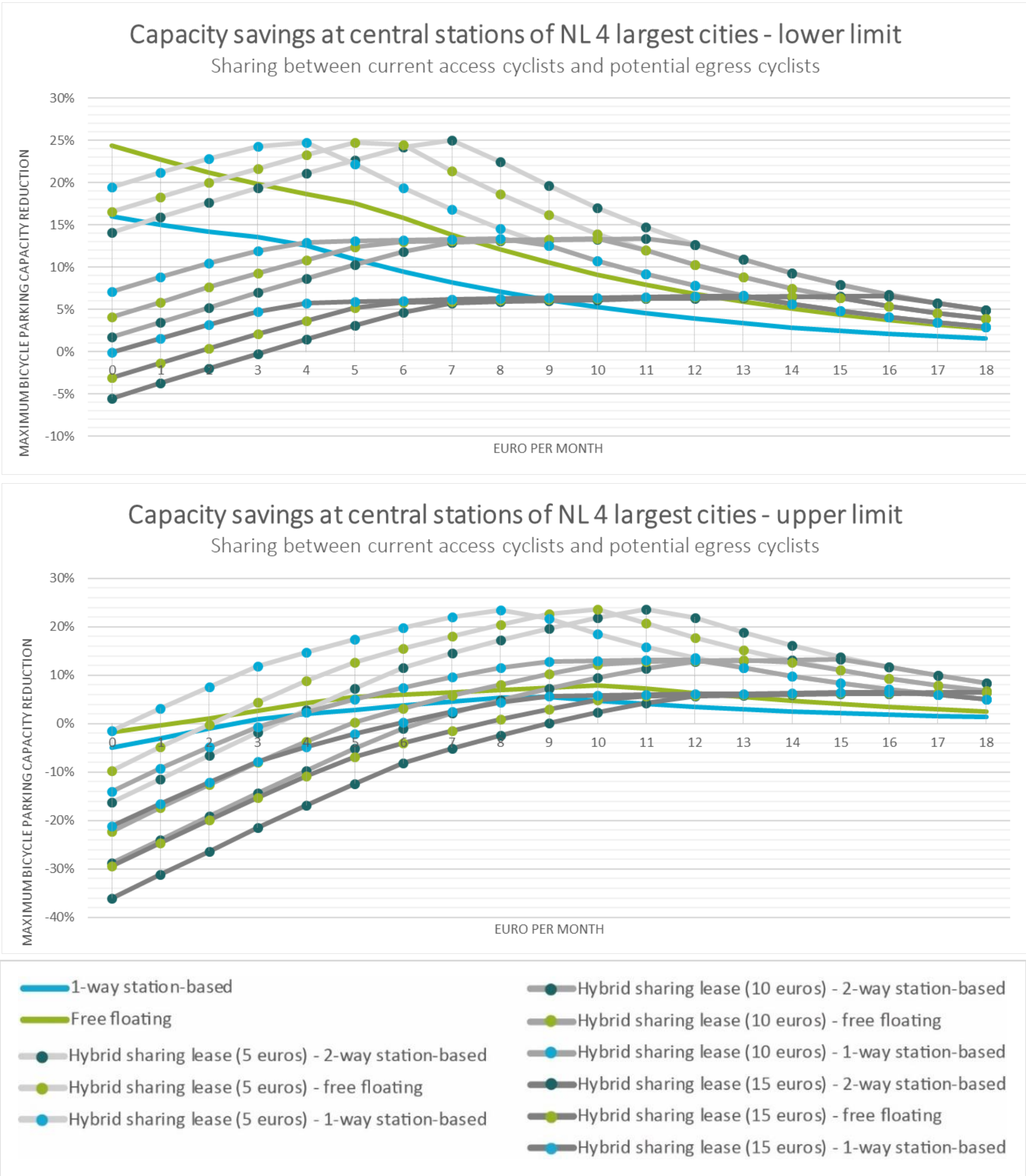

Figure 30: Possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between access cyclists and potential egress cyclists (compensated for needed buffer of additional shared bicycles)

8.3 Conclusion

This chapter investigated the implications of user preferences for different bicycle sharing system set-ups on the possible savings of bicycle parking capacity at railway stations. Using Microdata of the Dutch National Travel Survey possible capacity savings at the central stations of the four largest Dutch cities and at the main stations of other large Dutch cities were estimated.

It appears that the design of the efficient bicycle sharing system is of large importance and a determining factor for a significant contribution to bicycle parking capacity savings. These system designs involve the combination of a BSS for access trips (home-end) and a BSS for egress trips (activity-end), in which the systems can be the same at both trip-ends and are serviced by the same bicycles. The demand for the different proposed systems in Chapter 3, varies widely: ranging from a few percent by tariffs higher than 15 euros, to 18-47% when use of the systems is free of charge. The large variety in demand is mainly due to the fact that price is of primary importance in cyclists' choice to use a shared bicycle. The demand for the same systems and prices among access and egress cyclists are fairly in line with each other. However, in general the proportion of current egress cyclists willing to use a shared bicycle instead of their private bicycle is slightly higher and access cyclists should be offered a premium parking place to bring demand more in line with the demand among egress cyclists.

Estimations of the proportion of possible shared bicycle users among current access cyclists and current egress cyclists showed that the number of shared bicycles supplied by access cyclists cannot always satisfy the demand among (potential) egress cyclists. When bicycles are only shared between current access cyclists and current egress cyclists, most systems can ensure a sufficient supply of shared bicycles in order to meet the demand. The capacity savings will however remain limited: 1-8% capacity savings under current tariffs, 3-9% for tariffs between 5 and 10 euro per month and 9-15% when the systems are free of charge. In addition, it will be difficult to preclude use of the system to current egress cyclists.

When potential egress cyclists (egress travellers making trips with a distance between 1 and 5 km are assumed to be a potential egress cyclists) also participate in the system, the capacity savings can be significantly higher. However, for even more systems the demand will be larger than the supply. Therefore, a buffer of additional bicycles is needed to facilitate the availability of sufficient shared bicycles to all interested potential egress cyclists, otherwise the demand among all travellers will decrease. This results in a rise in the number of parked bicycles, mainly during the night and during peak hours. In some cases the buffer even cancelled out the capacity savings. Overall results varied between a capacity increase of 8% to capacity savings of 25%. In Table 18 an overview of all estimations for both combinations of stations is provided. The possible capacity savings at the main stations of other large cities in the Netherlands are higher compared to the four largest cities, due to a smaller proportion of (potential) egress cyclists.

It can be concluded, that it is of primary importance that current access cyclists switch to use of a shared bicycle. Access bicycles are essential in order to provide sufficient supply, make a buffer of additional shared bicycles superfluous and determine the success of the efficient BSS.. A system of hybrid sharing (lease), a low tariff and the availability of premium parking places are found to be beneficial in creating a large supply of access bicycles. An additional advantage is that access cyclists are more willing to pay for this type of system than for the other investigated systems.

It also appears that it is not in all cases beneficial to offer the most attractive system at the activity-end. A very attractive system will increase the demand and may lead to a mismatch between supply and demand, as a large demands creates a larger risk for the unavailability of shared bicycles. A buffer of additional bicycles is needed to meet the demand.

A system at the activity end with a price between 7 and 11 euro per month seems to be most beneficial in capacity savings, where for a 2-way station-based the system tariffs should have the highest tariff followed by free floating and lastly a 1-way station-based system. At other main stations in the Netherlands, the prices should be somewhat higher, because of the low number of potential egress cyclists. Offering hybrid sharing (lease) for a lower subscription tariff than a shared bicycle subscription for egress trips, is however inconsistent and will encourage frequent travellers to opt for a lease subscription. As an alternative, in case hybrid sharing only trip tariff should be offered to shared bicycles for egress transportation. As a consequence the proportion of current egress cyclists willing to switch to use of shared bicycles will be low and probably more travellers who currently use other modes than current cyclists will use the system.

For this reason and because of the broad range of capacity savings, the proportion of (frequent) potential egress cyclists asks for further research. Also the needed buffer of shared bicycles between the stations in the four largest cities and other cities illustrate the importance of further research into the scale of the needed buffer in order to respond to fluctuations in demand and supply and to guarantee availability under all circumstances.

Table 18: Overview of possible capacity savings at central stations of the Dutch four largest cities

System / Tariff*	Sharing between current cyclists		Sharing between current and potential cyclists			
			Availability not guaranteed		Compensated for additional buffer of shared bicycles	
	4 largest cities	Other large cities	4 largest cities	Other large cities	4 largest cities	Other large cities
1-WAY STATION BASED						
Low tariff	5%	6%	10%	11%	4% - 9%	10%
Average tariff	2%	2%	4%	4%	3% - 4%	4%
High tariff	1%	1%	2%	2%	1% - 2%	2%
FREE FLOATING						
Low tariff	7%	8%	17%	16% - 17%	6% - 16%	16%
Average tariff	3%	3%	7%	7%	6% - 7%	7%
High tariff	1%	1%	3%	3%	3%	3%
HYBRID SHARING (LEASE SUBSCRIPTION) COMBINED WITH 2-WAY STATION BASED						
Hybrid sharing (5 euro subscription) – 2-way station-based						
Low tariff	8%	9%	26%	19% - 27%	11% - 24%	19% - 25%
Average tariff	3%	4%	13% - 22%	8% - 13%	13% - 22%	8% - 13%
High tariff	1%	2%	5% - 8%	3% - 5%	5% - 8%	3% - 5%
Hybrid sharing (10 euro subscription) – 2-way station-based						
Low tariff	8%	9%	14%	14%	-1% - 12%	14%
Average tariff	3%	4%	13%-14%	8% - 13%	13%	8% - 12%
High tariff	1%	2%	5%-8%	3% - 5%	5% - 8%	3% - 5%
Hybrid sharing (15 euro subscription) – 2-way station-based						
Low tariff	7%	7%	7%	7%	-8% - 5%	7%
Average tariff	3%	4%	7%	7%	6%	7%
High tariff	1%	2%	5% - 7%	3% - 5%	5% - 6%	3% - 5%
HYBRID SHARING (LEASE SUBSCRIPTION) COMBINED WITH FREE FLOATING						
Hybrid sharing (5 euro subscription) – Free floating						
Low tariff	7%	8%	24%-25%	16% - 24%	16% - 24%	16% - 24%
Average tariff	3%	3%	`10% - 18%	7% - 10%	10% - 18%	7% - 10%
High tariff	1%	1%	4% - 7%	3% - 4%	4% - 7%	3% - 4%
Hybrid sharing (10 euro subscription) – Free floating						
Low tariff	7%	8%	14%	14%	3% - 13%	14%
Average tariff	3%	3%	`10% - 14%	7% - 10%	10% - 13%	7% - 10%
High tariff	1%	1%	4% - 7%	3% - 4%	4% - 7%	3% - 4%
Hybrid sharing (15 euro subscription) – Free floating						
Low tariff	7%	7%	7%	7%	-4% - 6%	7%
Average tariff	3%	3%	7%	7%	6%	7%
High tariff	1%	1%	4% - 6%	3% - 4%	4% - 7%	3% - 4%
HYBRID SHARING (LEASE SUBSCRIPTION) COMBINED WITH 1-WAY STATION BASED						
Hybrid sharing (5 euro subscription) – 1-way station-based						
Low tariff	5%	6%	19% - 25%	13% - 19%	19% - 20%	13% - 19%
Average tariff	2%	2%	8% - 14%	5% - 8%	8% - 14%	5% - 8%
High tariff	1%	1%	3% - 5%	2% - 3%	3% - 5%	2% - 3%
Hybrid sharing (10 euro subscription) – 1-way station-based						
Low tariff	5%	6%	14%	13% - 14%	7% - 13%	13% - 14%
Average tariff	2%	2%	8% - 13%	5% - 8%	8% - 13%	5% - 8%
High tariff	1%	1%	3% - 5%	2% - 3%	3% - 5%	2% - 3%
Hybrid sharing (15 euro subscription) – 1-way station-based						
Low tariff	5%	6%	7%	7%	0% - 6%	7%
Average tariff	2%	2%	7%	5% - 7%	6% - 7%	5% - 7%
High tariff	1%	1%	3% - 5%	2% - 3%	3% - 5%	2% - 3%

**Tariffs:*
Low: 6 euros/month, 0.30 euros/single trip
Average: 12 euros/month or 0.60 euros/single trip
High: 18 euros/month or 0.90 euros/single trip

9. Conclusions, discussion and recommendations

This chapter provides a conclusion on the findings of this research by answering the different sub questions and main research question in Section 9.1. This is followed by a discussion of the results and the used methodology in Section 9.2. This chapter closes with recommendations for further research and recommendations for the setup of a bicycle sharing system design in order to reduce bicycle parking pressure at major railway stations in Section 9.3.

9.1 Conclusions

The goal of this research is to provide insights into potential user preferences and demand for bicycle sharing systems among current access and egress cyclists. Doing so provides recommendations for the design set-up of an efficient bicycle sharing system that contributes to bicycle parking capacity savings at major Dutch railway stations. The knowledge required to meet the goal of this research is gained by answering the following main research question:

"What are the preferences of current cyclists regarding an efficient bicycle sharing system in order to relieve bicycle parking capacity shortages at major Dutch railway stations?"

By means of a stated preference experiment among current access and egress cyclists, insights are gained on the importance of different bicycle sharing attributes and the influence of personal and trip characteristics on preferences. Eventually these results are used to estimate the potential demand for bicycle sharing and implications for bicycle parking capacity savings at major Dutch railway stations.

An efficient bicycle sharing system (BSS) is defined as a system that makes use of the already parked bicycles and the reverse commuting flows at major railway stations to save as many parking places as possible. The design of an efficient BSS involves the combination of a BSS for access trips (home-end) and a BSS for egress trips (activity-end), where the systems can be the same at both sides and are serviced by the same bicycles.

In order for a BSS to function efficiently and result in significant bicycle parking capacity savings, several conditions need to be met. Firstly, a high number of access cyclists must be willing to use a shared bicycle as these cyclists are responsible for the supply of shared bicycles. Secondly, a significant number of egress travellers must be willing to use a shared bicycle. In particular, current egress cyclists, of whom it is assumed a private bicycle is used for egress transportation, can contribute to relatively large capacity savings for each bicycle supplied by access cyclists. One egress cyclist switching to a shared bicycle can contribute to a reduced parking pressure of on average four parked access bicycles. Thirdly, a certain balance between supply and demand is needed, which implies a supply that is at least slightly higher than the demand. It is not preferable to have an additional buffer of shared bicycles as this will lead to an increase in the number of parked bicycles at peak moments.

By means of a literature study the different BSSs that are currently available in the Netherlands and abroad were investigated. These bicycle sharing systems cannot be defined as efficient BSSs as bicycles are not shared between access and egress cyclists. Although, the existing systems do provide a basis for the design of an efficient BSS. An efficient BSS can be made up by combining the following existing BSSs and bicycle service initiatives:

	Home-end:	*Activity-end:*	*System type:*
▪	Hybrid sharing (lease)	– 2-way station-based	Open PT system
▪	Hybrid sharing (lease)	– 1-way station-based	Hybrid open urban system
▪	Hybrid sharing (lease)	– Free floating	Hybrid open urban system
▪	1-way station-based	– 1-way station-based	Open urban system
▪	Free floating	– Free floating	Open urban system

Hybrid sharing is a new proposed system and is an extension of currently available lease bicycle initiatives, which offer a standardised bicycle for a monthly subscription tariff. Hybrid sharing combines this lease system with bicycle sharing at railway stations. A 2-way station-based system solely allows for round trips from and to the railway station (open PT system). The open urban systems allow for single trips from and to a railway station, where 1-way station-based systems offer shared bicycles which can be parked at assigned racks or parking zones and shared bicycles of free floating systems can be parked everywhere.

The extent to which the attributes that make up the different BSSs are important in the choices of current cyclists to use a shared bicycle instead of a private bicycle were investigated by using a stated preference study and questionnaire. In this experiment, respondents made choices between using their private bicycle and two shared bicycle alternatives, which varied in price, walking times from bicycle parking place to home or destination, parking convenience at the railway station and accessibility at the trip starting points and at the railway station. At three Amsterdam railway stations respondents were recruited during peak hours on average working days to participate in an online survey. This resulted in 961 useful responses.

Based on the SP data a multinomial logit (MNL) model is estimated. The results showed that for both access cyclists and egress cyclists price is a key factor in their choice to use a shared bicycle. After price, accessibility at the trip starting points (home or destination) are most important. Price is, however, on average, still more than three to four times more important. In addition, it appeared that the availability of a guaranteed premium parking place forms an incentive for access cyclist to use a shared bicycle. For egress cyclists a premium parking place is on average not relevant. Figure 31 provides a relative comparison of the attributes by visualising the average relative importance of the investigated attributes.

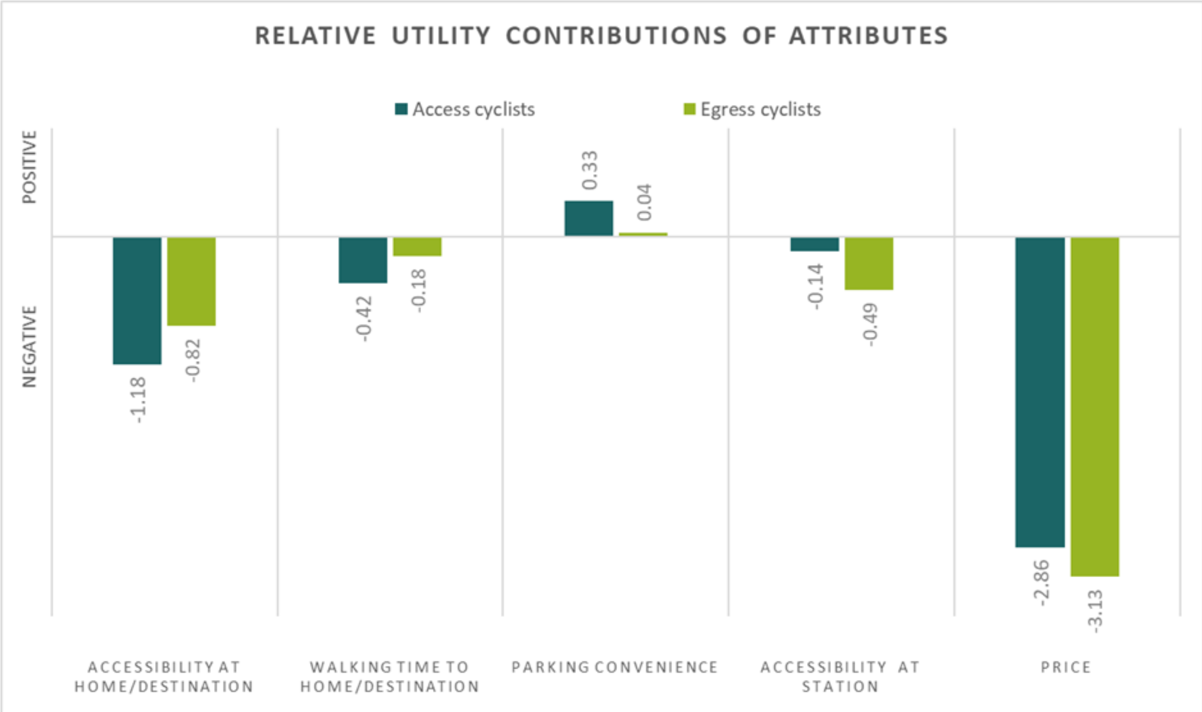

Figure 31: Visualisation of the average relative importance of the investigated attributes

By including trip and personal characteristics as interaction effects in the MNL model, heterogeneity in preferences among different groups of respondents was investigated. The most important findings are that younger cyclists (< 38 years) are more likely to opt for a shared bicycle than older cyclists. This is in accordance with existing literature on the characteristics of shared bicycle users. Moreover, significant interaction effects with trip characteristics are found. It appeared that bicycle-train users who pay for bicycle parking are less sensitive towards the cost of shared bicycle use. In addition, it was found that access cyclists who have difficulties finding an empty parking spot do attach more value to the availability of a premium parking place. Finally, the results showed that cyclists making trips of an average cycle distance (between 5 and 15 minutes) are more likely to choose a shared bicycle.

Using the estimated parameters of the base MNL models the choice probabilities for the different efficient BSS set-ups were predicted. The potential demand that can be expected for the different proposed systems varied widely: ranging from a few percent by tariffs higher than 15 euros, to 18-47% when use of the systems is free of charge. The large variety in demand is mainly due to the fact that price is of primary importance in cyclists' choice to use a shared bicycle. In general, the proportion of current egress cyclists willing to use a shared bicycle instead of their private bicycle is slightly higher than the proportion of access cyclists. Access cyclists should be offered a premium parking place to bring demand more in line with the demand among egress cyclists. Imbalance in demand requires more buffer space, hence reducing the bicycle parking capacity savings of the system.

Based on the choice probabilities for use of the different system set-ups and based on data of the Dutch National Travel Survey, the possible bicycle parking capacity savings as a result of bicycle sharing are estimated. It appeared that the savings are limited when bicycles are only shared between current access and egress cyclists: the peak of parked bicycles could be reduced by 2-5% for tariffs between 10 and 15 euros per month, 5-9% for tariffs between 5 and 10 euros per month, and 7-15% for tariffs between 0 and 5 euros per month. Assuming that the peak of parked bicycles is on an average workday, an efficient BSS would allow for a capacity reduction of the aforementioned percentages. It appeared that for some system set-ups the supply of shared bicycles will not be sufficient to facilitate the full demand among current egress cyclists. This is mainly the case when the system is relatively unattractive for access cyclists because of a high tariff.

When access bicycles are also shared with egress travellers who currently use other modes of transportation, the capacity savings can be significantly higher. In this study travellers making trips with a distance between 1 and 5 km are assumed to be a potential egress cyclist. In addition, assumptions were made on the proportion of interested egress travellers (see section 8.2.2). These estimations resulted in a broad range of possible capacity savings for the different set-ups. For a large number of systems the demand for shared bicycles will be larger than the supply of shared bicycles. This implies that there will not be a shared bicycle for every interested shared bicycle user, which will result in a decrease in the willingness to participate in the system. In the end this will also lead to a decrease in the possible capacity savings or even lead to a rise in the number of parked bicycles if the needed buffer of additional shared bicycles in order to guarantee availability is too large.

The highest capacity savings that could be possible, compensating for the additional buffer of bicycles, are between 16-25% at the central stations for the four largest cities and 19-25% at the main stations of other large cities. Overall it is found that the possible capacity savings at the main stations of other large cities in the Netherlands are slightly higher compared to the four largest cities, due to a smaller proportion of (potential) egress cyclists at these stations. A total overview of the estimations can be found in Appendix H. The capacity savings are highly dependent on the prices for both access and egress transportation. In addition, the needed buffer is of great influence on the possible bicycle parking capacity savings. As no accurate estimation can be made for the required buffer in order to respond to fluctuations in demand and supply, and because of the assumptions on the number of potential egress cyclists willing to participate in the system, the estimated capacity savings need to be interpreted with care.

The findings of this study highlight that there is an even greater need to optimize the existing BSSs at railway stations as policies are aimed at more cycling to railway stations. The availability of an accessible, but inefficient BSS, will only contribute to additional parked bicycle and causes a greater need for bicycle parking capacity at morning and evening peak hours.

9.2 Discussion

This section provides a methodological evaluation as well as a discussion of the results of this study. First, different research considerations, simplifications and limitations that effected the results of this study will be discussed. Subsequently, the findings of the research will be elaborated on in light of existing literature and the consequences of the research results for (urban) mobility in the Netherlands will be discussed.

9.2.1 Comparison of the results of this study to literature

To the best of the author’s knowledge no existing studies investigated the choice between shared bicycle use and use of a private bicycle for access and egress trips in the Dutch context or worldwide. It is therefore not possible to directly compare the results of this study with findings in literature. On the preferences of (potential) egress travellers on shared bicycle use studies have been conducted. Van Heijningen (2016) studied the preferences of Dutch commuters on the design of shared bicycle systems. Steegman (2016) investigated shared bicycle mode choice among students in Utrecht. In both studies is found that price is a key factor in the choice to use a shared bicycle as egress mode. It also appeared from this study that price is the most important attribute in a cyclist’s choice to use a shared bicycle.

Molin & Maat (2015) investigated the trade-offs between walking time at bicycle parking facilities and price. They found that walking time has a quadratic relationship with utility, which implies that as walking time increases, utility decreases even stronger. In this study this non-linear relationship has not been found.

In this study is found that younger cyclists are more likely to opt for a shared bicycle. This is in accordance with studies that investigated characteristics of shared bicycle users. In other studies, it is found that males are more likely to use a shared bicycle. In this study this relationship has not been found, however Dutch cycling culture differs greatly from that in other countries in this regard. On other found significant interaction effects between personal and trip characteristics and BSS attributes in this study, literature is lacking.

9.2.2 Online survey & stated choice design

Regarding the online questionnaire and stated choice questions some improvements can be made. First, the levels of the attribute 'accessibility at the railway station' appeared to be unclear to some respondents, as the parameter estimates for the different attribute levels showed some peculiarities. A more extensive pilot study could have solved this issue.

A comment of a large number of respondents was that they experienced the stated choice experiment as long and exhausting, despite the limited number of eight choice sets. The number of questions about the shared bicycle alternatives could have been reduced by first asking respondents to choose between two shared bicycle alternatives and the private bicycle, and subsequently asking to choose between both shared bicycle alternatives in case was opted for the private bicycle. This would have limited the number of questions for a part of the respondents significantly.

9.2.3 Quality of the data

As in any study based on a survey, self-selection might have played a role. People that are more interested in the topic of the survey or people that have positive attitude towards bicycle sharing or a negative attitude towards the current form of bicycle parking are more likely to participate in the survey. Therefore the conclusions of the research should not be overestimated and should be interpreted with care.

In addition, some people might have participated in the survey because of the prize that was raffled among the respondents. Although the minimum time used to complete the choice tasks and the time to complete the questionnaire gave no grounds to exclude any respondents from the data, it is possible that some respondents did not fill in the survey seriously. Possibly a number of people did not read the explanation of the stated choice experiment or did not understand the concept of bicycle sharing and the investigated attributes. It is, for example, possible that access cyclists have not read and understood that the monthly subscription implies that they can use the described shared bicycle for all their trips and not only for their trip to the railway station. This may have biased respondents' answers.

A number of respondents reported that the images of the stated choice questions were not visible or disappeared for some questions. The probable explanation is a bad internet connection for those who experienced this issue. The concerned respondents are excluded from the data estimations, however it cannot be guaranteed that other respondents have seen the choice questions and participated seriously in the survey.

In this study it is assumed that the respondent sample gives a fair representation of cyclists at railway stations during the peak hours. On some aspects however, the respondent characteristics differed from what would be expected from literature on Dutch bicycle-train users in general. The number of work related trips may be overrepresented for the total number of current cyclists during the day. In addition, the number of younger cyclists may also be overrepresented and the number of students of students might be underrepresented. No assumptions can be made on the extent to which bicycle-train users in Amsterdam are representative for bicycle-train users at other major railway stations in the Netherlands during the day. This fact may have affected the estimations of possible bicycle parking capacity saving, as will be discussed in section 9.2.5.

9.2.4 Model

In this study a Multinomial Logit Model (MNL model) is used in order to predict cyclists' choices in bicycle sharing. This MNL model is a proper and efficient model to use in order to provide first insights in choice behaviour. A disadvantage of this model is that it ignores heterogeneity in preferences. Including personal and trip characteristics in the model accommodated for this disadvantage. Another disadvantage is that some respondents may have had a strong preference for use of their private bicycle and may have chosen for the base alternative a large number of times. These correlations between choices made by the same individual over time (panel effects) are not taken into account in the MNL model. Use of the more advanced Mixed Logit (ML) model could have resolved this issue as it accommodates for panel effects. Use of an ML model would probably have led to a more negative alternative specific constant for bicycle sharing.

In this study two MNL models are estimated: one based on the choices of access cyclists and the other based on the choices of egress cyclists. The parameters of the attributes of both stated choice experiments were estimated separately, as it was assumed that choice behaviour of access cyclists will differ from that of egress cyclists. The estimation results of both MNL models could, therefore, not be directly compared with each other because the error components of the two models may differ. On a closer examination, the estimation of a single model for both cyclists choices would have led to more simplified model. By including interaction effects of the groups of cyclists could be tested if the differences in preferences are statistically significant. Using a scale factor would have allowed for direct comparison of the preferences of both groups.

9.2.5 Limitations of this research

In this study a stated preference survey is used in order to be able to predict cyclists' choices for a number of shared bicycle systems that are currently not available. This implies that the data represents respondents' choices in hypothetical situations. It is uncertain whether, and to what extent, respondents would make the same choices when the systems are available in real life and after they have experienced the use of shared bicycles of an efficient BSS. In addition, this research does not provide insights in the reasons behind cyclists' choices and preferences.

This study is limited to a number of attributes that are assumed to be the most important characteristics of different BSSs and most important factors in current cyclists' choices to use a shared bicycle. Other attributes may also play a role in the choice between a shared bicycle and a private bicycle, for example bicycle comfort and bicycle design. The importance of all attributes that are not varied in the experiment have ended up in the alternative specific constant and no statements can be made about the individual utility contributions of these factors.

In this research respondents did not directly opt for the different proposed bicycle sharing systems. As mentioned, the systems were made up of five important and most distinguishing characteristics of the systems. It may be that for the respondents other aspects of the systems play a role in their choice to use the system. For example, flexibility in return options (returning the bicycle at different locations) was not included in the stated choice experiment. Including additional aspects in the stated choice experiment would have increased the knowledge on cyclists' preferences for the systems. In practice, however, extension of the experiment with additional attributes would decrease the reliability of the experiment, since respondents can only handle a limited number of attributes.

In this research it is assumed that the preferences of the surveyed cyclists at the studied Amsterdam railway stations at peak hours are representative for the preferences of all other cyclists at Dutch major railway stations during the whole day. First, it can be questioned to what extent the preferences of cyclists during peak hours are similar to preferences of cyclists arriving or departing during the rest of the day. Secondly, the generalisation of the results at three Amsterdam railway stations to other Dutch railway stations can be questioned. In this study, preferences were found to differ for cyclists experiencing a different bicycle parking pressure and for cyclists using paid facilities. In addition younger cyclists and cyclists making trips between 5 and 15 minutes were found to be more likely to choose for a shared bicycles. As the characteristics of bicycle parking facilities and the population using these facilities may differ for every railway station, preferences may also differ. Projecting the preferences of the Amsterdam cyclists on cyclists at other railway stations might therefore have led to and under- or overestimation of the possible bicycle parking capacity savings.

Additionally, the estimations of possible bicycle parking capacity savings are limited by the lack of knowledge on preferences of potential access and egress cyclists and the demand for bicycle sharing that can be expected among these groups. Assumptions are made on the proportion of egress travellers who will switch from other modes to use of shared bicycles. This resulted in a broad range of possible bicycle parking capacity savings when bicycles are shared between current access cyclists and potential egress cyclists. Moreover, in this study the latend demand for bicycle parking by travellers currently using other modes of transportation is ignored, as no information on the latend demand for bicycle parking is available. Therefore the estimations provide an overestimation of the savings that can be achieved in practice. In addition, the estimations are limited to figures for combinations of stations (central stations of the four largest Dutch cities and main stations of other cities in the Netherlands), as the number of observations at individual stations was too small for an accurate estimation. Lastly, the estimations are limited to possible capacity savings on an average workday. The aforementioned limitations affected the accuracy of the estimations and may have led to an overestimation of bicycle parking capacity savings.

