

EXPLORING THE DESIGN OF URBAN BIKE SHARING SYSTEMS INTENDED FOR COMMUTERS IN THE NETHERLANDS

Thesis for the MSc. Programme in

Systems Engineering, Policy Analysis & Management

Delft University of Technology

Date: June 2016

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PREFACE

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Systems Engineering, Policy Analysis and Management. It contains work done from February 2015 to June 2016.

This research was conducted at consultancy firm Mobycon. Mobycon was interested in gaining knowledge on the possibilities of (electric) shared bicycles that facilitate both commuting and business trips from which my thesis subject was conceived. During my time at Mobycon I worked part-time on my thesis research as well as on Mobycon projects, which lengthened the process of completing this research while I was also able to gain useful experience in the field of mobility.

Writing this thesis, doing the related research, distributing the survey and analysing the data has been a difficult, but satisfying process in which I have had the opportunity to learn how to design a stated choice experiment in addition to learning how to estimate and interpret different types of discrete choice models.

I would like to thank my supervisor, Dr. Kees Maat, for the guidance he has offered throughout the entire process of my thesis research. Thanks also to Dr. Eric Molin for his immense expertise on the subject of discrete choice modelling and on the design of stated choice experiments. Furthermore, lots of thanks are due to Prof. dr. Bert van Wee for his enthusiasm and interest in the research subject.

Furthermore, I would like to thank Matthijs for his patience and help throughout the process of writing my thesis, as well as Liesbeth van Alphen, without whom I would not have been able to finish this thesis. Finally, I also want to thank Mobycon and its employees for providing me with the opportunity to do this research.

Hélène van Heijningen Delft June 2016

SUMMARY

Ever since the rise of the industrial revolution, one of the greatest challenges for governments relates to the variety of traffic problems that have emerged in urbanized areas (Buchanan, 2015; Headicar, 2015). A vastly growing and promising worldwide spread transport policy is the development of urban bike sharing programmes. These programmes can be found in cities all over the world and have been proven to contribute to: a modal shift towards the use of more sustainable transportation modes, a reduction in externalities of non-sustainable modes, an increase in the accessibility of urban regions and a decrease in bicycle parking and traffic congestion (e.g. DeMaio, 2009; Fishman et al., 2014).

These systems provide the public with shared use of a bicycle fleet for a small fee, making cycling a possible mode choice at any location throughout an urban region (Shaheen et al., 2010a). There is currently only one bike sharing system found in the Netherlands: the Public Transport bicycle (PT-bicycle). This system is found at medium to large railway stations where the PT-bicycle can be used for the last leg of the journey (NS, 2015). Although this system is very successful, it does not provide the variety of trip options and flexibility that urban bike sharing systems offer in other countries. Its success does indicate however that there is indeed a demand for bicycles at locations where the privately owned bicycle is not available. This raises the question whether there is a market for destination-based bike sharing systems in the Netherlands which are not limited to train stations, and what such a system should look like.

Since commuting and business travel highly contribute to urban traffic congestion and emissions in the Netherlands, it is important to increase the use of sustainable modalities for these travel motives. The objective of this research is therefore to provide recommendations for bike sharing system design in order to introduce the service as an attractive mode option to commuters and business travellers in the Netherlands. This objective corresponds to the main research question:

How should an urban bike sharing system be designed in order to attract commuters and business travellers in the Netherlands?

The first step in this research is to determine the basic elements of a bike sharing concept aimed towards Dutch commuters and business travellers based on extensive background research and expert interviews. This concept is developed to serve as a basis for testing preferences with regards to bike sharing system design and its use as well as to determine the characteristics of Dutch commuters and business travellers that are interested in using a shared bicycle. Based on this research it was found that several conditions are to be met in order for this bike sharing concept to be a realistic representation of how bike sharing will exist in Dutch cities in the future, so that preferences and user characteristics can be determined. Firstly, the concept should be able to provide a mix of both traditional and electric bicycles so that preferences regarding the type of bicycle can be studied in more detail. Secondly, the bicycles should be able to be picked up at any location thereby creating a hypothetical situation in which all potential users are able to access the system, allowing their preferences to be tested. Thirdly, the system should be flexible with regards to two aspects: the system should allow the bicycles to be able to be locked anywhere and at any time and in addition the drop-off or return location of the bicycles should be flexible. This means

that the shared bicycle should be allowed to be returned at any docking station. Lastly, the pricing structure presented in the concept has to allow the potential user to pay for use through a fixed fee per kilometre so that the trip costs reflect the cost structure that is expected to be used in Dutch bike sharing systems.

Preferences and the perception with regards to making use of a shared bicycle as well as preferences regarding several system characteristics and the characteristics of potential users are studied using a web survey which consists of a questionnaire as well as a stated choice (SC) experiment. The questionnaire consists of questions that study the characteristics of potential users, the current trip characteristics of the respondents and questions that explore user preferences regarding the use of a shared bicycle, while the SC experiment is used to study preferences regarding several system characteristics. A SC experiment is used here as this method allows us to be able to determine the influence of design attributes upon the choices that are observed, thereby gaining understanding of how different characteristics or attributes are balanced against each other in the bike share mode choice. The SC experiment that is developed in order to study how several system characteristics influence the bike share mode choice consists of a series of choice sets, in which for every choice set three alternatives are presented to the respondent. The first two involve shared bicycle alternatives varying in attribute values, while the third alternative is a no-choice alternative, representing any other transport mode. The attributes that make up the shared bicycle alternatives are the bicycle type (traditional versus electric), access time, egress time and the trip costs. While making their choices, respondents are told to assume that they have to travel a certain distance with the shared bicycle, which varies across the choice sets. This context variable allows for examining how different trip distances influence the preference for certain attribute values and the general preference for a shared bicycle over other transport modes.

The web survey is distributed amongst a sample of the population of Dutch commuters and business travellers to gather stated preference data on potential users of a bike sharing system that aims to facilitate commuting and business trips. In order to incorporate commuters and business travellers who vary regarding their preferences towards driving and cycling, the survey was distributed amongst employees from one large and three smaller employers whom all have multiple office locations throughout the country. The 293 respondents were found to be predominantly male, on average aged 47 years old, have different educational backgrounds and professions. A large portion of the respondents uses a (company) car for their commuting trip, while public transportation and the bicycle are chosen by smaller portions of the respondent sample. This sample is therefore believed to be a reasonable representation of the population.

From the observed choices made in the SC experiment and a mixed logit (ML) model taking into account panel effects is estimated which includes taste heterogeneity for the bike sharing constant as well as the bicycle type parameter. This ML panel model shows that for this model setup there is a high degree of variation in unobserved preferences for bike sharing over other modalities. However, there is no preference for a shared bicycle compared to other modalities or vice versa when averaged over all respondents. Next to the bike sharing constant, the results show that the trip cost and interaction effects with trip cost are the most important attributes influencing the commuters' bike share mode choice. The parameter estimates for the random parameters bicycle type and the

bike sharing constant are by far the most accurately measured estimates. Other attributes such as the trip distance and education seem secondary attributes in determining the bike share mode choice.

In addition there is quite a bit of unobserved variation in the importance of the bicycle type parameter. Furthermore, the interaction effect of trip distance on bicycle type shows that the traditional bicycle is preferred for shorter distances while the electric bicycle is preferred for trip distances of over 4.5 kilometres. The difference in utility between both types of bicycles however is relatively small. With regards to the utility of trip distance itself, it is found that commuters are open towards using a shared bicycle for trips up to 8 kilometres.

In addition to determining the influence of design attributes upon the choices that are observed, an SC experiment can be used to predict the choice probabilities of people opting for a shared bicycle based on the estimated bike share mode choice model. Several system design scenarios are tested using this method to determine recommendations for bike sharing system design.

The traditional bicycle is found to be preferred for short distances while the electric bicycle is preferred for longer distances. Due to the electric bicycles being much more costly than the traditional bicycles however, it is recommended to only provide electric bicycles in a bike sharing system if the system specifically focuses on facilitating medium to long distance trips and enough funds are available to implement these bicycles while still aiming to limit trip costs. Depending on the target groups and the types of trips the system has to facilitate, one can either opt for a fine-grained network of docking stations, which expands the reach of the system, or for a coarsely distributed network of docking station that minimizes costs. As it is recommended to design a flexible bike sharing system in the Netherlands, meaning that users can return the shared bicycle at any docking station, redistribution of bicycles will be necessary. A method to decrease the cost of redistribution is the implementation of user-based redistribution schemes. As the trip costs have a large effect on the attractiveness of the system, these should be minimized which can be achieved by making choices on the distribution of docking stations and the bicycle type that is provided. In addition, employers should be stimulated to include the use of shared bicycles into the travel allowances that are granted to their employees.

Based on the results from the questionnaire and the SC experiment it can be concluded that a significant group of people is interested in using a shared bicycle for their commuting trips, and even more so for business trips if their current trip characteristics allow them to make use of a shared bicycle. From the perspective of the user there are three preferred system design scenarios with regards to commuting trips. The first two scenarios describe a bike sharing system implemented on a citywide scale, with either a coarsely distributed or a fine-grained network of docking stations, which only provides traditional bicycles limits the trip costs. The third option is a system that only focuses on a limited group of commuters and business travellers in a smaller region. Such a system would minimize access and egress time through providing electric bicycles exactly where needed. To implement such a system however, trip costs need to be minimized through providing users with a travel allowance aimed towards using a shared bicycle.

It can be concluded that the decision on whether to implement a bike sharing system in Dutch cities is not straightforward. Due to the nature of the Dutch population, it remains unclear whether a shared vehicle system will be found to be attractive by a significant part of the population. In addition, as bicycle usage does not need to be stimulated as much as in foreign countries, and the focus lies more on decreasing traffic congestion and increasing the accessibility of urban regions, it is less likely that these problems can be solved through the implementation of a costly citywide bike sharing system. Systems introduced in smaller regions like industrial areas will however be able to tackle specific problems and thereby achieve the goals that were set with regards to traffic congestion and accessibility. The introduction of bike sharing systems at specific locations is therefore more likely to be effective as well as feasible. The decision on whether citywide bike sharing systems in Dutch cities are to be implemented should therefore not be taken lightly.

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1. INTRODUCTION

Ever since the rise of the industrial revolution, one of the greatest challenges for governments relates to the variety of traffic problems that have emerged in urbanized areas (Buchanan, 2015; Headicar, 2015). Traffic congestion and other externalities from non-sustainable transport modes have a huge economic impact, and are the cause of major health as well as environmental issues. A study on traffic externalities conducted in the Netherlands shows that the costs of traffic externalities caused by passenger cars equal over 12 billion euros in 2010 alone (Schroten, van Essen, Aarnink, Verhoef, & Knockaert, 2014). The Dutch national government as well as the various municipalities aim to increase usage of sustainable transportation modes in order to reduce traffic congestion, create a healthier living environment and increase the accessibility of urban regions without causing environmental damage (Ministerie van Infrastructuur & Milieu, 2014).

The bicycle has emerged globally as a key part of the solution to traffic problems (e.g. Krizek, Handy, & Forsyth, 2009; Ministerie van Infrastructuur & Milieu, 2014; Tang, Pan, & Shen, 2010). There is a wide range of interventions available to promote bicycling, like travel-related infrastructure interventions, end-of-trip facilities, transit integration, bicycling stimulation programs and interventions related to bicycle access (Pucher, Dill, & Handy, 2010). A vastly growing and promising worldwide spread transport policy is the development of urban bike sharing programmes. These programmes can be found in cities all over the world and seem to be a good starting point to boost cycling usage in urban areas (Bachand-Marleau, Lee, & El-Geneidy, 2012; Shaheen et al., 2010a).

Bike sharing has been defined by Paul DeMaio as "short term bicycle rental available at unattended bicycle docking stations" (2009). These systems provide the public with shared use of a bicycle fleet for a small fee, making cycling a possible mode choice at any location throughout an urban region (Shaheen et al., 2010a). The most widely known bike sharing system in Europe is Vélib', stationed in Paris. With over 20.000 bicycles at 1.800 locations, Vélib' has bikes available 24/7 at every 300 meters (Vélib', 2015). It operates on a fee-based system, encouraging users to use bicycles for short trips by offering the first 30 min of cycling free to users. One velib' (bicycle) is being rented every second in Paris, resulting in 86,400 rentals per day, making it a very successful system (Melvin, 2014). The North American bike sharing experience is more limited, however a large number of bike sharing programmes can now be found all over North America and Canada, which are mostly ITbased¹ bike sharing systems (Shaheen et al., 2010a; Shaheen, Martin, Cohen, & Finson, 2012). Bike sharing history is limited in Asia as well, although it is the fasted growing market for bike sharing activity at present (Shaheen et al., 2010a). Asia's largest and most famous bike sharing program, the Public Bicycle system in Hangzhou, China, was the first IT-based system in Mainland China and grew rapidly due to the high-density distribution of the bike sharing stations and it being almost free of charge to all citizens and tourists (Tang et al., 2010). Research done on the effects of such systems shows that they can contribute to a modal shift towards the use of more sustainable transportation modes, a reduction in externalities of non-sustainable modes, an increase in the accessibility of urban regions and a decrease in traffic congestion (Bachand-Marleau et al., 2012; DeMaio, 2009; Fishman et al., 2014; Midgley, 2011; Shaheen, Cohen, & Martin, 2013)

¹ IT-based systems introduce user interface technology at docking stations and the use of smart technology for check-in and checkout, as well as theft deterrents and payment in the form of a membership service (Shaheen et al., 2010a)

As of December 2015, 980 cities around the world have a bike sharing system with 1.258.500 bicycles and 9.300 e-bikes (Shaheen, 2016). In the Netherlands however only a few examples of bike sharing systems exist, and none of these are on the scale as in other European countries. A possible reason for this is that bicycle ownership is extremely high, with 84% of the Dutch population owning one or more bicycles, resulting in 1.1 bicycle per person as of 2012 (Landelijk Fietsplatform, 2013). However, one Dutch bike sharing system is very successful: the Public Transport bicycle (PT-bicycle). This system is found at railway stations where the PT-bicycle can be used for the last leg of the journey (NS, 2015). This system however does not provide the variety of trip options and flexibility that urban bike sharing systems offer in other countries, as the bicycles are only available at train stations and have to be returned to the trip's original starting location. Its success does indicate however that there is demand for bicycles at locations where the privately owned bicycle is not available. This raises the question whether there is a market for destination-based bike sharing systems in the Netherlands, not limited to train stations, and what such a system should look like.

Since commuting and business travel highly contribute to urban traffic congestion and emissions in the Netherlands, it is important to increase the use of sustainable modalities for these travel motives. At present companies increasingly strive to stimulate their employees to use sustainable modes, such as public transportation or the (electric) bicycle, as they are struggling with shortage of car parking capacity, in particular at urban locations. A bike sharing programme specifically focused on facilitating commuting and business trips can also help tackle these issues as well as contribute to a modal shift towards the use of more sustainable transportation modes thereby reducing externalities of non-sustainable modes. In order for such a system to be successful however, it must be designed according to the preferences of potential users so that enough demand is reached for the system to be feasible and have the effects that are aimed for.

Research on bike sharing system design focuses on methods with which bike sharing demand can be determined (Frade & Ribeiro, 2014; Rahul Nair, 2010), approaches to tackling rebalancing issues (Forma, Raviv, & Tzur, 2015; Kloimullner, Papazek, Hu, & Raidl, 2014) and on barriers and facilitators of bike sharing. This last branch of research can help answer how a bike sharing system focused on commuters and business travellers should be designed. However, knowledge gained through previous studies on these aspects cannot be easily transferred to the question at hand. A study in Spain by Bordagaray et al. (2012) for example only includes existing users of bike sharing programmes, while a study from Denmark by Kaplan et al. (2015) only focuses on leisure cycling. Many studies come from other continents, for example China (Zhao et al., 2014), Australia (Fishman et al., 2015) and North-America (Bachand-Marleau et al., 2012; Langford, Cherry, Yoon, Worley, & Smith, 2014). These papers discuss many factors that positively influence bike share membership or the perceived quality of the system like speed, convenience, safety and available information. It is difficult however to generalize these results to the Netherlands as the cities, the cycling habits and the infrastructure are very different. To add to this, many cities are currently introducing electric bicycles which introduces an extra level of complexity to bike sharing system design (Dill & Rose, 2012). Much research is currently being done on the subject (Cherry, Worley, & Jordan, 2011; Ji, Cherry, Han, & Jordan, 2014; Langford et al., 2014; Paul & Bogenberger, 2014), however it remains unclear what the user preferences are regarding this type of bicycle in the Netherlands and how to best introduce them into Dutch urban bike sharing systems.

1.1 RESEARCH QUESTIONS

The objective of this research is to provide recommendations for bike sharing system design in order to introduce the service as an attractive mode option to commuters and business travellers in the Netherlands. This objective corresponds to the following main research question:

How should an urban bike sharing system be designed in order to attract commuters and business travellers in the Netherlands?

In order to answer the main research question and achieve the objective of this research, it is first necessary to get a clear overview of the different elements and characteristics of various bike sharing systems which is studied through answering the first research question stated below. Research question two is introduced to study the bike share mode choice: to gain understanding of to what extent a series of mode choice determinants influence the bike share mode choice. The bike share mode choice determinants expected to influence the Dutch bike share mode choice among commuters and business travellers have to be identified before this research question can be answered. The knowledge gained on the determinants that are studied in research question two form the basis for answering the other research questions. The third research question focuses on the characteristics of potential bike sharing users, thereby gaining insight into what kind of people are interested in using a bike sharing service and how preferences differ for the different target groups. Research question four will then go into the circumstances under which potential users would be interested in using a bike sharing service. This research question will focus on the trip characteristics that make a bike sharing system an attractive mode choice. In the fifth research question different potential bike sharing system designs are tested in order to understand how different system setups influence the attractiveness of the system as well as trade-offs that can be made in the design phase. This concludes the research questions that are to be answered to be able to answer the main research question of this thesis. The thesis will then end with a series of recommendations regarding the design of an urban bike sharing system aimed at commuters and business travellers in the Netherlands.

- 1. What are the characteristics of existing and innovative bike sharing concepts and services?
- 2. To what extent do bike share mode choice determinants influence the bike sharing mode choice for commuters and business travellers in the Netherlands?
- 3. What are characteristics and preferences of potential Dutch bike sharing users?
- 4. Under which circumstances would commuters and business travellers make use of a bike sharing service in the Netherlands?
- 5. To what extent do different bike sharing system designs influence the attractiveness of the system for Dutch commuters and business travellers?

1.2 RESEARCH APPROACH

In this research understanding the bike share mode choice is at the centre of attention. Through understanding the effect of different factors on the bike share mode choice conclusions can be drawn on a set of aspects of bike sharing system design in order to be able to design the system in such a way that it is attractive for commuters and business travellers. The design of a bike sharing system in this thesis will explore a variety of aspects like the preferred placement of the system in relation to the existing mobility system as well as system and trip characteristics that are found to be attractive by potential users. User preferences are at the basis of this research, therefore this thesis will also discuss the characteristics of potential users and their preferences with regards to using a bike sharing system for their commuting and business trips.

A method which is seen as a proven way to obtain insight into travellers' behaviour through the modelling of the mode choice process is a discrete choice model (Ben-Akiva & Lerman, 1985). Such models can be used to analyse and predict a decision maker's choice of one alternative from a finite set of mutually exclusive and collectively exhaustive alternatives (Koppelman & Bhat, 2006). The ultimate interest in discrete choice modelling lies in being able to predict the decision making behaviour of a group of individuals (Train, 2009). In addition, it is used to determine the relative influence of different attributes of alternatives and characteristics of decision makers when they make choice decisions. Discrete choice models are generally based on the theory of utility maximization, meaning that an individual chooses the alternative with the highest utility. In this case, the utility of the travelling mode, a shared bicycle, is defined as an attraction associated to the travelling mode by an individual for a specific trip (Minal, 2014).

The results from the discrete choice model are influenced by the type of data that is gathered and how transport mode alternatives are presented to the respondent in order to gain data on the mode choice process. Two types of data can be distinguished: revealed-preference (RP) data and statedpreference (SP) data. Revealed-preference (RP) data is data that relates to people's actual choices in real-world situations. Gathering data in experimental or survey situations where respondents are presented with hypothetical choice situations is called stated-preference (SP) data (Train, 2009). SP techniques are generally used to quantify the individual's economic valuation or willingness-to-pay (WTP) for public and private initiatives.

There are advantages and disadvantages with regards to both types of data. RP data has the advantage that it reflects choices made in real life. However, this type of data can only present and study the choice situations and attributes of alternatives that currently exist or have existed historically (Train, 2009). Researchers may want to study hypothetical situations, or study variations on existing situations by changing attribute values. This is only possible using SP data. While it is unclear how an urban bike sharing system would be designed in the Netherlands, a SP survey allows for studying of the attitude of potential users towards a hypothetical bike sharing service and testing of various options in the design setup and attribute variations such as with regards to price.

There are also several limitations that need to be kept in mind when using SP data. What people say they will do is often not the same as what they will actually do in real life. This discrepancy is called hypothetical bias. The respondents' idea of what they would do might also be influenced by factors that wouldn't arise in the real choice situations, such as their perception of what the interviewer expects or wants as answers (Train, 2009). Insights gained throughout modelling SP data should therefore be interpreted with caution, but can give a variety of insights that cannot be explored using RP data. Because of its advantages compared to RP experiments and because no RP data is available, SP data is gathered through a web survey in which a hypothetical bike sharing service is presented to respondents. It must be kept in mind however that while discrete choice modelling can be used to predict market shares, when SP data is gathered the estimated market shares of a product or service will be unreliable. RP data or a combination of both types of data is necessary to be able to predict accurate market shares.

The SP data will be gathered through a stated choice (SC) experiment, used to determine preferences and trade-offs that people make with regards to their mode choices (J. Louviere, 1988; Merino, 2003). In a SC experiment respondents are presented with a hypothetical choice situation between several shared bicycle alternatives that differ on a number of attribute dimensions and a status-quo alternative representing the choice for any other transport mode. The respondents are asked to specify their preferred alternative from the proposed set of alternatives for the presented choice situation.

1.2.1 RESEARCH METHODS

This section will shortly discuss the research methods used to answer the different research questions. Firstly, desk research is used to gain knowledge on existing and innovative bike sharing found all over the world. Desk research is conducted using Google Scholar and Google as most information on characteristics of bike sharing systems is available on the websites of bike sharing services. Literature research is then used to study research done on bike sharing systems using databases like ScienceDirect, Scopus, Google Scholar and Web of Science. Next, as a basis to answer the second research question literature research is used to identify factors that are expected to influence the Dutch bike share mode choice amongst commuters and business travellers. Knowledge gained through literature and desk research with regards to the first and second research question is then complemented through the use of expert interviews.

To form a basis for the survey which will be conducted in order to gather SP data, a basic design for a Dutch bike sharing system will be conceptualized to introduce to the respondents. This is necessary as the respondents are most likely not familiar with an urban bike sharing concept. The concept will be based on the knowledge gained on bike sharing systems in research question 1, expert interviews discussing the needs of Dutch commuters and business travellers, and a focus group with experts to validate the proposed design.

The interviews are semi-structured interviews (Wilson, 2014b), in which a certain guideline is used to structure the conversation, using an introduction to the topic, a list of topics and questions that need to be discussed, some follow-up questions that might be asked and finally a closing statement. Experts are contacted from a wide variety of backgrounds, such as experts from Dutch bike sharing initiatives, the Dutch Cycling Embassy, the Dutch Cyclists' Union, experts on the public transport bicycle, and experts of existing foreign bike sharing systems.

Focus groups are generally used for gaining insight into general attitudes, perceptions or preferences regarding a product, in this case a bike sharing system, and also to use as a brainstorming session on possible new or improved products (Cbo, 2012; Wilson, 2014a). A focus group provides a way to do this using few resources in terms of time and money compared to a survey to explore interesting bike sharing concepts. A focus group with experts instead of potential users has been chosen because bike sharing is relatively unknown in the Netherlands and participants of a focus group need to have enough knowledge and background about the topic of interest to provide meaningful feedback (Wilson, 2014a).

1.3 THESIS STRUCTURE

The thesis consists of three parts. Part I discusses the findings from an extensive background research as well as from several expert interviews in Chapter 2. These findings are then used to determine the basic elements of a Dutch bike sharing system focused on commuters and business travellers which are described in Chapter 3 alongside an explanation of the system, trip and user characteristics that are studied throughout this thesis. Part II of the thesis then discusses the design of the stated choice experiment in Chapter 4, the setup and distribution of the web survey in Chapter 5 and the estimation method for the discrete choice models in Chapter 6. In part III of this thesis the results of the bike share mode choice model are discussed in Chapter 7 as well as the results from the analyses done on the data gathered throughout the questionnaire. In Chapter 8 different bike sharing system designs will be tested which results in a set of recommendations on bike sharing system design. The conclusions of this research are finally summarized in Chapter 9.

PART I

BACKGROUND RESEARCH & CONCEPTUALISATION

2. BACKGROUND ON BIKE SHARING

This chapter will discuss several aspects related to background information on bike sharing. The chapter will start off by discussing the history and evolution of bike sharing systems in Section 2.1, after which characteristics of several examples of bike sharing systems that can be found in Europe will be discussed in Section 2.2, alongside some innovative bike sharing concepts that are currently being developed. Section 2.3 discusses the elements of bike sharing system design, and how these elements are filled in for different systems found all over the world. This chapter is based on literature, desk research and interviews with experts on several existing bike sharing systems. The experts that have been interviewed for this chapter are listed in Appendix A.

2.1 THE EVOLUTION OF BIKE SHARING SYSTEMS

Bike sharing has started growing all around the world since 1965, as of December 2015 operating in over 980 cities with 1.258.500 bicycles and 9.300 electric bicycles (Shaheen, 2016). The development of bike sharing services available for the different continents between December 2007 and December 2012 is shown in Figure 1, clearly showing the exponential growth that has kicked in only a decade ago.



Figure 1: Development of bike sharing services per continent (Metrobike.net, 2013)

Although not much research has been done yet on the effects of bike sharing systems, as these systems are still maturing, the research that has been done so far by Shaheen et al. (2012) for example indicates a significant reduction in car usage and a sustained growth in the number of bike sharing members. DeMaio (2009) has found that bike sharing has large effects on creating a larger cycling population, increasing transit use, decreasing greenhouse gases, and improving public health.

Bike sharing systems have evolved throughout the years, starting with the first generation bike sharing system, introducing White Bikes (or free bike systems) in the Netherlands in 1965, where bicycles which were usually painted in one bright colour could be unlocked for free and were placed randomly throughout an area. The second generation bike sharing systems, Coin-Deposit Systems, were founded in Copenhagen in 1995 with the main components being distinguishable bicycles, designated docking stations in which bikes can be locked, borrowed, and returned and small deposits to unlock the bicycles (Shaheen et al., 2010). Third generation bike sharing programmes gained popularity by incorporating advanced technologies for bicycle reservations, pickup, drop-off, and information tracking in 1998 (Shaheen et al., 2012). The four main components of these systems are distinguishable bicycles (by colour, special design or advertisement), docking stations, kiosk or user interface technology for check-in and checkout and advanced technology (e.g., magnetic stried card, smartcards). Theft deterrents are also put in place by requiring members to provide their ID, bankcard or mobile phone number to identify themselves. Failure to return a bicycle would incur charges to recover the bicycle and may also include high punitive costs. Programmes are paid for as a membership service instead of through coin-deposits, and are typically free for the first specified time interval with gradually increasing costs enforced.

Although most existing systems are third generation bike sharing systems, research is currently being done into fourth generation bike sharing systems and some existing systems are exploring or exhibiting the potential for innovation towards fourth generation systems. These systems are called demand-responsive, multimodal systems. In this new generation the focus turns to the bicycle redistribution innovations, smartcard integration with other transportation modes, technological advances such as GPS tracking and electric bicycles, and finally flexible, clean docking stations (DeMaio, 2009; Midgley, 2009; Shaheen et al., 2010). Not only do these new technologies make the system more easily accessible and provide more information on the system, these 'smart' bike sharing systems, as Midgley (2009) calls them, provide a connection between existing public transport stops and desired destinations so that the BSS can complement the existing public transport system.