9.2.6 Consequences for (urban) mobility

The results of this study showed a significant demand to use a shared bicycle as access or egress mode among current cyclists and a significant possible reduction in the number of parked bicycles at major railway stations. The released bicycle parking places lead to more convenient bicycle parking for (potential) cyclists (latend bicycle demand). As a result, travellers currently using other modes, may switch to the bicycle as feeder mode or switch from other main mode use to use of the combination of bicycle and train. Train use and bicycle use will, therefore, increase. The use of urban PT systems like bus, tram and metro, and car use will decrease

The attractiveness of train travelling also increases as a direct result of the availability of a large-scale and accessible BSS. Depending on the design of the efficient BSS, travellers using other modes will become shared bicycle users. This particularly holds for travellers for whom bicycle parking forms a barrier to use a bicycle as access or egress mode or to use the combination of bicycle and train, for example because of difficulties finding a parking place, long walking distances and risk of theft. Use of shared bicycles negates these inconveniences of bicycle parking and will make bicycle-train use more attractive, hence increasing the number of train users.

If the eventual bicycle parking capacity savings measure up the additional capacity needs for the future, no further expansion of the bicycle parking facility is required. Space which is currently used for bicycle parking may be released. This space could be used for other functions, which can make railway stations a more attractive transfer node, improving the quality of train travelling, and hence increasing the number of train travellers.

Conventional BSSs which do not share bicycles between access and egress cyclists (e.g. the PT-bicycle system) are not able to offer seamless travel in PT on the long term. Expansion of these systems is limited by the unavailability of space. A well-designed efficient BSS does not require additional bicycle parking space. Therefore an efficient BSS is able to maintain the quality of combined bicycle and PT use on the long-term and preserving the high usage of train as mode of transportation.

Another consequence of a large efficient BSS at railway stations is that parked bicycles at railway stations will be moved to other places that attract many visitors, such as office locations, campuses, shopping centres and other locations. Therefore the need for bicycle parking capacity expansion will be shifted to other places, albeit to a much lower level as the parking locations will be more spread.

In short, the availability of an efficient BSS will probably result in an increased train capacity need, a decreased urban PT capacity need, and an increased bicycle parking capacity need at other locations in the city.

9.3 Recommendations

9.3.1 Recommendations for science

As described in the discussion, within this research assumptions are made on the proportion of egress travellers who will switch from other modes to shared bicycles. It appeared that the total savings that can be achieved and the extent to which availability can be guaranteed to users are highly dependent on the number of potential egress cyclists participating in the system. Additional research into the demand among and preferences of potential egress cyclists is therefore necessary in order to be able to give a final conclusion on the contribution to a reduction of bicycle parking capacity savings of an efficient BSS. It is recommended to make a distinction between frequent and less frequent travellers in this follow-up study. This information will help to determine a price-setting (a monthly price, a price per trip or a combination of both) that will lead to a right balance in demand and supply, and higher capacity savings therewith.

Moreover, additional research into user preferences and trade-offs for other attributes, for example bicycle design, bicycle comfort and return options is needed. Primarily among access cyclists knowledge on the mentioned topics is lacking. In addition, it is advised to study the influence of paid parking on the choice probabilities and the demand for bicycle sharing among both current access and egress cyclists. As explained in the discussion, it is recommended to use prediction models that take into account heterogeneity among respondents and accommodate for panel effects.

Additional research into the implications of fluctuations on demand, for example at Wednesdays and Fridays, weekend days, during school holidays or because of weather conditions, and research into the needed additional buffer in order to respond to such fluctuations is necessary. A study into travel behaviour at individual railway stations providing detailed information on the number of travellers and cyclists during all days of the week and year will be most beneficial and is therefore recommended.

After carrying out the aforementioned studies, it is recommended to further investigate the costs and business models of different types of shared bicycle systems. This investigation will help to eventually determine the cost-effectiveness of an efficient BSS at railway stations and the feasibility of such a system. Subsequently it is advised to carry out a cost benefit analysis (considering a large time span) in order to conclude to what extent an efficient BSS and relating policies can contribute to societal benefits as a result of the possible bicycle parking capacity savings. For this, it is also advised that research focusing on the influence of systems on bicycle pressure at other places in the cities and the consequent societal costs. Large scale free floating, 2-way or 1-way station-based systems could move the bicycle parking pressure problem to other places in the city when egress travellers will become users of these systems.

Besides the aforementioned theoretical studies, it is recommended to study efficient bicycle sharing in practice in a pilot study. This can provide insights in user experiences regarding for example the swapping of bicycles at the (premium) parking place during peak hours when the bicycle parking facility is crowded, the (un)availability of shared bicycles, the design of the shared bicycles, and other issues that may pop up. This information is needed in order to support theoretical studies on the further design of a user-friendly and space efficient system, and helps determining the size of the needed buffer of additional shared bicycles.

9.3.2 Recommendations for society

It appeared that the participation of current access cyclists in an efficient BSS is of primary importance to provide sufficient supply of shared bicycles, make a buffer unnecessary and increase capacity savings. It is therefore recommended to offer a bicycle sharing system at the home-end that is as inviting as possible for this group. This implies that accessibility of shared bicycles should be guaranteed, and no walking times should be required, which can be found in a hybrid sharing (lease) system and is therefore highly recommended. In addition, access cyclists are most willing to pay for use of this system. A hybrid sharing system offers a standardised lease bicycle for a monthly subscription tariff and is used as a private bicycle for inner-city trips but will be shared with egress travellers at the railway station.

In order to create a large supply of these lease bicycles, first, a premium parking place near the platform should be offered to shared bicycle users. Premium parking places are a small investment but form a large incentive for access cyclists. Secondly, it is advised to take measures in order to guarantee availability as a hybrid sharing system cannot guarantee the availability of shared bicycles. This can be done by for example reservation via an app and possible synchronisation with a user's calendar and travel planners. Also, a limited buffer of additional shared bicycles should be offered in case the stock of shared bicycles depletes. Thirdly, the tariff for the hybrid system should be as low as possible, however in no case lower than the monthly subscription for the BSS for egress transportation.

A system with a low tariff can be offered by support and financial contributions of different actors involved. First the Dutch national government should consider subsidisation, because benefits in bicycle parking capacity expansion, assuming that the bicycle systems benefits outweigh the costs. Additionally, the positive effects of an efficient BSS go hand in hand with driven national policies aimed at increasing use of more sustainable transport modes and cutting down car traffic delays. Also employers could be stimulated to include use of the efficient BSS in their employees travel allowances. Moreover, compensation for shared bicycle use to students (student PT card) is recommend.

Besides subsidies, other options to create an attractive pricing are by discount opportunities and good subscription conditions. For example, a discount could be offered to users of a lease bicycle for every time that they share their bicycle used for access transportation at the railway station. This strategy will prevent that access cyclists with a hybrid shared bicycle park a bicycle at other parking places at the railway station. This discount could be offered in the form of a financial discount on the monthly subscription or free use of a shared bicycle at another railway station. It is in no case recommended to require access cyclists to park their bicycle a minimal number of times per week or per month at the railway station, as was the case with OV-fiets@home in the past (see Chapter 3). This increases the complexity of the system and will reduce the attractiveness of the system significantly. Lastly, solely considering the bicycle parking capacity savings, it is recommended to consider the introduction of a charge for parking (< 24h), as it is found that cyclists who pay for bicycle parking will be more likely to choose for bicycle sharing. Cyclists will more easily opt for the use of a shared bicycle instead of their private bicycle and bicycle parking capacity savings will increase.

Contradictory to the recommendations for the system aimed at home-bound trips, it is advised to not offer as low as possible prices for a system aimed at activity-bound trips. As explained in the conclusions, this will increase the demand among egress cyclists and will in the end lead to lower bicycle parking capacity savings or even an increase in the number of parked bicycles. For this reason, a system with an average price (between 7 and 11 euros per month) is recommended, as this price setting leads to the highest capacity savings. However, further research is needed as mentioned. In addition, the monthly tariffs should be translated to a price per (single) trip. For a 2-way station-based system the tariffs can be highest, followed by free floating and lastly a 1-way station-based system.

With all three systems the same capacity savings can be achieved, however a 2-way station-based system is experienced as most attractive and egress cyclists are most willing to pay for this system, because of the guaranteed accessibility at destination and limited walking times. In addition, this system can prevent an imbalance in demand and supply and contribute to a higher availability at railway stations as it is required to return the bicycle to the station, which is not the case for a free floating or 1-way system.

All in all, as a strategy to reduce bicycle parking pressure at railway stations and to facilitate bicycle parking capacity savings, a system combining hybrid sharing (lease) at the home-end in combination with a 2-way station-based system at the activity-end is recommended. As discussed, the combination of these systems could lead to the highest capacity savings. In addition, lease (without sharing) and a 2-way station-based system are already available on a relatively large scale and the systems are known to travellers. Meaning this combination could be most easily tested and implemented on a short term. Moreover, with this system parking problems in inner cities will remain limited, as users keep their responsibility for the bicycles and there is no direct need for additional municipal policies on shared bicycles.

The implementation of the mentioned BSS can be organised in different ways. A publicly owned and operated BSS seems not feasible. Dutch governmental organisations (Ministry of Infrastructure, provinces, city-regions and municipalities) and semi-governmental organisations (ProRail) involved in bicycle parking do not have the required knowledge and expertise available to operate a bicycle sharing system. More reasonable is that the system will be operated by an commercial operator. This commercial operator can be one of the already existing bicycle sharing operators or bicycle service operators in the Netherlands, or one or more new operating parties. Commercial parties, however, aim at high profits and will not design a system aimed at achieving as large as possible bicycle parking capacity savings. Governmental organisations will not have control over the quality of service and cannot held the BSS providers liable for a poor service management since there is no service level agreement between them. A BSS operating from an open market position is therefore not desirable.

A concession allows for requirements on quality, reliability and efficiency of the system. Requesting parties award a contract to one or more operators to provide the system's hardware, operations or both. Operators can be incentivised to operate the system as efficient as possible, considering bicycle parking space. Governmental organisations are expected to request the concession as an efficient system meets their goals, as earlier explained. In the author's view, a concession will be most promising in establishing one or more efficient BSSs at railway stations and is therefore recommended. This organisational model will lead to the most reliable system and highest bicycle parking capacity savings. As the exact division of tasks between the actors in bicycle parking is not formally defined and varies at different railway stations, it is, however, questionable to what extent the mentioned governmental organisations will proactively take the lead in the implementation of an efficient BSS. When an efficient BSS is initiated by a bicycle operator itself it is recommend that parties involved in bicycle parking intervene in the design and operation of the system in order to prevent the system adding bicycles to the number of already parked bicycles at railway stations, hence increasing the need for capacity and decreasing the attractiveness of the combined use of bicycle and train.

It appeared that younger bicycle-train users are in principle more likely to choose a shared bicycle. Therefore, it is advised to aim at cyclists with an age higher than the age of the average bicycle-train user (> 38 years) in the marketing of the efficient BSS. For example, could be focused on the advantages of the more convenient parking (premium parking place and no need to lift the bicycle in top racks), no risk for theft and no need for maintenance. Moreover, it is important to make cyclists understand that they can make a significant contribution to the reduction of bicycle parking pressure by using a shared bicycle and will at the same time experience more convenient parking as a result, as in this study appeared that cyclists who experience more difficulties finding a bicycle parking place at railway stations have a more negative base preference for bicycle sharing.

It is recommended to start with a relatively high tariff for the egress system, for example more than 15 euros per month. This starting tariff creates the possibility to investigate the operation of the system without the need for a large buffer of shared bicycles. When the supply of access bicycles appears to be sufficient to facilitate a larger demand, prices of the egress systems can be lowered, and total bicycle parking capacity savings will increase. In the future this proposed system might be operating on such large scale that no or limited expansion of bicycle parking facilities is needed in the future and the shared bicycles can be found at almost at every corner of the street. When the market asks for, the system can be expanded to an open urban system (1-way station-based or free floating whether or not in combination with hybrid sharing), as walking times could be limited and accessibility could (almost) be guaranteed because of the large scale of the system.

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Appendices

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The appendices of this thesis provide a total overview of all supplementary information for each research part. Some content is for this reason identical to figures and tables provided in the main thesis.

Appendix A: Study into existing and possible BSSs

A.1. Main characteristics of BSSs

Categorisation and explanation of five main characteristics of BSSs based on APPM & The New Drive (2017).

1. Accessibility

- Open systems: accessible for (almost) everyone
- Closed systems: accessible for specific groups only (e.g. corporate, tourism-related, users of a hotel or students)

2. Registration

- Registration before each use.
  The user has to register and show identification. This type mainly includes traditional rental bicycles.
- One-off registration.
  After one registration the system can be used multiple times over a larger period by a card or mobile phone

3. Return options

- 2-way station-based: Back-2-one (B21).
  A bicycle must normally be returned to the original pick-up location.
- 1-way station-based: Back-2-many (B2M).
  A bicycle can be returned at different locations without additional costs. In this type of BSS two different types of stations can be distinguished:
  - Docked stations: bicycles are parked in physical parking racks.
  - Geofenced stations: bicycles are parked in specified intangible parking places defined by GPS coordinates.
- Free Floating (FF)
  A bicycle can be dropped at any location (in a logical defined geographical area). This type of BSS is made possible by GPS technology in a bicycle (or lock).

The last two types of systems require a lot of effort in organisation as the bicycles must be relocated regularly among the area of use.

4. Number of locations

Different rental types / networks:

- One single location. Mainly traditional bicycle rental with one pick-up and return location.
- A limited number of multiple spread locations.
- A large number of locations with high density. Mainly urban BSSs.

5. Type of locations

A network can consist out of several different type of locations. Although one product is often aiming at one specific type of location:

- Inner-city locations
- Touristic hotpots
- Public transport stops/hubs
- Transferia at the edge of the city
- Business parks

A.2. BSS characterisation

	Corporate	Closed Park & Bike	Peer-to-peer	Bike subscription (hybrid sharing)	Traditional	Open PT systems incl. Park & Bike	Open urban systems	
	1-way and 2-way station-based	2-way station-based	Peer-to-peer	Lease (hybrid sharing)	2-way station-based	2-way station-based	1-way station-based/ geo-hub based	Free floating
Accessibility	Closed	Closed	Open	Open	Open and occasional	Open	Open	Open
Registration	Via company	One-off / every use	One-off / every use	One-off	Every use	One-off	One-off	One-off
Return options	B21 (/ B2M)	B21	B21	-	B21	B21 (/B2M)	B2M	FF
Network	Small scale	Small scale	Small scale	-	One location	Large scale / spread	Large scale / high dense	Large scale / high dense
Locations	Company / PT node	Transferia / PT node	Urban	-	Urban	PT node	Urban	Urban
Use	Activity end / Main mode	Activity end	Main mode	Activity end / Main mode / Home end	Activity end / Main mode	Activity end	Activity end / Main mode / Home end	Activity end / Main mode / Home end
Target groups	Employees	Commuters	Tourists / visitors	Students / other inhabitants	Tourists / visitors	Business people / visitors / tourists	Business people / visitors / tourists / inhabitants	Visitors / tourists / inhabitants

Closed systems ⟷ Open systems

Figure 32: Overview of different bicycle sharing system designs and their most distinctive characteristics

A.3. BSSs tariffs

Table 19: Overview of user tariffs of different existing BSSs in the Netherlands (tariffs derived on 04-12-2017)

Operator	Type	Actual price [€]	Time	Additional conditions
oBike	Free floating	0.25	15 min	€ 79 security deposit (€49 for students)
Mobike	Free floating	0.5	30 min	
Gobike	1-way station-based	0.03	1 min	€15 membership fee, parking 0,01 €/min
Donkey Republic (Amsterdam)	2-way station-based	0.75	30 min	Return the bicycle at other stations costs €3
		5.1	720 min	Return the bicycle at other stations costs €3
		10/15*	Month **	* €10 for a commuter / €15 for a city tripper, ** only 12 hours a day, return the bicycle at other stations costs €3
Donkey Republic (Rotterdam)	2-way station-based	0.88	30 min	Return the bicycle at other stations costs €1
		5.95	720 min	Return the bicycle at other stations costs €1
		9	Month **	** only 12 hours a day, return the bicycle at other stations costs €1
Hello-Bike	geo-hub based (1-way)	1	60 min	
		4	720	
		6	day	
Hoppers	1-way station-based	8	day	
OV-fiets	2-way station-based	3.85	day	

Table 20: Overview of user tariffs of different existing BSSs in the Netherlands, converted

Operator	Type	Tariff for 30 min	Tariff for 60 min	Tariff per day [on the basis of 12 hours]	Tariff per month [on the basis of 5 days a week, 12 hours a day]
oBike	Free floating	0.5	1	12	240
Mobike	Free floating	0.5	1	12	240
Gobike	1-way station-based	0.9	1.8	21.6	432
Donkey Republic (Amsterdam)	2-way station-based	0.75	1.5	5.1	10/15
Donkey Republic (Rotterdam)	2-way station-based	0.88	1.76	5.95	9
Hello-Bike	geo-hub based (1-way)	1	1	6	120
Hoppers	1-way station-based			8	160
OV-fiets	2-way station-based			3.85	77

Appendix B: Study into efficient BSSs

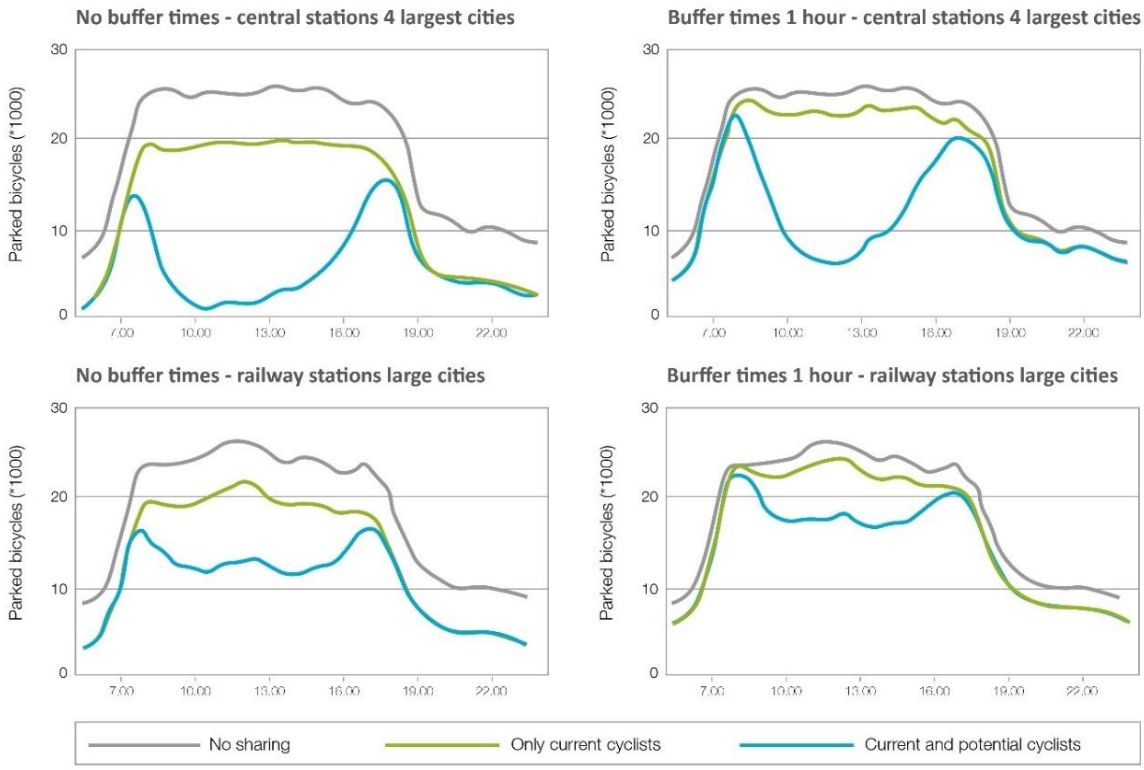


Figure 33: Bicycle parking pressure over time for a sharing systems without buffer times and a sharing system with buffer times of 1 hour, central stations of the four largest cities (top) and other large cities (bottom) (Goeverden & Correia, 2018).

Table 21: Potential capacity reduction for different buffer times (Goeverden & Correia, 2018)

	No buffer times	No buffer time before use, 0.5 hour buffer time after use	Buffer times 0.5 hour	Buffer times 1 hour
Whole Netherlands				
Sharing between current cyclists	20-20%	19-20%	17-19%	12-13%
Sharing between current and potential cyclists	46-51%	43-46%	34-37%	23-25%
Central stations of the four largest cities				
Sharing between current cyclists	22-25%	19-24%	14-21%	6-10%
Sharing between current and potential cyclists	40-47%	35-39%	25-34%	11-15%
Central stations of other large cities				
Sharing between current cyclists	19-29%	15-26%	13-22%	8-16%
Sharing between current and potential cyclists	37-50%	30-43%	24-35%	15-23%

Appendix C: Literature review on influencing factors

Table 22: Literature review on work studying factors influencing shared bicycle use

	Title and author(s) of the study	Study location	Methodologies employed	Main findings
1	Are Bikeshare Users Different from Regular Cyclists? (Buck et al., 2013).	Washington DC region (USA)	*Data type:* User and member survey *Modelling type: statistical analysis*	Users and members of the studied BSS are more likely to be women, to be younger, to have lower incomes and to make utilitarian trips in comparison with regular area cyclists. In addition they tend to be less likely to own a bicycle.
2	Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use (Bachand-Marleau et al., 2012)	Montreal (Canada)	*Data type:* Revealed preference data *Modelling type*: Binary logistic regression model	A closer proximity to and a higher number of stations will generate more users. Proximity of stations to origins is more important than to destinations. Person whose bicycle have been stolen or persons that are more concerned about bicycle theft are more likely to use shared bicycles. Persons who liked the design of shared bicycles tended to use the system more often.
3	Barriers to bikesharing: An analysis from Melbourne and Brisbane (Fishman, Washington, Haworth, & Mazzei, 2014).	Brisbane and Melbourne (Australia)	*Data type:* User survey data, census data *Modelling type:* Focus groups, spatial analysis, factor analysis	The key motivator for current bikeshare members to become members is convenience (of bicycle sharing). This is for example the presence of docking stations, which will incline people to use shared bicycles.
4	Factors influencing bike share membership: An analysis of Melbourne and Brisbane (Fishman, Washington, Haworth, & Watson, 2014).	Brisbane and Melbourne (Australia)	*Data type:* Revealed preference data *Modelling type:* Logistic regression model	The distance to the closes bicycle docking station have been found to be an important predictor of membership. Also persons with higher incomes are more likely to be users of shared bicycles (which is also due to the positions of the stations in areas with higher incomes).
5	Bicycle sharing system ‘success’ determinants (Médard de Chardon et al., 2017)	Cities worldwide (predominantly Europe and USA)	*Data type:* BSS usage data and GIS data *Modelling type:* Iterative mixed regression model	The density of stations has been found to be an important factor in increasing performance of a BSS. I.e. having many small stations is more important than having a few larger stations.
6	The Role of Bicycle-sharing in the City: Analysis of the Irish	Dublin (Ireland)	*Data type:* User survey data	Users of Dublin’s BSS are found to be young males with a middle or upper middle

	Experience (Murphy & Usher, 2015)		*Modelling type:* Statistical analysis (chi square tests)	income. Users had different trip purposes: leisure and retailing trips (mainly during the off-peak period) as well as work-related trips (mainly during the peak period).
7	Public Bikesharing in North America: Early Operator and User Understanding (Susan A. Shaheen et al., 2012).	North America	*Data type:* User survey data *Modelling type:* Statistical analysis	Most shared bicycle users are younger than 34 years of age (60%), highly educated (85%) and had a at least a bachelor's degree. User's trip purposes varied across different cities, but most trips were work or school related trips.
8	Exploring the Design of Urban Bike Sharing Systems Intended for Commuters in The Netherlands (H Heijningen, 2016)	The Netherlands	*Data type:* Stated preference data *Modelling type:* Mixed logit model	Trip cost is the most important attribute influencing in the choice to use a shared bicycle for commuting. Other important factors have been found to be bicycle type (electrical versus traditional), trip distance and education. A traditional bicycle is preferred for shorter distance trips while an electrical bicycle is preferred for trip with distances of over 4.5 kilometres.
9	Investigating the factors influencing the use of public bike sharing schemes for the last mile travel in Belgium (Altaf, 2017).	Flanders (Belgium)	*Data type: Stated preference data* *Modelling type:* Binary logistic regression model	Cost have been found to be the most important factor in public bicycle use. Higher educated persons are more inclined to use a shared bicycle, while trip purpose is of no importance. In this study also have been found that more available parking at destination has a positive influence on shared bicycle use.
10	Analysis of Preferences for the Use of a Bicycling Sharing System in Athens (Yannis et al., 2015)	Athens (Greece)	*Data type:* stated preference data *Modelling type:* logistic regression model, multinomial and mixed logit models	The main influencing factors in the probability for using shared bicycles in Athens have been found to be (a decreased) travel time, cost and comfort. Age and gender are traveller's characteristics that will influence the choice. Men and people between 18-24 are more likely to choose to use a shared bicycle.

Appendix D: Brainstorm session

Figure 34 shows the results of a brainstorm session on influencing factors with Hélène van Heijningen and Lennart Nout, two experts in the field of bicycle sharing. The factors are categorised by variable type.

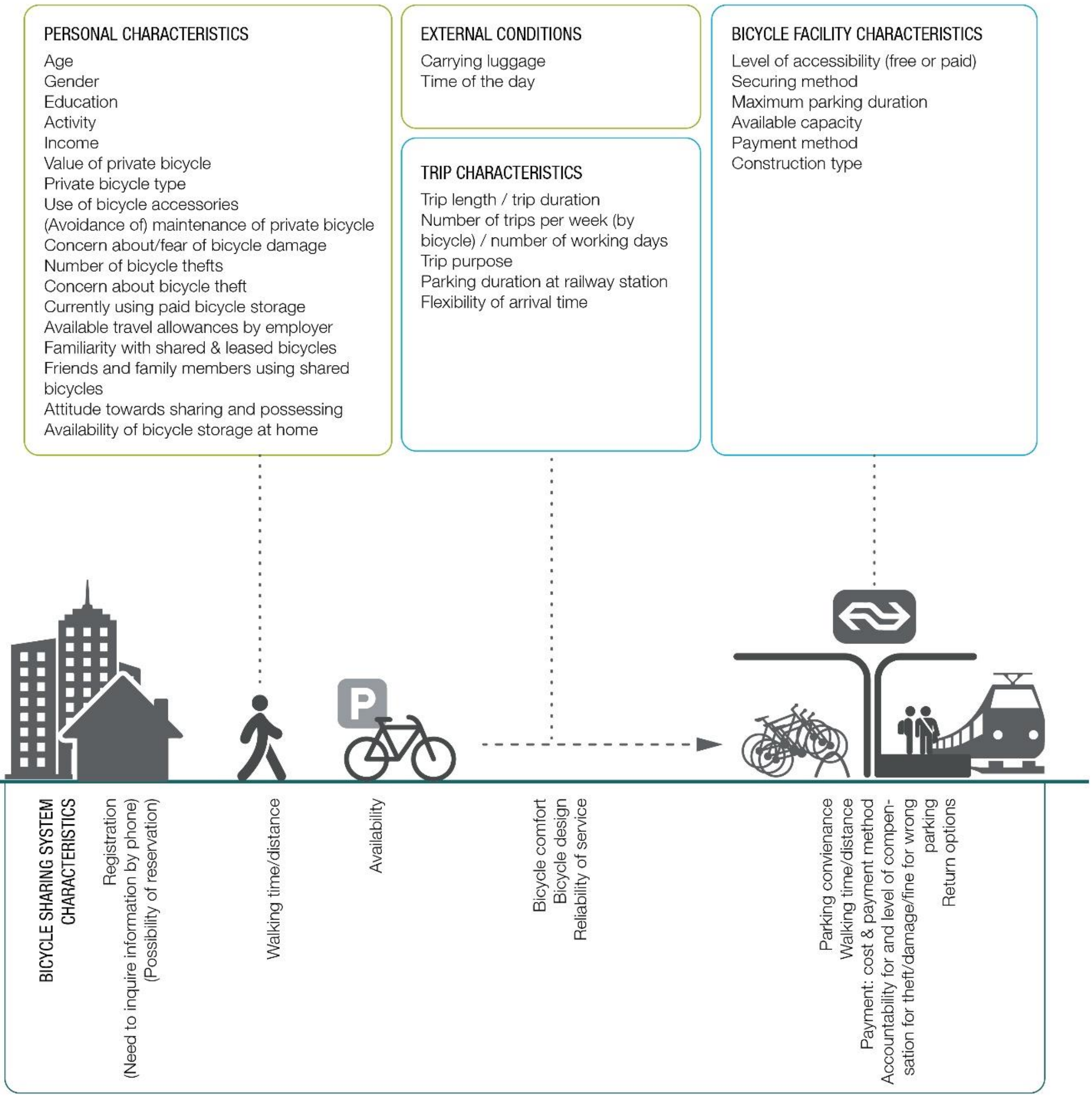


Figure 34: Overview of all possible factors influencing shared bicycle use among current cyclists

Appendix E: Multi Criteria Analysis

The table below presents the criteria and values for the assessment of factors possibly influencing the choice between using a shared or private bicycle by current cyclists.

Table 23: Criteria and values to derive most important factors

Criterion	Value explanation	Value
Expected influence on shared bicycle use by current cyclists	Rating from low to high	1 to 4
Measurability with a survey and stated choice experiment	Yes, measurable	+
	Hardly measurable	+/-
	No, not measurable	-
Manageability by government or BSS operator	Yes, manageable	+
	Yes, manageable but challenging	+/-
	No, not manageable	-

Factors are selected when:
Influence > 2 AND measurability > + AND manageability > +/-

In the final selection for the survey also socio-demographic and trip characteristics are included.

Table 24: Assessment of factors

	Influence		Measurability	Manageability by government or BSS operator	Selection based on MCA	Included in survey
	Expected influence	Type of relationship				
EXOGENEOUS VARIABLES						
User characteristics						
Age	2	0	+	-		
Gender	2	N/A	+	-		
Education	2	0	+	-		
Activity	2	N/A	+	-		
Income	2	+	+	-		
Value of private bicycle	1	0	+	-		
Private bicycle type	2	0	+	-		
Use of bicycle accessories	2	-	+	-		
(Avoidance of) maintenance of private bicycle	2	+	+	-		
Concern about/fear of bicycle damage	2*	+	+/-	-		
Number of bicycle thefts	2	+	+	-		
Concern about bicycle theft	2*	+	+/-	-		
Currently using paid bicycle storage	1	0	+	-		
Available travel allowances by employer	4	+	+	+/-		
Familiarity with shared & leased bicycles	3	+	+	+/-		
Friends and family members using shared bicycles	2	+	+	-		
Attitude towards sharing and possessing	2	N/A	+/-	-		

Availability of bicycle storage at home / type of bicycle storage at home	1	-	+	-
Trip characteristics				
Trip length / trip duration	3	-	+	-
Number of trips per week (by bicycle) / number of working days	2	0	+	-
Trip purpose	1	N/A	+	-
Parking duration at railway station	2	+		
Flexibility of arrival time	4	+	-	-
CONTEXT FACTORS				
External conditions				
Carrying luggage	1	-	+/-	-
Time of day	1	0	+/-	-
Bicycle facility characteristics				
Level of accessibility (free or paid)	3	N/A	+	+
Securing method	2	-	+	+
Maximum parking duration	3*	-	+	+
Available capacity	3	-	+/-	+
Payment method	2	N/A	+	+
Construction type	1	N/A	+	+
ATTRIBUTES				
Bicycle sharing system characteristics				
Bicycle comfort	3	+	+/-	+
Bicycle design	3	0	+/-	+
Return options	2	+	+	+
Registration	1	-	+	+
Payment method	1	+	+	+
Price	4	-	+	+
Walking time/ walking distance at trip start	4	-	+	+/-
Walking time/ walking distance at trip end	4	-	+	+/-
Parking convenience	4	+	+	+
Bicycle availability at trip start	4	+	+	+/-
Bicycle availability at trip end	4	+	+	+/-
Reliability of service	4	+	+/-	+/-
Possibility of reservation	2	+	+	+
Need to inquire information by phone application	2	-	+/-	+
Accountability for and level of compensation for theft/damage/fine for wrong parking	1	-	+/-	+

N/A.: not applicable

Appendix F: SP survey

F.1. Experimental design

Table 25: Orthogonal design: used columns of fold-over design of basic plan 3

choiceset	1*	2*	3*	4*	13	15
1	0	0	0	0	0	0
2	0	1	1	2	1	0
3	0	2	2	3	0	1
4	0	3	3	1	1	1
5	1	0	1	1	0	1
6	1	1	0	3	1	1
7	1	2	3	2	0	0
8	1	3	2	0	1	0
9	2	0	2	2	1	1
10	2	1	3	0	0	1
11	2	2	0	1	1	0
12	2	3	1	3	0	0
13	3	0	3	3	1	0
14	3	1	2	1	0	0
15	3	2	1	0	1	1
16	3	3	0	2	0	1
17	3	3	3	3	1	2
18	3	2	2	1	0	2
19	3	1	1	0	1	3
20	3	0	0	2	0	3
21	2	3	2	2	1	3
22	2	2	3	0	0	3
23	2	1	0	1	1	2
24	2	0	1	3	0	2
25	1	3	1	1	0	3
26	1	2	0	3	1	3
27	1	1	3	2	0	2
28	1	0	2	0	1	2
29	0	3	0	0	0	2
30	0	2	1	2	1	2
31	0	1	2	3	0	3
32	0	0	3	1	1	3

Table 26: Attributes and their levels in relation to the used basic plan

	Levels	Coding	Column
Accessibility at home / at destination	Mostly in 2 mins, always in 6 mins	0	1*
	Mostly in 2 mins, always in 4 mins	1	
	Always in 2 mins	2	
	Guaranteed at front door	3	
Walking time to home / to destination	0 mins	0	2*
	1 mins	1	
	2 mins	2	
	3 mins	3	
Parking convenience	Self search for parking place	0	13
	Premium parking place near platform	1	
Accessibility at railway station	Mostly in 2 mins, always in 6 mins	0	3*
	Mostly in 2 mins, always in 4 mins	1	
	Always in 2 mins	2	
	Direct available for use	3	
Price	Free of charge	0	4*
	6 €/month (0.30 €/single trip)	1	
	12 €/month (0.60 €/single trip)	2	
	18 €/month (0.90 €/single trip)	3	

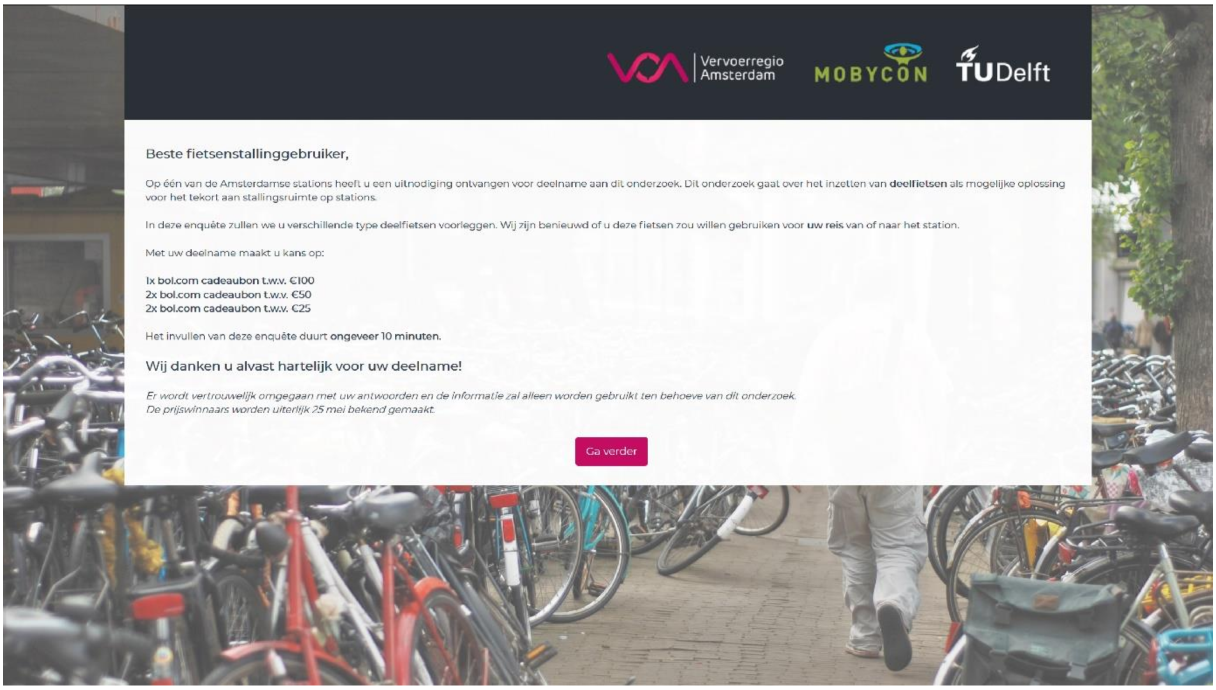
Table 27: Final experimental design

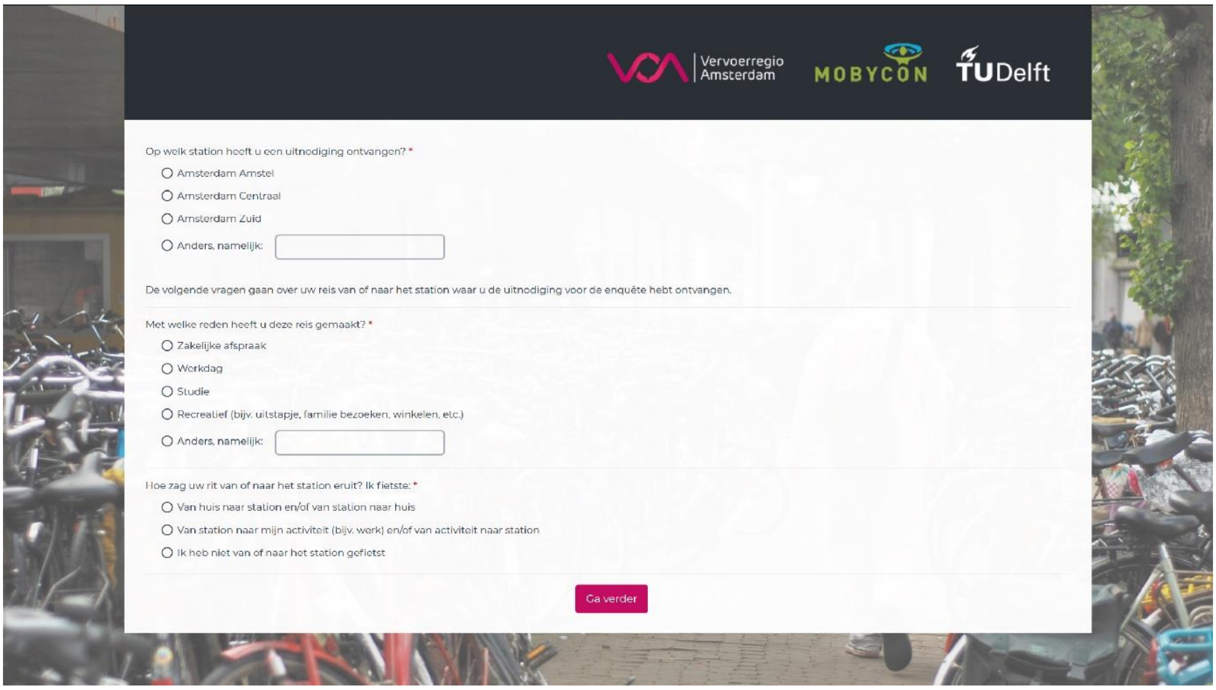
Shared bicycle 1								Shared bicycle 2							
Choice set	row	access hd	parking	walking	access st	price	block	**Choice set**	row	access hd	parking	walking	access st	price	block
1	13	3	1	0	3	3	0	**1**	8	1	1	3	2	0	0
2	1	0	0	0	0	0	0	**2**	13	3	1	0	3	3	0
3	11	2	1	2	0	1	0	**3**	14	3	0	1	2	1	0
4	8	1	1	3	2	0	0	**4**	7	1	0	2	3	2	0
5	14	3	0	1	2	1	0	**5**	2	0	1	1	1	2	0
6	7	1	0	2	3	2	0	**6**	12	2	0	3	1	3	0
7	2	0	1	1	1	2	0	**7**	1	0	0	0	0	0	0
8	12	2	0	3	1	3	0	**8**	11	2	1	2	0	1	0
9	4	0	1	3	3	1	1	**9**	5	1	0	0	1	1	1
10	9	2	1	0	2	2	1	**10**	10	2	0	1	3	0	1
11	6	1	1	1	0	3	1	**11**	16	3	0	3	0	2	1
12	16	3	0	3	0	2	1	**12**	4	0	1	3	3	1	1
13	10	2	0	1	3	0	1	**13**	6	1	1	1	0	3	1
14	5	1	0	0	1	1	1	**14**	3	0	0	2	2	3	1
15	15	3	1	2	1	0	1	**15**	9	2	1	0	2	2	1
16	3	0	0	2	2	3	1	**16**	15	3	1	2	1	0	1
17	17	3	1	3	3	3	2	**17**	30	0	1	2	1	2	2
18	18	3	0	2	2	1	2	**18**	24	2	0	0	1	3	2
19	23	2	1	1	0	1	2	**19**	17	3	1	3	3	3	2
20	24	2	0	0	1	3	2	**20**	28	1	1	0	2	0	2
21	27	1	0	1	3	2	2	**21**	18	3	0	2	2	1	2
22	28	1	1	0	2	0	2	**22**	27	1	0	1	3	2	2
23	29	0	0	3	0	0	2	**23**	23	2	1	1	0	1	2
24	30	0	1	2	1	2	2	**24**	29	0	0	3	0	0	2
25	19	3	1	1	1	0	3	**25**	32	0	1	0	3	1	3
26	20	3	0	0	0	2	3	**26**	21	2	1	3	2	2	3
27	21	2	1	3	2	2	3	**27**	26	1	1	2	0	3	3
28	31	0	0	1	2	3	3	**28**	25	1	0	3	1	1	3
29	26	1	1	2	0	3	3	**29**	20	3	0	0	0	2	3
30	25	1	0	3	1	1	3	**30**	31	0	0	1	2	3	3
31	22	2	0	2	3	0	3	**31**	19	3	1	1	1	0	3
32	32	0	1	0	3	1	3	**32**	22	2	0	2	3	0	3

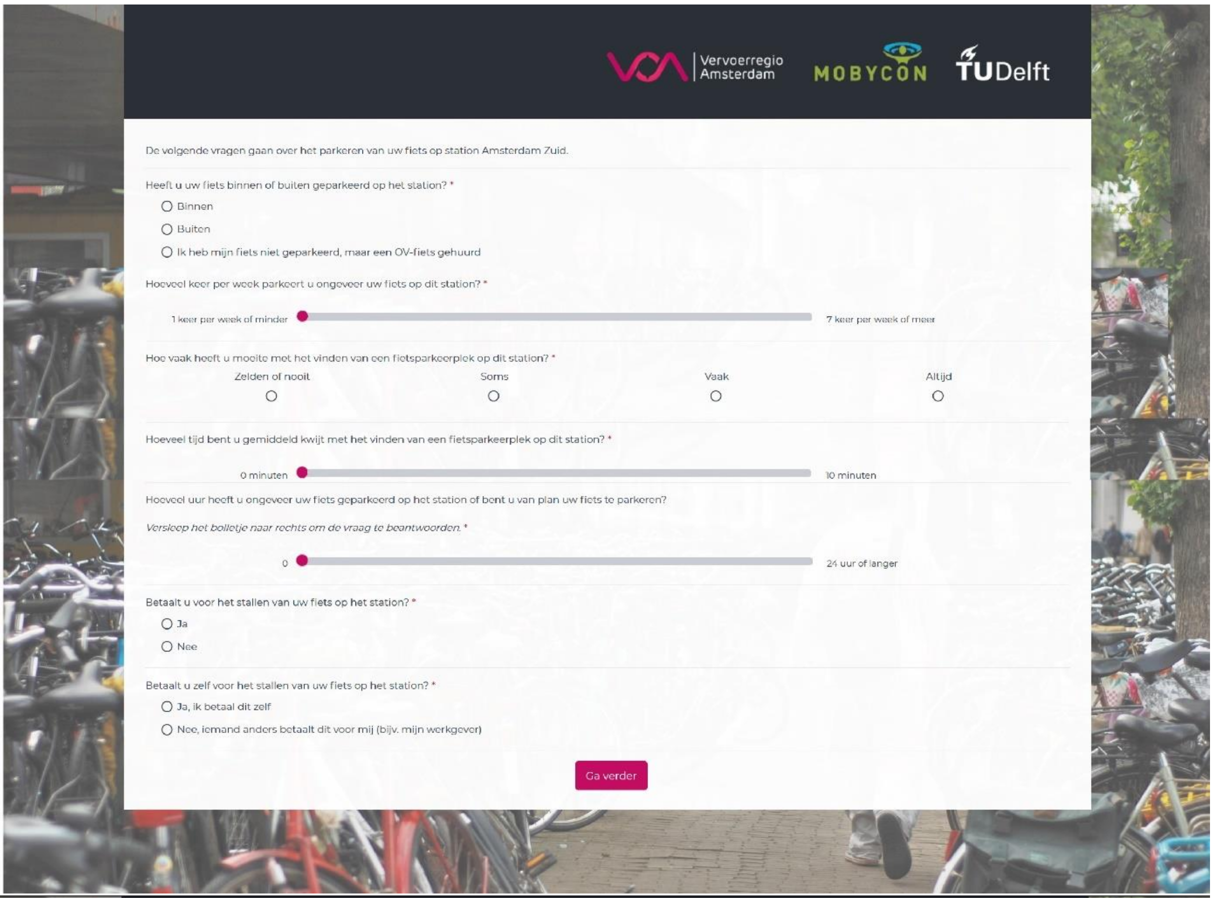
F.2. Invitation flyer

-

F.3. Web survey







De volgende vragen gaan over het parkeren van uw fiets op station Amsterdam Zuid.

Heeft u uw fiets binnen of buiten geparkeerd op het station? *

- Binnen
- Buiten
- Ik heb mijn fiets niet geparkeerd, maar een OV-fiets gehuurd

Hoeveel keer per week parkeert u ongeveer uw fiets op dit station? *

1 keer per week of minder — 7 keer per week of meer

Hoe vaak heeft u moeite met het vinden van een fietsparkeerplek op dit station? *

Zelden of nooit | Soms | Vaak | Altijd

Hoeveel tijd bent u gemiddeld kwijt met het vinden van een fietsparkeerplek op dit station? *

0 minuten — 10 minuten

Hoeveel uur heeft u ongeveer uw fiets geparkeerd op het station of bent u van plan uw fiets te parkeren?

Versleep het bolletje naar rechts om de vraag te beantwoorden. *

0 — 24 uur of langer

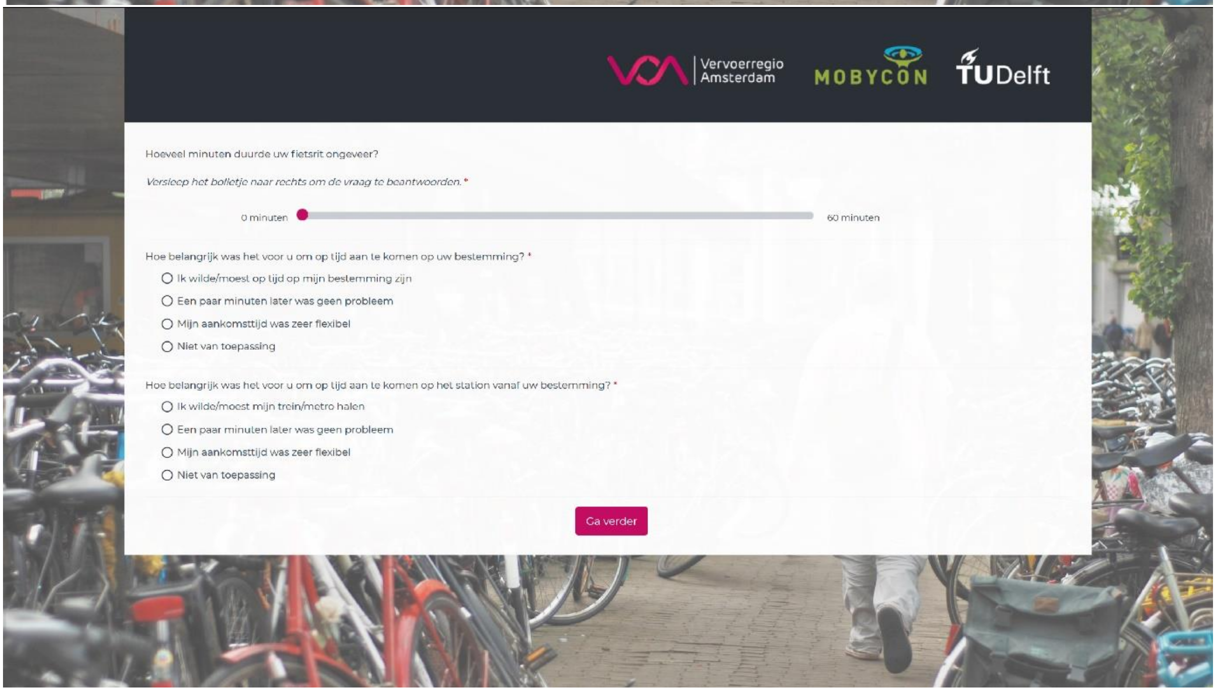
Betaalt u voor het stallen van uw fiets op het station? *

- Ja
- Nee

Betaalt u zelf voor het stallen van uw fiets op het station? *

- Ja, ik betaal dit zelf
- Nee, iemand anders betaalt dit voor mij (bijv. mijn werkgever)

Ga verder



Hoeveel minuten duurde uw fietsrit ongeveer?

Versleep het bolletje naar rechts om de vraag te beantwoorden. *

0 minuten — 60 minuten

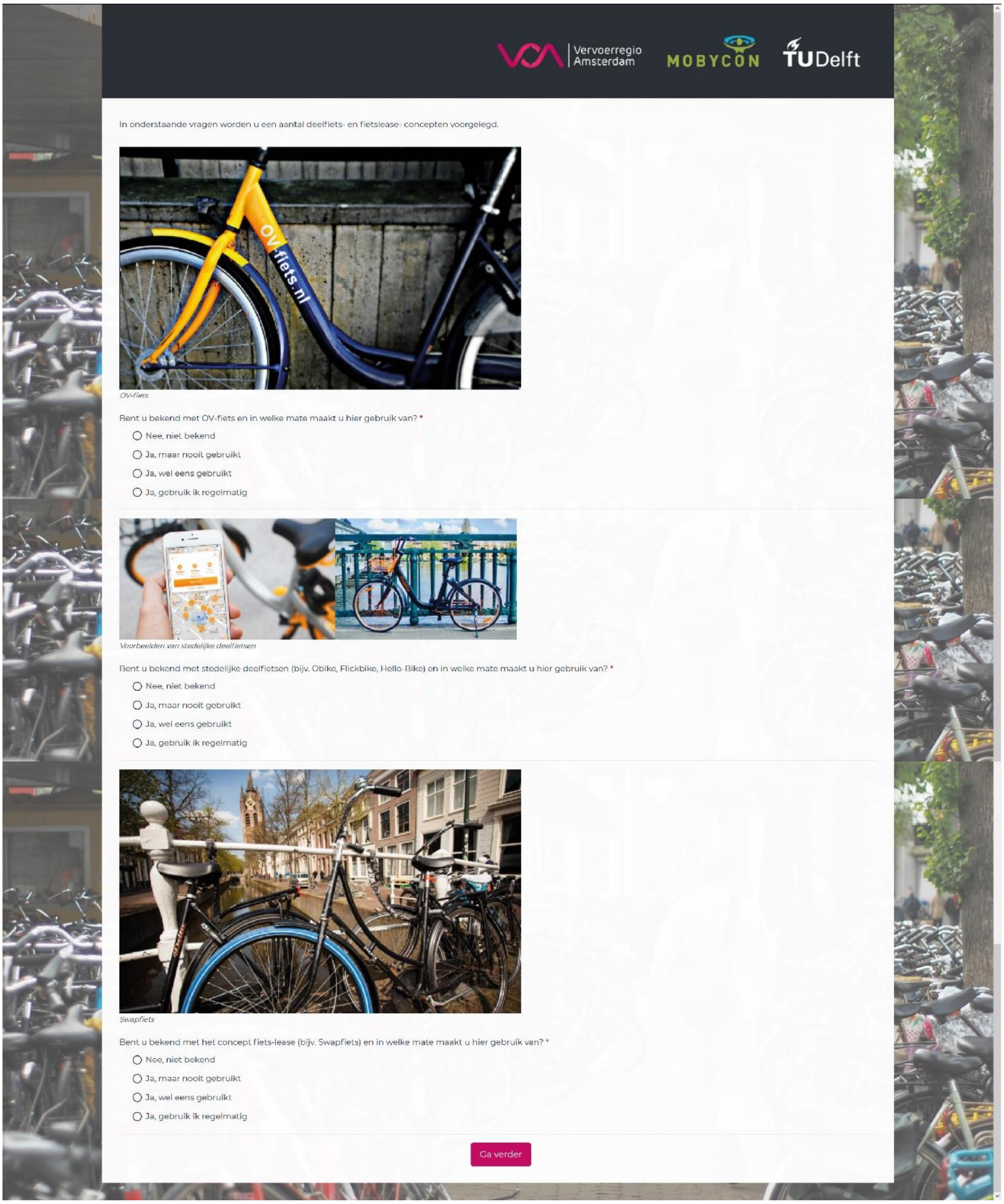
Hoe belangrijk was het voor u om op tijd aan te komen op uw bestemming? *

- Ik wilde/moest op tijd op mijn bestemming zijn
- Een paar minuten later was geen probleem
- Mijn aankomsttijd was zeer flexibel
- Niet van toepassing

Hoe belangrijk was het voor u om op tijd aan te komen op het station vanaf uw bestemming? *

- Ik wilde/moest mijn trein/metro halen
- Een paar minuten later was geen probleem
- Mijn aankomsttijd was zeer flexibel
- Niet van toepassing

Ga verder



Vervoerregio Amsterdam MOBYCON TUDelft

In onderstaande vragen worden u een aantal deelfiets- en fietslease- concepten voorgelegd.

OV-fiets

Bent u bekend met OV-fiets en in welke mate maakt u hier gebruik van? *

- Nee, niet bekend
- Ja, maar nooit gebruikt
- Ja, wel eens gebruikt
- Ja, gebruik ik regelmatig

Voorbeelden van stedelijke deelfietsen

Bent u bekend met stedelijke deelfietsen (bijv. Obike, Flickbike, Hello-Bike) en in welke mate maakt u hier gebruik van? *

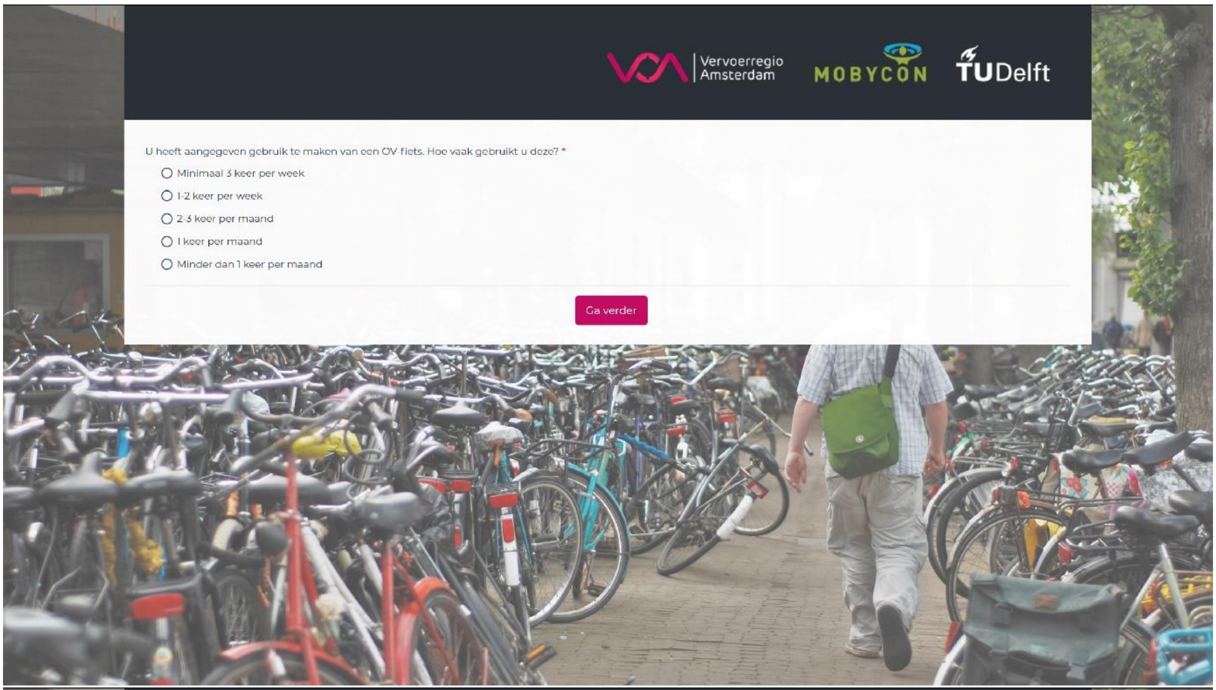
- Nee, niet bekend
- Ja, maar nooit gebruikt
- Ja, wel eens gebruikt
- Ja, gebruik ik regelmatig

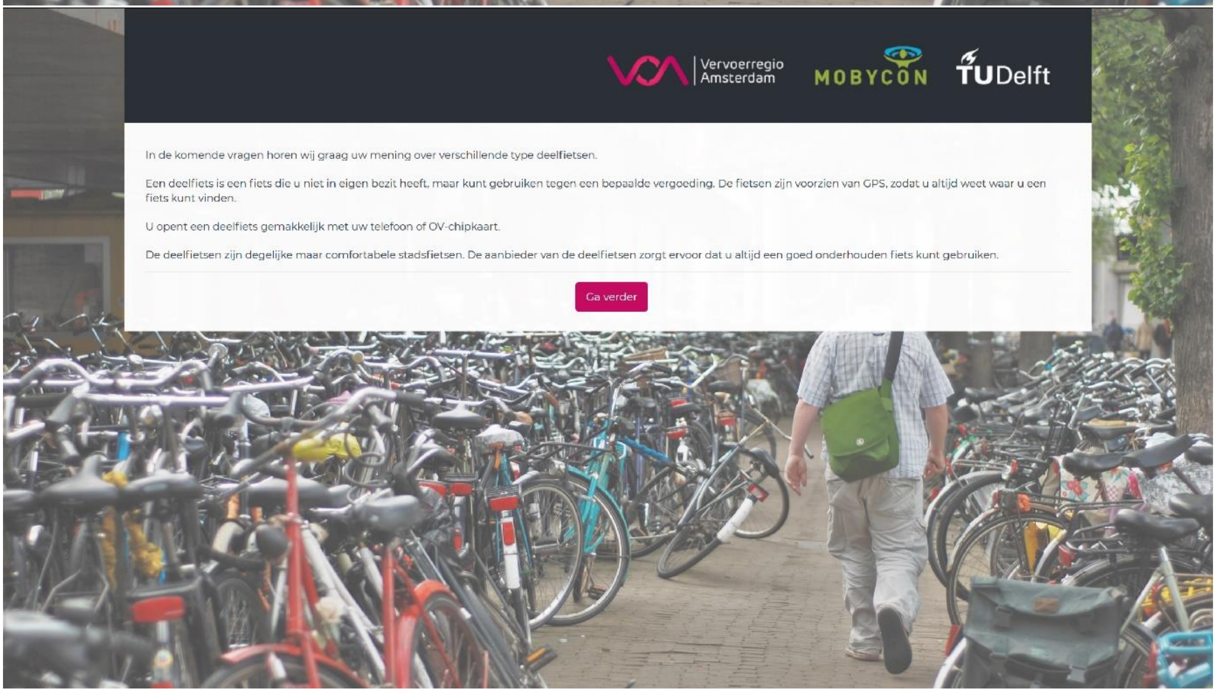
Swapfiets

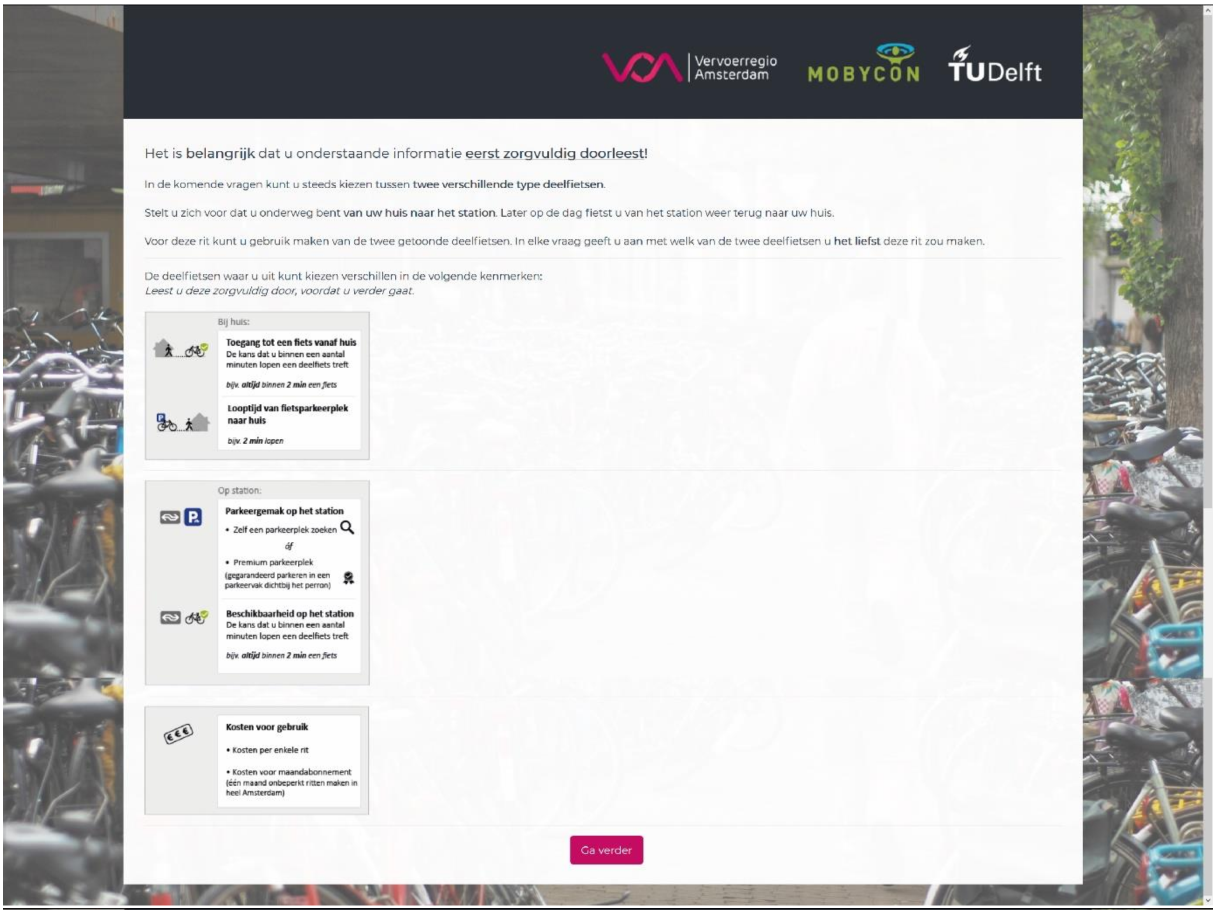
Bent u bekend met het concept fiets-lease (bijv. Swapfiets) en in welke mate maakt u hier gebruik van? *