New technologies can also be used in order to decrease theft, vandalism and the amount of times users keep the bicycle longer than the allowed period. Theft can be reduced for example by using a GPS tracking system that can track every bicycle that has a unique identifier. Another system in London uses an algorithm to generate unique codes to open and lock the bikes, thereby decreasing theft (Curran, 2008). In most modern BSSs users have to provide credit or debit card information which can be used to charge users with replacement costs or fees when they do not return the bike or return it too late. Lastly, to reduce vandalism, smart bikes can be designed to require the use of special tools for disassembly and the bikes consist of components that are of uncommon dimensions that would not be usable on other bikes.

2.1.1 INTRODUCTION OF E-BIKES

Research done in Germany by Paul & Bogenberger (2014) indicates there is a strong interest in introducing electric bikes (E-bikes) in a regular bike sharing system since the system will eliminate the thresholds for use, such as their high acquisition costs. With the introduction of the electric bicycle in such a system, users can make longer trips with the same or even less effort and in a shorter time period (Shaheen et al., 2010). These bikes would be used for leisure trips, trips to work and as substitute bikes. Their research also shows that car trips might be replaced by bike share leading to an even higher acceptance to substitute car trips, if the traditional bike sharing system would be significantly enlarged and enhanced by the implementation of E-bikes. Research done in the Netherlands on people who own an E-bike also shows many people find that the electric bicycle

replaces short automobile trips (62%) as well as trips normally done by their traditional bicycle (68%) (Lee et al., 2014). This indicates that bike sharing systems that introduce electric bicycles could indeed reduce congestion on roads in the Netherlands, if enough people are willing to switch to a new mode of transport. Because of this, the possibility of providing an E-bike in a bike sharing setting will also be taken into account in this research by determining whether the option to use an E-bike in a bike sharing system will improve the attractiveness of the service and to what extent.

Introducing E-bikes in a bike sharing system causes new challenges for the bike sharing industry. Ebikes are of course similar to bicycles, but many new aspects have to be incorporated into the existing bike sharing systems in order to introduce electric bicycles. This section will shortly identify several of these challenges.

- High costs: DeMaio (2009) compares bike sharing systems with acquisition costs ranging from \$3.000 to \$4.400 per bicycle and estimates an average operating cost of about \$1.600 per bicycle per year. Also maintenance of E-bikes is relatively expensive.
- Powering infrastructure: E-bikes need to be charged at docking stations, which requires electrical wiring or for example solar panels as done by the BIXI program (PBSC Urban Solutions, 2014) in order to remove the spatial challenges. This also influences the regulations of use as electric bicycles will need to be returned to a docking station after a certain amount of kilometres and they cannot be used again until they are fully charged.
- Legislation: depending on the type of bicycle, helmets may become mandatory, speed restrictions may be imposed and for even faster electric bicycles, called 'speed pedelecs', license plates are mandatory (Fietsenwinkel, 2015) and helmets will become mandatory in 2017 (de Vries, 2014). These extra regulations can harm the acceptance of the E-bike as an easy mode of transport.

Stimulating the electric bicycle amongst commuters is a difficult task as changing someone's travel behaviour is a slow process which requires the right, yet still unclear incentives (Aarts & Dijksterhuis, 2000; Meloni et al., 2013). Companies are only recently becoming more interested in what an E-bike can bring to the table. For example, city region Arnhem Nijmegen has subsidized the acquisition of 650 e-bikes thereby stimulating commuters to use this mode of transport for their daily commuting trips (Redactie Wijchen Nieuws, 2012). This arrangement has had great success, until funds ran out. E-bikes in a bike sharing setting have not yet been successfully implemented in the Netherlands. This is partly because until recently bike sharing systems only focused on regular bicycles, however since the last few years institutions and companies are testing the implementation of E-bikes in the same setting. A few examples are Belgium's e-Blue-bike, their first urban bike sharing system with electric bicycles (Olympus, 2015) and Switzerland's PubliBike (PubliBike, 2015). Except for the 'PT-bicycle', bike sharing is not yet widely implemented in the Netherlands. Nonetheless, Rotterdam recently started a bike sharing pilot with electric bicycles that are also found in a Danish bike sharing system (Verkeersnet, 2016) and these same bikes have also been implemented at several industrial terrains to stimulate bike usage for commuting and business trips (Fietsersbond, 2014). Usage numbers of these bike sharing initiatives are still unknown.

2.2 BIKE SHARING SYSTEMS IN PRACTICE

In this section several examples of European bike sharing systems will be elaborated on in order to gain understanding of the different types of systems available and their characteristics. Only bike sharing systems from Europe are reviewed here as findings from these systems are easier to generalize to the Dutch situation compared to systems from Asia and North America where the infrastructure and cycling habits are very different. However, as the Netherlands has a very special cycling culture, and infrastructure is of very high quality compared to other European countries, bike sharing systems that are found in other European cities are not expected to have the same results when implemented in the Netherlands. Findings must therefore be interpreted with caution in relation to the possibilities of bike sharing in the Netherlands.

The systems that will be discussed below are:

- Vélib', stationed in Paris, France.
- Bycyklen, stationed in Copenhagen, Denmark.
- Call a Bike, stationed in several German cities.
- The PT-bicycle, found at medium to large Dutch train stations.

These bike sharing systems are chosen to review further for several reasons. Vélib' is Europe's largest and most successful bike sharing system. It is necessary to understand how its characteristics make this system so successful. The Bycyklen bike sharing system is reviewed in detail as Copenhagen has a similar cycling culture as is found in Dutch cities and has chosen to mainly introduce electric bicycles. If the Bycyklen system is successful it is very likely similar system will be implemented in the Netherlands as both countries are very similar with regards to cycling culture and infrastructure. Next the German Call a Bike system is studied more closely as it is a very different system than most European system in the sense that it allows a lot of flexibility in the usage of the bicycles and has a more coarse docking station network which is expected to be very important in Dutch bike sharing systems. Lastly the PT-bicycle is described in more detail as this is the only large scale bike sharing system that can be found in the Netherlands. The system is very successful so it is important to identify the lessons learned and apply them to urban bike sharing system design.

To complement the knowledge gained through literature and desk research, expert interviews were conducted with people who are employed at or otherwise related to the companies who operate the bike sharing systems, which are discussed below.

2.2.1 VÉLIB', PARIS

Vélib' is one of the largest bike-sharing systems in the world, stationed in Paris, France. It is a thirdgeneration bike sharing system although it is currently exploring innovations found in fourth generation systems with self-service electric bicycles which have an innovative battery design (JCDecaux, 2015).

With over 20,000 bicycles this system covers the city all day every day with 1,800 bicycle stations distributed over the city resulting in an astonishing 300 metres between every bicycle station (Vélib',

2015). Vélib' is run by the Paris Town Hall together with the company JCDecaux since 2007 and has become very successful over the years with one velib' (bicycle) being rented every second in Paris, coming down to about 86,400 rentals per day (Melvin, 2014). One might think the Parisian bike-sharing system is mostly used by tourists, but the number of commuters that use the system has doubled in a time span of 5 years since the introduction of the system, clearly indicating this system is suitable for commuting as well as recreational trips (Startt, 2014). Despite its success, this bike sharing system does have several drawbacks, mainly when it comes to costs, theft and vandalism. Administration and maintenance for each bicycle costs €3,000 euro per year, which makes implementing this system very costly (Godoy, 2012). In addition, 9,000 bikes were reported to be mangled or missing in 2012 alone (FRANCE 24, 2013).

So how does the system work and why is it so successful? Bicycles are located at a bicycle station every 300 to 400 meter in the city of Paris. A bicycle can be picked up at these stations by both short-term users and long-term subscribers. While short-term users have to rent a bicycle via a terminal at a Vélib' station, long-term subscribers only have to swipe their long-term subscriber card along the card reader of the chosen bicycle to rent it. Long-term subscribers have to pay a small fee to be able to use the system all year round. What is special about Vélib's tariffs is the fact that journeys under 30 minutes are always free of charge. Then for the first additional half-hours you pay an increasing fee (Vélib', 2015). This tariff structure and the fine-grained docking station network can be found in most European bike sharing systems. Due to its setup, the system is very flexible as users are able to place their bicycle at any of the stations and do not have to bring the bicycle back to the station they originated from.

This does however create a large redistribution issue since the flow of bicycles from one station to another is almost never equal to the flow of bicycles in the opposite direction (Rahul Nair, 2010). The bike sharing fleet will thus become imbalanced. Vélib' operates several teams for redistribution purposes. They redistribute bicycles based on historical demand information, which lets them be able to meet most of the future demand scenarios, but not all. Redistribution of bicycles is Vélib's biggest issue and is accompanied with massive costs (A. Darbon, personal communication, May 21, 2015). Vélib' is currently testing a set of user focused interventions.

2.2.2 BYCYKLEN, COPENHAGEN

The Bycyklen bike sharing system is located in the city of Copenhagen and has been launched in 2014. The previously implemented bike sharing system in Copenhagen, named Copenhagen City Bikes (founded in 1995), was the world's first second generation urban bike sharing system after its Dutch predecessor (White Bikes). It featured elements like a (refundable) coin deposit, fixed stands and specially designed bicycles with parts that cannot be used on regular bicycles. This system came to an end due to budget constraints meant to upgrade the system. In 2014 the Bycyklen system was implemented as a commuter focused bike sharing programme. Unlike the Copenhagen City Bikes, Bycyklen is not free but features electric bicycles equipped with a GPS routing device to provide the latest innovations to its customers. The system has been marketed as a highly advanced bike sharing program featuring the world's first smart bike. Its aim was to provide a way for Copenhagen commuters to use the bicycles for their whole commute or to use them for the first or last mile

connection when used with mass transit. Unfortunately the system is not meeting expectations. The city inhabitants are ignoring the bikes, few trips are being made with them and the bicycles are mostly used by tourists instead of commuters. There seem to be several reasons for its failure. First of all, the costs of the system were too high. The highly advanced bicycles cost \$3,000 each and cost \$10,000 per bike in total for purchase and maintenance over eight years (Neuteboom, personal communication, April 22, 2015). Bicycles from successful bike-sharing systems in Paris and the PT-bicycle system in the Netherlands cost only \$400 to \$800. Next to the costs of the system, an influential blog called 'Copenhagenize' says the biggest mistake is "a complete misunderstanding of how people think and of civic pride" (Copenhagenize, 2015). They believe the Bycyklen system is not focused on the city's inhabitants, and the bicycles are more suitable for tourists. Because of this the locals will not want to use the system since they do not want to resemble tourists in their own city. The Bycyklen system seems to have developed this image through the design of the bicycles and the system boundaries. The bike sharing systems in Seville and Barcelona for example, the bicycles can only be used by the locals, thereby making sure the system has the right focus and image to succeed in the city.

Unfortunately this seemingly innovative, modern bike sharing system implemented in a city which has a lot of experience with cycling and bike sharing system is used less and less. Lessons need to be learned its failure, especially since this is the first western country to have implemented a fully electric bike sharing system. The system's supposed failure is blamed by representatives of GoBike on poor promotion of the system by the city's government and on their bicycle supplier who has been unable to supply the city with enough bicycles because of financial problems (C. Neuteboom, personal communication, April 22, 2015). The GoBikes that are used in the Bycyklen system however, which are very expensive and seemingly overcomplicated as stated earlier, are being implemented in pilots in the Netherlands as we speak. The 'De Nieuwe Fiets van Rotterdam' project will be implementing a fleet of GoBikes in Rotterdam in the summer of 2015 (Stadsregio Rotterdam, 2015) and the NU-Connect project in Utrecht has also made use of GoBikes in their pilot amongst companies in the U15 region (De Boom en het Meer, 2015a). It will be interesting to see if these bicycles are viewed differently in the Netherlands or not and how this influences the demand for an E-bike sharing system in the Netherlands.

2.2.3 CALL A BIKE, GERMANY

Call a Bike is a public bike sharing system found in over 60 major cities in Germany (Mobility Network Logistics, 2012). Although the systems are not entirely the same in every city, some characteristics are similar for most systems. In Hamburg for example the system is called StadtRAD Hamburg (StadtRAD Hamburg, 2016). Bicycle docking stations are distributed over the entire city mainly found at public transport spots, major city squares and intersections, while smaller cities only provide bicycles at train stations (Deutsche Bahn, 2010). The docking stations are fixed, however the bicycles can be locked anywhere temporarily. The system uses authentication codes to automatically lock and unlock the bikes, which can be obtained by calling a telephone number given on the bike which includes the bike's ID or via an app. The customer then types the given 4 digit opening code onto the bike's touch screen to unlock it. The same method is used to 'return' the bike, along with providing the system with the street name or the cross roads at which the bicycle is returned.

The system facilitates both one-way and return trips, and is found to be an ideal addition to local public transport for customers who only have to cover short distances and are looking for an alternative to the car. As in many other bike sharing systems, the first half-hour is free, after which a price per minute is set in place while the bike is not returned to a docking station. Customers who have a public transport card can pay a reduced tariff. To allow long term use of the bicycle, a maximum fee per day is set. The provision model of Call a Bike is a transport agency business model, as all the systems are operated by the Deutsche Bahn (DB), the national railway company.

The number of registered customers has multiplied by five since 2005, reaching a total of 430.000 by 2012 (Mobility Network Logistics, 2012). The system's success is owed to its flexibility, ease of use and having bicycles ready for use all over the city. It is continuously being improved; terminals have been implemented in several cities so that customers can simply use a chip card to check in, and thanks to GPS customers can now simply check out using the press of a button in Frankfurt am Main.

2.2.4 OV-FIETS (PT-BICYCLE), THE NETHERLANDS

OV-fiets, or PT-bicycle, is a successful Dutch bike sharing initiative managed by NS Stations. The system provides bicycles at large NS (railway company) train stations for public transport users where subscribers can rent a bicycle for &2,85 per trip to use for the egress part of the trip (NS Stations, 2015). Users are always required to return the bicycle at the end of the day at the docking station from which they picked up the bicycle, unlike other bike sharing systems found across Europe. Users are able to lock the bicycle anywhere at any time during their day, making it possible to rent the bicycle for the entire day for a relatively low fee without having to find a docking station to return or lock it until the end of the day.

The network currently involves 200 locations and more than 1 million trips are made each year. According to the Manager Product and Format of the PT-bicycle, the system is becoming so successful that they are unable to provide enough bicycles to meet demand due to lack of parking spaces for the bicycles (Witmer, personal communication, June 16, 2015). This problem is most apparent at train stations such as The Hague or Utrecht Central, where the PT-bicycle docking stations are empty almost every morning. Even though the system is so successful, they do not want to focus on expanding the system to entire cities as their main focus will always lie on the railway operations, seeing the PT-bicycle only as a supporting feature for their users.

In 2014 the introduction of electric bicycles alongside the regular PT-bicycle was tested. This initiative was stopped after a couple of months due to various reasons (Eg, 2014). According to a representative of the PT-bicycle, NS Stations has stopped renting electric bicycles and scooters because of low users numbers, high operational costs and the space that the e-bikes take in the bicycle parking areas (Van Grol, personal communication, March 18, 2015). Furthermore, specifically regarding the e-bikes, the company ran into issues with the supply of spare parts, which caused maintenance delays. Because of this they were unable to provide enough bicycles to maintain a customer friendly offer.

Users choose the PT-bicycle to travel to friends and family (60%), to recreational destinations (43%), for business related trips (32%), for general cycling trips (22%) and commuting trips (20%). The PTbicycle is not used on a frequent basis, with about 5% of people using the bicycle once or more than once a week. Most people (55%) use the bicycles less than once a month. Users choose the PTbicycle because of its convenience (80%), the freedom it provides (68%), the speed with which the destination is reached (44%), the low costs (32%), and lastly for environmental (32%), health related (22%), comfort (15%) and other reasons (5%) (Fietsersbond, 2011).

Other municipalities and communities are also looking into the possibilities of bike sharing, often including electric bicycles. Bike sharing initiatives are being developed and introduced in the city centre of Rotterdam (Verkeersnet, 2016), on several business parks in for example Utrecht (Fietsersbond, 2014) and in Noord-Brabant (Redactie OV-Magazine, 2016). Results from these initiatives are still unknown. The companies behind these initiatives believe that currently the most market potential lies in providing commuters and business travellers with the added benefits of electric bicycles. They claim that in the future when bike sharing has become more acceptable in the Netherlands that a mix of vehicles can be provided in the same setting (Vermeulen & Neuteboom, personal communication, June 22, 2015).

2.2.5 PEER-TO-PEER BIKE SHARING

Peer-to-peer bike sharing can be found in several cities worldwide since 2013. The concept involves cyclists who own spare bikes to share with the community and thereby open the possibility to find a bike to ride in cities where you do not have your own bicycle or the city does not have a bike sharing plan. Peer-to-peer bike sharing is generally facilitated by an online platform such as offered by Spinlister, Spokefly or VanMoof. These platforms provide the possibility for private bike owners to make their bicycle available to the public in return for a small fee, and people visiting a city or for whatever other reason can find these bikes on these online platforms and reserve it, meet up with the bicycle and possible also the owner and use the bicycle for as long as they need it before placing it anywhere in the city, using a lock provided with the bicycle.

In 2008 the creators of the PT-bicycle came forward with a commuter bike called the 'Forens-fiets' or the 'PT-bicycle@home' to deal with the inflexibility of the PT-bicycle without causing increasing redistribution costs. The concept was tested in Amsterdam, by letting people take home their PT-bicycle after picking one up at the station near their home and returning it the next morning so another user could pick it up at the train station to use it to go to work and back (Maartens, 2008). This way the bicycles are used twice as much as usual, they take less parking space at the train stations. Although the concept has a lot of potential, the pilot showed that by allowing users to take home a PT-bicycle, a range of issues emerge (Haverman, personal communication, May 1, 2015). For example, users have to be incentivized to return the bicycle as soon as possible and cannot leave it at home for longer than one day. In addition, issues emerge with regards to repairs that have to be made. It is expected that such a system will only work when bicycles are shared amongst people themselves, and not with the PT-bicycles that are provided by the NS (van Eerden, Joosten, Leferink, & Velthuijs, 2015).

2.2.6 BIKE SHARING FOR BUSINESSES

Bike sharing is not always a public endeavour. Like the peer-to-peer bike sharing platforms, there are other ways to offer a bike sharing service to people. One way is to implement small scale bike sharing systems specifically designed for businesses. These companies provide a bicycle docking station at a company so that employees can make use of the bicycles to get around. Most of the time these bicycles are electric bicycle, as these drastically lower the threshold for use amongst commuters as these bicycles do not leave you exhausted or sweating and get you to the destination much faster than a regular bicycle.

2.3 THE ELEMENTS OF BIKE SHARING

In order to design an urban bike sharing system and to understand which factors influence the attractiveness and feasibility of the system it is important to distinguish the bike sharing system components and how the interact with each other. This chapter will discuss the following bike sharing system components in detail after which interactions between these components will also be described:

- Bicycles
- Docking spaces, stations and terminals
- System access and user registration
- System status information system
- Bicycle redistribution mechanisms
- Models of provision
- Pricing

2.3.1 BICYCLES

When it comes to shared bicycles, there are a lot of factors to keep in mind when designing the bicycle. It needs to fit a lot of different sizes and thus be easily adjustable. Furthermore, it needs to be robust, low-maintenance, secure, safe and have the ability to include storage (Institute for Transportation & Development Policy (ITDP), 2013). Because all of this has to be included in the design of the bicycle so that it will not be easy or attractive to steal or vandalize, the bicycles are typically heavier than a regular bicycle. In general bicycles are equipped with a GPS unit or a RFID tag or any other type of tracking mechanism so that the bike sharing operator knows where a bike is at all times and can retrieve it when stolen. Additionally, shared bicycles typically have a distinctive look or a standardised design so that theft is discouraged further. The downside of such a distinctive bicycle is that it does not necessarily look pretty or attractive to users and will discourage business people to travel with a shared bicycle. The target group focus of the system must thus also be translated into an image that should be portrayed with the bicycle, which will be different for commuters compared to tourists.

The electric shared bicycles are of course very different from traditional shared bicycles. Next to the battery and the charging facilities needed, some bike sharing operators have chosen to use very

modern electric bicycles which include a digital lock so that the bicycle can be locked even if there is not a docking station nearby, puncture free tires, LED lights, a belt drive to lower maintenance, and finally a tablet located below the steer. An example of such a bicycle is the Danish GoBike, shown in Figure 2. The tablet is multi-functional; the user can log in, unlock the bicycle, adjust the electric assist level, and use extensive navigation options. Bikes like these are often referred to as 'Smart Bikes', as these bicycles involve IT Figure 1: The electric GoBike



systems which takes care of several functions of the bicycle which would otherwise be done using physical tools such as a regular key. Another good example of a Smart Bike is the nextbike (nextbike, 2015). Rental is done via an App, smart card or login at the on-Board computer. It uses GPS, GSM (2G) & WPAN modules for on- & offline communication with Smart Boxes and the central server. Return is possible in docking stations and stand-alone via an integrated Smart Lock. These bicycles are thus capable of existing in a fixed and a flexible system. An RFID chip is used for compatibility with Smart Docks (docking stations) and LED signals are used for system notification.

2.3.2 DOCKING SPACES, STATIONS AND TERMINALS

Docking stations consist of docking spaces, where the bicycles are parked and locked, and terminals, where users get information on the service and can register for the service or check in and out bicycles (Institute for Transportation & Development Policy (ITDP), 2013). Bike sharing services can either be fixed or flexible when it comes to docking stations (Bührmann, 2008; DeMaio, 2009).



Figure 3: A docking station from Vélib', Paris

Figure 2: Shared bicycles from Call a Bike, Germany

When fixed docking stations are used, for example in Paris, the bicycles can only be locked and thus returned at docking stations found throughout the city. With **flexible** bike sharing systems, bicycles are equipped with their own lock so they can be placed and locked at any location throughout the city, meaning that physical docking stations, which cost a lot of money and take up quite some space, are no longer needed. A downside of this system is that bicycles will be spread throughout the city at random locations, which creates the need for expensive redistribution of bicycles. An example of such a system is Call a Bike in Cologne, where bicycles can generally be found at major railways stations, underground stations, city squares and intersections but can be returned at any crossroads in the city as long as they are locked to a fixed object (DB Bahn, 2010; Mobility Network Logistics, 2012). Figure 3 shows an example of a fixed bike sharing system and Figure 4 shows an example of a flexible system.



Figure 4: A docking station from the Dutch PT-bicycle system

For both Vélib' and Call a Bike, it is allowed to return the bicycle at another location than the original pickup location, be it a docking station in Vélib's case and a regular parking spot with the Call a Bike system. The PTbicycle system however can be seen as a hybrid form. The system does not involve expensive docking stations, but it simply uses bicycle stands which can be found anywhere

in the Netherlands. Users are however required to return the bicycle at the same location where they originally picked up the bicycle. The bicycles can then only be picked up at specific locations, although no expensive docking station is needed to lock these bicycles since they work with a physical key as any other bicycle. Because the bicycles have their own lock, they can be locked where-ever during a trip, as long as they are returned at the end of the day at the location where the user picked up the bicycle. Figure 5 shows a typical PT-bicycle pickup and return point, involving regular bicycle stands but also a terminal to access the system. This is an example of an automated PT-bicycle station.

When it comes to electric sharing bicycles, a docking station will always be required as the bicycles will need to be charged in between trips (Cherry et al., 2011). This limits the design options and makes a flexible system difficult to manage, as the bicycle will need to be returned after a certain distance and furthermore, locking an electric bicycle anywhere in the city in between charging it might not be desirable as it will be more prone to theft.

2.3.3 SYSTEM ACCESS AND USER REGISTRATION

When it comes to bike sharing systems, there are several system approaches that can be identified. When it comes to how transactions are taken care off, bike sharing systems can be categorized into either manual or automated systems (Midgley, 2008).

When using a **manual** bicycle-sharing system, transactions related to taking out and returning a bicycle are supervised by staff. These types of systems are becoming rarer as it is relatively costly to provide such a service throughout an entire city. The PT-bicycle still offers supervised services at some of their renting stations. Urban bike sharing systems almost never offer this kind of service. Transactions in an **automated** bicycle-sharing system are unsupervised; the systems thus rely on self-service. Bicycles can either be locked to bicycle docking stations or are equipped with an electronically controlled lock of their own. Because of these type of systems, automated systems rely heavily on information technology for the user interface, system control and monitoring.

When the bicycles are locked to a docking station, the bicycles are checked out using a smartcard or magnetic strip card which can be inserted at the terminal. When the bicycles have an automated

lock on the bicycle itself, the bicycle can be unlocked using a mobile phone which will provide the user with an entry code. Currently there are many more methods that can be used and they are different for each system. Research is being done into the possibility of Bluetooth connection between someone's phone and a sharing bicycle as to unlock them with ease.

User registration is typically done using the terminal at a docking station or online, using a debit / credit card or a public transport card to authenticate the user. Registration can be seen as a frustrating process when a user wants to simply make use of a shared bicycle for the first time. Increasing the ease of registering and gaining access to the bicycles is one of the factors which makes one time or first time use of the bicycles more difficult and therefore less attractive. The Dutch Cycling Embassy is currently exploring the possibilities of an 'open standaard', which would allow users to use any bike sharing system all over the country without having to register for the different systems (van Boggelen, Personal communication, May 1, 2015). Authorization would be combined into one database to which all bike sharing operators would have access.



In order to be able to find a shared bicycle in a city, most bike sharing systems provide real time information on websites about bicycle availability per docking station in the system, often shown on a map of the city. Figure 6 shows such a map of Antwerp's bike sharing system Velo where orange stations have bikes available, blue stations are empty, red stations are full and grey stations are currently out of order.

Figure 5: Map of docking stations from Velo distributed over Antwerp

Next to using IT to show the locations of stations and the availability of bicycles for users, these systems can also be used to give users the option to reserve a bicycle up front. This way, the user can be sure that there will be a bicycle available for him or her. However, this can be very frustrating for people who want to pick up a bicycle without previously planning to, and finding out that even though there are bicycles standing at the docking stations, they have been reserved and therefore not available for use. Choices have to be made on how much time in advance the bicycles can be reserved and whether users have to pay extra for such a service. There is also a possibility to include the option to reserve a return spot at a docking station. This is mainly important for systems such as Vélib' since users have to return their bicycle at a docking station. When they encounter a docking station which is full they are obliged to cycle further to a docking station where they are able to return their bicycle, so if this happens and they have to cycle further to return their bicycle, their trip costs also increases per time unit.

2.3.5 BICYCLE REDISTRIBUTION MECHANISMS

Redistribution schemes related to shared vehicle operations can be divided into two categories, namely 'user based' and 'operator based' redistribution schemes (Barth & Todd, 2014; Kek et al., 2006; Vogel & Mattfeld, 2010). User based means that users are stimulated to return their vehicle to a non-saturated station, thereby rebalancing the distribution of the bikes without operating costs. This can be done by providing a discount, a free ride or giving money when users place their bicycle at an empty station (Maartens, 2008). In the operator based redistribution schemes the relocation is done by the service staff. The user based redistribution is seen as feasible for mid-term operations while the operator based redistribution is effective in a short-term period.

Some literature can be found on specific operator based bike sharing redistribution problems, called Bike Sharing Pickup and Delivery Problem (BS-PDP) (Caggiani & Ottomanelli, 2013). The BSS reallocation is defined as either static repositioning, where the reallocation is carried our during periods when the bike demand is negligible, or dynamic repositioning, when the distribution of bicycles among docking changes is continuously changing due to high demand.