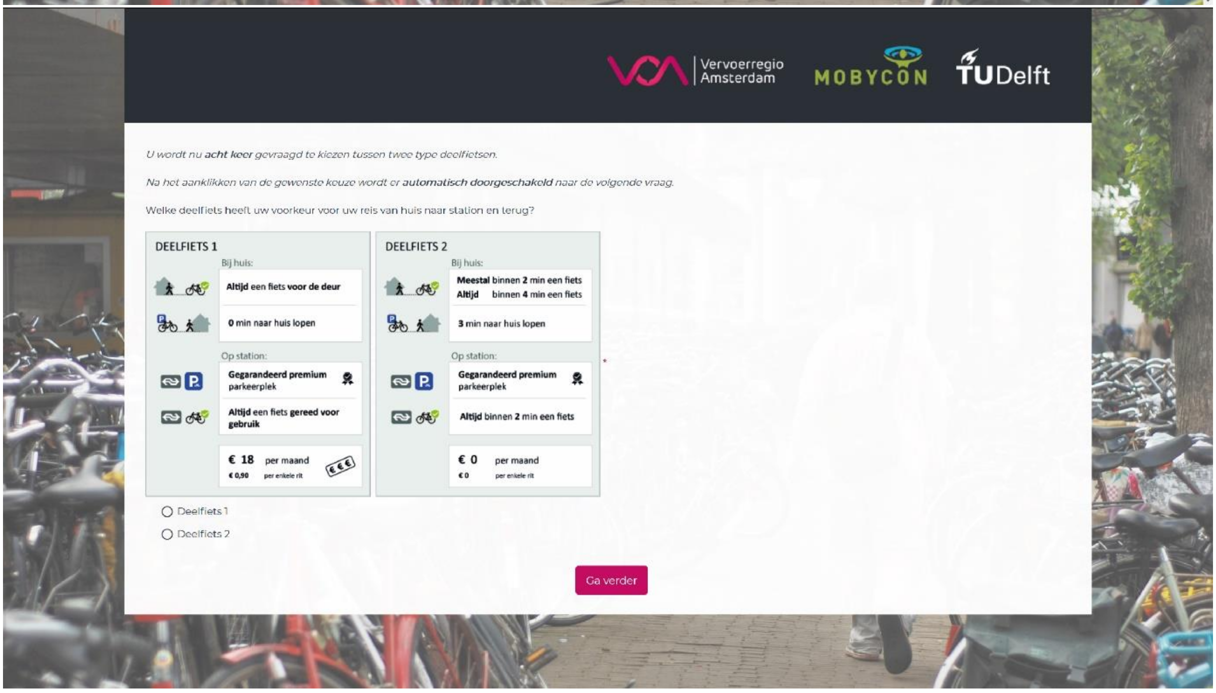
- Nee, niet bekend
- Ja, maar nooit gebruikt
- Ja, wel eens gebruikt
- Ja, gebruik ik regelmatig

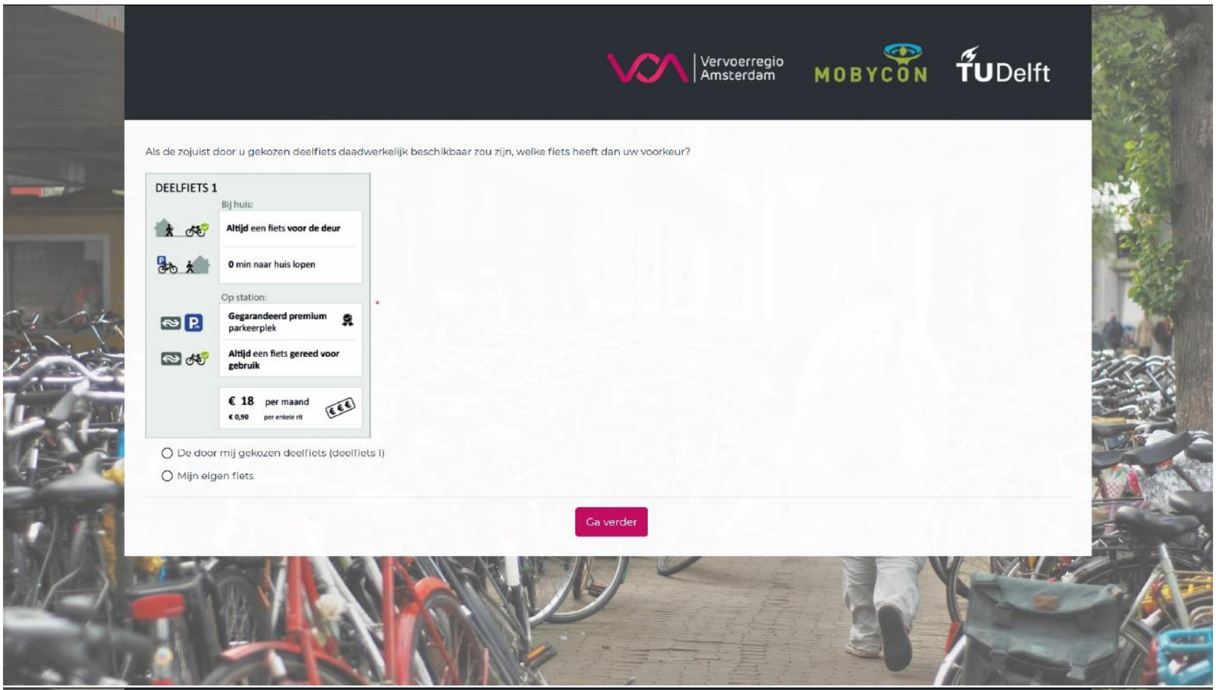
Ga verder

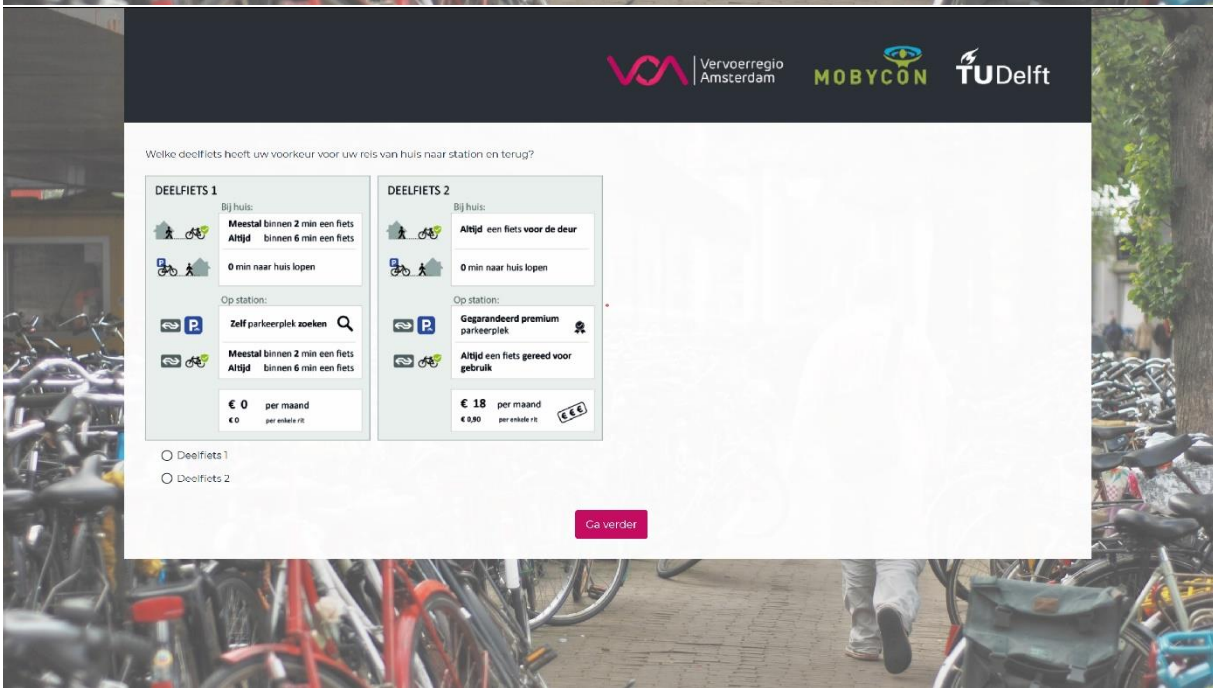

Vervoerregio Amsterdam
MOBYCON
TUDelft
U heeft aangegeven gebruik te maken van een OV fiets. Hoe vaak gebruikt u deze? *
Minimaal 3 keer per week
1-2 keer per week
2-3 keer per maand
1 keer per maand
Minder dan 1 keer per maand
Ga verder

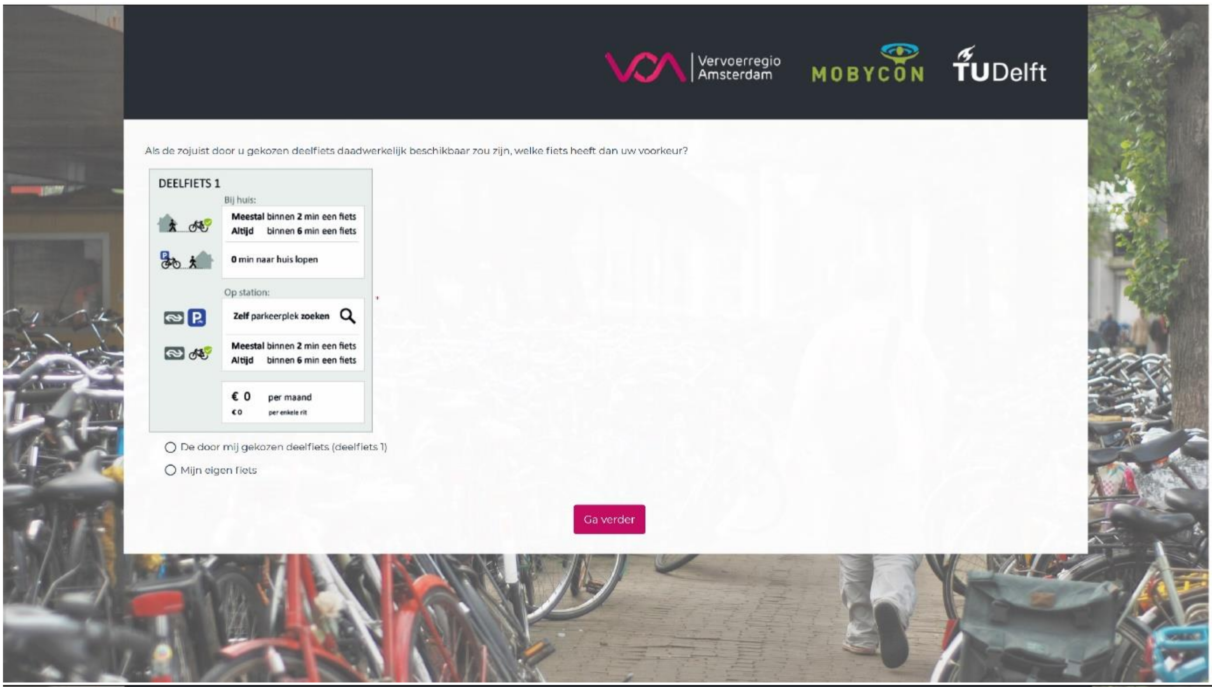

Vervoerregio Amsterdam
MOBYCON
TUDelft
In de komende vragen horen wij graag uw mening over verschillende type deelfietsen.
Een deelfiets is een fiets die u niet in eigen bezit heeft, maar kunt gebruiken tegen een bepaalde vergoeding. De fietsen zijn voorzien van GPS, zodat u altijd weet waar u een fiets kunt vinden.
U opent een deelfiets gemakkelijk met uw telefoon of OV-chipkaart.
De deelfietsen zijn degelijke maar comfortabele stadsfietsen. De aanbieder van de deelfietsen zorgt ervoor dat u altijd een goed onderhouden fiets kunt gebruiken.
Ga verder

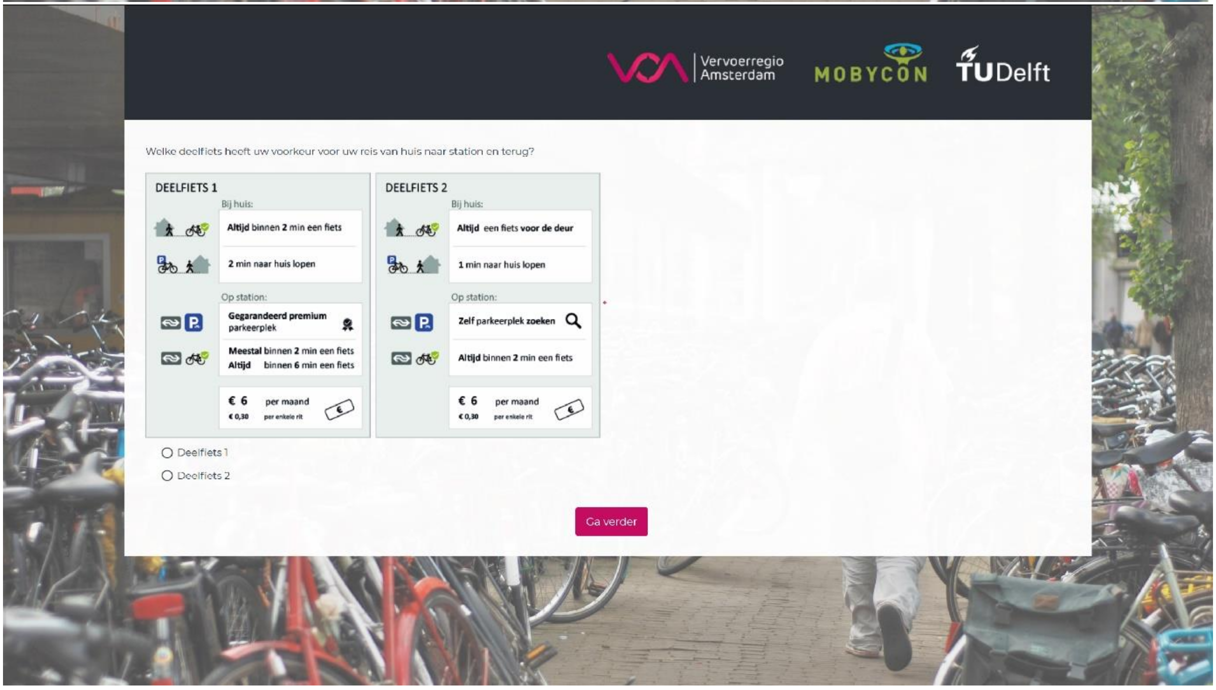

Vervoerregio Amsterdam
MOBYCON
TUDelft
Het is belangrijk dat u onderstaande informatie eerst zorgvuldig doorleest!
In de komende vragen kunt u steeds kiezen tussen twee verschillende type deelfietsen.
Stelt u zich voor dat u onderweg bent van uw huis naar het station. Later op de dag fietst u van het station weer terug naar uw huis.
Voor deze rit kunt u gebruik maken van de twee getoonde deelfietsen. In elke vraag geeft u aan met welk van de twee deelfietsen u het liefst deze rit zou maken.
De deelfietsen waar u uit kunt kiezen verschillen in de volgende kenmerken:
Leest u deze zorgvuldig door, voordat u verder gaat.
Bij huis:
Toegang tot een fiets vanaf huis
De kans dat u binnen een aantal minuten lopen een deelfiets treft
bijv. altijd binnen 2 min een fiets
Looptijd van fietsparkeerplek naar huis
bijv. 2 min lopen
Op station:
Parkeergemak op het station
• Zelf een parkeerplek zoeken
óf
• Premium parkeerplek
(gegarandeerd parkeren in een parkeervak dichtbij het perron)
Beschikbaarheid op het station
De kans dat u binnen een aantal minuten lopen een deelfiets treft
bijv. altijd binnen 2 min een fiets
Kosten voor gebruik
• Kosten per enkele rit
• Kosten voor maandabonnement
(één maand onbeperkt ritten maken in heel Amsterdam)
Ga verder

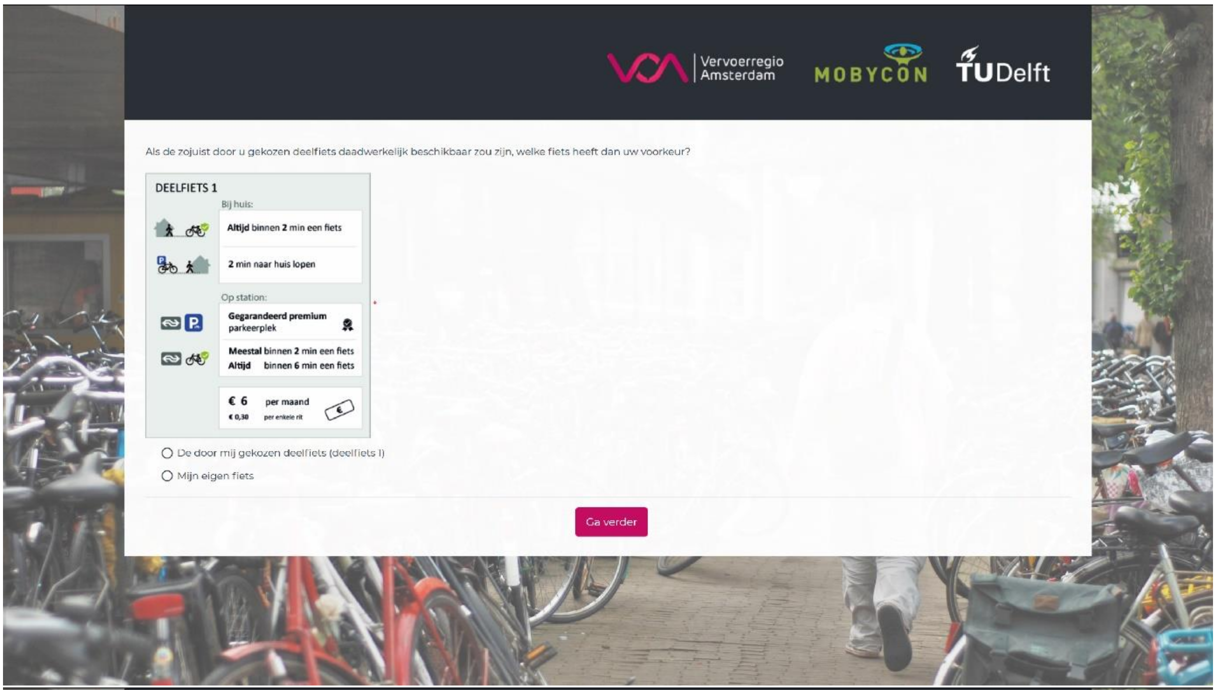

Vervoerregio Amsterdam
MOBYCON
TUDelft
U wordt nu acht keer gevraagd te kiezen tussen twee type deelfietsen.
Na het aanklikken van de gewenste keuze wordt er automatisch doorgeschakeld naar de volgende vraag.
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Altijd een fiets voor de deur
0 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd een fiets gereed voor gebruik
€ 18 per maand
€ 0,90 per enkele rit
DEELFIETS 2
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
3 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd binnen 2 min een fiets
€ 0 per maand
€ 0 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder

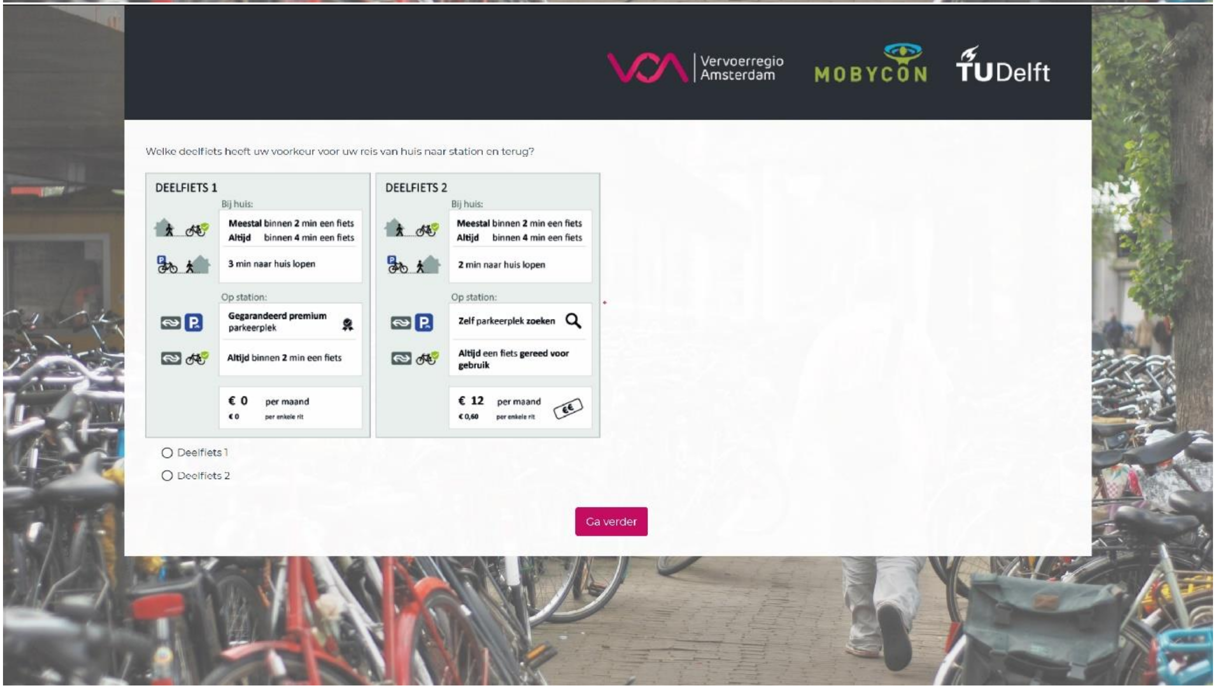

Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de zojuist door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Altijd een fiets voor de deur
0 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd een fiets gereed voor gebruik
€ 18 per maand
€ 0,90 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

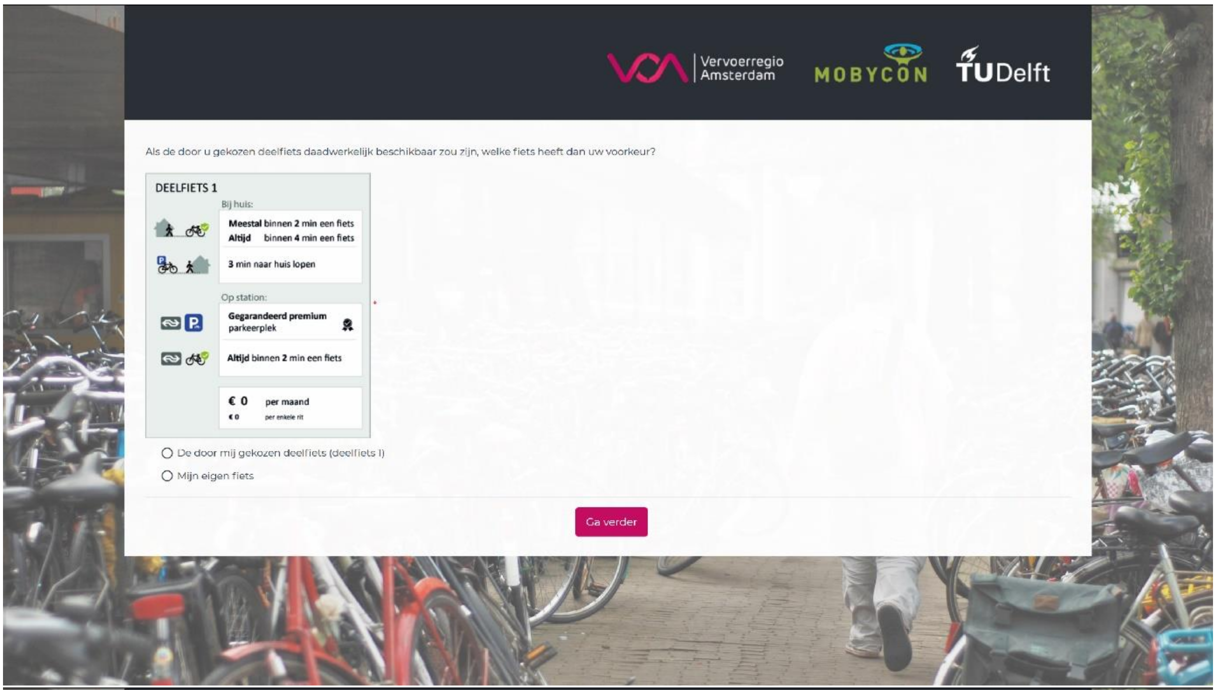

Vervoerregio Amsterdam
MOBYCON
TUDelft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
0 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 0 per maand
€ 0 per enkele rit
DEELFIETS 2
Bij huis:
Altijd een fiets voor de deur
0 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd een fiets gereed voor gebruik
€ 18 per maand
€ 0,90 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder


Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de zojuist door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
0 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 0 per maand
€ 0 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

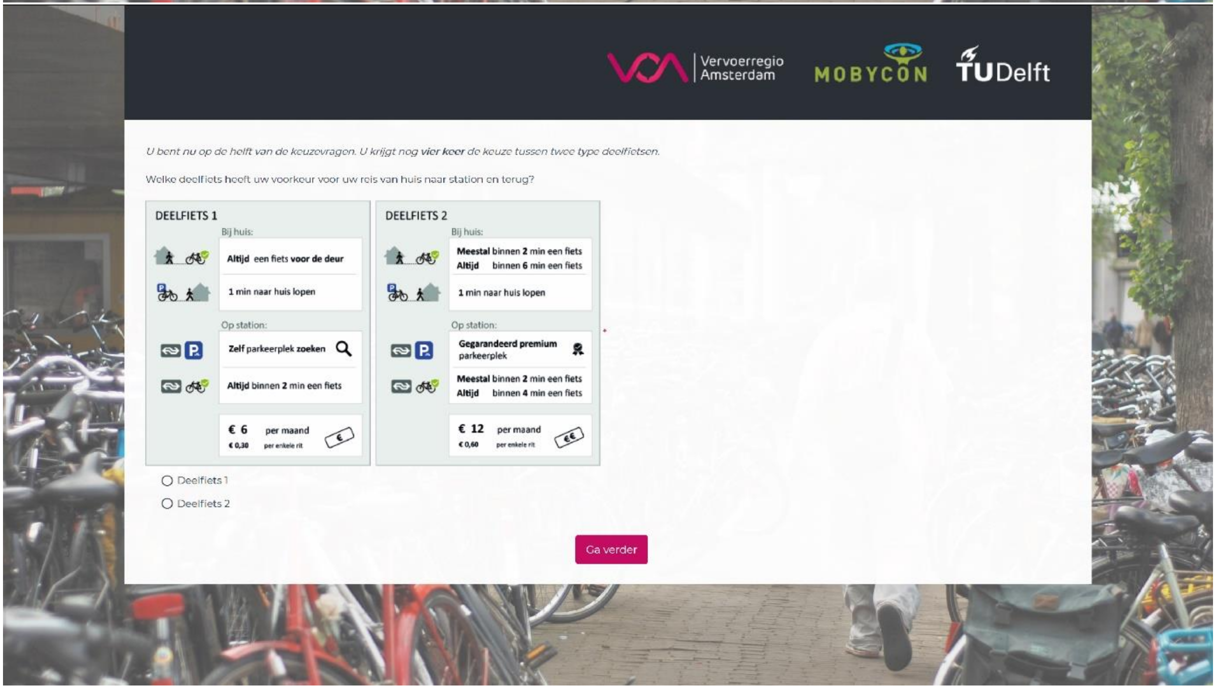

Vervoerregio Amsterdam
MOBYCON
TUDelft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Altijd binnen 2 min een fiets
2 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
DEELFIETS 2
Bij huis:
Altijd een fiets voor de deur
1 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd binnen 2 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder

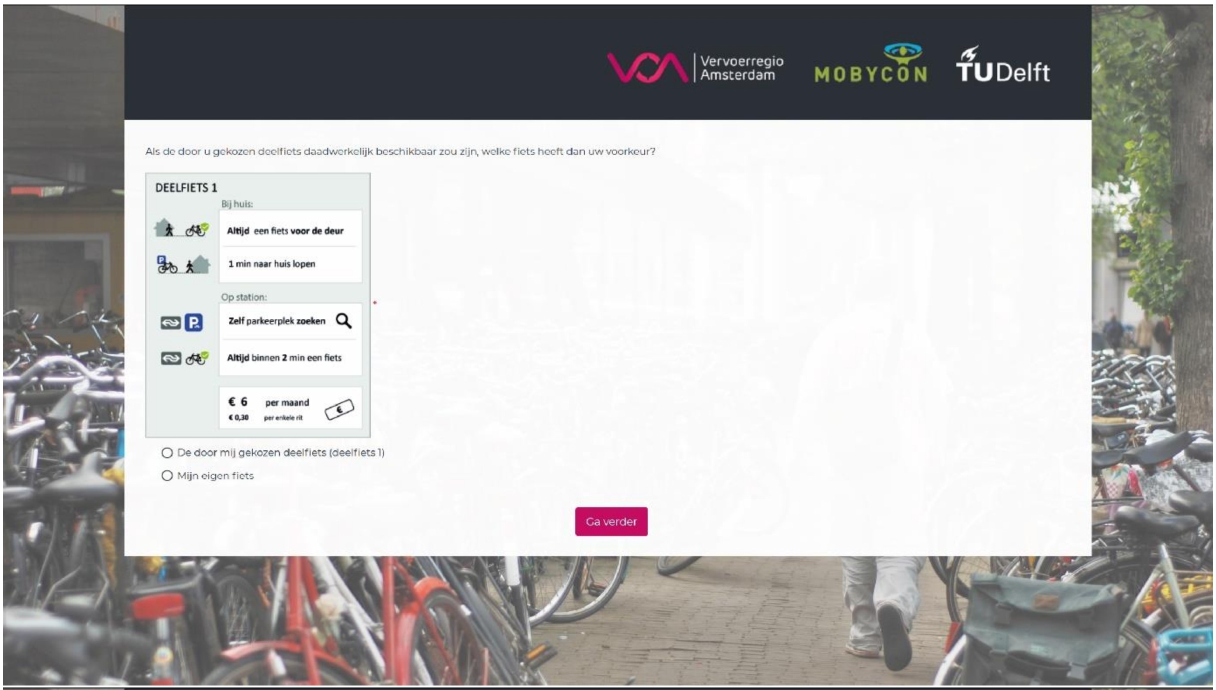

Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de zojuist door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Altijd binnen 2 min een fiets
2 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

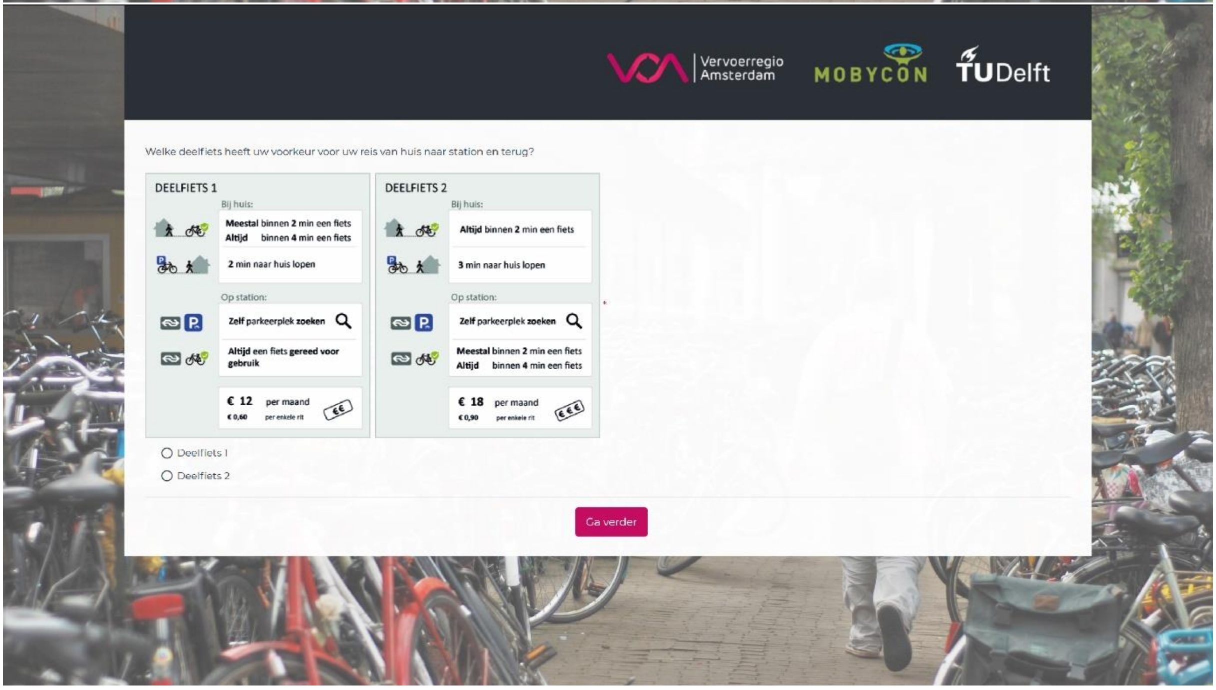

Vervoerregio Amsterdam
MOBYCON
TUDelft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
3 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd binnen 2 min een fiets
€ 0 per maand
€ 0 per enkele rit
DEELFIETS 2
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
2 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd een fiets gereed voor gebruik
€ 12 per maand
€ 0,60 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder

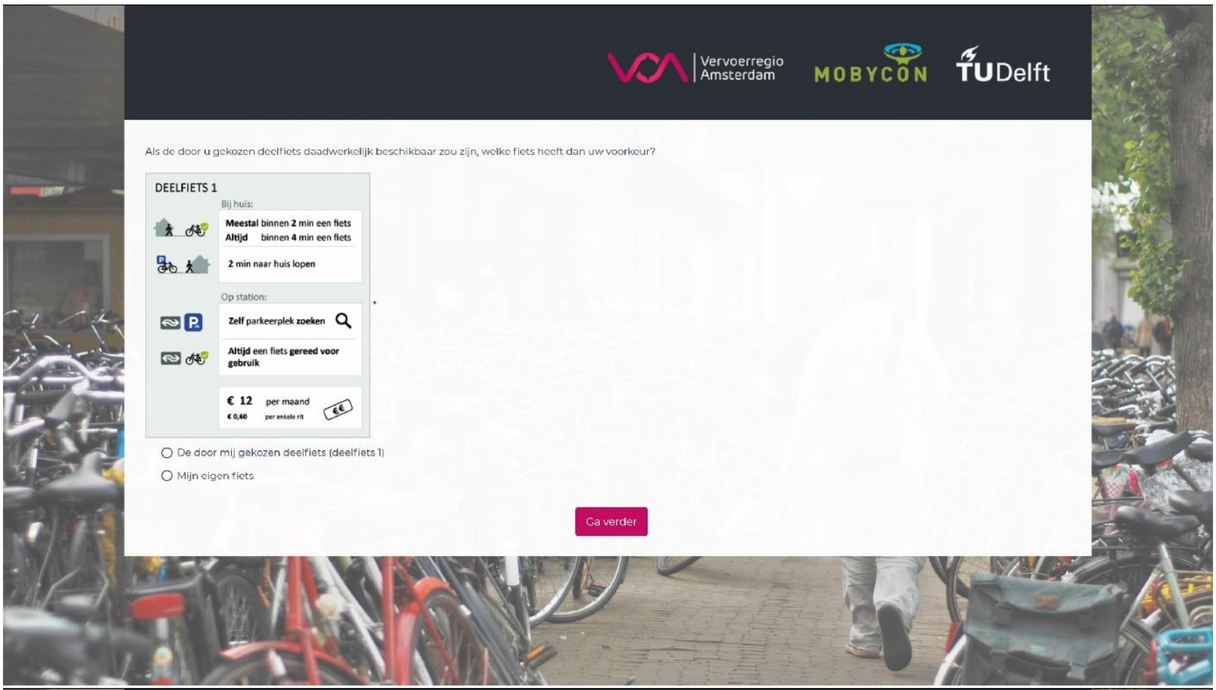

Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
3 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Altijd binnen 2 min een fiets
€ 0 per maand
€ 0 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

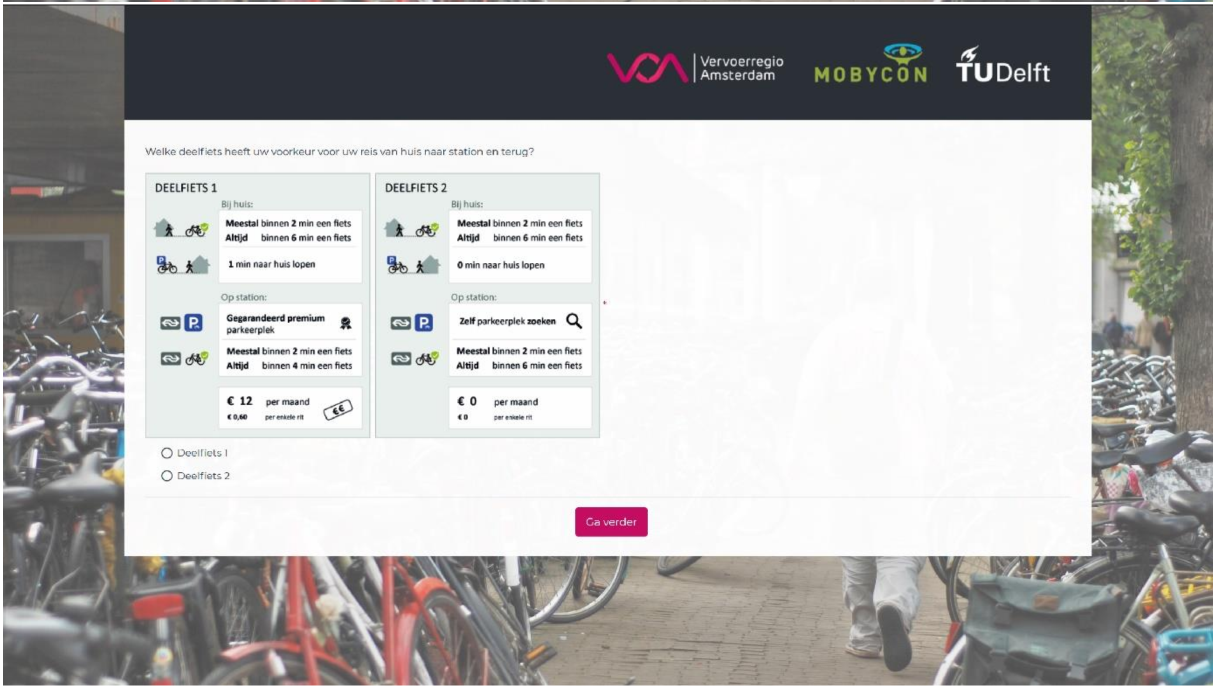
-

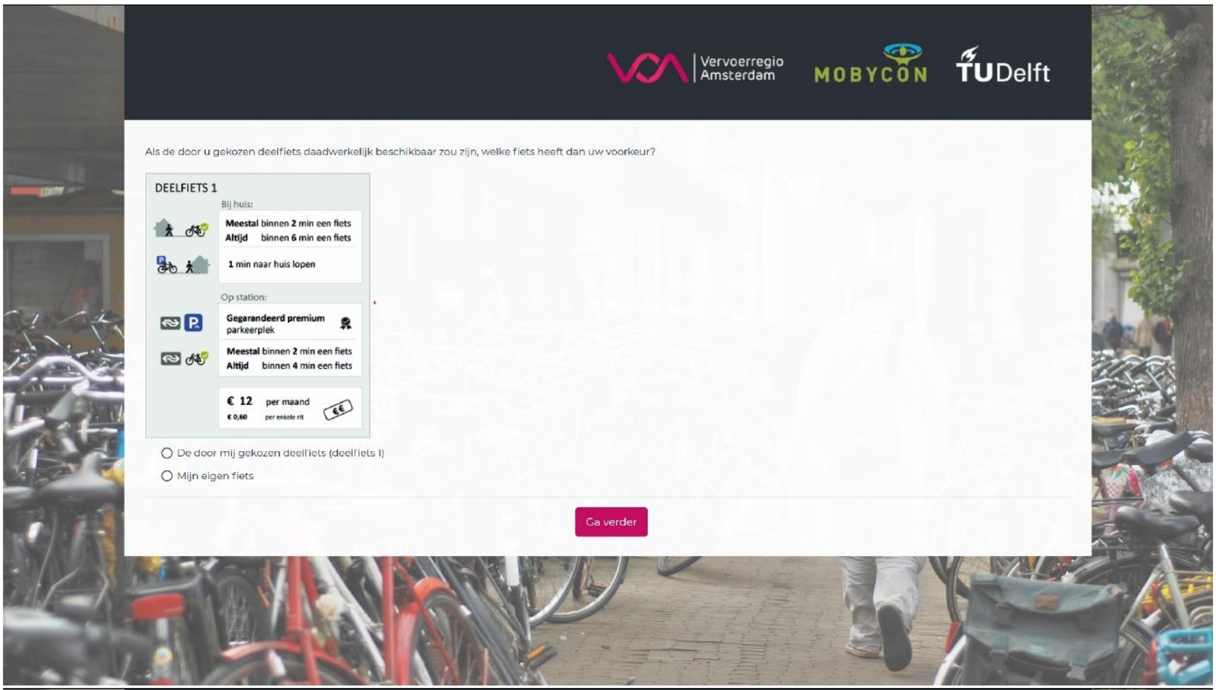

Vervoerregio Amsterdam
MOBYCON
TUDelft
U bent nu op de helft van de keuzevragen. U krijgt nog vier keer de keuze tussen twee type deelfietsen.
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Altijd een fiets voor de deur
1 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd binnen 2 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
DEELFIETS 2
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
1 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 12 per maand
€ 0,60 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder

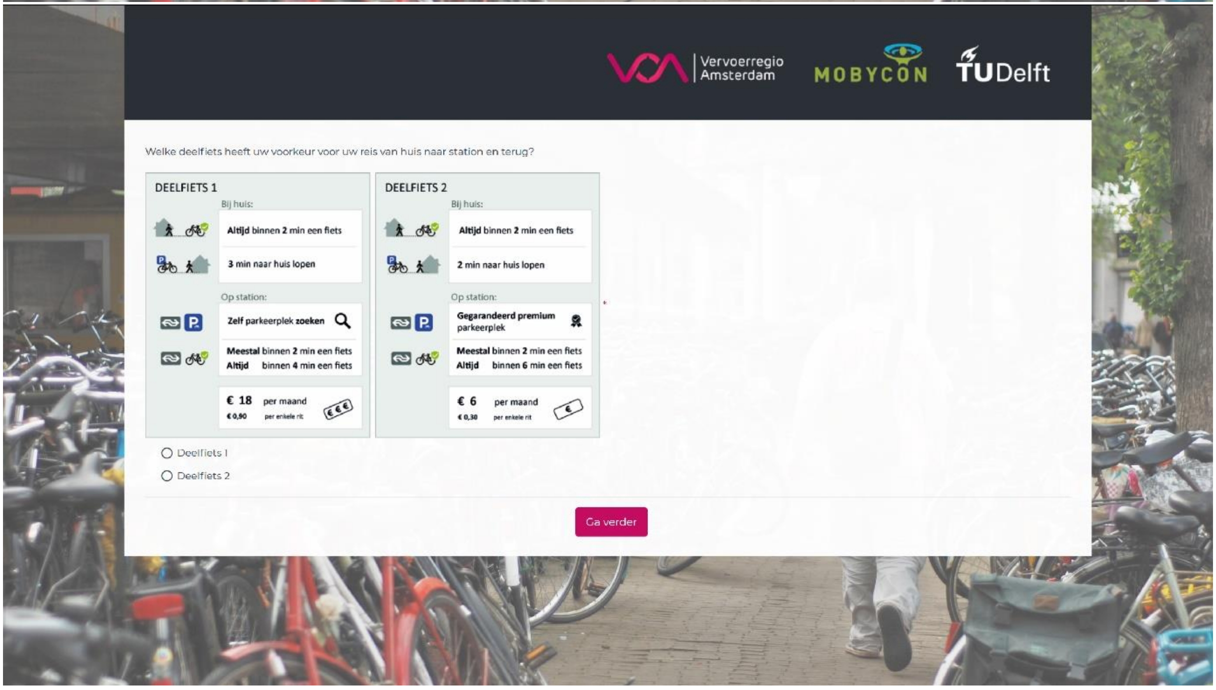

Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Altijd een fiets voor de deur
1 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd binnen 2 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

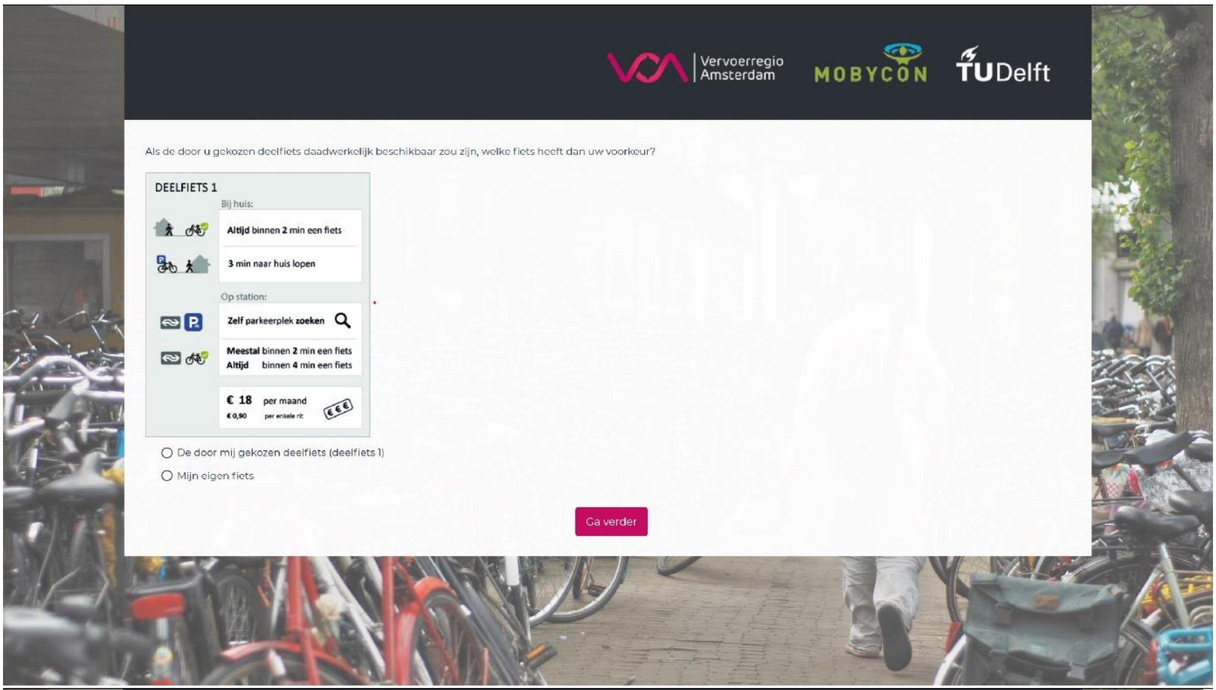

Vervoerregio Amsterdam
MOBYCON
TUDelft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
2 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd een fiets gereed voor gebruik
€ 12 per maand
€ 0,60 per enkele rit
DEELFIETS 2
Bij huis:
Altijd binnen 2 min een fiets
3 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 18 per maand
€ 0,90 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder

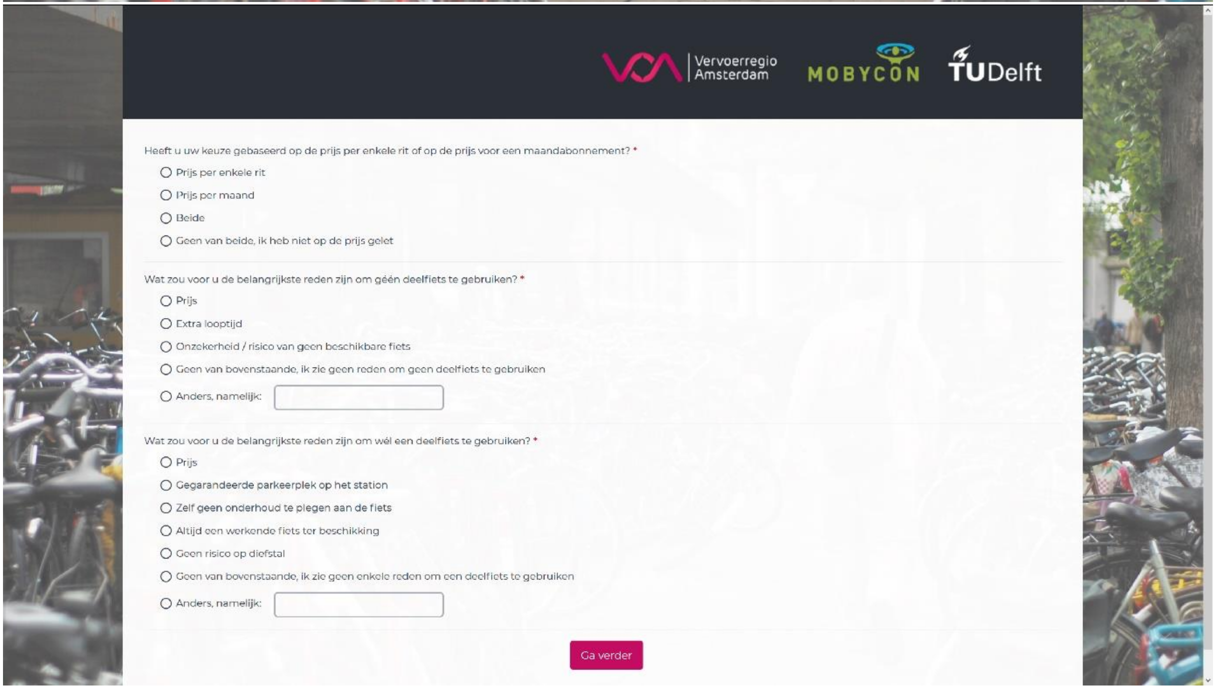

Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
2 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Altijd een fiets gereed voor gebruik
€ 12 per maand
€ 0,60 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder

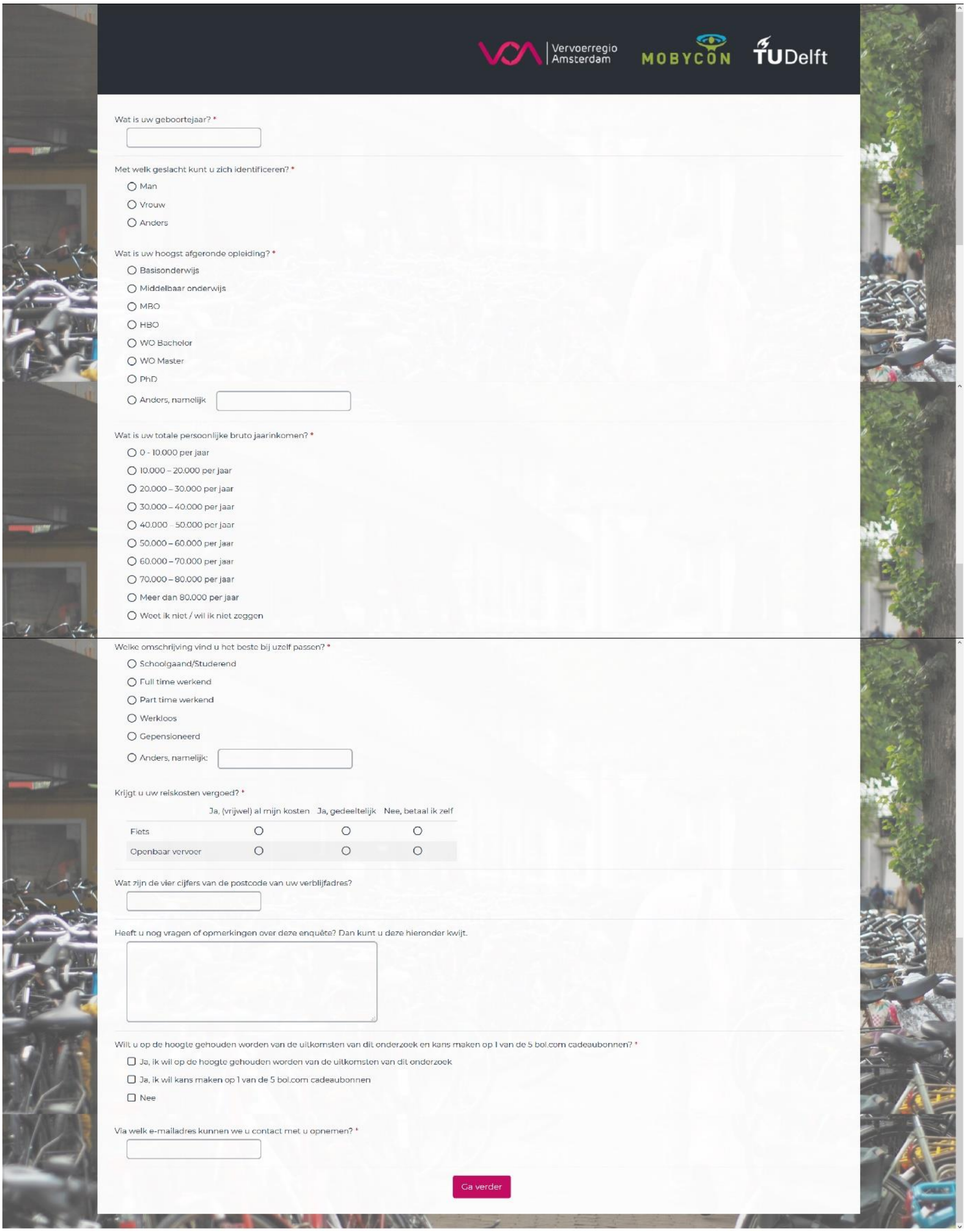

Vervoerregio Amsterdam
MOBYCON
TUDelft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
1 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 12 per maand
€ 0,60 per enkele rit
DEELFIETS 2
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
0 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 0 per maand
€ 0 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder


Vervoerregio Amsterdam
MOBYCON
TU Delft
Als de door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur?
DEELFIETS 1
Bij huis:
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
1 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 12 per maand
€ 0,60 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder


Vervoerregio Amsterdam
MOBYCON
TU Delft
Welke deelfiets heeft uw voorkeur voor uw reis van huis naar station en terug?
DEELFIETS 1
Bij huis:
Altijd binnen 2 min een fiets
3 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 18 per maand
€ 0,90 per enkele rit
DEELFIETS 2
Bij huis:
Altijd binnen 2 min een fiets
2 min naar huis lopen
Op station:
Gegarandeerd premium parkeerplek
Meestal binnen 2 min een fiets
Altijd binnen 6 min een fiets
€ 6 per maand
€ 0,30 per enkele rit
Deelfiets 1
Deelfiets 2
Ga verder


Vervoerregio Amsterdam
MOBYCON
TUDelft
Als de door u gekozen deelfiets daadwerkelijk beschikbaar zou zijn, welke fiets heeft dan uw voorkeur? *
DEELFIETS 1
Bij huis:
Altijd binnen 2 min een fiets
3 min naar huis lopen
Op station:
Zelf parkeerplek zoeken
Meestal binnen 2 min een fiets
Altijd binnen 4 min een fiets
€ 18 per maand
€ 0,90 per enkele rit
De door mij gekozen deelfiets (deelfiets 1)
Mijn eigen fiets
Ga verder


Vervoerregio Amsterdam
MOBYCON
TUDelft
Heeft u uw keuze gebaseerd op de prijs per enkele rit of op de prijs voor een maandabonnement? *
Prijs per enkele rit
Prijs per maand
Beide
Geen van beide, ik heb niet op de prijs gelet
Wat zou voor u de belangrijkste reden zijn om géén deelfiets te gebruiken? *
Prijs
Extra looptijd
Onzekerheid / risico van geen beschikbare fiets
Geen van bovenstaande, ik zie geen reden om geen deelfiets te gebruiken
Anders, namelijk:
Wat zou voor u de belangrijkste reden zijn om wél een deelfiets te gebruiken? *
Prijs
Gegarandeerde parkeerplek op het station
Zelf geen onderhoud te plegen aan de fiets
Altijd een werkende fiets ter beschikking
Geen risico op diefstal
Geen van bovenstaande, ik zie geen enkele reden om een deelfiets te gebruiken
Anders, namelijk:
Ga verder



Vervoerregio Amsterdam MOBYCON TUDelft

Wat is uw geboortejaar? *

Met welk geslacht kunt u zich identificeren? *

- Man
- Vrouw
- Anders

Wat is uw hoogst afgeronde opleiding? *

- Basisonderwijs
- Middelbaar onderwijs
- MBO
- HBO
- WO Bachelor
- WO Master
- PhD
- Anders, namelijk

Wat is uw totale persoonlijke bruto jaarinkomen? *

- 0 - 10.000 per jaar
- 10.000 – 20.000 per jaar
- 20.000 – 30.000 per jaar
- 30.000 – 40.000 per jaar
- 40.000 – 50.000 per jaar
- 50.000 – 60.000 per jaar
- 60.000 – 70.000 per jaar
- 70.000 – 80.000 per jaar
- Meer dan 80.000 per jaar
- Weet ik niet / wil ik niet zeggen

Welke omschrijving vind u het beste bij uzelf passen? *

- Schoolgaand/Studerend
- Full time werkend
- Part time werkend
- Werkloos
- Gepensioneerd
- Anders, namelijk:

Krijgt u uw reiskosten vergoed? *

	Ja, (vrijwel) al mijn kosten	Ja, gedeeltelijk	Nee, betaal ik zelf
Fiets	○	○	○
Openbaar vervoer	○	○	○

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

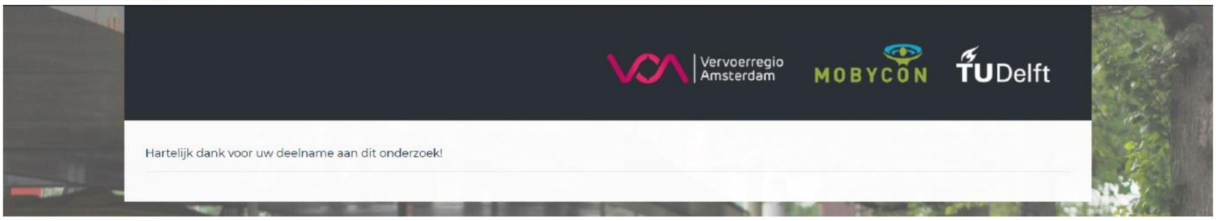
Heeft u nog vragen of opmerkingen over deze enquête? Dan kunt u deze hieronder kwijt.

Wilt u op de hoogte gehouden worden van de uitkomsten van dit onderzoek en kans maken op 1 van de 5 bol.com cadeaubonnen? *

- Ja, ik wil op de hoogte gehouden worden van de uitkomsten van dit onderzoek
- Ja, ik wil kans maken op 1 van de 5 bol.com cadeaubonnen
- Nee

Via welk e-mailadres kunnen we u contact met u opnemen? *

Ga verder



Vervoerregio Amsterdam MOBYCON TUDelft

Hartelijk dank voor uw deelname aan dit onderzoek!