What type of redistribution is most suitable depends on the system characteristics and usage numbers. A system like Vélib' which is continuously being used needs dynamic repositioning as to make sure that people can continue to make use of the system. Other, less busy systems could perform fine with just static repositioning and also thereby decreasing the operating costs. A combination of operator-based and user-based redistribution is also possible, as Vélib' is currently testing several policies with which users can be incentivized to help redistribute the bicycles to limit the high redistribution costs of the system (A. Darbon, personal communication, May 21, 2015).

Some systems, like the PT-bicycle, purposefully choose not to have any redistribution costs by fining users when they do not return the bicycle to its original pickup location. However, this does greatly decrease the flexibility and attractiveness of the system.

2.3.6 BUSINESS MODELS

There are many possible business models when operating a bike sharing system. Shaheen (2013) illustrates these different business models with definitions and examples in Figure 7. Several of these business models will now be discussed based on the information shown in Figure 7 and a paper written by DeMaio (2009) where he further explains the benefits and detriments of these models.

The 'non-profit' model involves an organization which was specifically created for the operation of a bike sharing service or one that folds the service into its existing interests. Although the non-profit organization does operate the service, most of the time they receive funding from the jurisdiction in addition to collecting the revenues generated by membership and usage fees and sponsorships. In the 'for-profit' model the service is provided by a private company with limited or no government involvement. This way the private sector can start a service rather than wait for the public sector to do so. A downside is that the company may not receive funding assistance for the service compared to programs offered under other models.

The 'publicly owned and operated' model has the advantage that the government as operator has great control over the program and can ensure that the public's wishes are taken into account, although it may not have been the experience with managing a bike-sharing operation compared to existing bike-sharing operators. The quasi-government transport agency model's benefit is that the jurisdiction benefits from the experience and innovation of a bike-sharing service provider, without needing to develop these capabilities internally, unlike in the government model. Furthermore, the top priority of both the jurisdiction and the transport agency is to provide a useful transit service. A downside of this model is that there could be a more qualified operator as long as the locality is not releasing a tender for the service.

Business Model	Definition	Example
Non-Profit	 Goal of covering operational costs and expanding service Start-up and operational funding typically are supported by grants, sponsorships, and loans 	Denver B-cycle Denver, CO (Operational)
Privately Owned and Operated	 Owned and operated by a private entity Operator provides all funding for equipment and operations May have limited contractual agreement with public entities for rights-of-way 	DecoBike Miami, FL (Operational)
Publicly Owned and Operated	 Owned and operated by a public agency or local government Agency subsidizes bikesharing with system revenue 	Golden Community Bike Share Golden, BC (Operational)
Publicly Owned/Contractor Operated	 Owned by a public agency or local government, responsible for funding and administering the system Operations are contracted to a private operator 	Capital Bikeshare Washinton, DC (Operational)
Advertising Model (Street Furniture Contract)	 Operator permitted to operate in a jurisdiction in exchange for advertising rights, generally with street furniture System funded through advertising revenue 	SmartBike D.C. Washington, DC (Defunct)
Third-Party Operated	 Operated in partnership with local businesses in exchange for a percentage of the profit Hybrid operation scheme that can be paired with other business model 	Chicago B-cycle Chicago, IL (Operational)
Vendor Operated	 Operated by the same company that designs and/or manufactures the system equipment (the vendor) 	Bike Nation Anaheim Anaheim, CA (Proposed)

Figure 7: Categorization of typcial bike sharing business models (Shaheen et al., 2010b)

The advertising company model involves a company that offers a bike-sharing program to a jurisdiction, in exchange for the right to use public space to display revenue-generating advertisements on billboards, bus shelters, and kiosks for example. The downside of this model is, as DeMaio describes it, the problem of moral hazard as the advertising company's top priority is not to provide a high quality bike sharing service, nor do they have the expertise to operate one.

When a bike sharing system is operated in partnership with local businesses, the system will most likely only serve their needs. The benefit of such a model is that the businesses can provide and expand its transit service without having to rely on the municipality to provide this service. Downsides are that the surrounding areas will not be able to profit from the service and when the municipality introduces a bike sharing service in the surrounding areas, compatibility issues could arise. Lastly, benefits of the 'vendor operated' model are that the municipality or businesses for which the system is put in place do not have to worry about operating the system. A downside is that the vendor may not feel incentivized to make sure the needs of the users are well taken care of.

Which model of provision should be chosen depends on many factors like the size of the jurisdiction and the availability of both bike sharing systems able to operate in the country and local entrepreneurs to run the program. Other business models that are arising allow people to make use of an online bike sharing platforms in order to share their own bicycles, such as VanMoof.

2.3.7 PRICING

There are many different cost structures that are used in bike sharing systems all around the world. Many systems which have fixed docking stations distributed all over the city use a cost structure where the first half-hour of the trip is free, so it is possible to use the bicycles for free for short trips between docking stations, and increase the price of use every extra half-hour. This type of cost structure is mostly focused on promoting cycling, since in general the bicycle trips can be done for free. It is therefore not meant to be able to pay for the cost of the system, so extra funds have to come elsewhere, depending on the type of business model the system relies on. Other systems, such as the bike sharing systems which can be found in Germany, rely on a cost structure which allows users to pay per minute in addition to the free first half-hour for frequent users.

In the Netherlands, promoting bicycle usage in general is not the main goal of the system. It will focus on promoting the use of a bicycle for certain type of trips in addition to regular usage: for the last mile, commuting or business trips. Cost structures that are currently being considered by companies that are implementing bike sharing systems in Dutch cities do not incorporate a first half-hour for free, but combine a subscription fee with a usage fee based on the kilometres driven with the bicycle (Neuteboom, personal communication, April 22, 2015). This is explained by the fact that electric bicycles are mainly being implemented and this cost structure allows people to pay for the amount they use the bicycle (and thus the battery). The maximum acceptable trip fee is believed to be 28 cents per kilometre as this is equal to the costs of a trip with public transportation trips that compete with the shared bicycle, like the bus, tram or metro.

By offering cost structures for different target groups, the system can be made interesting for many types of people for many types of trips. Next to subscription and trip fees, it is possible to consider charging users with the use of certain facilities and options facilitated by the bike sharing platform.

3. THE DUTCH BIKE SHARE MODE CHOICE

Knowledge has now been gathered on bike sharing systems abroad, existing bike sharing systems in the Netherlands and on the elements of bike sharing system design. On the basis of the expert interviews together with the knowledge that has already been gathered, a general urban bike sharing concept can be formed. The idea of this concept is to present basic guidelines of what a bike sharing system would look like in the Netherlands to allow respondents of the web survey to form an opinion on the subject. Characteristics will not be worked out in detail as this concept will only serve as a basis in order to further study user preferences regarding bike sharing system design.

Experts were contacted from a wide variety of backgrounds to gain insight on the possibilities of bike sharing in the Netherlands, such as experts from existing Dutch bike sharing initiatives, the Dutch Cycling Embassy, and from the Dutch Cyclists' Union. These experts are knowledgeable on the Dutch cycling culture as well as the evolution and possibilities of bike sharing in the Netherlands.

To make sure the basic bike sharing concept represents a realistic view of bike sharing in Dutch cities, the concept is validated through a focus group with experts. The experts invited to this focus group consisted of experts that were previously interviewed and experts that were not approached before, as to check that the proposed basic bike sharing concept is agreed upon by a variety of experts and is not biased towards the opinions of the interviewed experts. The focus group discussion consisted of an explanation of the bike sharing concept, a discussion on the general characteristics of the concept and a discussion on the knowledge gaps regarding possible bike sharing system designs in the Netherlands. The experts that were interviewed and included in the focus group are listed in Appendix A.

3.1 THE DUTCH BIKE SHARING CONCEPT

The focus group agrees on that the vivid bicycle culture in the Netherlands influences the feasibility of a bike sharing system in Dutch cities. This does not mean however that bike sharing cannot be an attractive sustainable mode choice that needs to be introduced to give travellers more sustainable alternatives. The bike sharing system should solely focus however on providing people with a shared bicycle where the private bicycle is not available. This means that bicycles should not be distributed over the city as is done in Vélib' and many other European systems, but should only be found at key points in the city. For example, bicycles should be found at public transport stops, large intersections, office locations, city attractions, and in the city centre but not at residential areas in the city where the bicycle is already available. The experts agree that the system should resemble the types of systems that are found in Germany (Call-a-Bike), which offers flexibility and allows users to use the bicycle the entire day.

Bicycles When looking at E-bikes in a bike sharing setting, the opinions differ. The majority of experts believe E-bikes should be used for long distance trips and not in city centres, because the city traffic and structure will make it impossible to use the E-bike effectively. E-bikes are however more suitable for long distance trips from outer residential areas towards the city centre or on industrial terrains where the structure of the infrastructure does not limit the potential of the E-bike. Experts that are in charge of bike sharing initiatives in the Netherlands prefer to focus on providing E-bikes for

commuters and business travellers as the E-bike generally thought to be a more attractive mode option for commuting and business trips due to the added comfort and speed. The Danish bike sharing system Bycyklen has implemented a commuter focused bike sharing system with E-bikes but has failed to attract large crowds. This is blamed on the lack of proper marketing however and therefore it cannot be said whether the implementation of E-bikes in the system has anything to do with its failure. Although the E-bike is generally seen as the preferred option for commuting and business related trips, it remains unclear whether the traditional or electric bicycle should be implemented in Dutch bike sharing systems as the costs of a system providing E-bikes will also be higher. The basic bike sharing concept presented here will therefore offer both types of bicycles.

Docking spaces, Stations and Terminals All experts agree that the concept should be a flexible bike sharing system. The bicycles have to be able to be locked at any time during the day to provide maximum flexibility to the user. This is especially important to the Dutch cyclist as they are used to being able to store the bicycle whenever and where-ever they want. The PT-bicycle also offers this flexibility which is an important reason for its success alongside the destination-based focus of the system.

In addition, the majority of experts believe that users should be able to return the bicycle at another station from which they originally got the bicycle to provide maximum flexibility to the users. Another possibility would be to remove docking stations all together. This would not be possible when providing E-bikes as these need locations to be charged, but traditional bicycles could be placed all around the city without a docking station to remove the cost of renting space to store these bicycles when they are not being used. However, flexibility in return policy does lead to high redistribution costs. All in all, flexibility is expected to be very important with regards to user preferences, however implementing flexibility in the return policy of the shared bicycle can pose a problem. It should be studied further to what extent users find the flexibility of the bicycle return policy important in their mode choice.

System Access and User Registration Bicycles should be easily accessible, meaning that a new user should not have to go through the frustrating process of registering and authenticating in order to rent a bicycle. Solutions might be the 'open standaard' and the use of a mobile phone app, Bluetooth or linking the authentication system with a debit card or the public transport card: the OV chip card. This is especially true for commuting and business trips as punctuality is of more importance compared to recreational trips. Being able to reserve a bicycle might also be an attractive added feature to the system for commuters and business travellers to deal with the issue of punctuality.

System Status Information System The system status information should be optimized. When a commuter of business traveller wants to make use of a shared bicycle and they are not able to easily check whether a bicycle is available, or the information is not up to date, the bad experience with the system could cause the potential user to not opting for the system again as arriving on time on a commuting or business trip is much more important compared to recreational trips.

Bicycle redistribution Mechanisms As explained in Section 2.3.2, a flexible system is most attractive from the perspective of the users. However, a flexible system leads to high redistribution costs. User-based redistribution should be used to tackle such issues, but it remains unclear whether the added attractiveness of a flexible system can make up for the increased operational costs. Another option would be to incentivize users to return the bicycle to the original starting location as is done with the PT-bicycle, however this does again greatly limit flexibility as explained in the section on docking stations.

Models of Provision The preferred model of provision remains unclear. Other than the experience that has been gained through the transport agency led business model from the PT-bicycle, no long term experience has been gathered in the Netherlands from any other type of business model. As this system element has no direct effect on the setup of the system from the perspective of the user, not further discussions were started on this subject in the expert interviews to come up with a provision model that would be most attractive as this is very difficult to determine with limited knowledge on the actual business case.

Pricing The tariff constructions must make it possible to rent the bicycle for an entire day for a fair price as well as for short trips. Although many cost structures are possible, most experts propose to use a cost structure which allows users paying per kilometre as this would make most sense when an electric bicycle is provided due to the bicycle using energy while driving. They believe the maximum possible cost per kilometre equals 28 cents per kilometre as this is equal to the cost of a bus / tram or metro trip, which are modes that provide a solution for similar trip distances. The shared bicycle should not be made more expensive than these modes.

3.2 FACTORS INFLUENCING THE BIKE SHARE MODE CHOICE

This chapter will discuss the factors that are studied in this research with respect to their effect on the bike share mode choice from the perspective of Dutch commuters and business travellers. The factors that are identified will be based on literature research, knowledge gained in Chapter 2 and interviews that have been conducted with a variety of experts on the field of cycling and bike sharing in order to gain insight specifically into the bike share mode choice for Dutch commuters and business travellers. The bike share mode choice will be explored from three perspectives: the trip, system and user characteristics.

The effects of the factors described in this chapter on the bike share mode choice will be studied through distributing a web survey. Due to limited resources, which will be further explained in Chapter 5, the survey is restricted in length.

3.2.1 TRIP CHARACTERISTICS

People's current trip patterns are expected to have a major influence on the bike share mode choice, as this relates to an individual's habits, but also sets boundaries as to what a shared bicycle could offer compared to the current commuting or business trip, or when it could be used to complement the current commuting trip. To understand how and why a shared bicycle would or wouldn't fit into a person's trip pattern, respondent's trip characteristics need to be taken into account. To do this

without lengthening the survey too much, the current mode choice(s) and travelled distance per mode choice will be studied for the commuting trip and not the business trip as such trips tend to be different each time. One factor which could not be included in this study but is expected to have a large effect on the bike share mode choice is the availability of certain modalities. However, this factor combined with the other trip pattern factors would take up too much time in the web survey. One characteristic that can be studied regarding the business trip travel motive is the frequency of which people go on business trips. Combined with the knowledge on the interest in using a shared bicycle for business trips, it can be determined to a certain extent whether implementing shared bicycles for business trips will generate enough demand.

Next to the current trip characteristics, it is also important to determine at what point in the mobility chain a shared bicycle is found to be attractive. The bike sharing concept as described in Section 3.1 states the shared bicycles should be located at several key points throughout a city. It remains unclear however where preferences lie with regards to what type of trips potential users would like to use a shared bicycle (e.g. towards/from a train station, other PT stop, or Park & Ride location). This will therefore also be studied in the web survey. In addition, the general interest in using a shared bicycle for different travel motives needs to be studied.

An overview of the trip characteristics:

- Current mode choice(s) made for the commuting trip
- Travelled distance per mode choice for the commuting trip
- Preferred location of shared bicycle use in relation to the mobility chain (e.g. towards/from a train station, other PT stop, P+R location, etc.)
- Interest in using a shared bicycle for different travel motives
- Frequency of business trips

3.2.2 SYSTEM CHARACTERISTICS

There are a number of system characteristics, which have been explained in detail in Section 2.3. However not all of these system characteristics can be studied through the survey. The characteristics that are studied are expected to have a strong effect on the bike share mode choice, require more research as literature and experts are unsure about the effects of these factors on the bike share mode choice and play a major role in the basic setup of the system. In addition, these characteristics form not only the characteristics of the shared bicycle but also of what a trip would look like using a shared bicycle, thereby being able to study the attractiveness of the basic setup of the system which defines this mode compared to other modalities.

The first factor of importance is the type of bicycle (traditional or electric bicycle). As explained in Section 3.2 it remains unclear what type of bicycle should be implemented in a Dutch bike sharing system. The electric bicycle is generally preferred, but it is more costly. Because of this, it is important to determine to what extent the electric bicycle is preferred over the traditional bicycle.

The next factor is the distribution of bike sharing docking stations. The distribution of docking stations influences the access and egress time of the system which greatly influence the

attractiveness of the system as well as how well the system is connected to other modes of transport. As was explained in Section 3.1 the system will not be as fine-grained as can be seen in European bike sharing systems like Vélib'. The access and egress time cannot be too long however. It is therefore important how increasing access and egress times influence the attractiveness of the shared bicycle. Knowledge on acceptable access and egress times will also help determine the placement of a bike sharing station in relation to the trip starting point and destination.

The third factor is the trip costs which are naturally believed to play a big factor in the bike share mode choice, and even more so because people are very much used to being able to use a bike for free instead of having to pay for it. In order for such a system to be feasible however, the costs of the system must be covered to some extent by the income through the use of the provided shared bicycles. The attractiveness of different cost structures as well as the effect of different trip fees on the bike share mode choice must be studied.

Furthermore, the factor flexibility of the return policy is studied as experts are unsure on whether making people return the shared bicycle to the original starting location has a strong negative effect on the bike share mode choice. If this is not the case, operational costs will be much lower compared to a system which needs redistribution of bicycles, which is why bike sharing initiators do still sometimes opt to limit the flexibility of the system, as is done for the PT bicycle.

An overview of the system characteristics:

- Type of bicycle
- Distribution of docking stations (access and egress time)
- Trip costs (usage fees and cost structures)
- Flexibility of the drop-off location

3.2.3 USER CHARACTERISTICS

The characteristics gender, age, income and education are taken into account as it is expected that these background factors could influence the preference of a shared bicycle, and especially how the preference for an E-bike or traditional bicycle is translated into the valuation of a shared bicycle. Research on E-bikes in the Netherlands shows that gender as well as age influences the preference for or usage of an E-bike versus a traditional bicycle (Fietsberaad, 2013b). Based on such research it is expected that the preference for an E-bike will increase with age, and that women have a slight preference towards an E-bike compared to men. With regards to bike sharing, it is expected that the E-bike will improve the attractiveness of a shared bicycle as people are expected to prefer the comfort and speed of an E-bike for commuting and business trips compared to the traditional bicycle (Fietsberaad, 2013a). Although the E-bike does seem more interesting for commuters and business travellers, especially younger people are still expected to prefer the traditional bicycle as the E-bike has a relatively negative image amongst such age groups. Lastly, the effect of age and gender on the bike sharing mode choice in general is unknown, although cycling is quite evenly spread over the two genders when the type of bicycle is not taken into account, and the effect of age on cycling in general is unclear (Heinen, 2011).

Next to demographics, it is important to find out to what extent the public is aware of vehicle sharing concepts. This information will help determine whether such services are properly marketed, and whether the use of such concepts is negatively influenced because people are not aware of these services. It is expected that people who are aware of and / or sometimes make use of existing vehicle sharing services are more likely to be interested in using a bicycle sharing service.

The influence the employer (and colleagues) is also expected to influence the bike share mode choice. When the employer is not stimulating the use of sustainable transport modes, the employee will not be incentivized to try out a mode of transport that they would not typically use. For example, when an employer provides his or her employees with lease cars, they are stimulating the use of the car. It is expected that the bike share mode choice is negatively influenced by a social influence from the workplace that does not involve public transport or the bicycle or any other sustainable transport mode. In addition the available travel allowances need to be known as these will be expected to greatly influence the ability to use a certain type of vehicle like a bicycle.

People's perception of and attitude towards bike sharing is entirely unknown in the Netherlands. However, the attitude towards cycling for commuting trips is studied extensively. As this knowledge can also be applied to the attitude towards a shared bicycle, the attitude will only be studied towards the 'shared' aspect of the bike share mode and not to the 'cycling' aspect. The aspects that will be studied are then the degree of preference for the privately owned bicycle versus using a shared bicycle, the perceived attractiveness of using a shared bicycle when the privately owned bicycle is not available and the perception towards the added value of a shared bicycle for the commuting and business trip.

The last factor of interest studied in this research is the preferred or favourite means of transport; an individual's habit. It was found by Aarts (1996) that the habit for a certain mode choice is found to be a strong indicator for the future mode choices. It is therefore expected that this factor will greatly influence the bike share mode choice.

An overview of the user characteristics:

- Personal characteristics (gender, age, income and education)
- Knowledge of vehicle sharing services
- Influence from employer and colleagues
- Available travel allowances
- Perception on several aspects of bike sharing:
 - Degree of preference for the privately owned bicycle versus using a shared bicycle
 - Perceived attractiveness of using a shared bicycle when the privately owned bicycle is not available
 - Perception towards the added value of a shared bicycle for the commuting and business trip
- Preferred or favourite means of transportation
PART II

DATA AND METHOD

4. DESIGNING THE STATED CHOICE EXPERIMENT

In order to gain understanding of the bike share mode choice and be able to predict whether an individual would be interested in using a shared bicycle for their commuting or business trip a mode choice model will be estimated. Stated-preference (SP) data on the preferences of Dutch commuters will serve as input for this mode choice model. SP data is gathered through a stated choice (SC) experiment which is presented to respondents in a web survey as has been explained in Chapter 1.

A SC experiment has been defined by Bliemer & Rose (2006) as an experiment presenting a sample of respondents with a number of hypothetical scenarios, consisting of a universal but finite number of alternatives that differ on a number of attribute dimensions. SC experiments are used to determine the influence of design attributes upon the choices that are observed, thereby allowing us to understand how different characteristics or attributes are balanced against each other in the bike share mode choice, or in other words what weights these attributes have in the bike share mode choice. In addition an SC experiment can be used to predict the mode choice using a mode choice model based on data from the SC experiment (ChoiceMetrics, 2014; J. J. Louviere, Hensher, & Swait, 2000). SC experiments are a widely accepted data paradigm in the study of behaviour response of agents (Hensher, 2006) and are used here to study how different bike sharing system characteristics influence the mode choices that are made by a commuter when introduced to a shared bicycle.

This chapter will discuss the process of designing the SC experiment and the choices that were made in this process. This will be done according to the following steps that can be distinguished when designing a SC experiment (Bliemer & Rose, 2006):

- Identify the attributes that are to be studied
- Specify the choice experiment
 - How many alternatives are included in each choice set?
 - How many levels per attribute are used?
 - What are the attribute level ranges?
 - What type of experimental design should be used?
- Use the experimental design to construct alternatives or profiles
- Combine alternatives into choice situations

Firstly however two aspects regarding the design of this SC experiment will be discussed, which need to be addressed before going into depth on the design of the full SC experiment. The sections will discuss the limitations of the survey length, the chosen type of experimental design and how these aspects influence the design of the experiment which will be elaborated on throughout this chapter.

Limited survey length

Due to limited resources in terms of time and funds to collect survey data, which will be discussed further in Section 5.1, the number of choice situations presented to the respondents in the SC experiment, along with the number of questions posed in the questionnaire, must be minimized so that the length of the survey does not put off respondents from filling in the survey. As a guideline the survey should be able to be filled in within approximately 10 minutes. This guideline is set by various companies that were contacted which would not allow the survey to be distributed amongst their employees if the time it took to fill in the survey exceeded 10 minutes, as well as by experts on the collection of survey data who state that a survey which takes longer than 10 minutes to fill in will limit the response significantly.

Pilot SC experiment: Determining priors

In the experimental design of a stated choice experiment, a scheme of numbers is used to determine which attribute levels are to be combined in order to construct alternatives. There are different types of experimental designs one can use. The most used being an orthogonal design or an efficient design. Efficient designs will be able to outperform the orthogonal designs as these efficient designs are able to minimize the possible standard errors of the estimated parameters, however prior parameter estimates (priors) need to be available.

As the number of choice situations that will be presented to a respondent must be minimized and the data must be gathered as efficiently as possible, an efficient design is used to construct the alternatives for the SC experiment. In order to come up with an efficient design prior parameter estimates are required which are estimated through conducting a pilot SC study among a sample of 55 respondents consisting mostly of colleagues, friends and family. The design of the pilot SC experiment will not be discussed in this chapter, but is explained in Appendix B. The lessons learned from conducting this pilot SC study are discussed throughout this chapter however when describing the steps and choices made in the design of the final, complete SC experiment.

4.1 IDENTIFYING ATTRIBUTES

Based on desk and literature research, the expert interviews and discussions between several bike sharing experts on how bike sharing should be implemented in the Netherlands, several aspects of bike sharing system design were identified that need to be studied further, as discussed in Chapter 3. It was determined that the attributes that represent the aspects of bike sharing system design which describe the characteristics of a bike sharing trip are expected to have the largest influence on the bike share mode choice when compared to the attractiveness of other modalities, and will therefore be studied further in this choice experiment. The following attributes which were previously discussed in Chapter 3 are therefore included in the choice experiment:

- Bicycle type
- The flexibility of the drop-off location / bicycle return policy
- Access time
- Egress time
- Trip costs

The pilot SC experiment included the attributes bicycle type, access time, flexibility drop-off location and trip costs. The attribute egress time was left out of the pilot study as egress time only exists in a system where there is flexibility of the drop-off location. This is because when there is no flexibility of the drop-off location, users would park their shared bicycle as close to the destination as possible and only return it to the starting location at the end of the day, as returning it after a one-way trip would not be an option. When there is flexibility of the drop-off location, the shared bicycle can be returned after a one-way trip when docking stations are available nearby. The return trip then consists of walking to the closest docking station to pick up another shared bicycle to drive back home. As the flexibility of the drop-off location is included as an attribute in the pilot SC experiment, it does not make sense to include the attribute egress time when the choice situation could be presented without a flexible drop-off location.

However, remarks from respondents were focused on the flexibility of the drop-off location attribute, as they explained that this attribute does not matter as long as the contextual information does not explain a reason for them not being able to or wanting to return the bicycle to the drop-off location. The only way to be able to provide this contextual information would be through a variety of context variables which would cause too high of an increase in choice situations. As a result, the attribute 'drop-off location' was removed from the SC experiment and included in the questionnaire part of the web survey. This leaves an opening for the egress time attribute to be included in the choice experiment without this leading to too many choice situations. This leaves the SC experiment with the following attributes:

- Bicycle type
- Access time
- Egress time
- Trip costs

As this choice experiment focuses on system characteristics that describe the shared bicycle trip, the effect of the different attributes can be studied more in depth by adding varying situational information on the hypothetical trip the respondents are about take, like for example the trip distance, the travel motive and what type of trip (towards a train station, from a P+R location, etc.). Testing the effects of situational information on the attributes and the mode choice in general can be done through adding one or more context variables to a choice experiment.

4.1.2 CONTEXT VARIABLE

A context variable is a variable that has the same value for all alternatives in a choice situation. It is used to describe situational information on the hypothetical trip that is presented to the decisionmaker along with the alternatives from which the decision-maker has to choose. There are several interesting possibilities with regards to contextual information for this choice experiment.

As this research focusses on both commuting and business trips, including a context variable which describes the travel motive allows for studying the effects of the attributes for both these types of trips. Another interesting variable would be the location of a shared bicycle in the transport chain. The shared bicycle could be used for the entire trip, towards a public transport stop, towards a train station, from a public transport stop, from a train station or from a P&R location. Lastly, including the context variable trip distance would allow for studying for what trip distances a shared bicycle is an attractive mode choice, how the type of bicycle is influenced by different distances as well as how it influences the other attributes.

Adding a context variable to a choice experiment leads to a steep increase in choice situations, as every choice situation based on the shared bicycle attributes needs to be presented for each possible context. Since adding a context variable to a choice experiment leads to a major increase in choice situations that need to be presented to a decision-maker and the number of choice situations must be limited as stated earlier, the context variable must have sufficient added value to the experiment while limiting the increase in choice situations.

As the trip type context variable can take on a relatively high number of values, this would lead to too high an increase in choice situations. It is possible to only include a number of possible trip types, but as it remains very important to determine for what trip types a shared bicycle is interesting to commuters and business travellers, a variety of trip types need to be studied. This can be done more efficiently in the questionnaire that is included in the survey, through asking for which types of trips the respondents would be interested in using a shared bicycle, without relating this to different characteristics of bike sharing system design.

Furthermore, although it would be interesting to perform the experiment for both commuting and business trips through adding a context variable that describes the travel motive, the business travel motive is difficult to grasp. The context of a business trip would also have to include information on the type of business appointment, the location of the business appoint as well as many other aspects to determine whether the use of a shared bicycle is interesting for a business trip. Because of these reasons it is difficult to accurately test the interest in using shared bicycles for business trips without testing a variety of contextual variables. The commuting trip however is relatively stable for a decision-maker, and because of this the choice situations can be presented to respondents as hypothetical commuting trips without adding a range of contextual variables. In addition, since commuting trips have a much larger effect on traffic congestion than business trips do, studying the potential of shared bicycles can be implemented to help realize the goals set by the Dutch government. The trips in the choice experiments are therefore presented as commuting trips. This way insight will be gained on whether and under which circumstances the shared bicycle is an attractive mode

choice for commuters. This information can be generalized to a certain extent to business trips, while keeping in mind that the interest in shared bicycles for business trips is also dependent on a range of other aspects. Presenting the hypothetical shared bicycle trips as commuting trips does not lead to an increase of choice situations as this will be general contextual information and not a context variable as it will remain the same over the entire experiment.

The final proposed context variable is trip distance. It is expected that this trip characteristic has a large effect on the bike share mode choice as well as on the valuation of the other attributes, in particular the type of bicycle. Including this context variable will therefore provide more detailed information on the bike share mode choice, while it is possible to include this variable with a limited number of levels. For these reasons the trip distance will be included in the choice experiment as a context variable.

The other aspects that have been discussed in this section but cannot be included in the choice experiment will be included in the questionnaire as to gather more information on the circumstances under which people would be interested in using a shared bicycle.

4.2 NUMBER OF ALTERNATIVES

The number of alternatives included in a choice experiment plays a critical role in how individuals evaluate the choice experiment. Firstly, it is important to present realistic alternatives to the respondents, in order for them to be able to accurately determine their preferences based on what they would do in real life scenarios (Hensher, Rose, & Greene, 2005). Secondly, it is possible that an increase in complexity of the choice situation will compromise choice consistency (DeShazo & Fermo, 2002; Heiner, 1983). Lastly, due to limited resources when conducting the survey, the entire survey should be able to be filled in within approximately 10 minutes. The reasoning behind this limitation is explained in more detail in Section 5.1. Because of this the choice experiment cannot be too complex, or too long.

Since we want to determine how different system characteristics influence the bike share mode choice, a bike sharing alternative as well as an alternative representing other mode choices must be included in the choice experiment. As this research does not aim to determine the viability of the bike share mode choice for a particular trip where there is a choice between several modalities, the choice experiment will include a bike sharing alternative depicting generic bike sharing features which are not trip specific, and an alternative will be included that represents any other modality, often referred to as a 'no-choice' alternative: the decision-maker decides to not choose the shared bicycle as he or she would rather use another modality. A no-choice alternative is a form of a base alternative, as used in conjoint analysis and choice modelling to scale the utilities between the various choice sets and to make the choice more realistic (Haaijer, Kamakura, & Wedel, 2001).

This would mean the choice experiment will include two alternatives per choice situation: one shared bicycle alternative and one no-choice alternative. This poses a problem. Because it is expected that a bike sharing service is only interesting to a limited group of commuters and business travellers, it is possible that too many people will opt for the no-choice alternative, making it impossible to estimate the bike share mode choice model. To deal with these potential issues,

another shared bicycle alternative has been added, and each choice situation will be accompanied by two questions. The first question will force the respondent to choose between the two shared bicycle alternatives, and the second question will ask the respondent to choose between the selected shared bicycle from the first question, and the no-choice alternative. Data gathered from the second question will be used to determine the bike share mode choice model. However, when this is not possible due to too many opting for the no-choice alternative, the data gathered from the first question will provide insight into trade-offs between shared bicycle attributes, which can still be used to identify recommendations for bike sharing system design, but not to determine the market potential of a bike sharing service.

Because the no-choice alternative has no attributes and represents a simple opt-out option, it is not visually added to the choice set as an extra alternative, but it is simply asked of the respondent whether they would prefer the earlier chosen shared bicycle alternative over other modalities (the opt-out alternative). The choice sets, when including the no-choice alternative, then exhibit the three characteristics necessary to estimate a discrete mode choice model: they are mutually exclusive, exhaustive and the number of alternatives is finite (Train, 2009).

4.3 ATTRIBUTE LEVELS AND RANGES

The shared bicycle alternatives will be presented with a set of attributes with different values. Each attribute will have at least two levels, and if nonlinear effects are expected for a certain attribute, then a minimum of three attribute levels are needed in order to test and estimate these nonlinearities. Mixing too many different numbers of levels may cause an increase in the number of choice situations, which will therefore be avoided in the designing of this choice experiment. With regards to the range of the attribute levels, using a wider level range is found to be statistically better than using a narrow range by Bliemer & Rose (2006) because this leads to more reliable parameter estimates, thus with a smaller standard error. However, the level ranges need to be realistic in order for the decision-makers to be able to identify or imagine the situation in real life, and may not result in unrealistic combinations. Due to the limitations on the number of choice situations that can be included in the SC experiment, the number of levels for all attributes will be set to a minimum of 3 levels when nonlinear effects need to be estimated.

As the scope of this research only focuses on the traditional and the electric bicycle, the levels of the attribute 'bicycle type' are simple: either a traditional or electric bicycle is presented in the SC experiment. The range of the access time attribute is set 1 to 7 minutes in the pilot study as this reflects a realistic range of access times for which the shared bicycle would still be accessible within an acceptable range. This was validated in the expert focus group. For the trip costs, expert interviews stated that when a shared bicycle is presented to potential users, the trip costs cannot be higher than the competing price of public transport modalities like the tram, metro or bus. In the Netherlands such a public transport option costs approximately 30 cents per kilometre. This €0.30 p/km is set as the maximum value of the trip costs attribute as it represents the maximum realistic value the trip costs of a shared bicycle can take on. The minimum trip costs will be set to zero, as it is possible that travel compensation will be offered to commuters for use of a shared bicycle.

The trip cost structure is based on a certain amount that is paid for each kilometre driven with the shared bicycle as has been explained in Chapter 2. As currently only this cost structure is expected to be implemented in the Netherlands and the number of choice situations must be limited, it is chosen to include the attribute trip cost as having this cost structure and not to test any other options. This means no fixed amount is proposed to the respondents and this should be kept in mind when interpreting the results of the bike share mode choice model.

For all attributes and the context variable equal distances between the attribute levels are chosen to allow for easy interpretation of the coefficients. This results in the following utility function:

 $\beta_{type} * TYPE[0,1] + \beta_{access} * ACCESS[1,4,7] + \beta_{egress} * EGRESS[1,4,7] + \beta_{price} * PRICE[0,0.15,0.30]$

where β represents the parameter of the attribute x, and the levels are shown within the brackets after each attribute.

The trip distance in this experiment can take on values of 2, 6 or 10 kilometres, as this range represents short trips, medium distance trips and long distance trips as validated in the expert focus group.

4.4 EXPERIMENTAL DESIGN

In the experimental design of a stated choice experiment, the various attribute levels for each attribute are combined into a set of alternatives which are to be presented to the sample. How the levels of the design attributes are distributed in the experiment determines whether or not an independent assessment of each attribute's contribution to the choices observed can be determined. Furthermore, the allocation of the attribute levels within the experimental design may also impact the statistical power of the experiment. However, when the sample is large enough the statistical power of the experimental design may not matter. Nevertheless, the ability to retrieve statistically significant parameter estimates can be compromised when using a relatively poor design for the choice experiment. This section will discuss the different types of experimental designs and will elaborate on the chosen efficient design and the chosen efficiency measure. In addition this section will discuss the preferred number of choice situations included in the SC experiment.

4.4.1 TYPES OF EXPERIMENTAL DESIGNS

A full factorial design consists of all possible choice situations, and through using this design all possible effects can be estimated. However, the number of choice situations in a full factorial design is often much too large to use in practice. Therefore, most often people rely on so-called fractional factorial designs. Such a design consists of a subset of choice situations from the full factorial design. There are however a number of different types of these fractional factorial designs (ChoiceMetrics, 2014). The easiest way to get to a fractional factorial design is to randomly select choice situations from the full factorial design, but this is not the best approach. Rather, one selects choice situations in a structured manner, so that the best data is gathered from the choice experiment in order to estimate the model. The most well-known fractional factorial design type is the orthogonal design, which aims to minimize the correlation between the attribute levels in the choice situations.

orthogonal designs have limitations and cannot avoid choice situations where dominance exists. This dominance means that one alternative is clearly more preferred over the others. In general the design should be rejected when the expected probability of an alternative in a design is no higher than 0.90.

Recently however, efficient designs have been introduced. Instead of only looking at the correlation between the attribute levels, efficient designs aim to find designs that are statistically as efficient as possible in terms of the predicted standard errors of the parameter estimates. This means that these designs try to maximize the information that is gathered from each choice situation by balancing the utilities of the alternatives proposed to the respondents. Efficient designs will be able to outperform the orthogonal designs due to being able to minimize the standard errors of the estimated parameters, however prior parameter estimates need to be available. Therefore, efficient designs rely on the accuracy of the prior parameter estimates. It can be argued that an orthogonal design is efficient only in cases where there is no knowledge about the parameters, but whenever there is any prior parameter information available, the design can be improved.

For this stated choice experiment an efficient design is used as the number of choice situations need to be minimized and information must be gathered as efficiently as possible for all choice situations, however as stated earlier prior parameter information is necessary when wanting to determine an efficient design. Knowledge of the sign of the parameters (e.g. price typically has a negative sign) already provides enough information to improve the design. Since the objective of the choice experiment is to estimate these parameters however, knowledge on these parameter values was unavailable. Nevertheless, there are several approaches available to obtain prior parameters. Methods include using parameter estimates from literature research, focus groups, or rely on expert judgment. For this research a pilot study was conducted among a small number of respondents as was stated at the beginning of this chapter. This pilot study consists of generating a SC experiment where the estimated parameter estimates will be used as prior parameters when constructing the efficient SC experiment. The method of conducting a pilot study is one of the most accurate ways to determine prior parameter values, and is therefore used in this research. The design of the pilot SC experiment is described in Appendix B alongside the resulting experimental design in Appendix C.

EFFICIENCY MEASURES

In an efficient design the objective is to minimize the efficiency error, which represents the degree of inefficiency of the experimental design with which different designs can be compared to one another. This efficiency error is calculated using the asymptotic variance-covariance (AVC) matrix which requires prior information on parameter values. As no prior parameter information is estimated for egress time, the estimated coefficient for access time is used for this attribute.

The AVC matrix can be derived of these parameters and contains the covariances between the parameters and the variance of each parameter on the diagonal. Taking the root of the variance results in the standard error of a parameter in case a single respondent would complete the experiment. Several efficiency measures have been proposed in literature in order to calculate the efficiency error. The most widely used measure is the so-called D-error, which takes the determinant

of the AVC matrix Ω_1 , assuming only a single respondent. As priors are available, specifically the D_perror ('p' from priors) will be minimized while determining an efficient design. The D-error is a function of the experimental design X and the prior values $\tilde{\beta}$ and is mathematically formulated as:

$$D_p$$
-error = det $(\Omega_1(X, \tilde{\beta}))^{1/K}$

where K is the number of parameters to be estimated.

There are also A-efficient designs, which are based on the trace of the AVC matrix. The trace is the sum of values on the main diagonal; hence it focusses on standard errors only and ignores the covariates between attributes. The third type of efficient design is the S-efficient design, which looks for the design that minimizes the standard error of the parameter for which it is hardest to reach significance. As this choice experiment does not have features which would make the A or S-efficient design more interesting than the generally preferred D-efficient design, the efficiency of the designs will be compared based on the D_p -error.

4.4.2 NUMBER OF CHOICE SITUATIONS

The generation of efficient designs requires the same characteristics as when generating an orthogonal design, such as attribute level balance, which means that each attribute level appears an equal number of times for each attribute in the experimental design such that high levels and low levels are all represented well (Bliemer & Rose, 2006). According to Bliemer & Rose (2006) however the attribute level balance requirement does impose constraints on the problem of minimising the design's efficiency error, and more efficient designs may be found when this assumption is not considered. Because it is vital for this choice experiment to minimise the number of choice situations due to resource constraints, the attribute level balance requirement will be let go in the experimental design of this SC experiment.

When designing the D_p -efficient design without attribute level balance, the minimum number of choice situations is found through trial and error, trying to minimize the number of choice situations while finding the lowest possible D_p -error. The number of choice situations presented to each respondent can be minimized further by using a procedure called blocking (ChoiceMetrics, 2014). Blocking is generally used to limit the choice situations presented to a single respondent, by splitting the orthogonal design into smaller designs. Each block is then not orthogonal by itself, only the combination of all blocks is. Furthermore, it ensures that attribute level balance is satisfied within each block. Blocks are typically determined by using an extra uncorrelated column with a number of levels equal to the number of blocks.

When applying the blocking procedure to this specific design it cannot be used in the same way since the design is not orthogonal, and attribute level balance is let loose. It can be used however to deal with the increase in choice situations, which is caused by adding the context variable to the design, as will be explained in Section 4.5.

4.5 CONSTRUCTING ALTERNATIVES IN NGENE

As determining a "good" experimental design is not a simple task due to their being millions of possible designs, computer software is used to assist in finding the best experimental design. In this thesis, Ngene is used for this purpose. Ngene is software for generating experimental designs that are used in stated choice experiments for the purpose of estimating choice models, particularly of the logit type (ChoiceMetrics, 2014). The utility function of a shared bicycle as defined in Ngene is as follows:

 $\begin{aligned} CONSTANT + \beta_{TYPE}[0.32] * TYPE(-1,1) + \beta_{ACCESS}[-1.10|0] * ACCESS(1,4,7) \\ + \beta_{EGRESS}[-1.10|0] * EGRESS(1,4,7) + \beta_{PRICE}[-0.61|0] * PRICE(0,0.15,0.30) \end{aligned}$

where β_x is the parameter of attribute x, and the values in the brackets show the priors and the values in the square brackets define the levels included in the design for each attribute.

In order to be able to test for nonlinearity and improve interpretability, effect coding is applied in Ngene for all attributes. Using Ngene and the prior values estimated through the pilot SC experiment, the D_p -efficient design was found with a D_p -error of 0.396 based on Ngene not providing more efficient designs after iterating for new attempts for over an hour. The highest SP estimate is equal to 11.3, which indicates that only 12 respondents are needed in order for all parameter to become statistically significant. As this design is applied to all three context variable, in total 36 respondents are needed for all parameters to become statistically significant if their answers are in line with the prior parameter value information that was found through the pilot study.

Although this indicates that only a very limited number of respondents need to fill in the survey to produce significant effects in the choice model, it is expected that the respondents do not fill in the choice experiment in a completely similar way as respondents from the pilot survey did as this was a very small sample and the SC experiment was set up slightly different. However, such small SP estimates do indicate that even in case only a limited number of respondents answers the SC experiment, significant results can still be estimated.

Through checking the expected probabilities in Ngene it was found that no dominance exists in this design. The resulting design includes 8 choice situations as shown in Table 1. The last column 'Block' can be disregarded for now. Although the efficient design does not decrease the number of choice situations needed compared to the pilot SC design, it does increase the amount of information that can be gathered per choice situation through balancing the utility amongst the alternatives, and therefore decrease the number of respondents needed to be able to estimate significant effects. The D_p-efficient design with a D_p-error of 0.396 is made up of the following choice situations:

Choice situation	Type1	Access1	Egress1	Price1	Type2	Access2	Egress2	Price2	Block
1	-1	4	1	0.3	1	7	4	0.15	3
2	1	7	1	0.15	-1	1	7	0	1
3	-1	1	7	0.15	1	4	4	0.3	1
4	-1	7	4	0.3	1	4	7	0.15	2
5	1	1	7	0.3	-1	7	1	0	2
6	-1	4	4	0.15	1	7	1	0.3	1
7	1	4	7	0	-1	1	4	0.3	3
8	1	7	4	0	-1	4	7	0.15	2

Table 1: The choice situations resulting from the efficient design as generated by Ngene

More detailed information on the experimental design is found in Appendix C.

4.5.1 INCLUDING THE CONTEXT VARIABLE

Next the context variable trip distance needs to be added to SC experiment. Since it is not feasible to present respondents with an elaborate survey and a choice experiment consisting of 24 choice sets (8 choice situations times 3 context variable levels), the blocking procedure is used to distribute the 8 choice situations over 3 blocks, as is indicated by the column 'Block' in Table 1. The first set of respondents will then be presented with the first block with a trip distance of 2km, the second block with a trip distance of 6km and the third block with a trip distance of 10km. The blocks are then assigned to the second and third set of respondents together with certain trip distances as is shown in Table 2. Which set of choice situations has a 33% chance to be presented to the respondent. Within a set of choice situations that is presented to a respondent, the choice situations are ordered randomly so that the context variable is not kept constant for a series of choice situations.

A choice situation as will be presented to respondents through the web survey will be shown and explained further in Section 5.2.

Context variable level	Respondent set 1	Respondent set 2	Respondent set 3
2 kilometres	Block 1	Block 2	Block 3
6 kilometres	Block 2	Block 3	Block 1
10 kilometres	Block 3	Block 1	Block 2

Table 2: Assigning choice situation blocks with context variable levels to sets of respondents

5. CONSTRUCTION AND DISTRIBUTION OF THE WEB SURVEY

This chapter will discuss the construction of the web survey, the population sample, the distribution of the web survey and finally the demographics of the respondent sample and give a general overview of the collected data. The complete web survey (in Dutch) can be found in Appendix H.

5.1 SAMPLE

To study the bike share mode choice of Dutch commuters and business travellers, the working adult population that either work or live in an urban area is part of the population of interest. Several methods are possible when collecting a data sample from this population, like going door to door, to large office parking locations, public transport stops and so on. However, such methods are not preferred as it would take too much time and people travelling with public transportation would be easier to reach than for example car travellers, thereby ending up with a non-realistic reflection of the population. Another method would be to distribute the survey link via social media and using the snowball method through websites that focus on cyclists for example. Again this would result in a sample that would have a strong preference for cycling thereby not being a realistic reflection of the population.

It was chosen to distribute the web survey amongst the population of interest by contacting employers that have offices located in urban areas and asking them to contribute to this research by distributing the web survey amongst their employees. Depending on the number of companies and the type of companies that are willing to contribute to this research, the sample will not be a random sample in the sense that large portions of the sample would be experiencing the same company culture which is expected to influence the bike share mode choice. However, this method does ensure people from a variety of locations and with different trip characteristics are included in the sample which is most important for this research.

In the time frame of this research three small and one large employer were found to be interested in contributing to this research. The smaller employers together had about 50 employees, while the large employer has a total of 1900 employees. Both the small and large employers have office locations that can be found all over the country making the sample more diverse. In addition, all employers offer lease cars to a portion of the employees which would make the sample a more realistic reflection of the population of interest as most commuters and business travellers do indeed use the car for their commuting and business trips. A more detailed explanation of the characteristics of these companies can be found in Appendix D.

5.2 CONSTRUCTING THE WEB SURVEY

In Chapter 3 several factors have been identified that are expected to influence the bike sharing mode choice and will therefore be studied through this web survey. Most of the system characteristics discussed in Chapter 3 are studied through the choice experiment as has been explained in Chapter 4. In addition to these factors, several trip and user characteristics were also

identified in Chapter 3, which will be studied through regular questions posed in the questionnaire part of the survey. This section will explain the general setup of the web survey.

The web survey will start off with questions on the current trip patterns for the commuting trip. Respondents will be asked what modes they use on their trip and the trip distance they travel for each mode they use. This way the entire commuting trip will be known and it is possible to determine for this sample how their current trip characteristics influence the possibility to use a shared bicycle, hence determining for what percentage of respondents a shared bicycle could be an option.

Next information is gathered on the knowledge levels of the respondents on vehicle sharing services, their preferred mode of transportation and what mode of transport the respondent is expected to use by their employer and colleagues. These are studied at the start of the survey because no information is needed on bike sharing to answer these questions. In addition, respondents will be asked to state which type of travel allowances they are able to use as well as their business trip frequency to gain more insight into the business related travel motive.

Next the bike sharing concept needs to be explained as it has been introduced in Section 3.1 in order to ask questions where the answers require prior knowledge on bike sharing. The explanation that is given in the web survey is described in Section 5.2.1. After having explained the concept of bike sharing to the respondents, questions are asked on the perception of and attitude towards bike sharing. In addition, respondents will be asked for which part of the mobility chain they would like to use a shared bicycle for the commuting or business trip, which allows respondents to choose from the following options:

- The entire trip
- Trip towards a bus / metro / tram stop
- Trip towards a train station
- Trip from a P+R location
- Trip from a bus / metro / tram stop
- Trip from a train station

Next, people will be asked to what degree they would like to make use of a shared bicycle for a variety of trip motives. After these questions the choice experiment is explained in the web survey. The explanation is described in Section 5.2.2.

After the choice experiment the survey ends with several questions on characteristics of the respondents. These include the personal characteristics as discussed in Chapter 3 as well as the professional status, the type of employment and the type of job to gain more knowledge on the background of the respondents. Next respondents are asked to write down their residential address and the address of their three most visited office locations to gain more insight into their commuting trips, as well as to check the distances that the respondents wrote down in the first section of the web survey.

5.2.1 INTRODUCING THE CONCEPT OF BIKE SHARING

Based on the concept that has been explained in Section 3.1 a short explanation will be provided in the web survey of the general setup of the bike sharing system on which they have to base their opinions. This explanation will be very short as the respondents should only be informed of the basic setup of a bike sharing system, meaning that they will be able to pick up a shared bicycle (traditional or electric bicycle) at several locations, pay for it, and park it at a docking station near their destination. The following explanation is provided:

- An organisation (bike sharing company or municipality) provides bicycles, for which they ensure maintenance, which are distributed over a large region.
- A shared bicycle can be picked up at a bicycle docking station, as is shown in the picture below. This could either be a traditional or an electric bicycle.
- You will sign in at the terminal next to the docking station and will be able to take one of the shared bicycles with you.
- At the end of your trip the shared bicycle can be parked at a docking station nearby your destination.
- Bike sharing docking stations will be available at for example public transport stops, P+R locations, office locations, residential areas, the city centre, and so on. This means you will be able to pick up a shared bicycle anywhere.
- You will pay a certain amount per kilometre while using the shared bicycle.

5.2.2 EXPLAINING THE CHOICE EXPERIMENT

As explained in Chapter 4, the choice experiment will include two bike sharing alternatives, a question to choose between the two alternatives and a question in which respondents are asked to choose between their chosen shared bicycle or any other mode of transport. Each bike sharing alternative includes four attributes, and each choice situation is accompanied with a certain trip distance. The choice experiment was explained to the respondents as follows:

When answering the following questions, the respondent is asked to imagine that you are travelling from home to work and at some point during the commuting trip the respondent is presented with the choice to continue travelling with shared bicycle 1 or shared bicycle 2. The distance that the respondent is supposed to travel with the shared bicycle on the fictional trip varies and is reported for each choice situation. The two shared bicycles are described on the basis of the following characteristics:

- Bicycle type: A traditional or electric bicycle
- Access time: The number of minutes one has to walk to the docking station where the shared bicycle can be picked up.
- Egress time: The number of minutes one has to walk from the docking station where the bicycle is parked towards the destination.
- Trip costs: The price in euros for a one-way trip with a shared bicycle.

In Figure 8 visualisation is shown of how each shared bicycle trip was presented to the respondent. Although this figure is in Dutch, it is set up to show respondents the different components of the trip: access time, trip distance and egress time. In addition, the different figures at the start and end of the trip represent the variety of locations from where one can pick up a shared bicycle and the variety of locations one can use the shared bicycle to travel towards.



Figure 8: Visualization of the trip presented in the choice experiment as has been explained to respondents in the web survey

After this explanation the choice experiment starts. Each respondent is asked to answer two questions for each of the 8 choice situations that are presented to them. First the respondent is asked which of the two shared bicycles is preferred for the presented trip. Next, the respondent is asked whether they would prefer to use the chosen shared bicycle, or any other modality. A choice situation as presented to the respondents in the web survey is shown in Figure 9.

5.3 SAMPLE CHARACTERISTICS

The web survey was distributed in during October and November 2015. Of the 428 respondents that opened the web survey, 293 respondents have filled in the entire survey or up until the questions on demographics. These 293 respondents form the respondent sample on which the analysis in this study will be based. An overview of the different data cleaning steps that have been taken is given in Appendix E. The response is approximately 15% on average over the different companies. To incentivize people to fill in the survey people were promised the possibility to win a price worth €25,- when they filled in the survey.

Almost 82% of the respondents were male. This can be explained by the background of the companies where the survey has been distributed as these companies work in engineering related fields. The average age of the respondent sample is 47 years old, with most people aged between 50 and 55 years old. About 7.5% have only finished lower education, while 45.5% have finished medium level education as well and 47% have finished higher education. The percentage of people who have completed higher education is relatively high while percentage of people who have only finished lower education is very low. This could be explained by the types of jobs that people have with different educational backgrounds. People who have finished higher education are more likely to have daily access to a computer due to having an 'office job' while people who have only completed lower education will not. This means that people who have done higher education are more likely to fill in a web survey. In terms of income, most respondents report a net monthly household income between €3000,- and €3500,-. More detailed information on these characteristics can be found in Appendix F.

Trip explanation

The part of the commuting trip which you are about to take is 10 kilometres long.

	Shared bicycle 1	Shared bicycle 2
Shared bicycle type:	Traditioneel	Elektrisch
Access time bicycle:	4 minutes	7 minutes
Access time destination:	1 minute	4 minutes
Trip cost:	€3.00	€1.50

Which of the described shared bicylces do you prefer for this trip?

Shared bicycle 1

Shared bicycle 2

Which mode of transport do you prefer for this trip?

The shared bicycle I have chosen

Another mode of transport

Figure 9: A choice set as presented in the web survey

In terms of job characteristics, the respondent sample consists of almost 86% people that work fulltime and 14% of the respondents that work part-time. In addition, 7% of people have a temporary contract and 93% have permanent employment. Lastly some remarks will be made with regards to people's professions and whether this explains some of the characteristics of the respondent sample. Engineering is most frequently chosen with over 40 people reporting this profession alongside general management with almost 30 people, technical services with over 20 people and administrative services with 20 people, and less frequently reported jobs with a minimum of 10 people opting for this profession are production management, production planning and human resources. These numbers are still relatively low because almost a quarter of the respondent chose the option 'other profession'. In conclusion about half of the respondents report an engineering related profession and half of the respondents report professions related to administrative functions. After consulting the companies where the survey was distributed, it is found to be very likely that a very high percentage of people who perform jobs in the offices have filled in, thereby resulting in a relatively high number of administrative related professions, while employees with an engineering related profession are in reality much higher. The women that have filled in the survey, which only sums up to 20% of the respondents, is also believed to almost include all the women currently working at the consulted companies, due to women being more likely to have an office job. These findings have to be kept in mind when interpreting the results.

The respondents were also asked to state the frequency of their business trips. The results are visualized in Figure 10. Over 50% of the respondents do indeed travel for business reasons quite frequently, while only 10% of the respondents never travel for business meetings outside of the regular work place.



Figure 10: Frequency of business trips in percentages over the respondent sample

The respondents were also asked to state which type of travel allowances they are able to receive from their employer. The results are shown in Figure 11. After consulting the companies where the survey has been distributed it was found that a very large portion of the respondents is able to obtain any of the travel allowances that were included in the web survey. However, the results from this question show that the employees are very much unaware of the fact that they can obtain a bicycle mileage allowance. In addition, a large group states that they are not able to get any of the proposed travel allowances. It is unclear why such a large group of people have opted for 'no travel allowance' as the employers claim all employees are able to get any type of travel allowance. With regards to this study however, it is important to note that this data shows that a lot of the respondents are not aware of the possibility to get a bicycle mileage allowance which would make cycling on the commuting trip much more attractive.