-

Appendix G: Data analysis

G.1. Descriptive analysis

Table 28: Socio-demographic characteristics of the sample (excluding PT-bicycle users) divided by access and egress cyclists

	Total	Access cyclists	Egress cyclists
Total number of bicycle facility users	961 (100%)	668 (69.5%)	293 (30.5%)
Gender			
Male	453 (47.1%)	306 (45.8%)	147 (50.2%)
Female	500 (52.0%)	356 (53.3%)	144 (49.1%)
Other	8 (0.8%)	6 (0.9%)	2 (0.7%)
Age			
15 – 24 (1994 – 2003)	66 (6.9%)	45 (6.7%)	21 (7.2%)
25 – 34 (1984 – 1993)	441 (45.9%)	343 (51.3%)	98 (33.4%)
35 – 44 (1974 – 1983)	169 (17.6%)	112 (16.8%)	57 (19.5%)
45 – 54 (1964 – 1973)	140 (14.6%)	86 (12.9%)	54 (18.4%)
55 – 64 (1954 – 1963)	125 (13.0%)	70 (10.5%)	55 (18.8%)
≥ 65 (≤ 1953)	11 (1.1%)	8 (1.2%)	3 (0.3%)
Unknown	9 (0.9%)	4 (0.6%)	5 (1.6%)
Education			
Primary school	4 (0.4%)	1 (0.4%)	1 (0.3%)
Secondary school	38 (4.0%)	12 (4.9%)	13 (4.3%)
MBO	14 (1.5%)	3 (1.2%)	7 (2.3%)
HBO	221 (23.0%)	51 (20.7%)	83 (27.4%)
WO Bachelor	83 (8.6%)	20 (8.1%)	32 (10.6%)
WO Master	531 (55.3%)	137 (55.7%)	156 (51.5%)
PhD	61 (6.3%)	22 (8.9%)	9 (3.0%)
Other	9 (0.9%)	0 (0%)	2 (0.7%)
Income			
< €10,000	67 (7.0%)	46 (6.9%)	21 (7.2%)
€10,000 - €20,000	33 (3.4%)	25 (3.7%)	8 (2.7%)
€20,000 - €30,000	122 (12.7%)	78 (11.7%)	44 (15.0%)
€30,000 - €40,000	224 (23.3%)	154 (23.1%)	70 (23.9%)
€40,000 - €50,000	135 (14.0%)	98 (14.7%)	37 (12.6%)
€50,000 - €60,000	123 (12.8%)	92 (13.8%)	31 (10.6%)
€60,000 - €70,000	48 (5.0%)	30 (4.5%)	18 (6.1%)
€70,000 - €80,000	30 (3.1%)	23 (3.4%)	7 (2.4%)
> €80,000	73 (7.6%)	54 (8.1%)	19 (6.5%)
Unknown	106 (11.0%)	68 (10.2%)	38 (13.0%)
Job status			
Full time working	696 (72.4%)	500 (74.9%)	196 (66.9%)
Part time working	175 (18.2%)	102 (15.3%)	73 (24.9%)
Student	71 (7.4%)	50 (7.5%)	21 (7.2%)
Pensioner	4 (0.4%)	4 (0.6%)	0 (0%)
Jobless	2 (0.2%)	2 (0.3%)	0 (0%)
Other	13 (1.4%)	10 (1.5%)	3 (1.0%)

Table 29: Socio-demographic characteristics of the sample (excluding PT-bicycle users) divided by railway stations

	All three railway stations	Amsterdam Amstel station	Amsterdam Central station	Amsterdam Zuid station
Total number of bicycle facility users	961 (100%)	246 (25.4%)	303 (32.5%)	412 (42.1%)
Gender				
Male	453 (47.1%)	131 (53.3%)	143 (47.2%)	179 (43.4%)
Female	500 (52.0%)	112 (45.5%)	157 (51.8%)	231 (56.1%)
Other	8 (0.8%)	3 (1.2%)	3 (1.0%)	2 (0.5%)
Age				
15 – 24 (1994 – 2003)	66 (6.9%)	23 (9.3%)	14 (4.6%)	29 (7.0%)
25 – 34 (1984 – 1993)	441 (45.9%)	104 (42.3%)	137 (45.2%)	200 (48.5%)
35 – 44 (1974 – 1983)	169 (17.6%)	50 (20.3%)	51 (16.8%)	68 (16.5%)
45 – 54 (1964 – 1973)	140 (14.6%)	35 (14.2%)	54 (17.8%)	51 (12.4%)
55 – 64 (1954 – 1963)	125 (13.0%)	30 (12.2%)	40 (13.2%)	55 (13.3%)
≥ 65 (≤ 1953)	11 (1.1%)	4 (1.6%)	3 (1.0%)	4 (1.0%)
Unknown	9 (0.9%)	0 (0%)	4 (1.3%)	5 (1.2%)
Education				
Primary school	4 (0.4%)	1 (0.4%)	1 (0.3%)	2 (0.5%)
Secondary school	38 (4.0%)	12 (4.9%)	13 (4.3%)	13 (3.2%)
MBO	14 (1.5%)	3 (1.2%)	7 (2.3%)	4 (1.0%)
HBO	221 (23.0%)	51 (20.7%)	83 (27.4%)	87 (21.1%)
WO Bachelor	83 (8.6%)	20 (8.1%)	32 (10.6%)	31 (7.5%)
WO Master	531 (55.3%)	137 (55.7%)	156 (51.5%)	238 (57.8%)
PhD	61 (6.3%)	22 (8.9%)	9 (3.0%)	30 (7.3%)
Other	9 (0.9%)	0 (0%)	2 (0.7%)	7 (1.7%)
Income				
< €10,000	67 (7.0%)	17 (6.9%)	16 (5.3%)	34 (8.3%)
€10,000 - €20,000	33 (3.4%)	7 (2.8%)	12 (4.0%)	14 (3.4%)
€20,000 - €30,000	122 (12.7%)	29 (11.8%)	48 (15.8%)	45 (10.9%)
€30,000 - €40,000	224 (23.3%)	61 (24.8%)	74 (24.4%)	89 (21.6%)
€40,000 - €50,000	135 (14.0%)	32 (13.0%)	47 (15.5%)	56 (13.6%)
€50,000 - €60,000	123 (12.8%)	35 (14.2%)	34 (11.2%)	54 (13.1%)
€60,000 - €70,000	48 (5.0%)	10 (4.1%)	13 (4.3%)	25 (6.1%)
€70,000 - €80,000	30 (3.1%)	12 (4.9%)	4 (1.3%)	14 (3.4%)
> €80,000	73 (7.6%)	23 (9.3%)	21 (6.9%)	29 (7.0%)
Unknown	106 (11.0%)	20 (8.1%)	34 (11.2%)	52 (12.6%)
Job status				
Full time working	696 (72.4%)	175 (71.1%)	215 (71.0%)	306 (74.3%)
Part time working	175 (18.2%)	45 (18.3%)	66 (21.8%)	64 (15.5%)
Student	71 (7.4%)	23 (9.3%)	16 (5.3%)	32 (7.8%)
Pensioner	4 (0.4%)	1 (0.4%)	1 (0.3%)	2 (0.5%)
Jobless	2 (0.2%)	0 (0%)	1 (0.3%)	1 (0.2%)
Other	13 (1.4%)	2 (0.8%)	4 (1.3%)	7 (1.7%)

Table 30: Trip characteristics of the sample (excluding PT-bicycle users) divided by access and egress cyclists

	Total	Access cyclists	Egress cyclists
Number of bicycle facility users	961 (100%)	668 (69.5%)	293 (30.5%)
Railway station			
Amsterdam Amstel station	246 (25.6%)	163 (24.4%)	83 (28.3%)
Amsterdam Central station	303 (31.5%)	203 (30.4%)	100 (34.1%)
Amsterdam Zuid station	412 (42.9%)	302 (45.2%)	110 (37.5%)
Trip purpose			
Business meeting	62 (6.5%)	54 (8.1%)	8 (2.7%)
Work day	818 (85.1%)	550 (82.3%)	268 (91.5%)
Study	46 (4.8%)	36 (5.4%)	10 (3.4%)
Recreational	26 (2.7%)	24 (3.6%)	2 (0.7%)
Other	9 (0.9%)	4 (0.6%)	5 (1.7%)
Type of parking			
Paid parking (paid by themselves)	168 (17.5%)	45 (6.7%)	123 (42.0%)
Paid parking (paid by someone else)	37 (3.9%)	6 (0.9%)	31 (10.6%
Unpaid	755 (78.6%)	616 (92.2%)	139 (47.4%)
Experienced bicycle parking pressure			
Always	36 (3.7%)	26 (3.9%)	10 (3.4%)
Often	134 (13.9%)	92 (13.8%)	42 (14.3%)
Occasionally	378 (39.3%)	262 (39.2%)	116 (39.6%)
(Almost) never	412 (42.9%)	287 (43.0%)	125 (42.7%)

Table 31: Trip characteristics of the sample (excluding PT-bicycle users) divided by railway stations

	All three railway stations	Amsterdam Amstel station	Amsterdam Central station	Amsterdam Zuid station
Number of bicycle facility users	961 (100%)	246 (25.4%)	303 (32.5%)	412 (42.1%)
Type of cyclist				
Access cyclists	668 (69.5%)	163 (66.3%)	203 (67.0%)	302 (73.3%)
Egress cyclists	293 (30.5%)	83 (33.7%)	100 (33.0%)	110 (26.7%)
Trip purpose				
Business meeting	62 (6.5%)	16 (6.5%)	19 (6.3%)	27 (6.6%)
Work day	818 (85.1%)	200 (81.3%)	263 (86.8%)	355 (86.2%)
Study	46 (4.8%)	14 (5.7%)	11 (3.6%)	21 (5.1%)
Recreational	26 (2.7%)	14 (5.7%)	7 (2.3%)	5 (1.2%)
Other	9 (0.9%)	2 (0.8%)	3 (1.0%)	4 (1.0%)
Type of parking				
Paid parking (paid by cyclists themselves)	168 (17.5%)	47 (19.1%)	41 (13.5%)	80 (19.4%)
Paid parking (paid by someone else)	37 (3.9%)	9 (3.7%)	6 (2.0%)	22 (5.3%)
Unpaid	755 (78.6%)	190 (77.2%)	256 (84.5%)	309 (75.2%)
Experienced bicycle parking pressure				
Always	36 (3.7%)	2 (0.8%)	22 (7.3%)	12 (2.9%)
Often	134 (13.9%)	18 (7.3%)	58 (19.1%)	58 (14.1%)
Occasionally	378 (39.3%)	85 (34.6%)	127 (41.9%)	166 (40.3%)
(Almost) never	412 (42.9%)	141 (57.3%)	96 (31.7%)	175 (42.5%)

Table 32: Respondents familiarity and use of different (shared) bicycle concepts (excluding PT-bicycle users)

	NS PT-bicycle (railway station based bicycle system)	Urban bicycle sharing systems (e.g. Obike, Flickbike, Hello-bike)	Lease bicycle (e.g. Swapfiets)
Familiar with bicycle concept and used regularly	234 (24.3%)	0 (0%)	28 (2.9%)
Familiar with bicycle concept and used occasionally	415 (43.2%)	34 (3.5%)	4 (0.4%)
Familiar with bicycle concept but never used	299 (31.1%)	488 (50.8%)	426 (44.3%)
Unfamiliar with bicycle concept	13 (1.4%)	439 (45.7%)	503 (52.3%)

Table 33: PT-cyclist's use of PT-bicycles

	Access cyclists	Egress cyclists	Total
< Once a month	2 (4.0%)	5 (9.1%)	7 (12.7%)
Once a month	1 (1.8%)	1 (1.8%)	2 (4.0%)
2-3 times a month	2 (4.0%)	9 (16.4%)	11 (20%)
1-2 times a week	5 (9.1%)	12 (21.8%)	17 (30.9%)
≥ 3 times a week	1(1.8%)	17 (30.9%)	18 (32.7%)
	11 (20%)	**44 (80%)**	**55 (100%)**

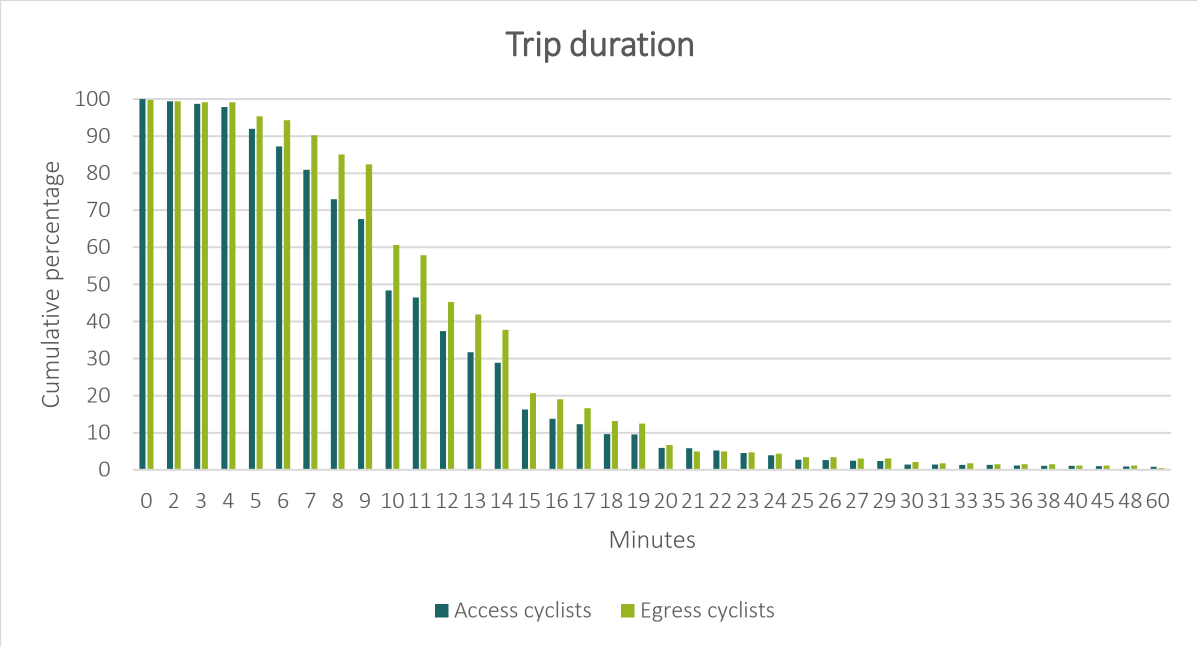


Figure 35: Visualisation of the respondents trip duration in minutes

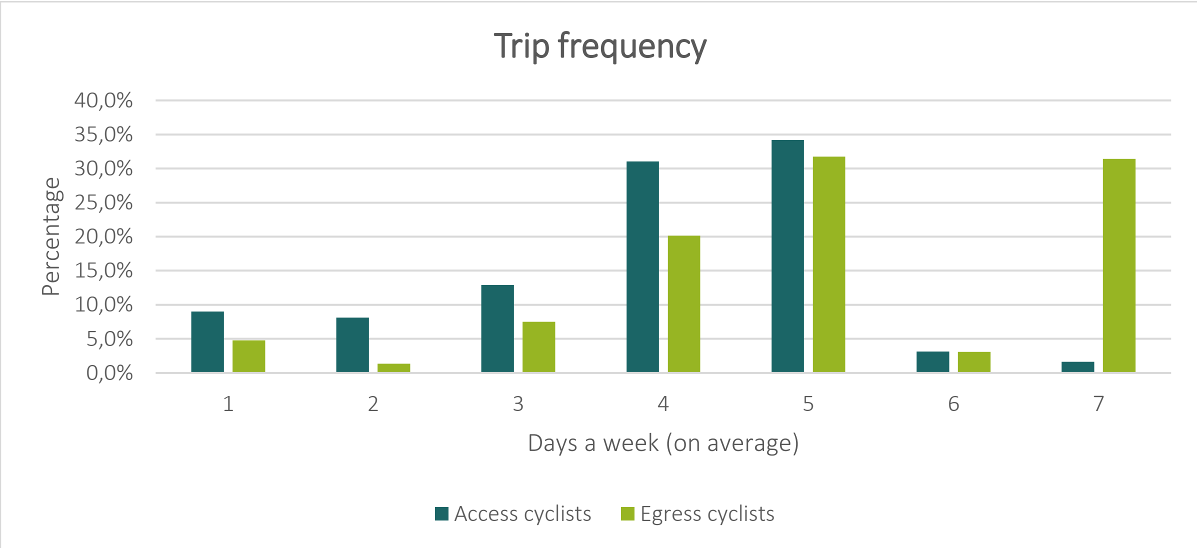


Figure 36: Distribution of the respondents' trip frequency

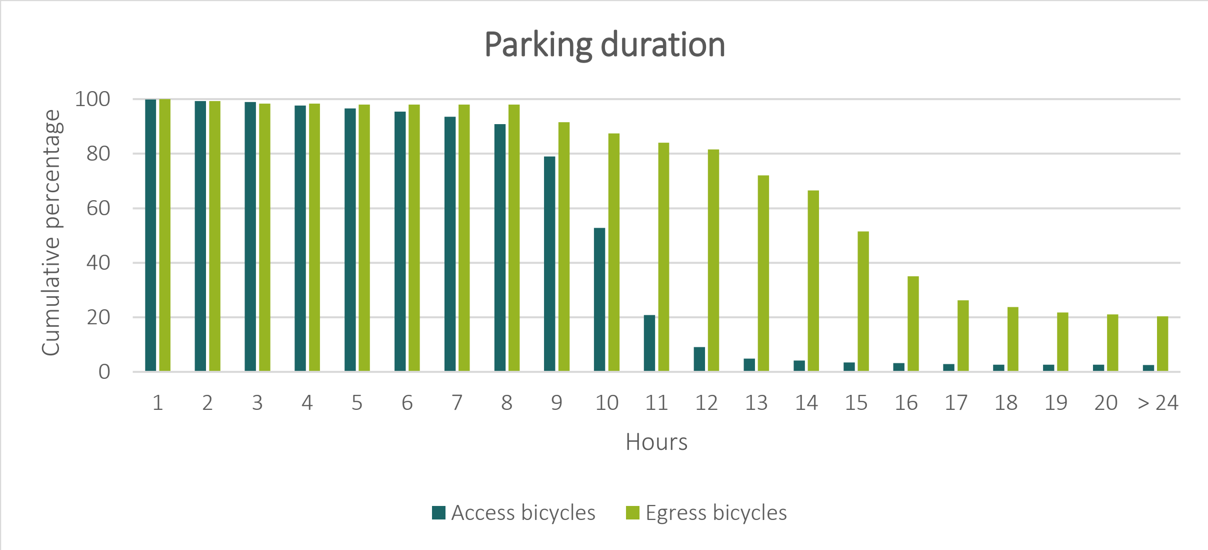


Figure 37: Distribution of respondent's parking duration

Representativeness of the sample

Age

Figure 38 shows a comparison between the age the sample population and the age of the population of the city of Amsterdam, based on figures of Central Bureau for Statistics (2017).

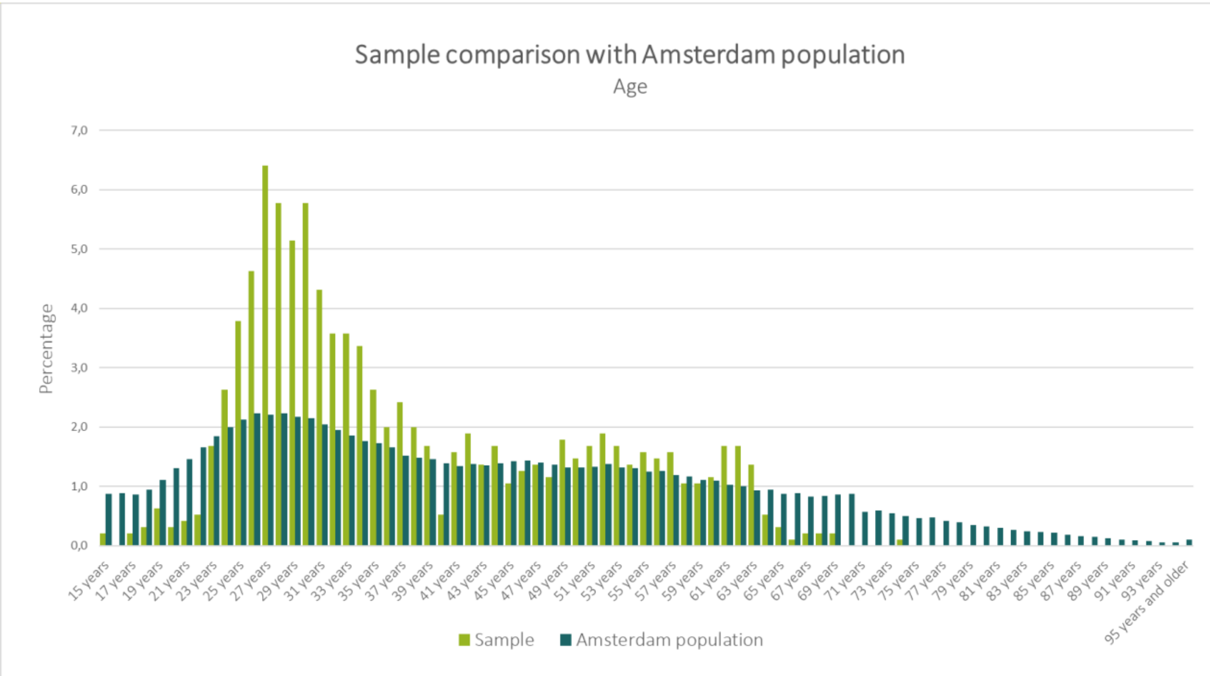


Figure 38: Sample comparison with the Amsterdam population considering age *(Centraal Bureau voor de Statistiek, 2017)*

Education

Figure 39 shows a comparison between the education level of the sample population and the age of the population of the city of Amsterdam based on figures of the Municipality of Amsterdam (2017).

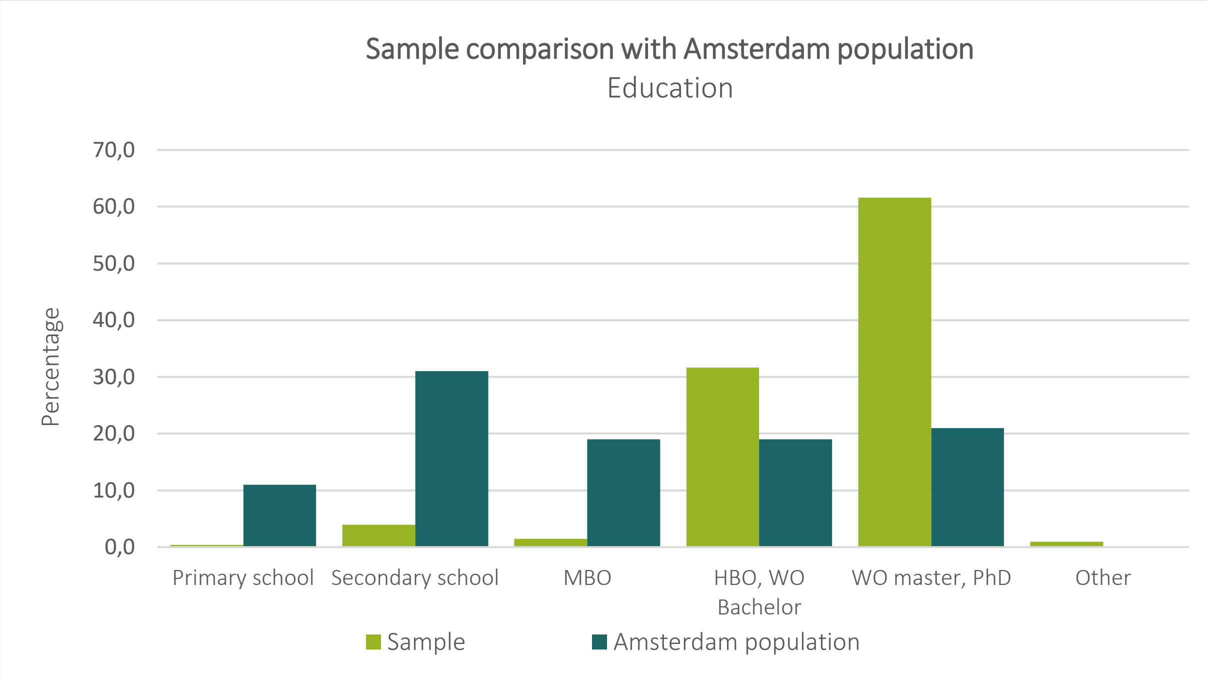


Figure 39: Sample comparison with the Amsterdam population considering education (Gemeente Amsterdam, 2017)

Income

Table 34: Sample comparison with the Amsterdam population considering income (Centraal Bureau voor de Statistiek, 2018), *income in euros*

	Dutch inhabitants	Amsterdam inhabitants	Respondents
Mean income (2014)	35,100	31,200	> 35,000*
Median income (2014)	29,000	23,900	35,000

** Calculated assuming that all respondents with an income higher than 80,000 euros, earn 80,000 euros and all respondents of the other categories earn the middle value of that category. This might give an underestimation of the actual income.*

G.2. Coding schemes

Table 35: Applied dummy coding schemes

Accessibility at home / at destination	AHD1	AHD2	AHD3	Walking time	WALK1
Mostly in 2 mins, always in 6 mins	1	0	0	3 mins	3
Mostly in 2 mins, always in 4 mins	0	1	0	2 mins	2
Always in 2 mins	0	0	1	1 mins	1
Guaranteed at front door	0	0	0	0 mins	0

Accessibility at station / Accessibility at destination	AS1	AS2	AS3	Price	PRICE1
Mostly in 2 mins, always in 4 mins	1	0	0	18 €/month	18
Mostly in 2 mins, always in 6 mins	0	1	0	12 €/month	12
Always in 2 mins	0	0	1	6 €/month	6
Guaranteed in front of the door	0	0	0	free of charge	0

Parking convenience	PARK1
Self search for parking place	1
Premium parking place near platform	0

Table 36: Effect coding scheme for the included personal characteristics with categorical levels

Segments	Applied effect coding		
Gender	GENDER		
Male	1		
Female	-1		
Income	INCOME1	INCOME2	INCOME3
> €60,000	1	0	0
€40,000 - €60,000	0	1	0
€20,000 - €40,000	0	0	1
< €20,000	-1	-1	-1
Job status	JOB1	JOB2	
Student	1	0	
Part time working	0	1	
Full time working	-1	-1	
Familiarity with bicycle sharing	FAM		
Familiar with PT-bicycle (regular or occasional user)	1		
Unfamiliar with PT-bicycle	-1		

Table 37: Effect coding scheme for the included trip characteristics with categorical levels

Segments	Applied effect coding		
Railway station	STATION1	STATION2	
Amsterdam Amstel	1	0	
Amsterdam Centraal	0	1	
Amsterdam Zuid	-1	-1	
Paid parking	PAID		
Paid parking (paid by cyclists themselves)	1		
Unpaid parking (not paid by cyclists themselves)	-1		
Experienced bicycle parking difficulties	PARKPRES		
Always or often	1		
Occasionally or never	-1		
Trip duration	TRIPDUR1	TRIPDUR2	TRIPDUR3
≥ 16 min	1	0	0
11 - 15 min	0	1	0
6 - 10 min	0	0	1
1 - 5 min	-1	-1	-1
Flexibility of arrival time at home / destination	FLEXHD1	FLEXHD2	
Not flexible	1	0	
Bit flexible	0	1	
Very flexible	-1	-1	
Flexibility of arrival time at station	FLEXST1	FLEXST2	
Not flexible	1	0	
Bit flexible	0	1	
Very flexible	-1	-1	
Bicycle reimbursement	BICREIMB1	BICREIMB2	BICREIMB1
Full reimbursement	1	0	1
Partial reimbursement	0	1	0
No reimbursement	-1	-1	-1

G.3. Model description

Base MNL model (main effects)

```
// File SHARED_BICYCLE_ACCESS.mod

[ModelDescription]

[Choice]
CHOICE2

[Beta]
// Name      Value  LowerBound  UpperBound  status (0=variable, 1=fixed)
ascsb           0      -10000      10000    0
ascob           0      -10000      10000    1
b_avh1          0      -10000      10000    0
b_avh2          0      -10000      10000    0
b_avh3          0      -10000      10000    0
b_walk          0      -10000      10000    0
b_park1 0     -10000     10000    0
b_avs1          0      -10000      10000    0
b_avs2          0      -10000      10000    0
b_avs3          0      -10000      10000    0
b_price         0      -10000      10000    0

[Utilities]
// Id  Name                  Avail     linear-in-parameter expression (beta1*x1 + beta2*x2 + ... )
1   SHARED_BICYCLE1        AV1       ascsb * CONST + b_avh1 * AVHA1 + b_avh2 * AVHA2 +
                                  b_avh3 *  AVHA3 + b_walk * WALKA + b_park1 * PARKA1 +
                           b_avs1 * AVSA1 + b_avs2 * AVSA2 + b_avs3 * AVSA3 +
                                      b_price * PRICEA
2   SHARED_BICYCLE2        AV2       ascsb * CONST + b_avh1 * AVHB1 + b_avh2 * AVHB2 +
                                      b_avh3 * AVHB3 + b_walk * WALKB + b_park1 * PARKB1 +
                                      b_avs1 * AVSB1 + b_avs2 * AVSB2 + b_avs3 * AVSB3 +
                                      b_price * PRICEB
3   OWN_BICYCLE            AV3       ascob * CONST

[Expressions]
AV1       = 1
AV2       = 1
AV3       = 1

[Model]
$MNL
```

Figure 40: Biogeme model description of the base MNL model

MNL model with interaction effect (gender)

```
// File SHARED_BICYCLE_ACCESS.mod

[Choice]
CHOICE2

[Beta]
// Name                    Value  LowerBound  UpperBound  status (0=variable, 1=fixed)
ascsb                       0     -10000      10000     0
ascob                       0     -10000      10000     1
b_gender                    0     -10000      10000     0
b_avh1                      0     -10000      10000     0
b_avh2                      0     -10000      10000     0
b_avh3                      0     -10000      10000     0
b_walk                      0     -10000      10000     0
b_park1                     0     -10000      10000     0
b_avs1                      0     -10000      10000     0
b_avs2                      0     -10000      10000     0
b_avs3                      0     -10000      10000     0
b_price                     0     -10000      10000     0
b_avh1_gender               0     -10000      10000     0
b_avh2_gender               0     -10000      10000     0
b_avh3_gender               0     -10000      10000     0
b_walk_gender               0     -10000      10000     0
b_park1_gender              0     -10000      10000     0
b_avs1_gender               0     -10000      10000     0
b_avs2_gender               0     -10000      10000     0
b_avs3_gender               0     -10000      10000     0
b_price_gender              0     -10000      10000     0

[Utilities]
// Id  Name          Avail  linear-in-parameter expression (beta1*x1 + beta2*x2 + ... )
  1  SHARED_BICYCLE1  AV1    ascsb * CONST + b_gender * GENDER + b_avh1 * AVHA1 + b_avh2 * AVHA2 + b_avh3 * AVHA3 + b_walk *
WALKA + b_park1 * PARKA1 + b_avs1 * AVSA1 + b_avs2 * AVSA2 + b_avs3 * AVSA3 + b_price * PRICEA

  2  SHARED_BICYCLE2  AV2    ascsb * CONST + b_gender * GENDER + b_avh1 * AVHB1 + b_avh2 * AVHB2 + b_avh3 * AVHB3 + b_walk *
WALKB + b_park1 * PARKB1 + b_avs1 * AVSB1 + b_avs2 * AVSB2 + b_avs3 * AVSB3 + b_price * PRICEB

  3  OWN_BICYCLE     AV3    ascob * CONST

[Expressions]
AV1        = 1
AV2        = 1
AV3        = 1

[GeneralizedUtilities]
1 b_avh1_gender * AVHA1 * GENDER
+ b_avh2_gender * AVHA2 * GENDER
+ b_avh3_gender * AVHA3 * GENDER
+ b_walk_gender * WALKA * GENDER
+ b_park1_gender * PARKA1 * GENDER
+ b_avs1_gender * AVSA1 * GENDER
+ b_avs2_gender * AVSA2 * GENDER
+ b_avs3_gender * AVSA3 * GENDER
+ b_price_gender * PRICEA * GENDER

2 b_avh1_gender * AVHB1 * GENDER
+ b_avh2_gender * AVHB2 * GENDER
+ b_avh3_gender * AVHB3 * GENDER
+ b_walk_gender * WALKB * GENDER
+ b_park1_gender * PARKB1 * GENDER
+ b_avs1_gender * AVSB1 * GENDER
+ b_avs2_gender * AVSB2 * GENDER
+ b_avs3_gender * AVSB3 * GENDER
+ b_price_gender * PRICEB * GENDER

[Model]
$MNL
```

Figure 41: Biogeme model description of the MNL model with gender as interaction effect

G.4. Estimation results

Estimation results of the base MNL model (main-effects)

Table 38: Utility contributions of attribute levels, std errors, t-values & p-values in the model for access transportation (MNL model)

Access cyclists (N = 5344 choices)

		Part worth utility	Std error	t-test	p-value
ASC shared bicycle		-0.512	0.124	-4.12	0.00
Accessibility at home	*Guaranteed*	0.000	-	-	-
	High	-0.414	0.104	-3.97	0.00
	Medium	-0.564	0.093	-6.05	0.00
	Low	-1.180	0.121	-9.81	0.00
Walking time to home		-0.141	0.031	-4.52	0.00
Parking convenience	*Premium parking*	0.329	0.071	4.63	0.00
	No premium parking	0.000	-	-	-
Accessibility at station	*Guaranteed*	0.000	-	-	-
	High	0.230	0.112	2.06	0.04
	Medium	-0.135	0.123	-1.10	0.27
	Low	-0.114	0.107	-1.07	0.28
Price		-0.512	0.124	-4.12	0.00

An absolute p-value smaller than 0.05 is considered as statistically significant.