Figure 11: The reported availability of travel allowances by respondents in percentages over the respondent sample

6. ESTIMATION AND APPLICATION OF DISCRETE CHOICE MODELS

This chapter will discuss the theory behind discrete choice models in Section 6.1 and the estimation method regarding the bike share mode choice models in Section 6.2.

6.1 THEORY ON DISCRETE CHOICE MODELLING

Discrete choice models can be used to analyse and predict a decision maker's choice of one alternative from a finite set of mutually exclusive and collectively exhaustive alternatives (Koppelman & Bhat, 2006). The ultimate interest in discrete choice modelling lies in being able to predict the decision making behaviour of a group of individuals. In addition, it is used to determine the relative influence of different attributes of alternatives and characteristics of decision makers when they make choice decisions. In this case, we are interested in predicting the fraction of commuters interested in using a shared bicycle under a variety of service conditions. Furthermore, these models can be used to predict the fraction of interested users for different groups of individuals and thereby identifying individuals who are most likely to favour one or another alternative. Similarly, it can be used to gain understanding of how different groups value different attributes of an alternative. Train (2009) describes the conceptual basis for discrete choice models in his book Discrete Choice Methods with Simulation. This book is used as a basis for understanding discrete choice modelling in this thesis and will be referred to throughout this research. For a full background on discrete choice models the reader is directed to (Train, 2009).

In a discrete choice model, as described by Train (2009), an agent faces a choice, or a series of choices over time, among a set of options where the outcome variable is discrete. The goal of the discrete choice model is to understand the behavioural process that leads to the agent's choice. A causal perspective is taken in this process. In the behavioural process a set of factors can be identified that collectively determine an agent's choice. Not all of these factors are observed by the researchers. The observed factors are labelled x, and the unobserved factors ε . The factors relate to the agent's choice through a function $y = h(x, \varepsilon)$. This function is often referred to as the behavioural process. This process can be called deterministic as when given x and ε , the choice of the agent is fully determined. However ε represents unobserved factors which cause the agent's choice to not be deterministic which means the choice cannot be predicted exactly. The unobserved terms are considered random with density $f(\varepsilon)$. The probability that the agent chooses a particular outcome from the set of all possible outcomes is then the probability that the unobserved factors are such that the behavioural process results in that outcome (Train, 2009):

$$P(y|x) = Prob(\varepsilon \text{ s.t. } h(x, \varepsilon) = y).$$

6.1.1 UTILITY MAXIMIZATION

Discrete choice models are usually derived under an assumption of utility-maximizing behaviour by the decision maker (Train, 2009). This means that an individual's preference for a certain good or service can be expressed in "utility", and people maximize this utility through the choices that they

make. Models that are derived on the basis of utility-maximizing behaviour are called random utility models (RUMs).

As explained in the introduction of this chapter, there are both observed factors and unobserved factors from the perspective of the analyst when estimating a choice model. In the case of utility-maximizing behaviour, the utility is therefore composed of two parts: the observed deterministic part V and the non-deterministic, unobserved part of the utility modelled as a random variable ε . More specifically, the utility $U_{ig} = V_{ig} + \varepsilon_{ig}$, $\forall i \in C_g$,

where the deterministic observed part V_{iq} is described by a function $f(\beta, X_{iq})$, where β is a vector of taste parameters and X_{iq} is a vector of attribute levels for alternative *i* that can be measured or observed. In addition, socio-demographic attributes of the decision-maker *q* (such as gender and income) and other determinants of the bike share mode choice as studied in the questionnaire can be included in the deterministic part of the utility function. The non-deterministic non-observable part of the utility function ε_{iq} is assumed to follow a given random probability distribution (Ben-Akiva & Lerman, 1985).

As it is assumed that all decision-makers aim to maximise their utility, and thus select the alternative that has the highest utility among the alternatives in the choice set, the probability that alternative i is chosen by decision-maker q from choice set C_{iq} is therefore:

$$P(i|C_q) = P[U_{iq} \ge U_{jq} \forall j \in C_q]$$

It is important to realize that only the differences between utilities are relevant here and not utilities themselves. This can be seen by rewriting equation X as follows:

$$P(i|C_q) = P[U_{iq} - U_{jq} \ge 0 \forall j \in C_q]$$

BASIC BIKE SHARE MODE CHOICE MODEL

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Applying this general utility maximising theory to the problem of bike share mode choice means that the function $f(\beta, X_{iq})$ can be filled in according to the attributes and levels identified in Chapter 4, while decisions need to be made on the distribution of random variable ε_{iq} . In this research, every alternative *i* will represent a commuting trip with a shared bicycle for a certain distance, while the no-choice alternative has a utility of zero. The utility function of the bike share mode choice model based on the choices made in Chapter 4 can be defined as:

$$U_{iq} = V_{iq} + \varepsilon_{iq} \qquad \forall i \in C_q$$

where V_{iq} is defined as:

$$V_{iq} = INTERCEPT + \beta_{TYPE} * TYPE_{iq} + \beta_{ACCESS} * ACCESS_{iq} + \beta_{EGRESS} * EGRESS_{iq} + \beta_{PRICE} * PRICE_{iq}$$

6.1.2 TYPES OF CHOICE MODELS: MULTINOMIAL LOGIT AND MIXED LOGIT

Assumptions need to be made with regards to the unobserved part ε_i , the random error term, of the utility function. When it is assumed that the random terms ε are independently and identically distributed (i.i.d.), following an extreme value type I (EVI) distribution, the so-called multinomial logit (MNL) model as proposed by McFadden (1973) can be used to estimate the parameter values. The choice probabilities of each alternative *i* from choice set C_q can then be calculated as:

$$P_{iq} = P(i|C_q) = \frac{e^{V_{iq}}}{\sum_{j \in C_q} e^{V_{jq}}}$$

The MNL model is the most widely used discrete choice model due to its simple mathematical structure and ease of estimation. However, the error term distribution of the MNL model is unrealistic, and it ignores several aspects of the decision-making process (Chorus, 2015):

- the existence of nests of alternatives as well as in unobserved attributes,
- the existence of random taste heterogeneity, and
- the correlation between choices made by the same individual across time.

This leads to biased predictions and large standard errors, which has led to the development of extension models to the MNL model, such as the mixed logit (ML) model. The ML model is a highly flexible model that can approximate any random utility model (McFadden & Train, 2000). It provides solutions to the three limitations of standard logit models by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time (Train, 2009).

RANDOM TASTE VARIATION

Whereas in MNL models the parameter β is fixed, in ML models different β s can be estimated for each person. The parameters of the distributions of the parameter β are then estimated meaning the degree of unobserved taste variation, or random taste heterogeneity, for a certain parameter can be determined. Hence, according to Train, the expected choice probabilities are not anymore as described in equation X and may be calculated as follows:

$$E(P_{iqs}) = \int_{\beta} \frac{e^{(V_{iqs})}}{\sum_{j} e^{(V_{jqs})}} f(\beta) d\beta,$$

where f is a multivariate distribution function over vector parameters β .

Such a model is estimated through simulation, which consists of drawing from a probability density function, calculating a statistic for each draw and averaging the results (Train, 2009).

UNRESTRICITED SUBSTITUTION PATTERNS

The mixed logit model is able to represent general substitution pattern as it does not exhibit logit's restrictive independence of irrelevant alternatives (IIA) property as with nonzero error components

in the utility function, utility becomes correlated over alternatives (Train, 2009). Several correlation patterns, and therefore also substitution patterns, can then be obtained by choosing the appropriate variables to enter as error components. Nests of alternatives and unobserved attributes can therefore be estimated using a mixed logit model.

CORRELATION IN UNOBSERVED FACTORS OVER TIME: PANEL EFFECTS

Lastly, a ML model can be used to capture panel effects, which means that it assumes that the different choices that one respondent makes in the choice experiment are correlated, resulting from correlation in preferences and tastes across time. To take into account both random taste variation and correlation in unobserved factors over time, the utility for respondent n for alternative i at time t is specified as follows:

$$U_{nit} = \beta_n X_{nit} + \varepsilon_{nit}$$

where the subscript t is the time dimension.

Adding panel effects means that each draw in the simulation is used for computing the entire sequence of logit probabilities for an individual. By doing so, one acknowledges that for example a drawn preference for bike sharing is represented in all choices made by the individual. This is referred to as a ML panel model.

PARAMETER CONVERGENCE

When simulating a ML panel model with random taste variation the number of draws that will be made during the simulation need to be specified. An increasing number of draws will give an increasingly good representation of the probability density function used to determine the random taste variation. However, making many draws leads to high computation times. A trade off must therefore be made by testing the stability for an increasing number of draws until parameter convergence is reached. Parameter convergence means that the parameters defining the distribution of the parameter for which random taste variation is estimated have reached an accurate evaluation for the distribution so as to obtain a good approximation of the function with which the choice probabilities are being simulated. One can say parameter convergence is reached when the parameter estimates (especially those with random taste variation), the Log Likelihood and the significance levels / t-values are stable for an increasing number of draws.

6.2 BIKE SHARE MODE CHOICE MODEL ESTIMATION

The following sections discuss the process of estimating both a MNL and a ML model which are used to gain insight into the effects of several factors that were identified in Chapter 3 on the bike share mode choice. As enough data was gathered through the choice experiment and respondents did not only opt for the no-choice alternative, the bike share mode choice models can be estimated as planned. All model estimations will be estimated using Biogeme, which is open source freeware designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models (Bierlaire, 2003).

This section will start off with an explanation of the coding used on the data before the models could be estimated in Section 6.2.1 after which the preparation of the gathered data is discussed in Section 6.2.2. Then the estimation process of the MNL model is discussed in Section 6.2.3 after which the estimation process of the ML panel model is discussed in Section 6.2.4. The resulting MNL and ML panel bike share mode choice models are presented in Chapter 7.

6.2.1 CODING

In order to estimate the choice model and being able to accurately interpret the coefficients, coding can be applied to the attribute levels in the choice experiment. Because it is important this model is easily interpreted, no coding is applied to the variables 'access', 'egress' and 'trip costs. However, the attribute 'bicycle type' needs to be coded as it is a nominal variable with levels that cannot be included in the utility function. Furthermore, when it is found that a variable has a nonlinear effect, coding this variable provides the possibility to interpret both the linear and nonlinear effect separately. The two main coding options are dummy coding and effect coding. Dummy coding uses only ones and zeros to convey all the necessary information on group membership. This means that the levels of the categorical variable will always be compared to the level which is coded with zeros, the reference level, which will have a part-worth utility of zero. By applying effect coding, which uses only ones, zeros and minus ones to convey all the necessary information, all attribute values have a part-worth utility. Dummy coding is generally applied in most modelling applications as most people are familiar with it as it is intuitive and simple. However, dummy coding poses an issue when estimating interaction effects which means that the different levels of the interaction effect will not be interpretable. Effects coding solves this issue.

Because it is expected that there is an interaction effect between the attribute 'bicycle type' and the context variable 'trip distance', the attribute bicycle type will be effect coded. When it becomes apparent that a certain variable shows a nonlinear effect and this variable is included in one or more estimated interaction effects, effect coding will also be applied. For example, it is expected that the variable trip distance shows a nonlinear effect. Coding would then be applied as shown in Table 3.

Bicycle type		Access time & Egress time		Trip c	osts	Trip distance		
Levels	Coding	Levels	Coding	Levels	Coding	Levels	Coding DistanceA	Coding DistanceB
Electric bicycle	1	7 minutes	7	€0.30	0.30	10 km	1	0
Traditional bicycle	-1	4 minutes	4	€0.15	0.15	6 km	0	1
		1 minute	1	€0.00	0	2 km	-1	-1

As the bike share mode choice model will also include several user characteristic parameters, linear coding is applied to most of these parameters in order to include them in the estimation process.

6.2.2 PREPARING SC EXPERIMENT DATA

Before the choice models are estimated, the dataset needs to be cleaned. In order to this, several steps have been taken. First all the observations are selected of respondents that have filled in the complete choice experiment, as well as all the survey questions before they were asked to fill in the choice experiment. This dataset now includes 2400 observations, from 300 respondents. Next observations are selected where the respondents have only opted for either the first or second shared bicycle alternative in all the presented choice situations. Since the choice situations that are presented to the respondents are designed in such a way that none of the shared bicycle alternative, it is unlikely that a respondent will find the first or second shared bicycle alternative to always be the most attractive one. After examining the answers of the 7 respondents for which this was the case, it was found that there did not seem to be any structured reasoning for their choices and therefore it was decided to remove these 7 respondents from the dataset. The dataset now includes 2232 observations, from 293 respondents.

When examining the dataset with regards to the second question posed for every choice situation, it was found that a large number of respondents had never selected the no-choice alternative for all presented choice situations. Since it was expected that the shared bicycle would only be preferred or interesting for a small group of people, these results were not as expected. This does not necessarily mean however that the respondents have failed to properly answer the second question posed in the choice experiment for every choice situation. When compared to the answers given in a general survey question in which respondents were asked how interested they would in using a shared bicycle for their commuting trips, only a small amount of people said that they would be interested, as was previously expected.

The results from this question are thus very different from the choice experiment data that has been gathered. This can be explained through the fact that a very different question is answered in the choice experiment than in the general survey question. In the general survey question respondents are asked whether they would in reality believe themselves to be interested in using a shared bicycle as had been previously explained to them (this question was posed before the choice experiment was explained) for their commuting trip. This means the respondent is asked whether they would want to use a shared bicycle for the current commuting trip which has many characteristics that can influence this choice. The choice experiment however is setup in such a way that it only provides the type of trip, namely the commuting trip, and the distance for which the shared bicycle will be used. No other trip characteristics are presented to the respondent. The answer to the choices posed to the respondent in the choice experiment will therefore be very different, and should be interpreted differently. Because of this, it is likely that the choice experiment has not been answered wrongly by the respondents, as all these respondents have filled in the entire rest of the survey without showing anomalies or odd answers, including the first question of the choice experiment. The choice models will therefore be estimated on a dataset that includes 2232 observations of 293 respondents, of which 14 are answered by employees from the Concordis Group consisting of three small employers, and 279 are answered by employees of Strukton Rail.

6.2.3 MULTINOMIAL LOGIT MODEL

Section 6.1.1 has presented the utility function for the bike share mode choice based on the attributes included in the choice experiment. A MNL model is used to estimate the parameters of this utility function, as well as to estimate the parameters of several other factors studied in the questionnaire if it is found that these factors improve the model fit. The steps taken to estimate the model which results are presented in Chapter 7 are described below.

• Estimating main effects

The MNL model was first estimated only including the main effects studied in the choice experiment:

- o Bicycle type
- o Access time
- o Egress time
- o Trip costs
- o Trip distance

• <u>Testing for nonlinearity</u>

It was then tested whether the attributes and context variable included in the choice experiment show nonlinear effects. This was done by adding the squared versions of these parameters to the model (e.g. access time * access time). When the squared versions of a main effect was found to be significant, effect coding was applied as has been explained in Section 6.2.1.

The parameter for trip distance was found to be nonlinear and is therefore split into the linear component distanceA and the nonlinear component distanceB.

<u>Estimating interaction effects</u>

Next using the likelihood-ratio test, it was determined whether adding a set of interaction effects would significantly increase the model fit. The likelihood-ratio test is a statistical test used to compare the goodness of fit of two models, where the log-likelihood of the reference model is compared to the log-likelihood of the model where an extra set of effects is added, and tested whether the differences in log-likelihood are statistically significant.

No interaction effects were included in the experimental design of the choice experiment because this would lead to double the amount of choice situations which was not possible due to resource limitations with regards to the survey. Even though this limits the chances that such effects can be estimated, interaction effects between bicycle type and the other main effects are included in the estimation of the mode choice model. These interaction effects are studied as it is important to determine not only what type of bicycle is more preferred, but also to see how the preferences regarding the access time, egress time and trip cost may differ when a different type of bicycle is presented. For example, when an electric bicycle is provided the system is likely to cost more and therefore it needs to be determined whether people are also willing to pay more to use this type of bicycle which offers more comfort. In addition, when an electric bicycle is provided it is interesting to find out whether people are also willing to walk further to access the shared bicycle so that the expensive electric bicycles can be spread more coarsely.

The following interaction effects are thus included in the model estimation if the likelihoodratio test shows that adding these effects in the model produces a significantly better model fit:

- Bicycle type * Access time
- Bicycle type * Egress time
- Bicycle type * Trip costs

No other interaction effects between the main effects are studied as these are not expected to give useful insight into design trade-offs for bike sharing systems.

The other interaction effects that are included in the choice model are interaction effects between the trip distance and the main effects which the choice experiment allows to be studied as trip distance was added as a context variable. This way the influence of the context variable trip distance is studied on the valuation of a certain type of bicycle, but also how it influences acceptable walking distances, pricing as well as its effect on the general preference of bike sharing over other modalities. The following interaction effects are thus also added to the model:

- Trip distance * Bicycle type
- Trip distance * Access time
- Trip distance * Egress time
- Trip distance * Trip costs

Including all these interaction effects improved the model fit significantly.

• Estimating the effect of user characteristics

Next to the factors studied through the choice experiment there are several user characteristics that were studied in the questionnaire which can be added to the bike share mode choice model to determine their influence on the bike share mode choice. The questions that study the perception / attitude towards bike sharing are not included in the mode choice model as these questions These include:

- o Age
 - Interaction effect Age * Type is also included here. As explained in Chapter 3 it is expected that older people prefer an electric bicycle, while younger people prefer the traditional bicycle.
- o **Gender**
- o Education
- o Income
- Preferred modality
 - Car; Public transportation; Bicycle

- o Influence from employer / colleagues towards the use of a certain modality
 - Car; Public transportation; Bicycle
- Knowledge, familiarity or experience with:
 - PT-bicycle; Car sharing services; Urban bike sharing services
- Available travel allowances
 - Car; Public transportation; Bicycle
- Degree of preference for the privately owned bicycle versus using a shared bicycle
- Perceived attractiveness of using a shared bicycle when the privately owned bicycle is not available

The third perception question posed in the survey, 'perception towards the added value of a shared bicycle for the commuting and business trip', focuses on the current commuting or business trip and is therefore not included in the bike share mode choice model.

The trip characteristics discussed in Chapter 3 cannot be added to the bike share mode choice model as these factors describe the current mode choice characteristics which do influence the bike share mode choice, but only from the perspective of the current trip characteristics. The bike share mode choice model is used to determine the interest in using a shared bicycle under generic circumstances, thereby not being linked to the individual's current commuting trip characteristics which of course can make it impossible, due to long distances for example, to use a bicycle for the commuting trip. The trip characteristics studied in the questionnaire will be used to discuss how these different factors influence the ability to make use of a shared bicycle in Chapter 7.

Including the factors stated above improved the model fit significantly. The results of the estimated MNL model are shown and discussed in Chapter 7.

6.2.4 ADVANCED ML MODEL

Next to the MNL model a Mixed Logit (ML) model will be estimated. This type of logit model is able to more realistically depict the decision-making process, as well as provide more realistic ways to model the error term as has been explained in Section 6.1.2 by being able to capture:

- the existence of nests of alternatives as well as in unobserved attributes,
- the existence of random taste heterogeneity, and
- the correlation between choices made by the same individual across time (panel effects)

For this ML model no nests of alternatives need to be specified. As the bike sharing alternatives have the same exact utility function the modelling software Biogeme will be able to determine a single constant for the bike sharing alternatives compared to the no-choice alternative.

With regards to including random taste variation, letting too many parameter tastes vary will result in the model not converging as it is unable to tell what parameter the variation should be assigned to. Because of this, only the parameters for which it is necessary to study the degree of taste variation from a research perspective will be included in the model. These are the intercept as well as the variable bicycle type. With regards to the constant or intercept, it is expected that some people will be more open towards using a shared bicycle than others. The degree of taste variation regarding the bike sharing intercept will then provide useful insight into the extent of which the population is divided on the attractiveness of this new modality that cannot be explained by the attributes already included in the model. With regards to the attribute bicycle type, it is expected that the population is divided in tastes towards either preferring the traditional or electric bicycle. This preference is generally determined by age differences, but by including taste variation for this parameter it can be determined whether there is more variation in tastes that cannot be attributed to the parameters included in the model. Regular normal distributions are used as distributions for both the bicycle type parameter and the intercept.

The model will be estimated as a ML panel model as there were a total of eight choice situations answered by each respondent and therefore panel effects are expected to be present.

The following steps were taken in estimating the ML model compared to the MNL model. Most of these steps are the same in the MNL model and are therefore not explained in detail. In addition to these steps, model convergence is tested throughout the iterative process of including new effects to the model. This is done by multiplying the number of draws each time a new version of the model is estimated, in order to test whether convergence has been reached before including new effects to the model.

- Estimating main effects
- <u>Testing for nonlinearity</u>

Trip distance showed nonlinear effects, and was therefore included in the model as 'distanceA' which is the linear component and 'distanceB' with is the nonlinear component. Trip distance was also effect coded as explained in Section 6.1.2.

- <u>Estimating random taste variation</u> Both the sigma for the intercept and bicycle type have high t-values and are therefore included in the final model.
- <u>Estimating interaction effects</u> The same interaction effects are estimated as in the MNL model and these effects significantly improved the model fit based on the likelihood-ratio test.
- <u>Estimating the effect of user characteristics</u> The user characteristics included in the MNL model also improve the model fit significantly for the ML panel model and are therefore included in the final model.

The number of draws needed to reach parameter convergence while limiting the run time of the model is 2000. The results of the estimated ML panel model are shown and discussed in Chapter 7.

PART III

RESULTS &

RECOMMENDATIONS FOR SYSTEM DESIGN

7. RESULTS

This chapter will discuss the results from the estimated bike share mode choice models as well as the results from the analyses conducted on the data gathered throughout the questionnaire. In Section 7.1 the MNL and ML panel model will be compared to each other after which the model which produces the best fit is interpreted in more detail. In Section 7.2 the results from the analyses conducted on data gathered throughout the questionnaire are presented.

7.1 ML PANEL MODEL RESULTS

The outcomes of the MNL and ML panel model are shown in Table 4. The model fit of the ML panel model is significantly better than that of the MNL model as was expected. The log-likelihood of the ML panel model is -1497 while that of the MNL model was -2265. In addition, the adjusted ρ^2 of the ML panel model is equal to 0.403 while that of the MNL model is only 0.106. As the ML panel model has a much better fit and enables more detailed interpretation through the addition of random taste variation for the intercept and the parameter bicycle type, only the ML panel model will be interpreted in more detail in this chapter. The interpretation of the MNL model will thus not be discussed here, but can be found in Appendix G. First however the differences between the MNL and ML panel model are discussed in more detail in Section 7.1.1.

7.1.1 DIFFERENCES BETWEEN THE MNL AND ML PANEL MODEL

The signs of the parameters estimates are the same for both the MNL and the ML panel model. The significance of quite some parameter estimates has changed however. The parameter estimate for bicycle type was significant in the MNL model while it is not significant in the ML panel model. The same is true for the interaction effect between type and access time as well as for several user characteristics, namely: gender, age, age / type, habit: public transportation, influence: bicycle, knowledge: pt-bicycle / carsharing / urban bikesharing and for the parameter travel allowance: bicycle. Some parameter estimates were not significant in the MNL model, which are found to be significant in the ML panel model: the interaction effect between type and access as well as the main effects access time and egress time. The values of the parameter estimates have also changed.

These differences can be explained by understanding the differences between the MNL and the ML panel model. Unobserved heterogeneity in tastes in the MNL model leads to biased choice probabilities and parameter estimates (Chorus, 2015). This is remedied in the ML model through the addition of random taste variation for the bike sharing constant and the bicycle type parameter for which most unobserved heterogeneity was expected. In addition, when ignoring correlation between choices that are made by the same person in the MNL model, the standard errors become inflated and thus the e-values are overestimated. Because of this the MNL model will think parameters are significant, while in fact they are not. By taking into account panel effects in the ML model this is also remedied.

Table 4: Results of estimated ML panel model

Variable	Coding	Unit	$m{eta}$ coefficient	t-value	$\boldsymbol{\beta}$ coefficient	t-value
			MNL model		Panel ML model	
					Random parameters	
Constant		-			5.04	10.99
Bicycle type		-			1.11	11.71
					Non-random	parameters
Bike sharing constant*	-	-	0.4680	0.80	3.2400	0.94
Bicycle type*	Electric = 1, Traditional = -1	-	-0.9950	-2.55	-0.8750	-1.28
Access time	-	Minutes	-0.04730	-1.22	-0.1670	-2.75
Egress time	-	Minutes	-0.01470	-0.44	-0.1020	-1.99
Trip cost	-	Euro / km	-2.7400	-5.88	-5.4800	-7.27
DistanceA (linear component)	10km = 1, 6km = 0, 2km = -1	Kilometre	-0.8990	-2.52	-1.9500	-3.06
DistanceB (non-linear component)	10km = 0, 6km = 1, 2km = -1	Kilometre	0.8240	2.29	1.7500	2.76
Type / Access*	-	Minutes	0.05230	1.48	0.03760	0.73
Type / Egress*	-	Minutes	0.07010	2.07	0.05060	0.96
Type / Trip cost	-	Euro / km	-0.5420	-1.31	-1.4700	-2.52
DistanceA / Type	-	-	0.1460	2.78	0.2690	3.17
DistanceA / Access*	-	Minutes	0.05530	1.46	0.08220	1.16
DistanceA / Egress*	-	Minutes	0.04900	1.41	0.08110	1.33
DistanceA / Trip cost*	-	Euro / km	0.06230	0.13	0.1090	0.15
DistanceB / Type	-	-	0.1540	2.90	0.2480	2.99
DistanceB / Access	-	Minutes	-0.07720	-2.02	-0.1620	-2.30
DistanceB / Egress*	-	Minutes	-0.04740	-1.36	-0.1120	-1.82
DistanceB / Trip cost	-	Euro / km	-0.9440	-2.01	-1.6700	-2.31
Gender*	Female = 0, Male = 1	-	0.4370	3.45	0.9390	0.91
Age*	-	Years	0.01260	2.40	0.3250	0.83
Age / Type*	-	-	0.009720	3.27	0.01390	1.61
Net monthly income*	Income categories (1-8)	Euro/month	0.01150	0.39	0.05300	0.28
Education	Low = 0, Medium = 1, High = 2	-	-0.6250	-7.02	-2.0400	-3.19
Habit: Car*	-	-	-0.3370	-1.78	-1.1700	-0.82
Habit: Public transportation*	-	-	-0.5270	-2.09	-1.8900	-1.01

Habit: Bicycle*	-	-	0.2100	1.03	0.4530	0.29	
(traditional or electric)							
Influence: Car*	-	-	0.2220	1.85	0.7200	0.87	
Influence: Public transportation*	-	-	0.06630	0.37	0.5640	0.43	
Influence: Bicycle*	-	-	0.8690	3.86	2.1300	1.04	
Knowledge: PT-bicycle*	Not familiar = 0	-	0.2240	2.50	0.8350	1.26	
	Familiar, but no user = 1						
	Infrequent user = 2						
	Frequent user = 3						
Knowledge: Urban bike sharing*	(See Knowledge: PT-bicycle)	-	0.1920	1.98	0.6610	0.93	
Knowledge: Car sharing*	(See Knowledge: PT-bicycle)	-	-0.2420	-1.99	-0.8740	-0.99	
Travel allowance: Car*	-	-	-0.1220	-1.16	-0.347	-0.46	
Travel allowance: Public transport.*	-	-	0.1060	0.99	0.205	0.26	
Travel allowance: Bicycle*	-	-	-0.9300	-4.73	-2.24	-1.41	
Preference for privately owned	Strongly agree = 4	-	-0.2200	-5.53	-0.681	-2.58	
bicycle over shared bicycle	Somewhat agree = 3						
	Neutral = 2						
	Somewhat disagree = 1						
	Strongly disagree = 0						
Perceived attractiveness of shared	Strongly agree = 3	-	0.2540	9.13	0.765	3.81	
bicycle when the privately owned	Somewhat agree = 1						
bicycle is not available	Neutral = 0						
	Somewhat agree = -1						
	Strongly agree = -3						
					Derived standa	rd deviation of	
					parameter distributions		
Constant		-			25.4	5.49	
Bicycle type		-			1.24	5.85	
		Model fit					
Log-Likelihood (LL)		-	-2265		-1497		
Adjusted ρ^2		-	0.106		0.403		

* Significance level of 95%, regarding the outcomes of the ML panel model

7.1.2 ML PANEL MODEL INTERPRETATION

The random bike sharing constant parameter, which is equal to 5.04, shows that there is a high degree of variation in unobserved preferences for bike sharing compared to other modalities that cannot be explained by the parameters included in the model. The non-random bike sharing constant parameter however is not significant; meaning that on average over all respondents there is no preference for a shared bicycle compared to other modalities or vice versa, for the reference alternative.

The interpretation of the reference alternative however is not straightforward for this model as a mix of effect coded variables (bicycle type and trip distance) and non-coded variables are used. Because effect coding is used for the bicycle type parameter, its reference alternative would be an "average" bicycle (neither electric nor traditional) which has no meaning in reality. Because of this, the reference alternative on which the constant is based for this model setup can be best described as the alternative which consists of an "average" bicycle, a travel distance of 6km and equals zero for all non-coded parameters. The interpretation given at the start of this section therefore only holds with regards to this reference alternative.

Next to the bike sharing constant, the results show that the trip cost and interaction effects with trip cost appear to be the most important attributes influencing the commuters' bike share mode choice, as they contribute the most to the utility (parameter * average attribute level). The parameter estimates for the random parameters bicycle type and the bike sharing constant are by far the most accurately measured estimates, shown by their high t-values. The fact that the trip cost parameters are the most important in the commuters' bike share mode choice is not a surprise, however its contribution to utility is very high, thereby indicating the trip cost is a major deterrent in the bike share mode choice. Other attributes such as the trip distance and educational levels seem secondary attributes which determine the bike share mode choice.

ESTIMATES DESCRIBING SYSTEM CHARACTERISTICS

The estimate of the random bicycle type parameter is equal to 1.11 which means that there is quite a bit of unobserved variation in the importance of the bicycle type parameter. This shows that there are different opinions regarding the preference towards either an electric or traditional bicycle. This was to be expected as the electric bicycle is only recently becoming more popular in the Netherlands, and its image does not yet reflect its added value in terms of comfort and speed. Many people still generally prefer the traditional bicycle as they are used to this type of bicycle, while others prefer the added benefits of the electric bicycle. As the non-random bicycle type parameter is not significant, the type of bicycle does not matter on average for all respondents. However, as the interaction effect of trip distance bicycle type is significant, the interpretation of the type of bicycle changes. The interaction effect of trip distance on bicycle type shows that the traditional bicycle is preferred for shorter distances while the electric bicycle is preferred for trip distances of over 4.5 kilometres. The difference in utility however is very small as can be seen in Figure 12 where the utility of the traditional bicycle and the electric bicycle are shown for different trip distances, as well as the utility of trip distance itself. This graph shows that commuters are open towards using a shared bicycle for trips up to 8 kilometres, after which the utility of trip distance becomes negative.



Figure 12: Visualisation of the utility of trip distance, an electric bicycle and an traditional bicycle for different trip distances in km

The utility of access time has a negative sign which becomes stronger for longer access times as expected. For an access time of 1 minute the utility is equal to -0.334, while for 5 minutes the access time is equal to -0.835. The utility of access time is not only influenced by the main effect access time but also by the interaction effect of the nonlinear component of distance on access time. This interaction effect shows that for distances up to 6 kilometres an increase in trip distance causes access time to be valued more negatively. While the utility of an access time of 5 minutes averaged for all distances is equal to -0.835, for a trip distance of 2 kilometres this utility of changes to +0.142 and for a trip distance of 6 kilometres to -1.478. While in reality a postive utility for any access time is unlikely, this interaction effect does show a strong dependence of the utility of access time on the trip distance.

As stated earlier, the parameter estimate for trip cost strongly influences the bike share mode choice. In addition, people value a certain trip cost more negatively when the trip distance with the shared bicycle increases (up to 6km). A trip cost of €0.28 averaged over all trip distances equals a disutility of -1.644. When taking into account the interaction effect of trip distance on the utility of trip cost, this utility changes from -1.644 to -1.176 for a trip distance of 2 kilometres and to -2.112 for a trip distance of 6 kilometres. The interaction effect of bicycle type on trip cost indicates that people are less willing to pay for an electric bicycle compared to a traditional bicycle. For example, the utility of trip cost when the attribute value is equal to €0.30 p/km changes from -1.644 to -2.085 when an electric bicycle is presented and from -1.644 to -1.203 when a traditional bicycle is presented. This could be because when people are presented with an electric bicycle for a certain price, they would rather use a traditional bicycle is experienced as being more expensive than the traditional bicycle even though in reality they cost the same. This is an important aspect that needs to be kept in mind when implementing electric bicycles in a bike sharing system.

Using the estimate trip costs the willingness to pay can be determined for both access and egress time. It is found that 1 minute extra access and egress time can be compensated by a trip cost reduction of respecitvely 0.03 p/km and 0.02 p/km.

ESTIMATES DESCRIBING USER CHARACTERISTICS

Most parameters that discuss user characteristics are found to not be significant in the ML panel model. This could either be because the effects, which were expected to influence the bike share mode choice are not of influence on the bike share mode choice, or because not enough respondents have answered the survey to find significant effects. The characteristics of potential users can therefore only be discussed with regards to the few effects which were found to be significant in the ML panel model, which are the education parameter, the parameter discussing the preference towards the privately owned bicycle over the shared bicycle and the parameter discussing the perceived attractiveness of a shared bicycle when the privately owned bicycle is not available.

Higher education levels show a relatively strong negative effect on the bike share mode choice. For example, this effect shows that highly educated people value the shared bicycle -4.08 utility points less when comparing this modality to other modalities than people with low levels of education. However, the sign of this parameter was expected to be positive as highly educated people are generally more focused on using sustainable modalities than people with low levels of education. It is possible that this parameter is a proxy for a different effect that relates to educational levels which is not included in the model which would explain the negative sign. Possible explanations could be that highly educated people more often own a lease car and therefore are less likely to be interested in using a shared bicycle. Although vehicle availability data is not available, the data on the used modalities does not support this theory. It remains unclear what the reason is for the negative sign of the education parameter.

Lastly the parameter estimates on the preference for the privately owned bicycle compared to a shared bicycle and the perceived attractiveness of a shared bicycle when the privately owned bicycle is not available are both significant. The estimates show that people who strongly prefer to use their own bicycle over a shared bicycle value a shared bicycle -0.88 utility points less compared to people to whom it does not matter at all whether they are using their own bicycle or a shared bicycle. In addition, people who strongly agree with the statement "a shared bicycle is an attractive mode choice when the privately owned bicycle is not available" value a shared bicycle 0.762 utility points more than people who strongly disagree with this statement. These effects are of course as expected, however it is interesting to see that these parameters have quite a strong effect on the bike share mode choice, indicating that the general perception of using a shared bicycle is an important factor in determining the bike share mode choice. The extent to which people have agreed or disagreed with these statements will be discussed in Section 7.2 to get a better understanding of the current perception towards bike sharing.

7.2 ANALYSES OF QUESTIONNAIRE DATA

The web survey explored several user preferences with regards to using a bike sharing service as explained in Section 5.2. The first one focuses on for what part of the mobility chain the respondents would prefer to use a shared bicycle with regards to their commuting and business trips. The results are shown in Figure 13. Respondents were able to choose more than one trip type for both travel motives.



Figure 13: Preferred trip types reported by respondents for both commuting and business trips

For the commuting trip respondents are most interested in using a shared bicycle for the trip towards and from a train station (26% and 33%), as well as for the entire trip (15%). For the business trip respondents are open to using a shared bicycle for a wider variety of trip types. Using it for the entire trip however is found to be the least attractive (5%). The highest scoring trip types are again the trips from and towards a train station (33% and 26%). Trips from the P+R location (12%) and from a bus / tram / metro stop (16%) are also chosen relatively often. This shows that the shared bicycle for the commuting trip is only wanted near train stations and at home, however for business trips the placement of shared bicycles can be distributed over a wider variety of locations.

Respondents are also asked to what extent they agree with the statement: "I would like to use a shared bicycle for (part of) the trip towards <insert activity or destination>." This statement was presented for a variety of travel motives. In Figure 14 the results are shown for the travel motives 'commuting' and 'business trips'.



Figure 14: The extent to which respondents agree with the statement "I would like to use a shared bicycle for (part of) the trip for the commuting / business trip"
Overall, people look to be more open to using a shared bicycle for business trips. 23% of the respondents indicate that they either agree strongly or agree somewhat with the statement regarding commuting trips and this is equal to 29% regarding business trips. The largest group of people indicate that the strongly disagree with the statement for both travel types, although more people have chosen this option for the commuting travel motive. To conclude, these results show that approximately 25% of the respondents are open to using a shared bicycle for either their commuting trip or business trips. Considering a large portion of the respondent sample currently uses a (lease) car to travel to work, and probably also uses the car to travel for their business trips, 25% is a relatively high portion of the respondent sample that is interested in a shared bicycle. This indicates that a bike sharing service will be interesting for a relatively large amount of people, even if the employer provides employees with a lease car and a large portion of employees is used to using a car to drive to work. It must be kept in mind however that even though people state they would be interested in using a shared bicycle, this does not mean that these people will use a shared bicycle when presented to them in reality.

The statement presented earlier was also provided for a range of other travel motives. The results are shown in Figure 15. The shared bicycle seems most interesting for outdoor recreational activities and visiting cultural or touristic attractions. When comparing the travel motives commuting and business trips to the travel motives depicted in Figure 15, it is found that using a shared bicycles for business trips is almost as interesting as using a shared bicycle for visiting cultural or touristic attractions. Of all the travel motives, the shared bicycle is least interesting to use for reaching activities / destinations related to sport, hobbies and association activities, visiting friends or family, shopping and commuting trips.



Figure 15: The extent to which respondents agree with the statement "I would like to use a shared bicycle for (part of) the trip towards <insert activity or destination>"

The factors that will now be discussed have already been included in the bike share mode choice model, however as they provide insight into the perception of and the attitude towards bike sharing it is important to study them in more detail. The respondents were asked with regards to the 'attractiveness of shared bicycle' and the 'preference for privately owned bicycle' to what extent the respondents agreed with the following statements on using a shared bicycle for the commuting or business trip:

- "The shared bicycle is an attractive transport mode when my own bicycle is not available"
- "I prefer using my own bicycle compared to a shared bicycle"

In addition they were asked to respondent on the following statements:

- "I would be able to reach my work address more easily when I use a shared bicycle instead of or combine a shared bicycle with the currently used transportation modes"
- "I would be able to reach business meetings more easily when I use a shared bicycle instead of or combine a shared bicycle with the currently used transportation modes"

The results regarding the first two statements are shown in Figure 16. Most people agree that the shared bicycle is an attractive transport mode when the privately owned bicycle is not available to them. This indicates that the general perception of using a shared bicycle is quite positive. As only a small part of the population do not find the shared bicycle to be an attractive mode choice when the privately owned bicycle is not available, it seems no measures need to be taken to improve people's perception of this new modality. Most people however also agree that they would (strongly) prefer to use their own bicycle compared to using a shared bicycle when the privately owned bicycle is available. This further supports the claim by experts that bike sharing in the Netherlands does have potential, but its implementation should only be focused on facilitating trips where the privately owned bicycle is not available.



Figure 6: The extent to which respondents agree with the statement "The shared bicycle is an attractive transport mode when my own bicycle is not available" and the statement "I prefer using my own bicycle compared to a shared bicycle"

The results regarding the third and fourth statement are shown in Figure 17. Not many people believe the shared bicycle could improve their commuting or business trips. These results combined with the results shown in Figure 14 indicate that even though a relatively large group of respondents would be interested in using a shared bicycle for their commuting and business trips, their current trip characteristics can either not be improved by using a shared bicycle or they do not believe the shared bicycle could improve their current commuting or business trips. In Section 8.4 it will be tested to what extent the respondents' current trip characteristics allow them to make use of shared bicycle to understand further why most people believe the shared bicycle cannot improve their current commuting trip. It is also possible that people are not willing to change their habits with regards to their mode choices, which are reflected in the responses to these statements.



Figure 17: The extent to which respondents agree with the statement "I would be able to reach my work address / business meetings more easily when I use a shared bicycle instead of or combine a shared bicycle with the currently used transportation modes"

Lastly, this section will discuss the perception people have towards the proposed cost structure in the web survey (paying per km), as well as towards inflexible drop-off locations. Again respondents were asked to state to what extent they agreed with the following statements on using a shared bicycle for the commuting or business trip:

- "The shared bicycle is attractive because I only have to pay for each driven kilometre"
- "It is no problem for me to always have to return the shared bicycle to the starting location of my trip"

The results of the first statement are shown in Figure 18 and of the second statement in Figure 19.



Figure 18: The extent to which respondents agree with the statement "The shared bicycle is attractive because I only have to pay for each driven kilometre'

Most people indicate that the cost structure has no influence on the attractiveness of the shared bicycle. Almost 20% of the respondents state that the cost structure does contribute to the attractiveness of the shared bicycle, while over 40% of the respondent stated that the cost structure does not contribute to the attractiveness of the shared bicycle, and even makes it less attractive. These results show that not everyone agrees on the attractiveness of the cost structure, and more research needs to be done into the possibilities of different cost structures and what cost structure fits which target group.



Figure 19: The extent to which respondents agree with the statement "It is no problem for me to always have to return the shared bicycle to the starting location of my trip"

Most people indicate they would not want to return the shared bicycle to the starting location of the trip, while a large portion states that it does not matter to them. Only about 17% of the respondents state they agree with the statement, while 58% disagree with the statement. This further supports the aim for a flexible bike sharing system where people are allowed to return their shared bicycle at different location from the original starting location like in the PT-bicycle system. This shows that being able to return the bicycle at any docking station or any location in general would be beneficial for the attractiveness of the system. Unfortunately, as explained in the bike sharing concept, including this type of flexibility in the system would mean redistribution of bicycles is necessary which is very costly.

8. TESTING BIKE SHARING SYSTEM DESIGNS

The goal of this chapter is to define recommendations for bike sharing system design. This will be done through determining the choice probabilities for different design setups and comparing these to determine preferred design scenarios. The choice probabilities averaged over the population are determined by applying the estimated bike share mode choice model to different bike sharing alternatives that reflect different design scenarios. As stated-preference data has been gathered in this research the choice probabilities should not be interpreted as market shares and thus do not indicate the potential of a certain design setup. The differences in choice probabilities for different design setups are used here to determine the differences in attractiveness for several design setups.

The theory and steps taken in the application of the bike share mode choice model is discussed in Section 8.1. Section 8.2 discusses the possible values that the attributes bicycle type, access time, egress time and trip cost can take on to form different bike sharing system design scenarios. Different system design scenarios will then be discussed and tested in Section 8.3. In Section 8.4 the estimated ML panel model will be used to gain understand of to what extent current trip characteristics influence the ability of the respondents to make use of a shared bicycle by applying the choice model to the studied sample. Section 8.5 will conclude this chapter with an overview of bike sharing system design recommendations.

8.1 APPLICATION OF THE BIKE SHARE MODE CHOICE MODEL

When a discrete choice model has been estimated, the probability that a decision maker opts for a certain alternative defined within that choice model can be calculated. Following McFadden (1974), the probability that decision maker n chooses alternative i is:

$$P_{ni} = Prob(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \forall j \neq i)$$

= $Prob(\varepsilon_{nj} < \varepsilon_{ni} + V_{ni} - V_{nj} \forall j \neq i)$

where V is the observed utility relating to alternative i or j and ε is the error term.

As the error term ε_{ni} is not given, the choice probability is therefore the integral of

$$P_{ni}|\varepsilon_{ni} = \int (\prod_{j\neq i} e^{-e^{-(\varepsilon_{ni}+V_{ni}-V_{nj})}})e^{-\varepsilon_{ni}}e^{-e^{-\varepsilon_{ni}}}d\varepsilon_{ni}.$$

This results after algebraic manipulation of this integral in a succinct, closed-form expression which makes logit models by far the easiest and most widely used discrete choice model (Train, 2009):

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j} e^{V_{nj}}},$$

which is the logit choice probability. As utility is specified in the bike share mode choice model to be linear in parameters, $V_{nj} = \beta' x_{nj}$, where x_{nj} is a vector of observed variables relating to alternative *j*. With this specification, the logit probabilities become

$$P_{ni} = \frac{e^{\beta \cdot x_{ni}}}{\sum_{j} e^{\beta \cdot x_{nj}}}.$$

The bike share mode choice model can be used to predict the probability that the decision-maker will opt for the shared bicycle alternative, or the no-choice alternative. As the utility of the no-choice alternative is equal to zero, the probability of a decision-maker opting for a shared bicycle becomes

$$P_{n \text{ shared bicycle}} = \frac{e^{\beta^{x} n \text{ shared bicycle}}}{(e^{\beta^{x} n \text{ shared bicycle} + 1)}}.$$

The bike share mode choice model that is estimated in order to determine the choice probability of a decision-maker opting for a shared bicycle is presented in Table 5. This ML panel model is different from the ML panel model presented in Chapter 7 as here the user characteristics have been left out of the estimation process. Using the previously estimated model would mean having to fill in the user characteristic parameters according to the population that is to be studied. An easier way to achieve this is to estimate the ML panel model once more without the addition of the user characteristic parameters. This is done as it is believed that the respondent sample is a reasonable reflection of the total population of commuters.

This bike share mode choice model shows the same effects as discussed for the extended ML panel model in Chapter 7. The only differences are in the estimates of the non-random and random bike sharing constant coefficients as was to be expected. The non-random bike sharing constant estimate is now significant, meaning that for the reference alternative specified for this model setup on average over all respondents there is a preference for the shared bicycle over other modalities equal to 1.95 utility points. In addition, the random bike sharing constant estimate is now equal to 5.48. This means that for the reference alternative defined in this model setup there is a high degree of variation in unobserved preferences towards a shared bicycle.

Variable Unit		β coefficient	t-value	
		Random parameters		
Bike sharing constant	-	5.48	11.15	
Bicycle type	-	1.13	11.70	
		Non-random parar	neters	
Bike sharing constant	-	1.95	2.76	
Bicycle type*	-	-0.190	-0.35	
Access time	Minutes	-0.169	-2.79	
Egress time	Minutes	-0.104	-2.03	
Trip cost	Euro / km	-5.51	-7.31	
DistanceA	Kilometre	-1.98	-3.09	
(linear component)				
DistanceB	Kilometre	1.75	2.74	
(non-linear component)				
Type / Access*	Minutes	0.0373	0.73	
Type / Egress*	Minutes	0.0501	0.95	

Table 5: Estimated ML panel model used for determining choice probabilities for different system design scenarios

Type / Trip cost	Euro / km	-1.44	-2.47
DistanceA / Type	-	0.270	3.17
DistanceA / Access*	Minutes	0.0847	1.20
DistanceA / Egress*	Minutes	0.0825	1.35
DistanceA / Trip cost*	Euro / km	0.132	0.18
DistanceB / Type	-	0.247	2.97
DistanceB / Access	Minutes	-0.162	-2.29
DistanceB / Egress*	Minutes	-0.110	-1.79
DistanceB / Trip cost	Euro / km	-1.69	-2.33
Model fit			
Log-likelihood = -1522			
Adjusted $\rho^2 = 0.401$			

* Significance level of 95%

Using the coefficients shown in Table 5 the probability of a decision-maker opting for a shared bicycle can now be determined. However, as the logit model that has been estimated to form the bike share mode choice model is a mixed logit model which includes random taste variation for the parameter bicycle type and the bike sharing constant, determining the choice probability becomes more complex than when a multinomial logit model is used.

The utility of the bicycle type is based on a normal distribution with a mean equal to zero (the nonrandom bicycle type parameter is not significant) and a standard deviation of 1.13 (the estimate of the random bicycle type parameter). The utility of the bike sharing constant is also based on a normal distribution with a mean of 1.95 (the estimate of the non-random bike sharing constant) and a standard deviation of 5.48 (the estimate of the random bike sharing constant). To determine the utility value of these parameters with regards to the bike share mode choice the inverse of the cumulative normal distribution function is determined using three inputs: a random number between 0 and 1, the distribution mean and the standard deviation. This value then needs to be replicated so that the mean contribution of these attributes to the utility of the shared bicycle can be determined. In order to determine this mean the number of replications has to be high enough so that the mean does not change when based on a new set of random numbers. For this mode choice model 200.000 replications are chosen to achieve this.

The utility of the shared bicycle alternative is then calculated by filling in the utility function of the bike share mode choice. The choice probability of a decision maker opting for the shared bicycle alternative can now be determined. As this bike share mode choice model is estimated for the entire population, the choice probability of one decision maker based on this model is equal to the choice probability averaged for the entire population. Because of this, the calculated choice probability for a certain setup of the shared bicycle can be interpreted as the averaged probability of the population opting for that shared bicycle.

8.1.1 INTERACTION EFFECT OF BICYCLE TYPE ON TRIP COST

As discussed in Chapter 7, it is believed that the interaction effect of bicycle type on trip costs shows that people experience an electric bicycle to be more expensive even though it costs just as much as the traditional bicycle. Although this cannot be proven, it will be assumed for the rest of this research that this effect is interpreted correctly. Due to this interaction effect, the utility of the

electric bicycle decreases and the utility of the traditional bicycle increases for the same trip cost which causes the electric bicycle to seem less attractive. In reality this effect would only apply when people can opt between both bicycles and not when only one type of bicycle is available. As several system design scenarios will provide only one type of bicycle, this interaction effect causes an unrealistic representation of the attractiveness of the electric bicycle versus the traditional bicycle. Therefore the interaction effect between trip cost and bicycle type will be ignored in the application of the choice model (hence set to equal zero) so that the choice probabilities better reflect the valuation of both bicycle types in reality.

8.2 DEFINING SYSTEM DESIGN ATTRIBUTE VALUES

The probability averaged over the population opting for a shared bicycle depends on the setup of the shared bicycle alternative. This alternative consists of the attributes bicycle type, access time, egress time and trip cost and is influenced by the context variable trip distance. Therefore these four attributes make up the design setup of a shared bicycle and can thus be altered to test different designs and understand trade-offs. Before testing different system design scenarios however, the values these attributes can take on in order to form a shared bicycle scenario are discussed.

Bicycle type The type of bicycle can take on three values: a traditional, an electric bicycle or a combination of both. While the traditional bicycle will be more preferred for short distance trips, the electric bicycle will be preferred for long distance trips. A combination of both bicycles can be chosen to facilitate both types of trips. The type of bicycle that is to be provided can therefore be chosen depending on the length of the trips that is to be facilitated with the bike sharing system. It must be kept in mind however that implementing electric bicycles in a bike sharing system leads to high acquisition costs, maintenance costs and high instalment costs regarding the charging infrastructure of the docking stations.

Access and egress times There are three options with regards to the distribution of docking stations that affect the access and egress times. The first is generally chosen when aiming to limit costs, which is done through placing docking stations at key locations where the expected demand is high, like for example a public transport stop, P+R locations and city attractions. This way a few locations are well connected to the bike sharing system while other locations with demand spaced over a bigger region are not well connected. This option will be represented in the scenarios by an access and egress time of 7 minutes; the maximum acceptable access time for a shared bicycle. Another option is to distribute docking stations more closely together which would mean more bicycle docking stations need to be implemented and more bicycles need to be made available which increases costs while being able to reach a larger group of potential users. Distributing the docking stations more evenly will be represented with a value of 4 minutes for both the access and egress time. Lastly, the access and egress times can be minimized by designing a system that focuses on a specific target group, on specific trips and on a relatively small region by placing docking stations at a few key locations in this region so that the target group will be able to pick up the bicycle with minimalized access times. The downside of this focus is that the bicycles will only be available at those few locations and therefore the system only provides a tailor-made service for a small group of people. This option is represented in the scenarios with an access and egress time of 1 minute. Depending on the target groups and the types of trips the system aims to facilitate choices need to be made regarding the distribution of docking stations which will impact the access and egress times.

Flexibility of the drop-off location was assumed for all possible setups of the shared bicycle alternative. The effect of choosing for no flexible drop-off location can therefore not be tested using the estimated choice model. Redistribution costs should be kept in mind when opting to provide a flexible system for users.

Trip cost For the trip costs four attribute values have been chosen which represent the combination of different choices that can be made on the attributes bicycle type and access and egress times:

- €0 p/km: employers provide users with travel allowances for usage of the shared bicycles
- €0.10 p/km = a combination of traditional bicycles and coarsely distributed docking stations
- €0.20 p/km = a combination of traditional bicycles and a fine-grained network of docking stations or a combination of electrical bicycles (and traditional bicycles) and a coarsely distributed network
- €0.30 p/km = electric bicycles and a fine-grained network of docking stations

8.3 TESTING BIKE SHARING SYSTEM DESIGN SCENARIOS

Several possible bike sharing system design scenarios will be discussed and tested in this chapter using the estimated ML panel model presented. The scenarios are based on the knowledge gathered on possible trade-offs and system design options throughout this research. These scenarios represent realistic possible bike sharing system setups that can be implemented in Dutch cities to discuss several trade-offs that can be made as well as to gain understanding of how the design setup influences the attractiveness of the system. For each scenario a shared bicycle alternative will be defined that reflects the characteristics of the system setup in order to determine the probabilities of people opting for this shared bicycle alternative for different trip distances. The calculated choice probabilities will not be interpreted as market shares or bike sharing potential but will be compared for the different scenarios to better understand the differences in attractiveness based on different system design setups. The findings are discussed and recommendations on bike sharing system design are summarized in Section 8.5.

8.3.1 SCENARIO 1: MINIMIZING COSTS

The first bike sharing system design scenario is a system that would be easy to implement and have low costs. Such a system would provide people with traditional bicycles and not with electric bicycles as these are both very costly and difficult to implement due to the need for charging infrastructure. To keep costs low, the docking stations are coarsely distributed and can therefore only be found at key points in a city like near public transport stops, P+R locations and city attractions. As the systems costs are kept low, the trip cost can be low as well. The following shared bicycle alternative is defined as to reflect the system characteristics described above:

- Bicycle type = Traditional
- Access time = 7 minutes
- Egress time = 7 minutes
- Trip costs = €0.10 p/km

The probabilities averaged over the population of people opting for this shared bicycle for different trip distances are shown in Table 6.

Table 6: Choice probabilities for different trip distance for system design scenario 1

Trip distance	2.5km	5km	7.5km	10km
Choice probability	58%	51%	43%	34%

While this system limits costs, the coarse distribution of docking stations causes the system to have a limited reach towards potential users. It can only facilitate trips for people who are travelling from a key point like a public transport stop, P+R location or city attraction. It is therefore well suited to complement public transportation and other locations where there is a large demand for transportation, but it does not allow for much flexibility and it is not able to facilitate a service for a variety of people at different locations.

8.3.2 SCENARIO 2: ACCEPTABLE COSTS AND A FINE-GRAINED NETWORK

Although it is important to keep costs low, implementing a relatively fine-grained network of docking stations can keep access and egress times low and expand reach of the system. This is done by not only placing docking stations at key points throughout the city, but by also placing them at even distances from each other at for example large crossings, neighbourhoods and nearby industrial areas. This way the distribution of docking stations becomes evenly distributed over the city. As more docking stations need to be implemented in this system the trip costs will be higher to compensate compared to the previous design scenario. The following shared bicycle alternative is defined as to reflect the system characteristics described above:

- Bicycle type = Traditional
- Access time = 4 minutes
- Egress time = 4 minutes
- Trip costs = €0.20

The probabilities averaged over the population of people opting for this shared bicycle for different trip distances are shown in Table 7.