Table 39: Utility contributions of attribute levels, std errors, t-values & p-values in the model for egress transportation (MNL model)

Egress cyclists (N = 2344 choices)

		Part worth utility	Std error	t-test	p-value
ASC shared bicycle		0.179	0.164	1.09	0.28
Accessibility at destination	*Guaranteed*	0.000	-	-	-
	High	-0.237	0.139	-1.70	0.09
	Medium	-0.359	0.122	-2.95	0.00
	Low	-0.822	0.152	-5.41	0.00
Walking time to destination		-0.059	0.040	-1.46	0.15
Parking convenience	*Premium parking*	0.036	0.091	0.40	0.69
	No premium parking	0.000	-	-	-
Accessibility at station	*Guaranteed*	0.000	-	-	-
	High	-0.053	0.144	-0.36	0.72
	Medium	-0.272	0.153	-1.78	0.07
	Low	-0.488	0.138	-3.54	0.00
Price		-0.174	0.008	-20.69	0.00

An absolute p-value smaller than 0.05 is considered as statistically significant.

Estimation results of the MNL model including interaction effects with personal characteristics

Table 40: Interaction effects with personal characteristics in the model of access cyclists

Access cyclists		Ascsb	Ah1	Ah2	Ah3	As1	As2	As3	Park	Price	Walk
GENDER											
Main		-0.423	-1.200	-0.557	-0.457	-0.128*	-0.171*	0.223*	0.345	-0.158	-0.142
Gender	Female	-0.068*	-0.174*	-0.108*	-0.144*	0.140*	0.030*	0.052*	0.094*	-0.007*	0.033*
	Male	0.068*	0.174*	0.108*	0.144*	-0.140*	-0.030*	-0.052*	-0.094*	0.007*	-0.033*
AGE											
Main		-0.425	-1.200	-0.543	-0.444	-0.133*	-0.183*	0.221*	0.347	-0.158	-0.141
Age continuous		-0.126*	0.086*	-0.085*	0.049*	0.013*	0.039*	0.056*	-0.072*	0.011*	0.051*
INCOME											
Main		-0.432	-1.200	-0.561	-0.412	-0.176*	-0.157*	0.195*	0.371	-0.154	-0.137
Income1	> €60,000	0.463*	-0.403*	-0.379*	-0.091*	-0.142*	-0.251*	-0.274*	-0.034*	-0.005*	-0.002*
Income2	€40,000 - €60,000	0.114*	0.031*	0.084*	-0.089*	-0.115*	-0.240*	0.127*	-0.105*	0.000*	-0.043*
Income3	€20,000 - €40,000	-0.054*	-0.063*	0.062*	-0.162*	0.303*	0.114*	-0.025*	-0.006*	-0.025	0.014*
	< €20,000	-0.523	0.435	0.234	0.341	-0.046	0.377	0.172	0.145	0.029	0.030
JOB STATUS											
Main		-0.570	-1.160	-0.760	-0.408	-0.472	-0.196*	0.108*	0.431	-0.155	-0.119
JOB1	Student	0.124*	0.013*	-0.198*	0.047*	-0.500*	-0.203*	-0.194*	0.203*	0.005*	-0.087*
JOB2	Part time working	-0.362*	0.043*	-0.081*	0.017*	0.063*	0.203*	0.039*	-0.104*	0.000*	0.126*
	Full time working	0.238	-0.056	0.279	-0.064	0.437	0.000	0.155	-0.099	-0.005	-0.039
FAMILIARITY											
Main		-0.515	-1.11	-0.498	-0.401	-0.189*	-0.179*	0.182*	0.346	-0.150	-0.122
Fam	Familiar with PT-bicycle (regular or occasional user)	0.221*	-0.220*	-0.141*	-0.122*	0.150*	0.001*	0.094*	-0.007*	-0.021	-0.042*
	Unfamiliar with PT-bicycle	-0.221	0.220	0.141	0.122	-0.150	-0.001	-0.094	0.007	0.021	0.042

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

Table 41: Interaction effects with personal characteristics in the model of egress cyclists

Egress cyclists		Ascsb	Ad1	Ad2	Ad3	As1	As2	As3	Park	Price	Walk
GENDER											
Main		0.137*	-0.719	-0.346	-0.206*	-0.446	-0.146*	-0.047*	-0.004*	-0.183	-0.063*
Gender	Female	0.115*	-0.115*	0.223*	-0.244*	0.184*	-0.264*	-0.226*	0.111*	0.011*	-0.054*
	Male	-0.115	0.115	-0.223	0.244	-0.184	0.264	0.226	-0.111	-0.011	0.054
AGE											
Main		0.136*	-0.714	-0.328	-0.178*	-0.444	-0.147*	-0.052*	-0.012*	-0.182	-0.065*
Age continuous		-0.405	0.284*	0.336	0.278*	0.093*	0.030*	0.309*	-0.034*	0.002	-0.040*
INCOME											
Main		0.012*	-0.627	-0.458	-0.221*	-0.355*	-0.164*	0.342*	-0.095*	-0.208	-0.062*
Income1	> €60,000	0.022*	-0.402*	0.019*	0.042*	-0.367*	-0.259*	0.156*	-0.042*	0.046	0.026*
Income2	€40,000 - €60,000	0.488*	0.392*	-0.051*	-0.146*	-1.360	-0.013*	-0.842	-0.024*	-0.045*	0.017*
Income3	€20,000 - €40,000	0.008*	-0.180*	-0.301*	0.122	0.192*	0.171*	-0.581*	0.145*	0.055	-0.022*
	< €20,000	-0.518	0.190	0.333	-0.018	1.535	0.101	1.267	-0.079	-0.056	-0.020
JOB STATUS											
Main		0.315*	-0.918	-0.518	-0.468*	-0.401*	-0.598*	-0.274*	0.006*	-0.203	-0.085*
JOB1	Student	0.526*	-0.819*	-0.683*	-0.807*	-0.222*	-1.06*	-0.870*	-0.115*	-0.004*	0.035*
JOB2	Part time working	-0.454*	0.770*	0.656*	0.620*	0.410*	0.613*	0.804*	0.161*	-0.029*	-0.098*
	Full time working	-0.072	0.049	0.027	0.187	-0.188	0.447	0.066	-0.046	0.033	0.063
FAMILIARITY											
Main		0.044*	-0.719	-0.262*	-0.185*	-0.378	-0.116*	-0.022*	-0.056*	-0.183	-0.056
Fam	Familiar with PT-bicycle (regular or occasional user)	0.439	-0.099*	-0.277	-0.053*	-0.205*	-0.149*	-0.112*	0.171*	0.002*	-0.036
	Unfamiliar with PT-bicycle	-0.439	0.099	0.277	0.053	0.205	0.149	0.112	-0.171	-0.002	0.036

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

Estimation results of the MNL model including interaction effects with trip characteristics

Table 42: Interaction effects with trip characteristics in the model of access cyclists

Access cyclists		Ascsb	Ah1	Ah2	Ah3	As1	As2	As3	Park	Price	Walk
STATION											
Main		-0.428*	-1.190*	-0.518*	-0.429*	-0.106	-0.162	0.238	0.322*	-0.161*	-0.152*
Station1	Amsterdam Amstel	0.166	-0.162	0.003	-0.075	0.188	0.037	0.103	-0.187	-0.021	-0.062
Station2	Amsterdam Centraal	-0.297	0.285	0.275	0.281	-0.094	0.046	-0.072	0.188	0.017	0.008
	Amsterdam Zuid	*0.131*	*-0.123*	*-0.278*	*-0.206*	*-0.095*	*-0.083*	*-0.031*	*-0.001*	*0.004*	*0.054*
PAID											
Main		-0.675*	-0.899*	-0.487*	-0.323	-0.138	-0.007	0.414*	0.281*	-0.125*	-0.111
Paid1	Paid parking (paid by cyclists themselves)	-0.335	0.396*	0.084	0.184	-0.011	0.236	0.260	-0.076	0.042*	0.031
Paid2	Unpaid parking (not paid by cyclists themselves)	*0.335*	*-0.396*	*-0.084*	*-0.184*	*0.011*	*-0.236*	*-0.260*	*0.076*	*-0.042*	*-0.031*
PARKING PRESSURE											
Main		-0.571*	-1.02*	-0.474*	-0.418*	-0.032	-0.149	0.328*	0.434*	-0.141*	-0.142*
Parkpres1	Always or often	-0.302*	0.396*	0.147	0.120	0.140	0.076	0.189	0.179*	0.036*	-0.004
Parkpres2	Occasionally or never	*0.302*	*-0.396*	*-0.147*	*-0.120*	*-0.140*	*-0.076*	*-0.189*	*-0.179*	*-0.036*	*0.004*
PARKING TIME CONTINUOUS											
Main		-0.378*	-1.24*	-0.566*	-0.485*	-0.138	-0.197	0.203	0.325*	-0.162*	-0.142*
Parkdur		-0.390*	0.317*	0.232*	0.239*	0.103	0.159	0.027	0.234*	0.020*	0.014

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

TRIP DURATION											
Main		-0.500*	-1.250*	-0.535*	-0.525*	-0.120	-0.221	0.191	0.411*	-0.161*	-0.135*
Tripdur1	≥ 16 min	-0.561	0.369	0.296	0.316	-0.019	0.154	0.164	-0.177	0.034*	0.083
Tripdur2	11 - 15 min	0.551*	-0.262	-0.286	-0.033	-0.439*	-0.171	-0.399	0.074	-0.010	-0.047
Tripdur3	6 - 10 min	-0.064	0.201	0.095	0.156	0.251	0.172	0.298	-0.179	0.008	-0.003
	1 - 5 min	*0.074*	*-0.308*	*-0.105*	*-0.439*	*0.207*	*-0.155*	*-0.063*	*0.282*	*-0.032*	*-0.034*
TRIP FREQUENCY CONTINUOUS											
Main		-0.432*	-1.200*	-0.551*	-0.446*	-0.139	-0.168	0.222	0.347*	-0.158*	-0.141*
Tripfreq		-0.169	0.138	0.038	0.076	0.309*	0.243	0.294*	-0.068	-0.001	0.006
FLEXIBILITY OF ARRIVAL TIME AT HOME											
Main		-0.461*	-1.130*	-0.603*	-0.495*	-0.124	-0.192	0.166	0.349*	-0.140*	-0.109*
Flexhd1	Not flexible	-0.777*	0.403	0.131	0.288	0.245	0.023	0.146	0.043	0.052*	0.152*
Flexhd2	Bit flexible	0.086	-0.273	-0.011	-0.068	-0.109	-0.150	0.020	0.045	-0.032*	-0.089
Flexhd3	Very flexible	*0.691*	*-0.130*	*-0.120*	*-0.220*	*-0.136*	*0.127*	*-0.166*	*-0.089*	*-0.020*	*-0.241*
Flexibility of arrival time at station											
Main		-0.445*	-0.995*	-0.521*	-0.479*	-0.217	-0.078	0.180	0.264*	-0.144*	-0.156*
Flexst1	Not flexible	0.173	-0.454*	-0.138	-0.142	0.095	-0.219	-0.047	0.080	-0.022	0.014
Flexst2	Bit flexible	-0.021	0.148	0.064	0.230	-0.201	0.043	-0.045	0.204	0.018	-0.018
Flexst3	Very flexible	*-0.152*	*0.306*	*0.074*	*-0.088*	*0.106*	*0.176*	*0.092*	*-0.284*	*0.004*	*0.004*
BICYCLE REIMBURSEMENT											
Main		-0.454*	-1.22*	-0.590*	-0.437*	-0.077	-0.156	0.311*	0.323*	-0.151*	-0.139*
Bicreimb1	Full reimbursement	0.098	-0.035	-0.141	-0.138	0.009	-0.270	0.174	-0.033	0.005	0.001
Bicreimb2	Partial reimbursement	-0.317	0.074	0.038	0.300	0.169	0.440*	0.208	-0.043	0.025*	0.001
Bicreimb3	No reimbursement	*0.219*	*-0.039*	*0.103*	*-0.162*	*-0.178*	*-0.170*	*-0.382*	*0.076*	*-0.029*	*-0.002*

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

Table 43: Interaction effects with trip characteristics in the model of egress cyclists

		Ascsb	Ad1	Ad2	Ad3	As1	As2	As3	Park	Price	Walk
STATION											
Main		0.181	-0.731*	-0.348*	-0.200	-0.474*	-0.175	-0.081	0.005	-0.182*	-0.070
Station1	Amsterdam Amstel	-0.016	0.265	0.125	0.143	-0.142	0.223	-0.078	-0.059	0.020	-0.006
Station2	Amsterdam Centraal	0.073	-0.162	-0.091	0.100	-0.073	-0.081	-0.016	0.169	-0.005	-0.065
Station3	Amsterdam Zuid	-0.057	-0.103	-0.035	-0.243	0.215	-0.142	0.094	-0.110	0.003	0.071
PAID											
Main		0.129	-0.740*	-0.340*	-0.194	-0.417*	-0.139	-0.045	-0.030	-0.180*	-0.065
Paid1	Paid parking (paid by cyclists themselves)	-0.224	0.019	0.053	0.067	0.185	0.161	0.130	-0.186	0.011	0.012
Paid2	Unpaid parking (not paid by cyclists themselves)	*0.224*	*-0.019*	*-0.053*	*-0.067*	*-0.185*	*-0.161*	*-0.130*	*0.186*	*-0.011*	*-0.012*
PARKING PRESSURE											
Main		0.042	-0.618*	-0.328	-0.221	-0.339	-0.096	0.056	0.057	-0.165*	-0.070
Parkpres1	Always or often	-0.219	0.233	0.030	0.012	0.167	0.136	0.226	0.096	0.029*	-0.016
Parkpres2	Occasionally or never	*0.219*	*-0.233*	*-0.030*	*-0.012*	*-0.167*	*-0.136*	*-0.226*	*-0.096*	*-0.029*	*0.016*

PARKING TIME CONTINUOUS											
Main		0.192	-0.763*	-0.366*	-0.236	-0.482*	-0.191	-0.085	-0.008	-0.183*	-0.062
Parkdur		-0.344*	0.246	0.203	0.090	0.334*	0.202	0.175	0.045	0.020*	0.021
TRIP DURATION											
Main		-0.208	-0.537*	-0.230	0.024	-0.495*	0.160	0.046	-0.073	-0.177*	-0.030
Tripdur1	≥ 16 min	-0.595	0.145	0.370	0.238	0.617	-0.008	0.395	-0.236	0.037	-0.019
Tripdur2	11 - 15 min	0.640	-0.382	-0.252	-0.352	0.0909	-0.125	-0.066	0.063	-0.020	-0.024
Tripdur3	6 - 10 min	0.724*	-0.391	-0.220	-0.511	-0.171	-1.07*	-0.446	0.259	-0.017	-0.057
	1 - 5 min	*-0.769*	*0.628*	*0.102*	*0.625*	*-0.537*	*1.203*	*0.117*	*-0.086*	*-0.000*	*0.100*
TRIP FREQUENCY CONTINUOUS											
Main		0.143	-0.728*	-0.345*	-0.197	-0.457*	-0.162	-0.072	-0.002	-0.181*	-0.057
Tripfreq c		0.253	-0.366*	-0.399*	-0.077	-0.039	-0.015	-0.116	-0.040	0.005	0.002
FLEXIBILITY OF ARRIVAL TIME AT DESTINATION											
Main		0.101	-0.745*	-0.184	-0.103	-0.555*	-0.259	-0.261	-0.025	-0.194*	-0.021
Flexhd1	Not flexible	-0.192	-0.138	-0.312	-0.085	-0.019	-0.287	0.209	-0.061	0.063*	0.006
Flexhd2	Bit flexible	0.245	0.121	-0.070	-0.139	0.072	0.301	0.055	0.108	-0.020	-0.082
Flexhd3	Very flexible	*-0.053*	*0.017*	*0.382*	*0.224*	*-0.052*	*-0.014*	*-0.264*	*-0.047*	*-0.043*	*0.076*
FLEXIBILITY OF ARRIVAL TIME AT STATION											
Main		0.304	-0.785*	-0.200	-0.280	-0.603*	-0.403	-0.323	0.077	-0.202*	-0.055
Flexst1	Not flexible	-0.201	-0.064	-0.124	0.023	0.063	0.177	0.197	-0.114	0.030	0.025
Flexst2	Bit flexible	-0.136	0.274	-0.184	0.236	0.184	0.460	0.204	-0.033	0.017	-0.045
Flexst3	Very flexible	*0.337*	*-0.210*	*0.308*	*-0.259*	*-0.247*	*-0.637*	*-0.401*	*0.147*	*-0.047*	*0.02*

BICYCLE REIMBURSEMENT											
Main		0.079	-0.724*	-0.398*	-0.303	-0.254	-0.283	-0.010	0.008	-0.183	-0.029
Bicreimb1	Full reimbursement	-1.150*	0.302	-0.111	-0.004*	0.499	0.358	0.570	0.265	0.060*	0.000
Bicreimb2	Partial reimbursement	1.030*	-0.217	0.028	-0.144	-0.135	-0.591	-0.456	-0.280	-0.062*	0.064
Bicreimb3	No reimbursement	*0.120*	*-0.085*	*0.083*	*0.148*	*-0.364*	*0.233*	*-0.114*	*0.015*	*0.002*	*-0.064*

** = significant. Parameter estimates with an absolute p-value smaller than 0.05 are considered as statistically significant.*

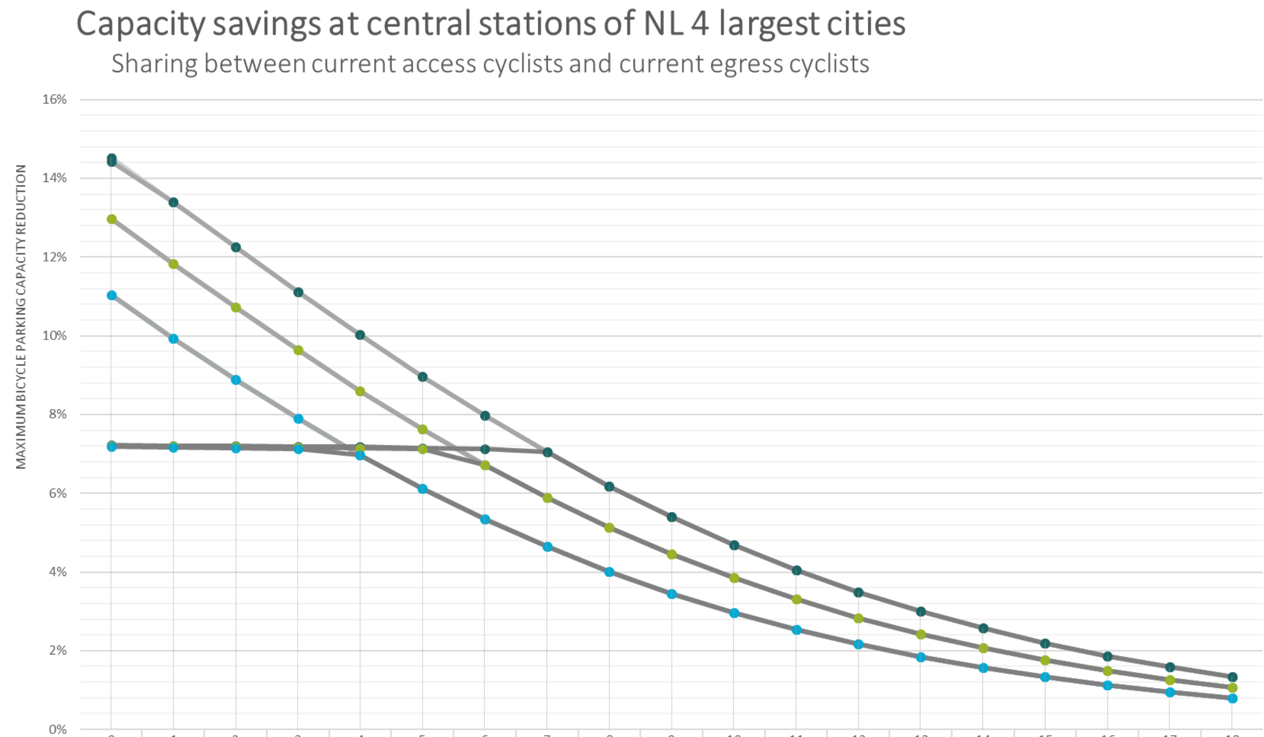
Appendix H: Estimations of possible bicycle parking capacity savings

H.1. Classification of combined railway stations & sample size

Table 44: Observed supply and demand of bicycles per train station on working days

	Projected numbers (numbers per day), based on MON 2004-2009			Number of observations in MON		
	Suppliers	Demanders		Suppliers	Demanders	
	Cyclist	*Cyclist*	*Potential cyclist*	*Cyclist*	*Cyclist*	*Potential cyclist*
CENTRAL STATIONS OF NL 4 LARGEST CITIES						
Utrecht Centraal	12691	3017	19340	78	18	159
Amsterdam Centraal	9036	1358	25694	28	16	225
Den Haag Centraal	3538	962	9242	14	12	92
Rotterdam Centraal	3023	1311	11804	13	13	90
Total	28288	6648	66080	133	59	566
CENTRAL STATIONS OF OTHER LARGE NL CITIES						
Groningen	2044	1417	5886	22	19	84
Zwolle	2398	2022	6701	16	19	58
Arnhem	2756	528	2733	18	5	26
Nijmegen	3565	826	8824	27	5	56
Hilversum	3402	232	522	22	3	6
Amersfoort	5588	515	2379	42	5	23
Almere Centrum	1832	0	2753	39	0	11
Alkmaar	5823	893	642	19	4	7
Haarlem	4480	1240	2626	39	9	20
Leiden Centraal	8058	1871	4832	66	8	32
Den Haag HS	1609	972	3450	8	4	22
Delft	3858	1801	3455	25	10	16
Breda	2664	450	2989	19	7	29
Tilburg	2797	190	2898	19	2	26
's-Hertogenbosch	2018	732	1795	18	7	17
Eindhoven	1723	1614	5465	10	13	47
Total	54615	15303	57950	409	120	480

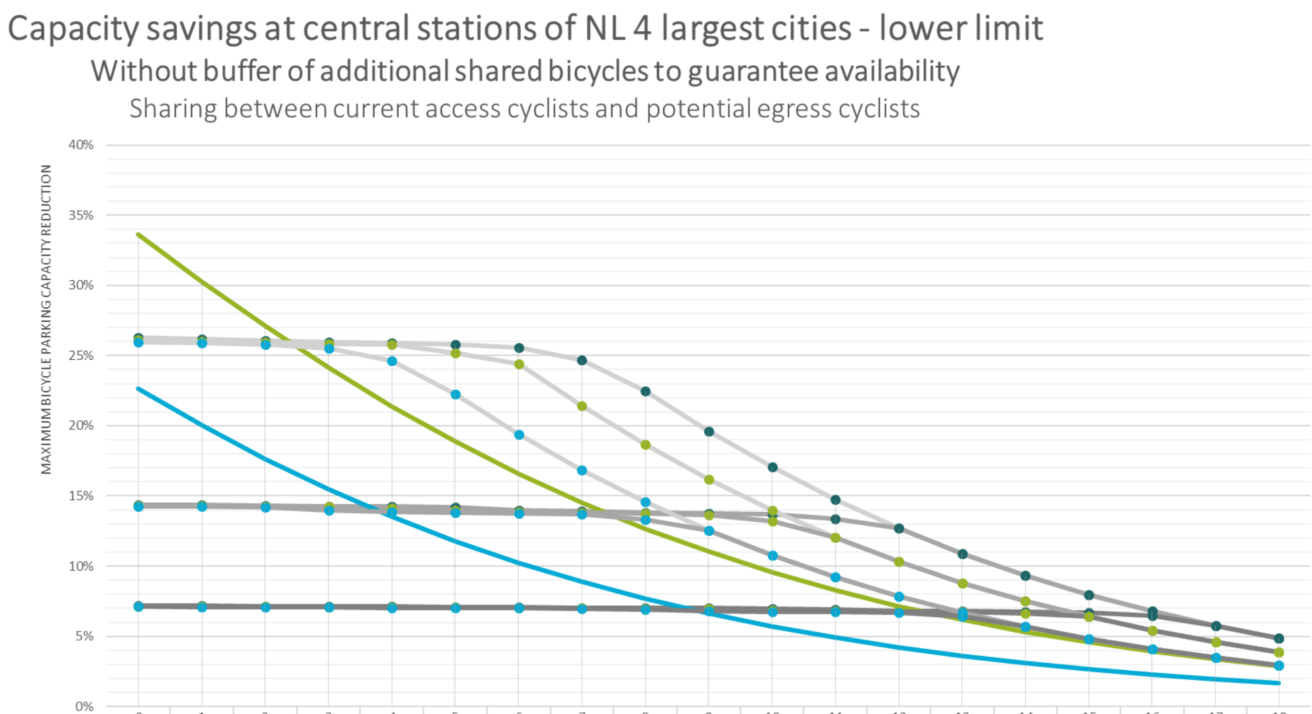
H.2. Possible capacity savings at central stations of the Dutch four largest cities



EURO PER MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-way station-based	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%	1%	1%	1%
Free floating	13%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (5 euros) - 2-way station-based	15%	13%	12%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%
Hybrid sharing lease (5 euros) - free floating	13%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (5 euros) - 1-way station-based	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%	1%	1%	1%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	13%	12%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%
Hybrid sharing lease (10 euros) - free floating	13%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (10 euros) - 1-way station-based	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%	1%	1%	1%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%	1%	1%	1%

EURO PER MONTH

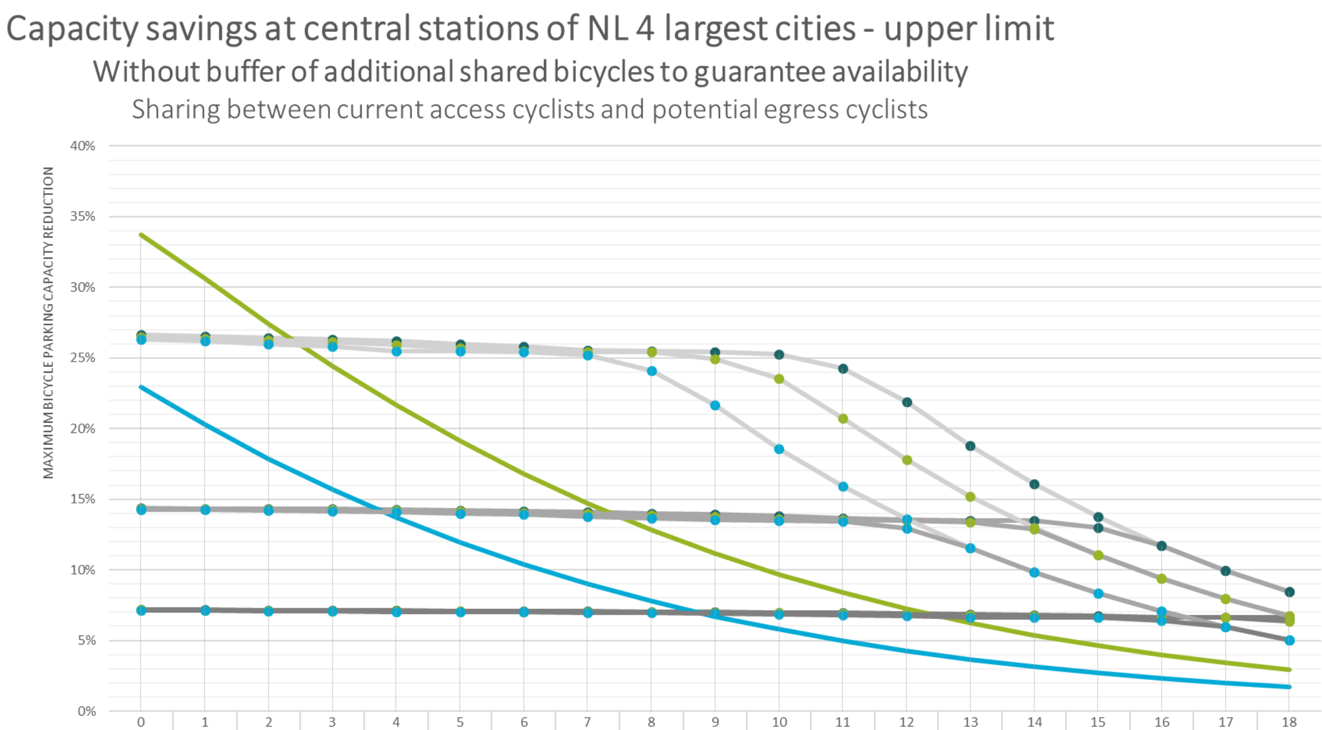
Figure 42: Possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access and egress cyclists



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	26%	26%	26%	26%	26%	26%	26%	25%	22%	20%	17%	15%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	6%	5%
Free floating	34%	30%	27%	24%	21%	19%	17%	15%	13%	11%	10%	8%	7%	6%	5%	5%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	26%	26%	26%	26%	26%	25%	24%	21%	19%	16%	14%	12%	10%	9%	8%	6%	5%	5%	4%
Hybrid sharing lease (10 euros) - free floating	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	12%	10%	9%	8%	6%	5%	5%	4%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%
1-way station-based	23%	20%	18%	15%	14%	12%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	26%	26%	26%	26%	25%	22%	19%	17%	15%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	13%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	6%	5%	4%	3%	3%

EURO PER MONTH

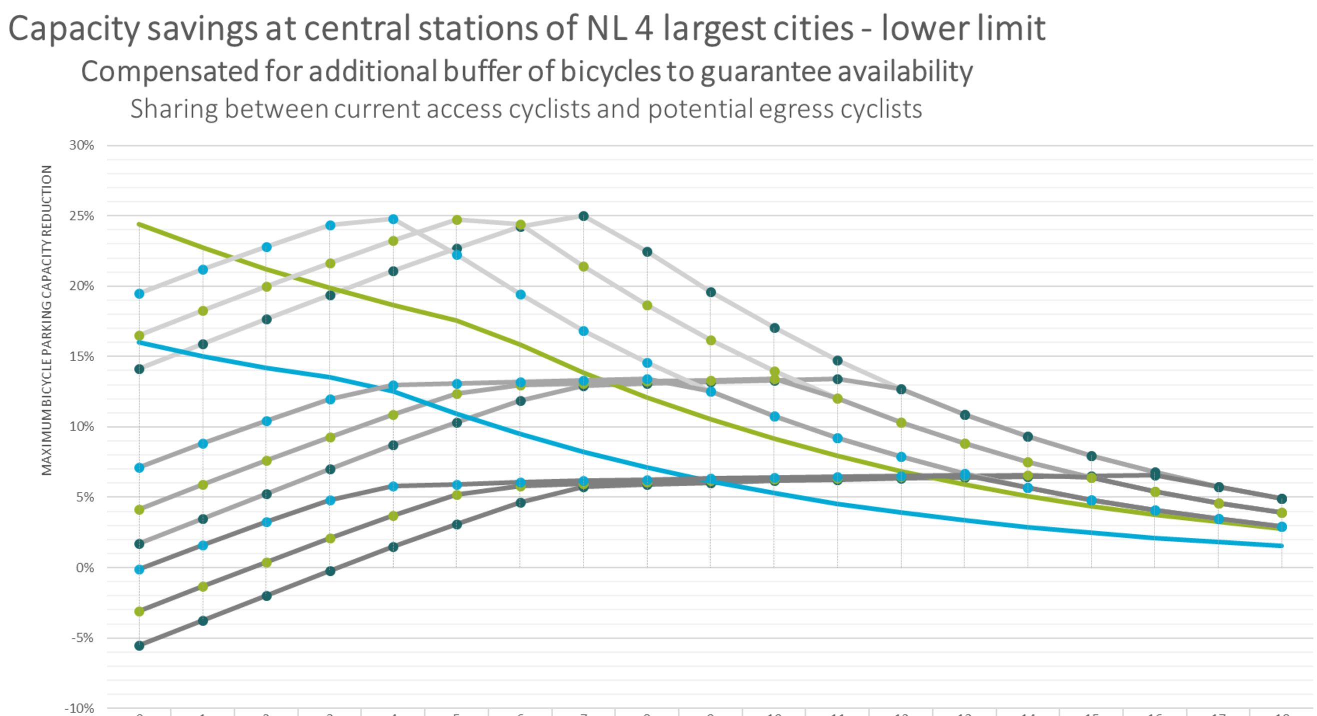
Figure 43: Lower limit of the possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (not compensated for need buffer of shared bicycles)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	27%	27%	26%	26%	26%	26%	26%	26%	25%	25%	25%	24%	22%	19%	16%	14%	12%	10%	8%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	13%	12%	10%	8%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Free floating	34%	31%	27%	24%	22%	19%	17%	15%	13%	11%	10%	8%	7%	6%	5%	5%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	27%	26%	26%	26%	26%	26%	25%	25%	25%	25%	24%	21%	18%	15%	13%	11%	9%	8%	7%
Hybrid sharing lease (10 euros) - free floating	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	13%	11%	9%	8%	7%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%
1-way station-based	23%	20%	18%	16%	14%	12%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	26%	26%	26%	26%	26%	25%	25%	25%	24%	22%	19%	16%	14%	12%	10%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	13%	12%	10%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	6%	5%

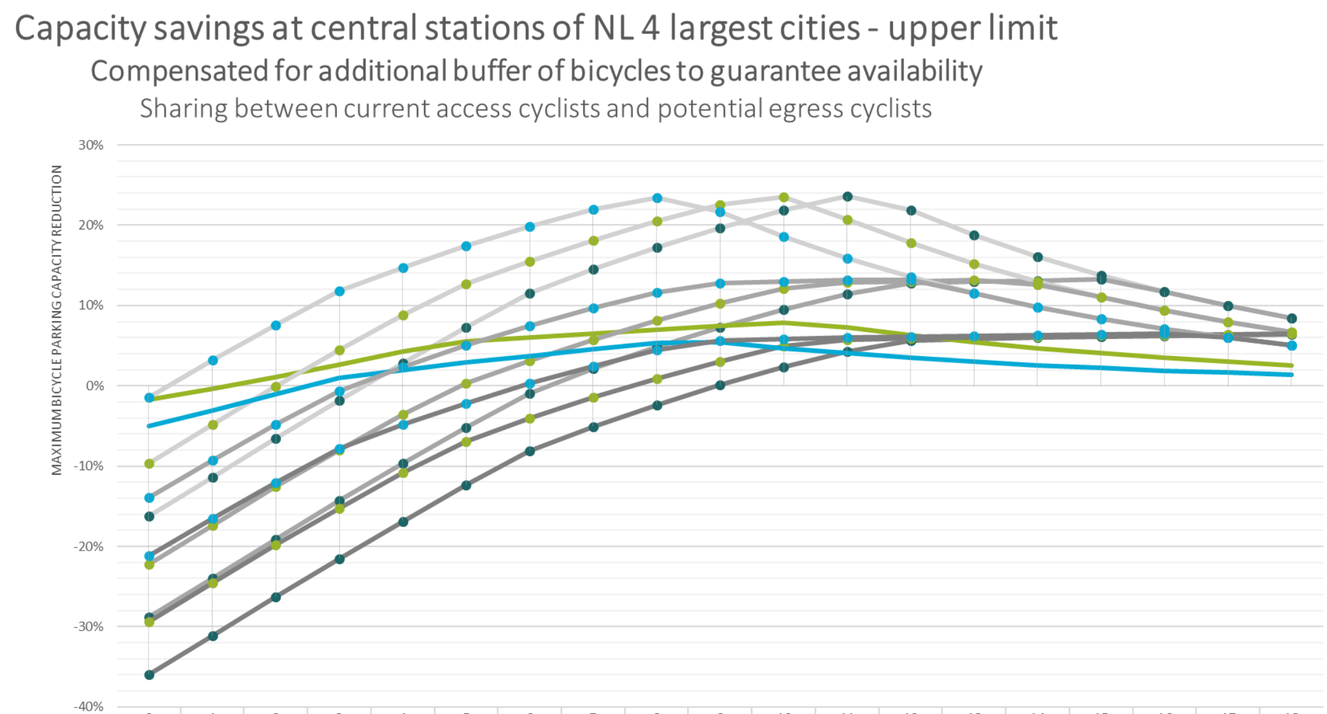
EURO PER MONTH

Figure 44: Upper limit of the possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (not compensated for need buffer of shared bicycles)



EURO PER MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	14%	16%	18%	19%	21%	23%	24%	25%	22%	20%	17%	15%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 2-way station-based	2%	3%	5%	7%	9%	10%	12%	13%	13%	13%	13%	13%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 2-way station-based	-5%	-4%	-2%	0%	1%	3%	5%	6%	6%	6%	6%	6%	6%	6%	6%	7%	7%	6%	5%
Free floating	24%	23%	21%	20%	19%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	17%	18%	20%	22%	23%	25%	24%	21%	19%	16%	14%	12%	10%	9%	8%	6%	5%	5%	4%
Hybrid sharing lease (10 euros) - free floating	4%	6%	8%	9%	11%	12%	13%	13%	13%	13%	13%	12%	10%	9%	8%	6%	5%	5%	4%
Hybrid sharing lease (15 euros) - free floating	-3%	-1%	0%	2%	4%	5%	6%	6%	6%	6%	6%	6%	6%	7%	7%	6%	5%	5%	4%
1-way station-based	16%	15%	14%	14%	13%	11%	9%	8%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	20%	21%	23%	24%	25%	22%	19%	17%	15%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (10 euros) - 1-way station-based	7%	9%	10%	12%	13%	13%	13%	13%	13%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (15 euros) - 1-way station-based	0%	2%	3%	5%	6%	6%	6%	6%	6%	6%	6%	6%	7%	7%	6%	5%	4%	3%	3%

Figure 45: Lower limit of the possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (compensated for needed buffer of additional shared bicycles)

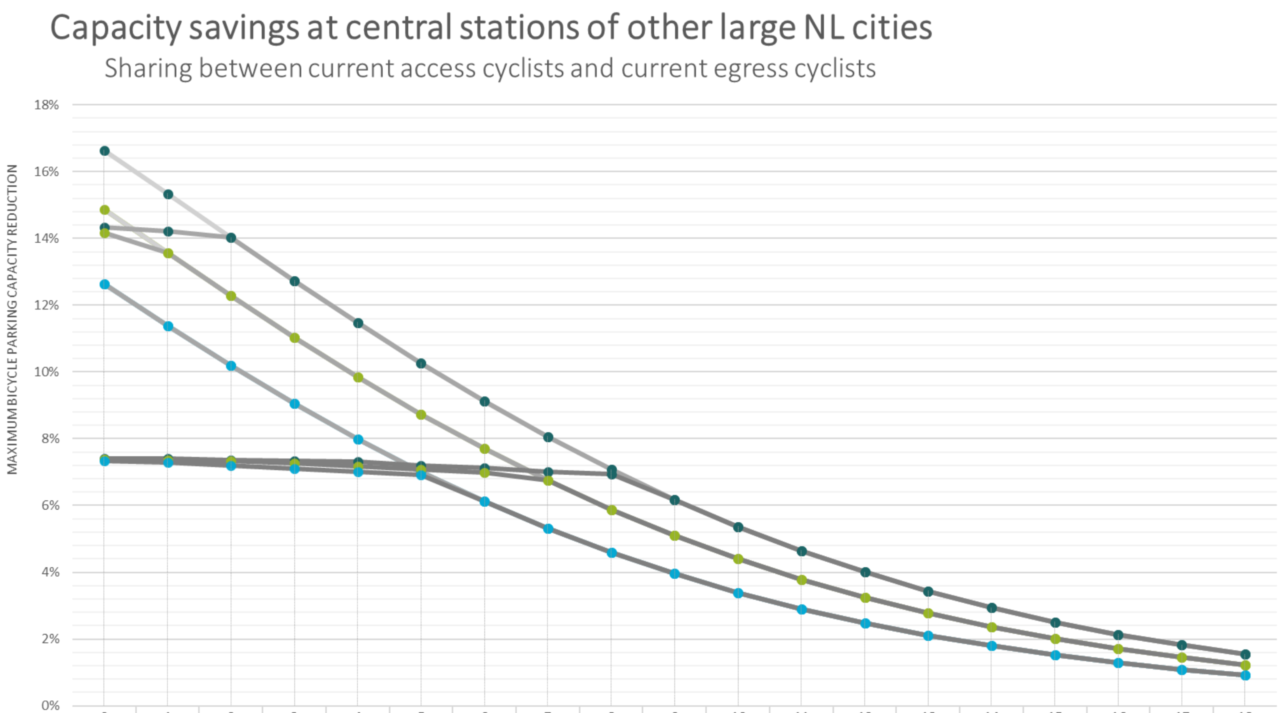


	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	-16%	-11%	-7%	-2%	3%	7%	11%	15%	17%	20%	22%	24%	22%	19%	16%	14%	12%	10%	8%
Hybrid sharing lease (10 euros) - 2-way station-based	-29%	-24%	-19%	-14%	-10%	-5%	-1%	2%	5%	7%	9%	11%	13%	13%	13%	13%	12%	10%	8%
Hybrid sharing lease (15 euros) - 2-way station-based	-36%	-31%	-26%	-22%	-17%	-12%	-8%	-5%	-2%	0%	2%	4%	6%	6%	6%	6%	6%	6%	6%
Free floating	-2%	0%	1%	3%	4%	6%	6%	7%	7%	7%	8%	7%	6%	5%	5%	4%	3%	3%	3%
Hybrid sharing lease (5 euros) - free floating	-10%	-5%	0%	4%	9%	13%	16%	18%	20%	23%	24%	21%	18%	15%	13%	11%	9%	8%	7%
Hybrid sharing lease (10 euros) - free floating	-22%	-17%	-13%	-8%	-4%	0%	3%	6%	8%	10%	12%	13%	13%	13%	13%	11%	9%	8%	7%
Hybrid sharing lease (15 euros) - free floating	-29%	-25%	-20%	-15%	-11%	-7%	-4%	-1%	1%	3%	5%	6%	6%	6%	6%	6%	6%	6%	7%
1-way station-based	-5%	-3%	-1%	1%	2%	3%	4%	5%	5%	5%	5%	4%	3%	3%	3%	2%	2%	2%	1%
Hybrid sharing lease (5 euros) - 1-way station-based	-1%	3%	8%	12%	15%	17%	20%	22%	23%	22%	19%	16%	14%	12%	10%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 1-way station-based	-14%	-9%	-5%	-1%	2%	5%	7%	10%	12%	13%	13%	13%	13%	12%	10%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 1-way station-based	-21%	-17%	-12%	-8%	-5%	-2%	0%	2%	4%	6%	6%	6%	6%	6%	6%	6%	6%	6%	5%

EURO PER MONTH

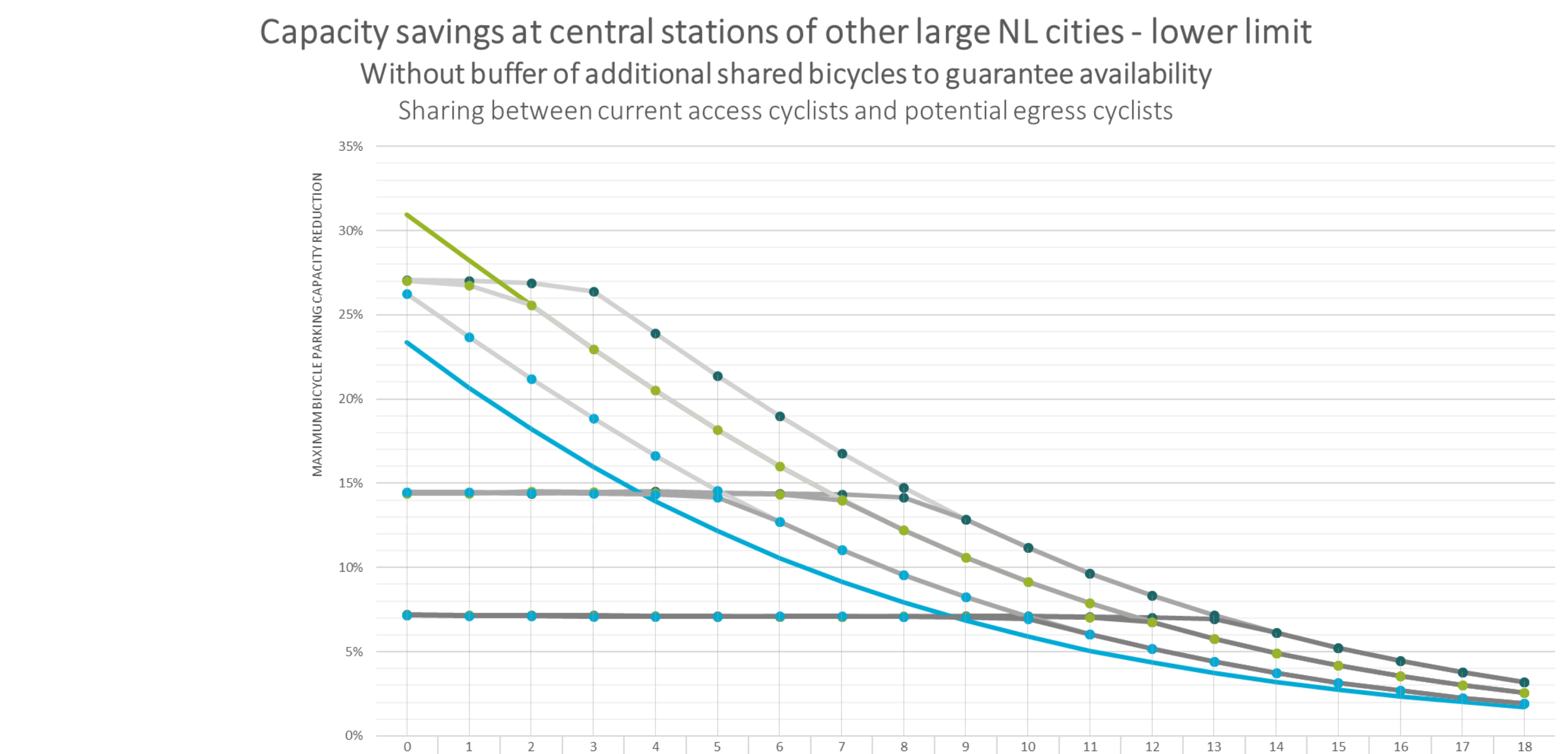
Figure 46: Upper limit of the possible capacity savings at the central stations of the four largest Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (compensated for needed buffer of additional shared bicycles)

H.3. Possible capacity savings at central stations of other large Dutch cities



EURO PER MONTH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-way station-based	13%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	2%	1%	1%	1%
Free floating	15%	14%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%
Hybrid sharing lease (5 euros) - 2-way station-based	17%	15%	14%	13%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - free floating	15%	14%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%
Hybrid sharing lease (5 euros) - 1-way station-based	13%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	13%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%
Hybrid sharing lease (10 euros) - free floating	14%	14%	12%	11%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%
Hybrid sharing lease (10 euros) - 1-way station-based	13%	11%	10%	9%	8%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	2%	1%	1%	1%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%	3%	3%	3%	2%	2%	2%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%	1%	1%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	2%	1%	1%	1%

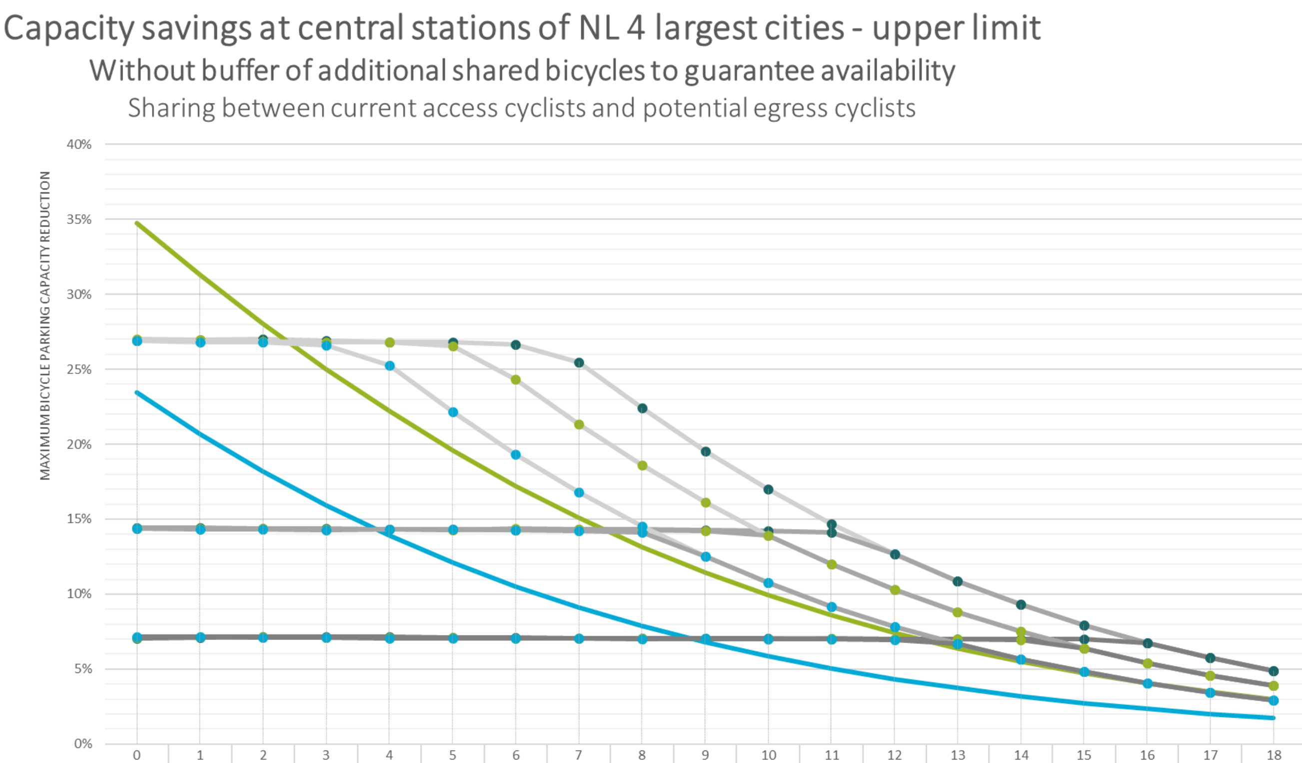
Figure 47: Possible capacity savings at the central stations of other large Dutch cities when bicycles are shared between current access and egress cyclists



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	27%	27%	27%	26%	24%	21%	19%	17%	15%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	14%	15%	14%	14%	14%	14%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%
Free floating	31%	28%	26%	23%	21%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	27%	27%	26%	23%	21%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (10 euros) - free floating	14%	14%	15%	14%	14%	14%	14%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%
1-way station-based	23%	21%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	26%	24%	21%	19%	17%	15%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	15%	14%	14%	14%	14%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%	2%	2%

EURO PER MONTH

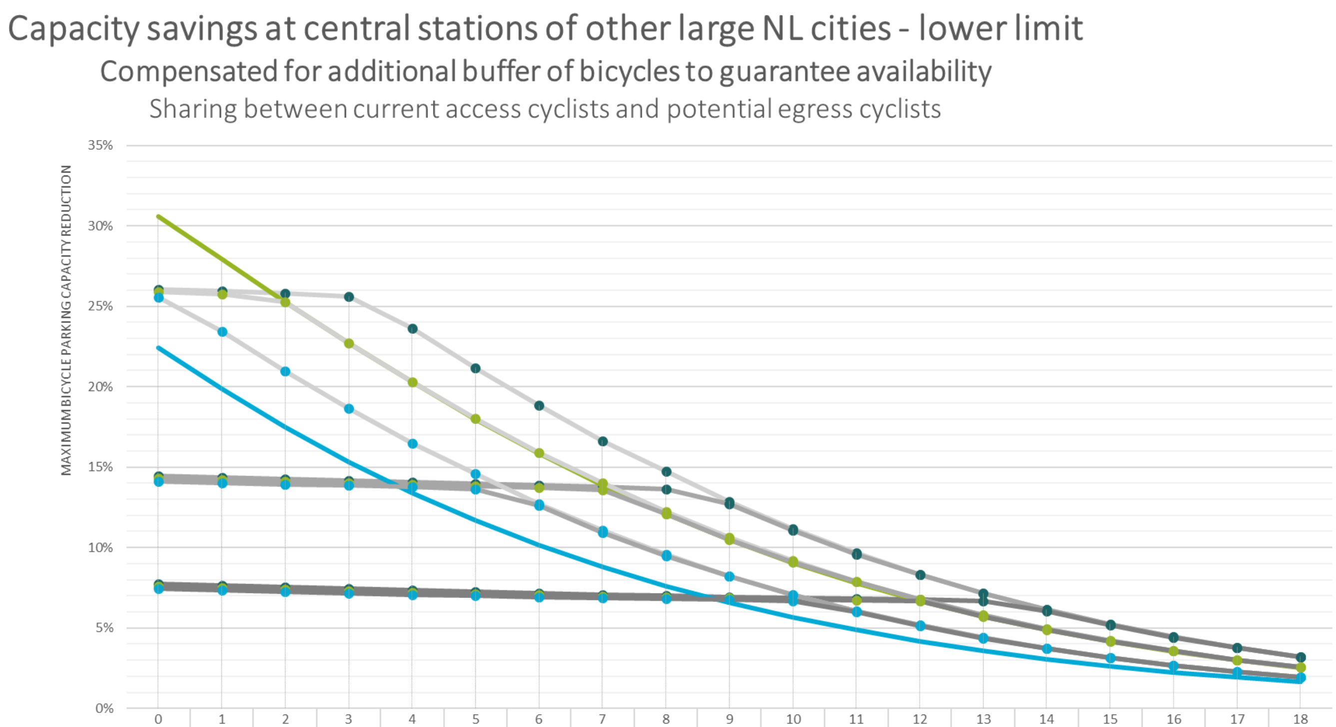
Figure 48: Lower limit of the possible capacity savings at the central stations of other large Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (not compensated for need buffer of shared bicycles)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	27%	27%	27%	27%	27%	27%	27%	25%	22%	20%	17%	15%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 2-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%
Free floating	35%	31%	28%	25%	22%	20%	17%	15%	13%	11%	10%	9%	7%	6%	6%	5%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	27%	27%	27%	27%	27%	27%	24%	21%	19%	16%	14%	12%	10%	9%	7%	6%	5%	5%	4%
Hybrid sharing lease (10 euros) - free floating	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	12%	10%	9%	7%	6%	5%	5%	4%
Hybrid sharing lease (15 euros) - free floating	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%
1-way station-based	23%	21%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	27%	27%	27%	27%	25%	22%	19%	17%	15%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	3%	3%

EURO PER MONTH

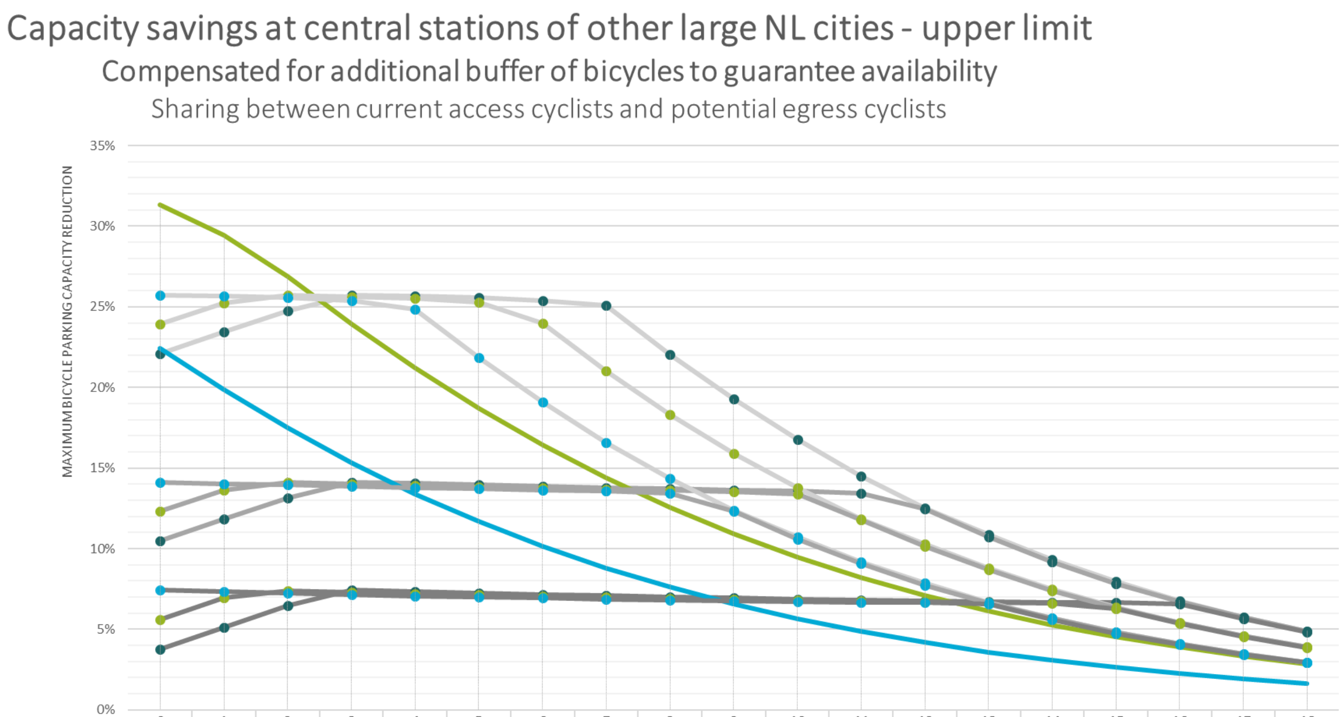
Figure 49: Upper limit of the possible capacity savings at the central stations of other large Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (not compensated for need buffer of shared bicycles)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	26%	26%	26%	26%	24%	21%	19%	17%	15%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%
Hybrid sharing lease (10 euros) - 2-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%
Hybrid sharing lease (15 euros) - 2-way station-based	8%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%
Free floating	31%	28%	25%	23%	20%	18%	16%	14%	12%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	26%	26%	25%	23%	20%	18%	16%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (10 euros) - free floating	14%	14%	14%	14%	14%	14%	14%	14%	12%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%
Hybrid sharing lease (15 euros) - free floating	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%
1-way station-based	22%	20%	17%	15%	13%	12%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	26%	23%	21%	19%	16%	15%	13%	11%	10%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	14%	14%	14%	14%	14%	13%	11%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	4%	3%	3%	2%	2%

EURO PER MONTH

Figure 50: Lower limit of the possible capacity savings at the central stations of other large Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (compensated for needed buffer of additional shared bicycles)



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hybrid sharing lease (5 euros) - 2-way station-based	22%	23%	25%	26%	26%	26%	25%	25%	22%	19%	17%	15%	13%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (10 euros) - 2-way station-based	10%	12%	13%	14%	14%	14%	14%	14%	14%	14%	14%	13%	12%	11%	9%	8%	7%	6%	5%
Hybrid sharing lease (15 euros) - 2-way station-based	4%	5%	6%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%
Free floating	31%	29%	27%	24%	21%	19%	16%	14%	13%	11%	9%	8%	7%	6%	5%	5%	4%	3%	3%
Hybrid sharing lease (5 euros) - free floating	24%	25%	26%	26%	26%	25%	24%	21%	18%	16%	14%	12%	10%	9%	7%	6%	5%	5%	4%
Hybrid sharing lease (10 euros) - free floating	12%	14%	14%	14%	14%	14%	14%	14%	14%	14%	13%	12%	10%	9%	7%	6%	5%	5%	4%
Hybrid sharing lease (15 euros) - free floating	6%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	5%	4%
1-way station-based	22%	20%	17%	15%	13%	12%	10%	9%	8%	7%	6%	5%	4%	4%	3%	3%	2%	2%	2%
Hybrid sharing lease (5 euros) - 1-way station-based	26%	26%	26%	25%	25%	22%	19%	17%	14%	12%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (10 euros) - 1-way station-based	14%	14%	14%	14%	14%	14%	14%	14%	13%	12%	11%	9%	8%	7%	6%	5%	4%	3%	3%
Hybrid sharing lease (15 euros) - 1-way station-based	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	5%	4%	3%	3%

EURO PER MONTH

Figure 51: Upper limit of the possible capacity savings at the central stations of other large Dutch cities when bicycles are shared between current access cyclists and potential egress cyclists (compensated for needed buffer of additional shared bicycles)