 Table 7: Choice probabilities for different trip distance for system design scenario 2

Trip distance	2.5km	5km	7.5km	10km
Choice probability	58%	53%	46%	36%

The choice probabilities are slightly higher for medium to long distances than for the previous scenario, indicating that this system setup is slightly more attractive because of its more evenly distributed network of docking stations which compensates for the rise in trip costs, especially for medium distance trips as people then value shorter access times more strongly. In reality this system

will have a much larger reach compared to the previous scenario because docking stations can be found at a variety of locations which makes returning the bicycle much easier as well. The flexibility of this system is greatly improved while maintaining acceptable trip costs.

8.3.3 SCENARIO 3: FACILITATING ALL

This design scenario focuses on a system which does not limit costs but provides a system in which bicycle sharing can be facilitated for all using the newest technology. This is done by both providing both traditional and electric bicycles so that the system allows use for different types of trips for different types of people. In addition, the bicycles can be found evenly distributed throughout the city to keep access and egress times low. Lastly, due to adding electric bicycles to the system and the fine-grained network of docking stations the trip costs are high. The following shared bicycle alternative is defined as to reflect the system characteristics described above:

- Bicycle type = Electric & Traditional
- Access time = 4 minutes
- Egress time = 4 minutes
- Trip costs = €0.30 p/km

The probabilities averaged over the population of people opting for this shared bicycle for different trip distances are shown in Table 8. As both types of bicycles are presented the highest choice probabilities are presented per trip distance.

Table 8: Choice probabilities for different trip distance for system design scenario 3

Trip distance	2.5km	5km	7.5km	10km
Choice probability	55%	50%	45%	36%

The choice probabilities for this scenario are lower compared to the first and second scenario especially for short to medium distances. This shows that even though this system provides both electric and traditional bicycles and has a fine-grained network, the high trip costs make the system less attractive from the users' perspective.

Implementation of this system described is extremely expensive due to the addition of electric bicycles as well as the fine-grained network of docking stations that needs to be implemented for both types of bicycles. It is unlikely that the maximum acceptable trip cost of ≤ 0.30 could cover even a portion of these costs. As the implementation and operation of this system is extremely expensive and it is not able to increase the attractiveness of the system due to the high trip costs, it is the least likely of the scenarios discussed up until now to be implemented.

Both the first and second scenarios are preferred from both a cost perspective and the users' perspective. The next two scenarios will discuss systems in which the implementation of electric bicycles is more realistically possible.

8.3.4 SCENARIO 4: ACCEPTABLE COSTS WHILE IMPLEMENTING ELECTRIC BICYCLES

This scenario limits costs while providing people with both types of bicycles through a coarsely distributed network of docking stations. Because of this the trip cost of the system stay at a moderate value. The following shared bicycle alternative is defined as to reflect the system characteristics described above:

- Bicycle type = Electric & Traditional
- Access time = 7 minutes
- Egress time = 7 minutes
- Trip costs = €0.20

The probabilities averaged over the population of people opting for this shared bicycle for different trip distances are shown in Table 9. As both types of bicycles are presented the highest choice probabilities are presented per trip distance.

 Table 9: Choice probabilities for different trip distances for system design scenario 4

Trip distance	2.5km	5km	7.5km	10km
Choice probability	55%	48%	42%	34%

The choice probabilities for this system are slightly lower as this system has its docking station more coarsely distributed. The difference in trip costs does not compensate for this. However, this system is more feasible from the perspective of the operator and from the party that has to implement the system. However, as other systems are slightly more attractive in the eyes of the users, it is advised implementing a system with only provides traditional bicycles for lower trip costs is recommended.

8.3.5 SCENARIO 5: BIKE SHARING EXCLUSIVELY FOR COMMUTING AND BUSINESS TRIPS

The second scenario in which electric bicycles can be provided to people would be when companies or industrial areas decide to provide their employees with electric bicycles. It is believed electric bicycles are preferred in this setting as electric bicycles create more comfort for commuters on which this system is specifically focused and because electric bicycles are more modern and better showcase the 'green' image companies want to project into the world.

As the bicycles will be located very close by the companies and people are allowed to take the bicycles home, such a system leads to minimization of access and egress times. In addition, as these systems are set up by or with the backing of the employers, the trip costs will be covered through giving people travel allowances to support the use of the sustainable electric shared bicycle. The following shared bicycle alternative is defined to reflect the system characteristics described above:

- Bicycle type = Electric
- Access time = 1 minute
- Egress time = 1 minute
- Trip costs = €0 p/km

The probabilities averaged over the population of people opting for this shared bicycle for different trip distances are shown in Table 10.

Trip distance	2.5km	5km	7.5km	10km
Choice probability	60%	67%	62%	50%

These choice probabilities show that this scenario is the most preferred from the user perspective, especially with regards to the medium to long distance trips which shows an increase in probability of approximately 15%. This is to be expected as both the trip costs and access and egress times are minimized and the electric bicycle is preferred for long distance trips.

This scenario is comparable to the bike sharing initiatives that are found in for example Utrecht where electric shared bicycles are placed at several locations spread over an industrial terrain so that people can use the bikes for their last mile and for business trips. For this system to function as described above however, the employers have to be willing to include the use of shared bicycles into their travel allowances so that the trip costs from the users' perspective are equal to zero. If this is not the case, the choice probabilities are as shown in Table 11 (with a trip cost of €0.30 p/km):

Table 11: Choice probabilities for different trip distances for system design scenario 5, with trip costs

Trip distance	2.5km	5km	7.5km	10km
Choice probability	53%	56%	51%	40%

While this system is still preferred for longer distances, its attractiveness for short distance trips is now the lowest of all scenarios discussed. A regular bike sharing system as discussed in scenario 1 or 2 with a traditional bicycle provides more possibilities with regards to short distance trips. The system design therefore also depends on the length of the trips the system should facilitate.

8.3.6 RECOMMENDED DESIGN SCENARIOS

From the perspective of the user several scenarios can be identified as having the most potential. The first and second scenario both describe a bike sharing system implemented on a broad scale, either with a coarsely or fine-grained network of docking stations and traditional bicycles. Costs are kept low which is preferred by the user and dependent on the goal of the system, which is either to facilitate trips at points of large demand or facilitate trips for a variety of people at a variety of locations, both of these systems are attractive from the users' perspective as well as from the perspective of the operating party. The operating party should keep in mind the needs of potential users found all over the city and aim to keep costs as low as possible. A public body like a municipality would be an appropriate choice for systems like these because of these reasons. The operations of the system could also be contracted out to a party with more knowledge on the knowledge on operating a bike sharing system, as long as a local government owns the system and is able to set goals for its implementation.

Another option is to design a system which is only focuses on a limited group of commuters and business travellers. The aim here can be to increase the use of sustainable modalities among a group of commuters or to improve accessibility of an industrial region. For such systems scenario 5 would

be most interesting as it provides the commuters with easily accessible sustainable transportation with no costs. To implement such a system however, employers need to include the usage of shared bicycles into the travel allowances granted to their employees. As there is no need to keep costs for users low and the aim of the system is not to provide transportation for a large group of people distributed over an entire region, such a system can be operated by a third party or a vendor.

8.4 THE EFFECT OF CURRENT TRIP CHARACTERISTICS

Using the gathered data on the current trip characteristics of the respondent sample, the effect of the current trip characteristics on the ability to make use of a shared bicycle can be determined. This is done to better understand how trip characteristics of commuters limit the possibility to make use of a shared bicycle, using this respondent sample as an example.

Trips that do not meet the following requirements do not allow commuters to make use of a shared bicycle. Firstly, the maximum trip distance must be no longer than 10 kilometres and secondly people who either walk or cycle for their entire commuting trip will typically not be interested in using a shared bicycle. Applying the bike share mode choice model to the trips that do meet these requirements will then yield the probability of the respondent sample (on average) being able to and being interested in using a shared bicycle for one or more parts of their current commuting trip.

For the most attractive scenario (scenario 5) discussed in the previous section, the probability for the population on average for a trip of 6 kilometres is equal to 63%. This value changes to only 17% when the current trip characteristics are taken into account as explained above. This shows that even if a relatively large group of the population would be open to using a shared bicycle, their current trip characteristics often do not allow them to make use of this new modality. This is important to keep in mind when designing a shared bicycle system, as the system should focus on facilitating trips for which the shared bicycle is an attractive alternative based on current mode choices and trip distances.

8.5 SYSTEM DESIGN RECOMMENDATIONS

Bicycles The traditional bicycle is preferred for short distances while the electric bicycle is preferred for longer distances. When both types of trips are to be facilitated a combination of bicycle types can be implemented. It must be kept in mind however that implementing electric bicycles in a bike sharing system leads to high acquisition costs, maintenance costs and high instalment costs regarding the charging infrastructure of the docking stations. Due to these increasing costs the trip cost of the system from the users' perspective will have to be increased which greatly decreases the attractiveness of the system. Therefore it is recommended to only provide electric bicycles in a bike sharing system if the system specifically focuses on facilitating medium to long distance trips. In order to keep the trip cost low however the distribution of docking stations will have to be coarse which means the reach of the system will be limited. Another possibility for the implementation of electric bicycles lies in systems that are setup in cooperation with employers who can include use of the shared bicycle in their employees' travel allowances, removing the issue of trip costs.

Distribution of docking stations A fine-grained network of docking station is preferred from the users' perspective as the reach of the system will be enhanced and the access and egress times will be minimized. A fine-grained network is costly however. To decrease costs one can opt to only place bicycles at key locations throughout the city like public transport stops, P+R locations and city attractions, however this would increase access and egress times as well as limit the system's ability to facilitate a variety of trips for a variety of people. Depending on the target groups and the types of trips the system has to facilitate, the operating party can either opt for a fine-grained or coarsely distributed network of docking station.

System access and user registration Bicycles should be easily accessible, meaning that a new user should not have to go through the frustrating process of registering and authenticating in order to rent a bicycle. Being able to reserve a bicycle might also be an attractive added feature to the system for commuters and business travellers to deal with the issue of punctuality. Research has to be done on ways to solve these issues and to determine the added value of features like being able to reserve a bicycle.

System status information system The system status information should be optimized. When a commuter of business traveller wants to make use of a shared bicycle and they are not able to easily check whether a bicycle is available, or the information is not up to date, the bad experience with the system could cause the potential user to not opting for the system again as arriving on time on a commuting or business trip is much more important compared to recreational trips.

Bicycle redistribution mechanisms As it is recommended to design a flexible bike sharing system in the Netherlands, meaning that users can return the shared bicycle at any docking station, redistribution of bicycles will be necessary. To decrease the cost of redistribution user-based redistribution schemes can be implemented in which users are stimulated to return their vehicle to a non-saturated station, thereby rebalancing the distribution of the bikes without operating costs. This can be done by providing a discount, a free ride or giving money when users place their bicycle at an empty station. Such schemes need to be studied in more detail to determine the most efficient way to deal with the problem of bicycle redistribution

Models of Provision The preferred model of provision is dependent on the focus and aim of the system. In case the system is focused on a broad region and the costs of the system need to be kept to a minimum so that a variety of people can make use of the system, the system should either be publicly owned and operated or publicly owned and operated by a contractor. In case this is not the case, the system can be either third-party operated or vendor operated. The advertising model should be avoided in as the focus of the operator will not be on providing the best service level.

Pricing As the trip costs have a large effect on the attractiveness of the system, these should be kept to a minimum which can be achieved by making choices on the distribution of docking stations and the bicycle type that is provided. In addition, by stimulating employers to include the use of shared bicycles into the travel allowances that are granted to their employees, users will be much more open towards using a shared bicycle for their commuting and business trips.

9. CONCLUSIONS

The objective of this research was to provide recommendations for bike sharing system design in order to introduce the service as an attractive mode option to commuters and business travellers in the Netherlands. The main research question that has been answered throughout this thesis in order to achieve this objective was:

How should an urban bike sharing system be designed in order to attract commuters and business travellers in the Netherlands?

Based on extensive background research and expert interviews a bike sharing concept was developed aimed towards Dutch commuters and business travellers which would serve as a basis for testing the preferences with regards to bike sharing system design and its use as well as to determine the characteristics of Dutch commuters and business travellers interested in using a shared bicycle. Based on this research it was found that several conditions needed to be met in order for this bike sharing concept to be a realistic representation of the likely basic elements that will make up a Dutch bike sharing service, so that preferences and user characteristics could be determined. Firstly, the concept should be able to provide a mix of both traditional and electric bicycles so that preferences regarding the type of bicycle can be studied in more detail. Secondly, the bicycles should be able to be picked up at any location thereby creating a hypothetical situation in which all potential users are able to access the system, allowing their preferences to be tested. Thirdly, the system should be flexible with regards to two aspects: the system should allow the bicycles to be able to be locked anywhere and at any time and in addition the drop-off or return location of the bicycles should be flexible. This means that the shared bicycle should be allowed to be returned at any docking station. Lastly, the pricing structure presented in the concept has to allow the potential user to pay for use through a fixed fee per kilometre so that the trip costs reflect the cost structure that is expected to be used in Dutch bike sharing systems.

Preferences and the perception with regards to making use of a shared bicycle as well as preferences regarding several system characteristics and the characteristics of potential users are studied using a web survey which consists of a questionnaire as well as a stated choice (SC) experiment. The questionnaire consisted of questions that studied the characteristics of potential users, the current trip characteristics of the respondents and explored user preferences regarding the use of a shared bicycle, while the SC experiment was used to study preferences regarding several system characteristics. An SC experiment is used here as this method allows us to be able to determine the influence of design attributes upon the choices that are observed, thereby gaining understanding of how different characteristics or attributes are balanced against each other in the bike share mode choice. The SC experiment consisted of a series of choice sets, in which for every choice set three alternatives were presented to the respondent. The first two involved shared bicycle alternatives varying in attribute values, while the third alternative was a no-choice alternative, representing any other transport mode. The attributes which describe the shared bicycle alternatives are the bicycle type (traditional versus electric), access time, egress time and the trip cost. While making their choices, respondents were told to assume that they have to travel a certain distance, which varies across the choice sets. This context variable allowed for examining how different trip distances

influence the preference for certain attribute values and the general preference for a shared bicycle over other transport modes.

The web survey was distributed amongst a sample of the population of Dutch commuters and business travellers to gather stated preference data on potential users of a bike sharing system that aims to facilitate commuting and business trips. In order to incorporate commuters and business travellers who vary regarding their preferences towards driving and cycling, the survey was distributed amongst employees from one large and three smaller employers whom all have multiple office locations throughout the country. The 293 respondents were found to be predominantly male, on average aged 47 years old, have different educational backgrounds and professions. A large portion of the respondents uses a (company) car for their commuting trip, while public transportation and the bicycle are chosen by smaller portions of the respondent sample. This sample is therefore believed to be a reasonable representation of the population.

From the observed choices made in the SC experiment and the data gathered on user characteristics throughout the questionnaire a multinomial logit (MNL) model was estimated as well as a mixed logit (ML) model taking into account panel effects. It was found that the ML panel model for which taste heterogeneity for the bike sharing constant as well as the bicycle type parameter was included, provided a significantly better model fit with a difference in log-likelihood of 3762 units over the multinomial logit model. The adjusted ρ^2 of the mixed logit model was also found to be significantly higher than for the MNL model (0.403 compared to 0.106).

The ML panel model shows there is a high degree of variation in unobserved preferences for bike sharing over other modalities. For the reference alternative however, averaged over all respondents, there is no preference for a shared bicycle compared to other modalities or vice versa. Next to the bike sharing constant, the results show that the trip cost and interaction effects with trip cost are the most important attributes influencing the commuters' bike share mode choice. The parameter estimates for the random parameters bicycle type and the bike sharing constant are by far the most accurately measured estimates. Other attributes such as the trip distance and education seem secondary attributes in determining the bike share mode choice.

In addition there is quite a bit of unobserved variation in the importance of the bicycle type parameter. Furthermore, the interaction effect of trip distance on bicycle type shows that the traditional bicycle is preferred for shorter distances while the electric bicycle is preferred for trip distances of over 4.5 kilometres. The difference in utility between both types of bicycles however is relatively small. With regards to the utility of trip distance itself, it is found that commuters are open towards using a shared bicycle for trips up to 8 kilometres.

Increasing access and egress times averaged over all trip distances do not affect the utility of the shared bicycle much, while the effect of access time becomes stronger for increasing distances up to 6 kilometres. The same type of interaction effect is true for the trip cost estimate. In additon, an interesting effect is shown by the interaction effect between bicycle type and trip cost, which indicates that people are less willing to pay a certain amount for an electric bicycle compared to a traditional bicycle. It is believed this is because the electric bicycle is experienced as being more expensive than the traditional bicycle even though they cost the same.

Of all user characteristic parameters included in the model, the education parameter as well as the parameters discussing the preference towards the privately owned bicycle over the shared bicycle and the perceived attractiveness of a shared bicycle when the privately owned bicycle is not available are found to be significant. Higher education levels show a relatively strong negative effect on the bike share mode choice. It remains unclear what the reason is for the negative sign of the education parameter. The other two parameters show that the general perception of using a shared bicycle is also a relatively important factor in determining the bike share mode choice. As most user characteristic parameters were not significant, no other conclusions can be made on the characteristics of potential users.

Next to the ML panel model, data gathered through the web survey was also used to study preferences regarding the use of a shared bicycle. It was found that for the commuting trip respondents are most interested in using a shared bicycle for the trip towards and from a train station, as well as for the entire trip. For the business trip respondents prefer to use a shared bicycle for a wider variety of trip types. In addition, approximately 25% of the respondents was found to be open to using a shared bicycle for either their commuting or business trips, while only 12% of the respondents believe the shared bicycle would improve their current commuting or business trip. Furthermore, the respondents strongly prefer to use their privately owned bicycle instead of the shared bicycle, but do find the shared bicycle an attractive mode choice when the privately owned bicycle is not available. Lastly, most respondents state that they would not be interested in a system without flexibility of the drop-off location.

In addition to determining the influence of design attributes upon the choices that are observed, an SC experiment can be used to predict the choice probabilities of people opting for a shared bicycle based on the estimated bike share mode choice model. Several system design scenarios were tested using this method to determine recommendations for bike sharing system design. As stated-preference data is gathered the choice probabilities are unreliable and should not be interpreted as such. They can be used however to test different designs by determining the change in choice probabilities for different design scenarios. The bike sharing system design recommendations as well as the preferred design scenarios will now be discussed.

The traditional bicycle is found to be preferred for short distances while the electric bicycle is preferred for longer distances. Due to the electric bicycles being much more costly than the traditional bicycles however, it is recommended to only provide electric bicycles in a bike sharing system if the system specifically focuses on facilitating medium to long distance trips and enough funds are available to implement these bicycles while limiting the trip costs. Depending on the target groups and the types of trips the system has to facilitate, one can either opt for a fine-grained network of docking stations which expands the reach of the system or a coarsely distributed network of docking station which limits costs. As it is recommended to design a flexible bike sharing system in the Netherlands, meaning that users can return the shared bicycle at any docking station, redistribution of bicycles will be necessary. To decrease the cost of redistribution user-based redistribution schemes should be implemented. As the trip costs have a large effect on the attractiveness of the system, these should be minimized which can be achieved by making choices on the distribution of docking stations and the bicycle type that is provided. In addition, employers

should be stimulated to include the use of shared bicycles into the travel allowances that are granted to their employees.

Based on the results from the questionnaire and the SC experiment it can be concluded that people are interested in using a shared bicycle for their commuting trips, and even more so for business trips. From the perspective of the user there are three preferred system design scenarios with regards to commuting trips. The first two scenarios describe a bike sharing system implemented on a citywide scale, with either a coarsely distributed or a fine-grained network of docking stations, which only provides traditional bicycles limits the trip costs. The third option is a system that only focuses on a limited group of commuters and business travellers in a smaller region. Such a system would minimize access and egress time through providing electric bicycles exactly where needed. To implement such a system however, trip costs need to be minimized through providing users with a travel allowance aimed towards using a shared bicycle.

9.1.1 DISCUSSION

The introduction of bike sharing systems in Dutch cities remains a controversial subject. Although in many countries people applaud the arising sharing economy and its possibilities in terms of shared mobility, such trends are not yet as visible and welcomed in the Netherlands. The Dutch population has a very high bicycle ownership and in addition the Dutch value flexibility and comfort strongly, which makes owning a vehicle very attractive. It remains to be seen whether shared mobility will catch on in the Netherlands, with regards to any vehicle sharing services.

In addition, it must be determined whether the implementation of bike sharing systems is really necessary, and whether it is worth the costs of implementation and operation. While people may be open to using a shared bicycle, such a system is very costly and should therefore have a clear and achievable goal. In foreign cities this goal is usually to stimulate bicycle use, thereby creating a healthier living environment, decreasing congestion and increasing accessibility of urban regions. In the Netherlands however bicycle usage only needs to be stimulated at specific points in the mobility chain where the privately owned bicycle is not available in order to tackle specific bottlenecks in the transport system. This goal is much more difficult to achieve using a citywide bike sharing system as it is not feasible for such a system to focus on specific bottlenecks. Systems introduced for smaller regions however, for example for industrial terrains located at the outskirts of cities, will be able to tackle congestion and accessibility problems as these systems can be tailor-made to the needs in the region and are able to provide an attractive alternative to the car for trips between the city centre and the industrial locations (up to 10km) and on the industrial area itself.

Another important aspect that needs to be discussed is how a new bike sharing system should be implemented in relation to the existing PT-bicycle system. The PT-bicycle system is very successful in facilitating both commuting and business trips with regards to the last mile after having used the train and should therefore either be complemented or substituted and expanded when a new bike sharing system is implemented. Substitution and expansion of the system is preferred from the perspective of the user which prefers an easily accessible and user-friendly system: it is important to

make sure users can access and return all available shared bicycles at all docking stations through accessing one single platform.

The preferred model of provision is dependent on the focus and aim of the system. In case the system is focused on a broad region and the costs of the system needs to be kept to a minimum so that a variety of people can make use of the system, the system should either be publicly owned and operated or publicly owned and operated by a contractor. When this is not the case, the system can be either third-party operated or vendor operated.

In conclusion, the decision on whether to implement a bike sharing system in Dutch cities is not straightforward. Due to the nature of the Dutch population, it remains unclear whether a shared vehicle system will be found to be attractive by a significant part of the population. In addition, as bicycle usage does not need to be stimulated as much as in foreign countries, and the focus lies more on decreasing traffic congestion and increasing the accessibility of urban regions, it is less likely that these problems can be solved through the implementation of a costly citywide bike sharing system. Systems introduced in smaller regions like industrial areas will however be able to tackle specific problems and thereby achieve the goals that were set with regards to traffic congestion and accessibility. The introduction of bike sharing systems at specific locations is therefore more likely to be effective as well as feasible. The decision on whether citywide bike sharing systems in Dutch cities are to be implemented should therefore not be taken lightly.

9.1.2 REFLECTION & FUTURE RESEARCH

This research is able to provide a general overview of the possibilities of urban bike sharing systems in the Netherlands focused on facilitating commuting and business trips in addition to providing several guidelines for system design so that urban bike sharing can be implemented as an attractive mode choice for commuters and business travellers. It is important however to complement this research with studies that gather revealed preference data on the bike share mode choice as to provide a more complete overview of the potential of bike sharing systems by determining expected market shares. Such data should be gathered on users of bike sharing pilots or existing initiatives or systems that can currently be found in for example Rotterdam.

As the user characteristic parameters were not found to be significant in the ML panel model, this research has not been able to provide conclusions on the characteristics of people who are generally interested in using a shared bicycle. As it is important to define the possible target groups in order to determine how these groups should be reached, research must be done to define the characteristics of different target groups in addition to defining the characteristics of people who are most likely to be interested in using a shared bicycle.

10. REFERENCES

- Aarts, H. (1996). *Habit and decision making. The case of travel mode choice.* Katholieke Universiteit Nijmegen, Nijmegen.
- Aarts, H., & Dijksterhuis, A. (2000). The Automatic Activation of Goal-Directed Behaviour: the Case of Travel Habit. *Journal of Environmental Psychology*, *20*, 75–82. doi:10.1006/jevp.1999.0156
- Bachand-Marleau, J., Lee, B. H. Y., & El-Geneidy, A. M. (2012). Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. *Transportation Research Record: Journal of the Transportation Research Board*, 2314, 66–71. doi:10.3141/2314-09
- Barth, M., & Todd, M. (2014). User Behavior Evaluation of an Intelligent Shared Electric Vehicle System. *Transportation Research Board*, *1760*(19), 145–.. Retrieved from http://trrjournalonline.trb.org/doi/pdf/10.3141/1760-19
- Ben-Akiva, M., & Lerman, S. R. (1985). Discrete Choice Analysis: Theory and Application to Travel Demand. Cambridge, Massachusetts, the USA: The MIT Press. Retrieved from https://mitpress.mit.edu/books/discrete-choice-analysis
- Bierlaire, M. (2003). BIOGEME: A free package for the estimation of discrete choice models. In *3rd Swiss Transportation Research Conference*. Ascona, Switzerland. Retrieved from http://biogeme.epfl.ch/home.html
- Bliemer, M., & Rose, J. M. (2006). Designing stated choice experiments: state-of-the-art. *International Conference on Travel Behavior Research (2006)*, 1–28. Retrieved from http://www.ivt.ethz.ch/vpl/publications/presentations/v205.pdf
- Bordagaray, M., Ibeas, A., & dell'Olio, L. (2012). Modeling User Perception of Public Bicycle Services. *Procedia Social and Behavioral Sciences*, 54, 1308–1316. doi:10.1016/j.sbspro.2012.09.845
- Buchanan, C. (2015). *Traffic in Towns: A Study of the Long Term Problems of Traffic in Urban Areas* (First.). Abingdon, Oxon, UK and New York, NY, USA: Routledge.
- Bührmann, S. (2008). Bicycles as public-individual transport European developments. *MEETBIKE European Conference on Bicycle Transport and Networking*, (April). Retrieved from http://www.sensaris.com/wp-content/uploads/old/2011/08/urban-bicycle-boom-in-Europe.pdf
- Caggiani, L., & Ottomanelli, M. (2013). A Dynamic Simulation based Model for Optimal Fleet Repositioning in Bike-sharing Systems. *Procedia - Social and Behavioral Sciences*, *87*, 203–210. doi:10.1016/j.sbspro.2013.10.604
- Cbo. (2012). Handleiding focusgroep onderzoek, 1–18.
- Cherry, C., Worley, S., & Jordan, D. (2011). Electric Bike Sharing System Requirements and Operational Concepts, 1–13.
- ChoiceMetrics. (2014). Ngene 1.1.2 User Manual & Reference Guide: The Cutting Edge in Experimental Design.
- Chorus, C. (2015). Choice models basics and recent advances. Retrieved from https://blackboard.tudelft.nl/bbcswebdav/pid-2410625-dt-content-rid-8161247_2/courses/34533-141502/Slides Chorus Total.pdf
- Copenhagenize. (2015). Watching Copenhagen Bike Share Die. Retrieved March 20, 2015, from http://www.copenhagenize.com/2015/02/watching-copenhagen-bike-share-die.html
- CROW-Fietsberaad. (2015). CROW fietsberaad kenniscentrum voor fietsbeleid. Retrieved May 7, 2015, from http://www.fietsberaad.nl/?lang=en
- Curran, A. (2008). TransLink Public Bike System Feasibility Study Business Strategy March 2008 Quay Communications Inc. Retrieved from http://www.translink.ca/
- DB Bahn. (2010). Call a Bike in Köln. Retrieved June 26, 2015, from https://www.callabikeinteraktiv.de/index.php?id=395&&f=500
- De Boom en het Meer. (2015a). E-bike. Retrieved April 20, 2015, from http://nu-connectutrecht.nl/nl/e-bike/

De Boom en het Meer. (2015b). U-Connect Haalbaarheidsstudie. Utrecht.

- de Vries, T. (2014, December 2). Helm wordt verplicht op razendsnelle fiets. *Metro*. Retrieved from http://www.metronieuws.nl/binnenland/2014/12/helm-wordt-verplicht-op-razendsnelle-fiets
- DeMaio, P. (2009). Bike-sharing: History, Impacts, Models of Provision, and Future. *Journal of Public Transportation*, 12(4), 41–56.
- DeShazo, J. R., & Fermo, G. (2002). Designing Choice Sets for Stated Preference Methods: The Effects of Complexity on Choice Consistency. *Journal of Environmental Economics and Management*, 44(1), 123–143. doi:10.1006/jeem.2001.1199
- Deutsche Bahn. (2010). So funktioniert's. Ausleihen, aufsteigen und losfahren. Retrieved from https://www.callabike-interaktiv.de/index.php?id=445&&f=500
- Dill, J., & Rose, G. (2012). Electric Bikes and Transportation Policy Insights from Early Adopters. *Transportation Research Record: Journal of the Transportation Research Board*, 2314, 1–6. doi:10.3141/2314-01
- Eg, R. (2014, December 9). NS trekt stekker uit elektrische OV-fiets en NS-scooter. *Metro*. Retrieved from http://www.metronieuws.nl/binnenland/2014/12/ns-trekt-stekker-uit-elektrische-ov-fiets-en-ns-scooter
- Fietsberaad. (2013a). Feiten over de elektrische fiets. Utrecht.
- Fietsberaad. (2013b). Verder met de e-fiets. Fietsverkeer, 32, 18–25.
- Fietsenwinkel. (2015). Speed Pedelecs: Hoe en wat. Retrieved March 11, 2015, from https://www.fietsenwinkel.nl/speed-pedelec-uitleg
- Fietsersbond. (2011). Hoe bevalt de OV-fiets? Utrecht.
- Fietsersbond. (2014). Utrecht heeft primeur elektrische deelfietsen van Gobike. Retrieved March 10, 2016, from http://www.fietsennaarhetwerk.nl/2014/10/utrecht-heeft-primeur-elektrische-deelfietsen-vangoike/
- Fishman, E., Washington, S., & Haworth, N. (2014). Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport and Environment*, 31, 13– 20. doi:10.1016/j.trd.2014.05.013
- Fishman, E., Washington, S., Haworth, N., & Watson, A. (2015). Factors influencing bike share membership: An analysis of Melbourne and Brisbane. *Transportation Research Part A: Policy and Practice*, *71*, 17–30. doi:10.1016/j.tra.2014.10.021
- Forma, I. a., Raviv, T., & Tzur, M. (2015). A 3-step math heuristic for the static repositioning problem in bikesharing systems. *Transportation Research Part B: Methodological*, 71, 230–247. doi:10.1016/j.trb.2014.10.003
- Frade, I., & Ribeiro, A. (2014). Bicycle Sharing Systems Demand. *Procedia Social and Behavioral Sciences*, 111(1999), 518–527. doi:10.1016/j.sbspro.2014.01.085
- FRANCE 24. (2013). Theft and vandalism blight Paris bike-share system. Retrieved March 17, 2015, from http://www.france24.com/en/20130920-france-theft-vandalism-paris-bike-share-system-velib/
- Godoy, J. (2012). The Bicycle Revolution in Paris, Five Years Later. Retrieved March 17, 2015, from http://www.ipsnews.net/2012/07/the-bicycle-revolution-in-paris-five-years-later/
- Haaijer, R., Kamakura, W., & Wedel, M. (2001). The "no-choice" alternative in conjoint experiments. International Journal of Market Research, 43(1).
- Headicar, P. (2015). Traffic and Towns: The next 50 years. ITC Occasional Paper, Number Six.
- Heinen, E. (2011). Bicycle commuting. Delft University of Technology.
- Heiner, R. a. (1983). The Origin of Predictable Behavior. *American Economic Review*, 73. doi:10.1016/0165-4896(83)90055-0
- Hensher, D. A. (2006). Revealing differences in willingness to pay due to the dimensionality of stated choice designs: An initial assessment. *Environmental and Resource Economics*, 34(1), 7–44. doi:10.1007/s10640-

005-3782-y

- Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). Applied choice analysis. *Applied Choice Analysis*, (April 2016), 1–1188. doi:10.1007/9781316136232
- Institute for Transportation & Development Policy (ITDP). (2013). The Bike-Sharing Planning Guide, 152. Retrieved from www.itpd.org
- JCDecaux. (2015, April 13). JCDecaux launches self-service electric bikes. *JCDecaux*. Paris. Retrieved from http://www.jcdecaux.com/en/Newsroom/Press-Releases/2015/JCDecaux-launches-self-service-electricbikes
- Ji, S., Cherry, C. R., Han, L. D., & Jordan, D. a. (2014). Electric bike sharing: simulation of user demand and system availability. *Journal of Cleaner Production*, *85*, 250–257. doi:10.1016/j.jclepro.2013.09.024
- Kaplan, S., Manca, F., Nielsen, T. A. S., & Prato, C. G. (2015). Intentions to use bike-sharing for holiday cycling: An application of the Theory of Planned Behavior. *Tourism Management*, 47, 34–46. doi:10.1016/j.tourman.2014.08.017
- Kek, A. G. H., Cheu, R. L., & Chor, M. L. (2006). Relocation Simulation Model for Multiple-Station Shared-Use Vehicle Systems. *Transportation Research Board*, 1986(13), 81–88. Retrieved from http://trrjournalonline.trb.org/doi/abs/10.3141/1986-13?journalCode=trr
- Kloimullner, C., Papazek, P., Hu, B., & Raidl, G. R. (2014). Balancing Bicycle Sharing Systems : An Approach for the Dynamic Case. *Springer LNCS*, *8600*, 73–84.
- Koppelman, F. S., & Bhat, C. (2006). A Self Instructing Course in Mode Choice Modeling: Multinomial and
NestedNodels.pdf.Retrievedfromhttp://www.ce.utexas.edu/prof/bhat/COURSES/LM_Draft_060131Final-060630.pdfFrom
- Krizek, K. J., Handy, S. L., & Forsyth, A. (2009). Explaining changes in walking and bicycling behavior: Challenges for transportation research. *Environment and Planning B: Planning and Design*, 36(4), 725–740. doi:10.1068/b34023
- Landelijk Fietsplatform. (2013). Verdieping Effecten en fietsbezit. Retrieved March 11, 2015, from http://www.fietsplatform.nl/uploads/Verdieping-2013-Fietsfeiten-Effecten-fietsbezit.pdf
- Langford, B. C., Cherry, C., Yoon, T., Worley, S., & Smith, D. (2014). North America's first e-bike share: A year of experience. *Transportation Research Record: Journal of the Transportation Research Board*, 2387, 1–20. doi:10.3141/2387-14
- Lee, A., Molin, E., Maat, K., & Sierzchula, W. (2014). Electric Bicycle Use and Mode Choice in the Netherlands. In *Transportation Research Board 2015* (pp. 1–14).
- Louviere, J. (1988). Conjoint Analysis Modelling of Stated Preferences: A Review of Theory, Methods, Recent Developments and External Validity. *Journal of Transport Economics and Policy*.
- Louviere, J. J., Hensher, D. a., & Swait, J. D. (2000). Stated choice methods: analysis and application. *Journal of Applied Econometrics*, *17*(6), 701–704. doi:10.1002/jae.701
- Louwerse, K., & van Boggelen, O. (2015). Tour de Force, Agenda Fiets 2015-2020 (concept). Utrecht: CROW-Fietsberaad.
- Maartens, M. (2008). OV-fiets wordt ook Forensfiets. Retrieved May 7, 2015, from https://sites.google.com/site/bikesharingnl/dutch-solution/ov-fiets--dutch/ov-fiets-wordt-ookforensfiets
- McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. *Frontiers in Econometrics*. Berkeley, California: Academic Press, New York. doi:10.1108/eb028592
- McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of Applied Econometrics*, 15(5), 447–470. doi:10.1002/1099-1255(200009/10)15:5<447::AID-JAE570>3.0.CO;2-1
- Meloni, I., Sanjust, B., Sottile, E., & Cherchi, E. (2013). Propensity for Voluntary Travel Behavior Changes: An Experimental Analysis. *Procedia Social and Behavioral Sciences, 87*, 31–43. doi:10.1016/j.sbspro.2013.10.592

- Melvin, J. (2014, July 15). Paris: Seven years of Velib' bikes in 7 stats. *The Local*. Retrieved from http://www.thelocal.fr/20140715/velib-seven-stats-for-bikes-7th-birthday
- Merino, A. (2003). Eliciting Consumers Preferences Using Stated Preference Discrete Choice Models : Contingent Ranking versus Choice, 29. Retrieved from http://ideas.repec.org/p/upf/upfses/705.html
- Metrobike.net. (2013). Bike Sharing Takes Off. Retrieved April 3, 2016, from https://www.statista.com/chart/1148/bike-sharing-takes-off/
- Midgley, P. (2008). The Role of Smart Bike-sharing Systems in Urban Mobility. Journeys, Sharing Ur(2), 23–31.
- Midgley, P. (2011). Bicycle-Sharing Schemes: Enhancing Sustainable Mobility in Urban Areas. Commission on Sustainable Development (Vol. 19th Sessi). New York.
- Minal, R. S. (2014). MODE CHOICE ANALYSIS : THE DATA , THE MODELS AND future ahead. International Journal of Traffic and Transportation Engineering, 4(3), 269–285.
- Ministerie van Infrastructuur & Milieu. (2014). Beter Benutten: less congestion in 2014, shorter journey times in 2017. Retrieved February 3, 2015, from http://www.beterbenutten.nl/en
- Mobility Network Logistics. (2012). Call a Bike celebrates its 10th birthday. Retrieved May 9, 2015, from http://www.deutschebahn.com/en/group/im_blickpunkt/2504892/10_jahre_callabike.html
- nextbike. (2015). NEXTBIKE PUBLIC BIKE SHARING. Retrieved June 26, 2015, from http://www.nextbike.net/products/public-bike-sharing/
- NS. (2015). De OV-fiets. Retrieved March 5, 2015, from http://www.ov-fiets.nl/ovfiets/wat-is-ov-fiets/submenu/ov-fiets.html
- NS Stations. (2015). OV-fiets. Retrieved March 20, 2015, from http://www.nsstations.nl/contact/detail/ov-fiets.html
- Olympus. (2015). "e-Blue-bike: het eerste stedelijke automatische deelfietssysteem met elektrische fietsen." Retrieved February 16, 2015, from http://www.proeftuin-olympus.be/nl/e-blue-bike-het-eerstestedelijke-automatische-deelfietssysteem-met-elektrische-fietsen-51.htm
- Paul, F., & Bogenberger, K. (2014). Evaluation-Method for a station based Urban-Pedelec Sharing System. *Transportation Research Procedia*, *4*, 482–493. doi:10.1016/j.trpro.2014.11.037
- PBSC Urban Solutions. (2014). The Station. Retrieved February 3, 2015, from http://www.publicbikesystem.com/what-we-do/the-station/
- PubliBike. (2015). E-Bikes. Retrieved February 16, 2015, from https://www.publibike.ch/en/e-bikes.html
- Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine*, *50*, S106–S125. doi:10.1016/j.ypmed.2009.07.028
- Rahul Nair. (2010). Design and Analysis of Vehicle Sharing Programs: a Systems Approach. University of Maryland.
- Redactie OV-Magazine. (2016). Hopperpoint, nieuwe zakelijke deelfiets. Retrieved May 22, 2016, from https://www.ovmagazine.nl/2016/01/hopperpoint-nieuwe-zakelijke-deelfiets-1312/
- Redactie Wijchen Nieuws. (2012). Stimuleringsregeling E-bike haalt werknemers uit de auto. Retrieved February 20, 2015, from http://wijchen.nieuws.nl/nieuws/20120929/stimuleringsregeling-e-bike-haalt-werknemers-uit-de-auto/
- Rose, K. (1994). Unstructured and semi-structured interviewing. *Nurse Researcher*, 1(3), 23–30. Retrieved from http://journals.rcni.com/doi/abs/10.7748/nr1994.04.1.3.23.c6294?journalCode=nr
- Schroten, A., van Essen, H. P., Aarnink, S. J., Verhoef, E., & Knockaert, J. (2014). *Externe en infrastructuurkosten* van verkeer: Een overzicht van Nederland in 2010. Delft.
- Shaheen, S. A. (2016). Shared mobility innovations and the sharing economy. *Transport Policy*, 1–2. doi:10.1016/j.tranpol.2016.01.008
- Shaheen, S. A., Cohen, A. P., & Martin, E. W. (2013). Public Bikesharing in North America: Early Operator Understanding and Emerging Trends. Transportation Research Record: Journal of the Transportation

Research Board. doi:10.3141/2387-10

- Shaheen, S. A., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia Past, Present, and Future. *Transportation Research Record: Journal of the Transportation Research Board*, (2143), 159–167. doi:10.3141/2143-20
- Shaheen, S. A., Martin, E. W., Cohen, A. P., & Finson, R. S. (2012). *Public Bikesharing in North America : Early Operator and User Understanding*. San José.
- Spinlister. (2015). Spinlister. Retrieved May 4, 2015, from https://www.spinlister.com/
- Stadsregio Rotterdam. (2015). De Nieuwe Fiets van Rotterdam. Retrieved February 16, 2015, from http://www.denieuwefietsvanrotterdam.nl/
- StadtRAD Hamburg. (2016). StadtRAD Hamburg on your bike and off you go! Retrieved September 8, 2016, from http://stadtrad.hamburg.de/kundenbuchung/process.php?proc=index&f=511
- Startt, J. (2014). Urban Cycling: Paris's Quiet Revolution. Retrieved March 17, 2015, from http://www.bicycling.com/news/featured-stories/urban-cycling-paris-s-quiet-revolution/page/0/1
- Tang, Y., Pan, H., & Shen, Q. (2010). Bike-sharing systems in Beijing, Shanghai and Hangzhou and their impact on travel behaviour. *Department of Urban Planning, Tongji University. ...*, (206). Retrieved from http://www.ecf.com/wp-content/uploads/Tang-Yang-Bike-sharing-Systems-in-Beijing-Shanghai-and-Hangzhou___.pdf
- Train, K. E. (2009). Discrete Choice Methods with Simulation (2nd ed.). New York: Cambridge University Press.
- Van de Riet, O. a. W. T., & Egeter, B. (1998). Systeemdiagram voor het beleidsveld vervoer en verkeer; beschrijving vervoer- en verkeerssysteem ten behoeve van het project Questa.
- van Eerden, R., Joosten, Z., Leferink, E., & Velthuijs, C. (2015). *ForensFiets: Een digitaal fietsdeelplatform voor forensen*. Utrecht. doi:10.1017/CBO9781107415324.004
- VanMoof. (2015). VanMoof. Retrieved May 4, 2015, from http://vanmoof.com/content/4-about-us
- Vélib'. (2015). Vélib' Mairie de Paris. Retrieved February 25, 2015, from http://en.velib.paris.fr/
- Verkeersnet. (2015). Leenfiets in Kopenhagen ten dode opgeschreven. Retrieved March 2, 2015, from http://www.verkeersnet.nl/14593/leenfiets-in-kopenhagen-ten-dode-opgeschreven/
- Verkeersnet. (2016). Gobike start toch in Rotterdam. Retrieved March 10, 2016, from http://www.verkeersnet.nl/18173/gobike-start-toch-in-rotterdam/
- Vogel, P., & Mattfeld, D. C. (2010). Modeling of respositioning activities in bike-sharing systems. Lisbon.
- Wilson, C. (2014a). Focus Groups. In Interview Techniques for Ux Practitioners A User-Centered Design Method (pp. 23–41). Waltham, USA: Morgan Kaufmann, an imprint of Elsevier. doi:10.1016/B978-0-12-410393-1.00002-8
- Wilson, C. (2014b). Semi-Structured Interviews. In *Interview Techniques for Ux Practitioners* (pp. 23–41). Waltham, USA: Morgan Kaufmann, an imprint of Elsevier. doi:10.1016/B978-0-12-410393-1.00002-8
- Zhao, J., Deng, W., & Song, Y. (2014). Ridership and effectiveness of bikesharing: The effects of urban features and system characteristics on daily use and turnover rate of public bikes in China. *Transport Policy*, 35, 253–264. doi:10.1016/j.tranpol.2014.06.008

11. APPENDIX A: INTERVIEWS AND FOCUS GROUP

This appendix consists of a list of experts that were interviewed or were part of the focus group. Although the interviews were recorded, it was decided to not release the transcripts of the interviews for the sake of the interviewees. Conclusions from all the interviews are described in Section 11.3.

11.1 INTERVIEWEES

The interviews have been held with the people shown in the list below, accompanied with the company or institution they represent.

- Christine Neuteboom; founder of 'De Boom en het Meer', initiator of Dutch bike sharing pilots and Dutch representative of the company GoBike.
- Frances Raboen; project leader of the urban bike sharing pilot 'De Nieuwe Fiets van Rotterdam'.
- Martijn van Es; lead communication and volunteer policy of the Dutch Cyclists' Union.
- Otto van Boggelen; programme manager of the Dutch Cycling Embassy.
- Ronald Haverman; director / CTO of MyWheels and creator of the OV-fiets and the 'forensfiets' pilot.
- Piero Witmer; Manager Product and Format (PT-Bicycle, bicycle parking, car parking and the 'zonetaxi'), from the company NS Stations.
- Anthonin Darbon; Chief of Operations in France for Cyclocity / JCDecaux.

11.2 FOCUS GROUP EXPERTS

The focus group consisted of the following participants, along with their backgrounds:

- Christine Neuteboom, founder of 'De Boom en het Meer', initiator of Dutch bike sharing pilots and Dutch representative of the company GoBike.
- Otto van Boggelen, programme manager of the Dutch Cycling Embassy.
- Coen Vermeulen, founder of the bike sharing initiative Hopperpoint in the city of Eindhoven.
- Angela van der Kloof, senior advisor on mobility with a focus on cycling at Mobycon
- Kees Maat, associate professor in Transport Studies at the TU Delft.

11.3 CONCLUSIONS

In this section the findings from the interviews are summarized.

All the interviewees agree on that the special bicycle culture in the Netherlands influences the feasibility of a bicycle sharing system in Dutch cities. However, they also all state that there is indeed a market for such a service especially focused on trips where the private bicycle is not available, even if it may only be small at first. The question rises whether it is then desired to offer such a service if only a small number of people will benefit. This will all depend on how many people will be

interested in such a service in reality. These numbers could also grow of course, as many bicycle sharing systems have found, including the Dutch OV-fiets system.

When looking at E-bikes in a bicycle sharing setting, the opinions differ, although most believe Ebikes should be used for long distance trips and not in city centres, because the city traffic and structure will make it impossible to use the E-bike effectively. Furthermore, the E-bike will need to be charged and because of this cannot be used as much as a traditional bicycle per day. This can also cause bikes being available but only able to drive for a short distance because the battery is almost empty and did not get time to charge yet. Lastly, E-bikes are much more expensive than a traditional bicycle and the charging infrastructure adds even more costs. E-bikes are however suitable to be used for long distance trips on industry terrains for example or for trips from outer residential areas towards the city centre.

When discussing how a bicycle sharing system should be set up on a citywide scale, most interviewees believed traditional bicycles should be used and docking stations should be placed at public transport stops and other busy locations. How dense the network must be is unclear, but the OV-fiets system should definitely be improved and enhanced. Several factors that need to be improved in order for a bicycle sharing system to be attractive according to the interviewees will now be summarized:

- Users should be able to return the bicycle at another station from which they originally got the bicycle, so the system becomes a network instead of a return trip only focused system. This also includes that more return stations have to be implemented other than only train stations.
- The bicycles should continue to have locks themselves, so they can be placed on the street while the rentee goes to work, has a drink or visits a tourist attraction.
- Bicycles should be easily accessible, meaning that a new user should not have to go through the frustrating process of registering and authenticating in order to rent a bicycle. Solutions might be the 'open standard' and the use of a mobile phone app, Bluetooth or linking the authentication system with a debit card of the OV chipcard.
- The tariff constructions must make it possible to rent the bicycle for an entire day for a fair price as well as for short trips.

12. APPENDIX B: PILOT STATED CHOICE EXPERIMENT

Based on desk and literature research, the expert interviews and the discussions had in the focus group, several attributes were selected to include in the SC experiment to present the shared bicycles. These attributes and the possible values these attributes can take on are:

- Bicycle type (traditional or electric)
- The flexibility of the drop-off location (flexible or inflexible)
- Access time (1, 3, 5 or 7 minutes)
- Trip costs (€0, €0.10, €0.20, €0.30)

A choice set or situation from this SC experiment setup will then look as shown in Figure 20.

Next to determining how an electric or traditional bicycle fits in bike sharing system design and how distance plays a role in this, access time has also been included in the setup which will indicate how far people are willing to walk in order to be able to pick up a shared bicycle. This knowledge will also help determine the placement of a bike sharing station in relation to the trip starting point. In addition, the attribute 'drop-off location' is included in the experiment. Since one of the most

Description choice situation

You are making a trip to a business meeting.

On the way you are presented with the option to use shared bicycle 1 or shared bicycle 2. The trip you are about to take with the shared bicycle is **2 kilometres** long.

	Shared bicycle 1	Shared bicycle 2
Bicycle type	Electric	Traditional
Drop-off location	Flexible	Flexible
Access time	5 minutes	1 minute
Trip cost	€0 p/km	€0.20 p/km
Which alternative do you prefer?		X
	1	Next choice situation

Figure 207: Choice set as presented in the SC pilot experiment survey

important downsides of the current PT bicycle system is that people are required to return their shared bicycle back to the location where they picked up the bicycle, it is important to determine how the flexibility of the drop-off location influences the mode choice. Finally, the last included attribute is the trip cost. It is important to determine how much people are willing to pay in order to use a certain shared bicycle, and whether they are willing to pay more for an electric bicycle as such a bicycle is much more costly to provide to users than a traditional bicycle. Both from literature research and expert interviews it was concluded that the E-bike would be most interesting for potential Dutch bike sharing users that want to use the bicycle for commuting and / or business trips. After speaking with several experts about possible cost structures, the most used cost structure in the Netherlands with regards to (electric) bike sharing is to make the shared bicycle competitive to public transport. This means that the cost of a trip must be no more expensive than 0.28 per kilometre, which are the average bus or tram costs. In order to incorporate this in the choice experiment, the chosen attribute values for trip costs are between 0.00 and 0.30 per kilometre. Gaining knowledge on how these attributes influence mode choice will provide a solid basis for bike sharing system design in the Netherlands.

12.1.1 EXPERIMENTAL DESIGN PILOT CHOICE EXPERIMENT

Although prior parameter information is not yet available other than the expected sign of the coefficients, the time frame of the thesis allows conducting a pilot stated choice experiment amongst a small group of respondents (N=30) to determine further prior parameter information, or 'priors'.

For the pilot SC experiment, an orthogonal fractional factorial design was used. The utility function is as follows:

Utility(Shared bicycle) = β_{type} * TYPE + $\beta_{drop-off}$ * DROP-OFF + β_{access} * ACCESS + β_{price} * PRICE

Using Ngene an orthogonal fractional factorial design of 8 rows was used to construct 8 alternatives or profiles. Sequential construction was then chosen to construct the choice sets, as this will result in the smallest possible number of choice sets. However, there will be correlations between attributes of different alternatives using sequential construction. Since this design is using unlabelled alternatives, correlations will pose no problem as all attributes will appear twice in the design. This results in a total of 8 sets of alternatives, or choice sets, shown in figure 5:

Choice set	Type1	Drop-off1	Access1	Price1	Type2	Drop-off2	Access2	Price2
1	1	1	5	0	0	1	1	0.1
2	1	0	1	0.2	0	0	7	0
3	0	1	3	0.2	1	1	5	0
4	0	0	7	0	0	1	3	0.2
5	0	0	5	0.3	1	1	7	0.3
6	0	1	1	0.1	0	0	5	0.3
7	1	0	3	0.1	1	0	1	0.2
8	1	1	7	0.3	1	0	3	0.1

Figure 8: The 8 choice sets resulting from the pilot SC experimental design

Next, to incorporate the context variable 'trip distance', the 8 choice sets are presented to respondents with a choice situation explaining the trip is 2, 6 or 10 kilometres long, resulting in the 8 * 3 = 24 choice sets that need to be presented to the respondent.

The pilot stated choice experiment was then presented to a group of 55 people, mostly consisting of colleagues, and a few friends and family members. Of the 55 people that were approached, 24 ended up filling in the pilot survey. They were asked to fill in the survey objectively, and before being

introduced to the setup of the choice experiment, the concept of a bike sharing system was explained. The choice sets were presented as is shown in figure 20.

12.1.2 RESULTS PILOT CHOICE EXPERIMENT

A multinomial logit model was estimated on the data gathered through the pilot survey. It was found that the coefficient of bicycle type was +0.32, indicating that on average over all distances the electric bicycle slightly increases the utility of a shared bicycle over a traditional bicycle. The access time coefficient is -1.10, indicating that a higher access time decreases the utility of a shared bicycle. The coefficient of price is equal to -0.61, indicating that a higher price will decrease the utility of a shared bicycle. Finally, it was found that there is no measurable effect from the parameter drop-off location, indicating that the flexibility of the drop-off location has no influence in people's mode choice. The signs of these coefficients are as expected.

An important remark was made by the respondents with regards to the attribute 'drop-off location' present in the pilot choice experiment. Respondents argue that it does not matter to them whether they can return the bicycle or not when answering the choice sets, as this is entirely trip context specific. As it is not possible to include a wide variety of context variables to test when people are willing to return the bicycle to the starting point of the trip, there is no added value of this attribute in this choice experiment. Because of this, it is decided to remove this attribute from the choice experiment, and further research the importance of a flexible drop-off location elsewhere in the survey.

13. APPENDIX C: EXPERIMENTAL DESIGN FINAL SC EXPERIMENT

In Table 12 the results from the D-efficient design as constructed by Ngene are shown. In addition the expected MNL probabilities and utilities are shown in Table 13, which were used to check for dominance in the alternatives.

MNL D-Error: 0.395915, Ev	aluation 301	.64							
MNL efficiency measures									
D error	0.395915								
A error	0.863628								
B estimate	88,508,044								
S estimate	11,273,055								
Prior	type	access(e0)	access(e1)	egress(e0)	egress(e1)	price(e0)	price(e1)		
Fixed prior value	0.32	-1.1	0	-1.1	0	-0.61	0		
Sp estimates	11,273,055	6,253,362	Undefined	5,744,141	Undefined	8,291,271	Undefined		
Sp t-ratios	0.583761	0.783789	0	0.817793	0	0.680684	0		
Design									
Choice situation	bss1.type	bss1.access	bss1.egress	bss1.price	bss2.type	bss2.access	bss2.egress	bss2.price	Block
1	-1	4	1	0.3	1	7	4	0.15	3
2	1	7	1	0.15	-1	1	7	0	1
3	-1	1	7	0.15	1	4	4	0.3	1
4	-1	7	4	0.3	1	4	7	0.15	2
5	1	1	7	0.3	-1	7	1	0	2
6	-1	4	4	0.15	1	7	1	0.3	1
7	1	4	7	0	-1	1	4	0.3	3
8	1	7	4	0	-1	4	7	0.15	2
Correlations (Pearson Pro	duct Mome	nt)							
Attribute	bss1.type	bss1.access	bss1.egress	bss1.price	bss2.type	bss2.access	bss2.egress	bss2.price	Block
bss1.type	1	0.160128	0.160128	-0.480384	-1	-0.480384	0.160128	-0.480384	0.160128
bss1.access	0.160128	1	-0.641026	-0.230769	-0.160128	-0.435897	0.794872	-0.230769	0.025641
bss1.egress	0.160128	-0.641026	1	-0.230769	-0.160128	-0.025641	-0.435897	0.384615	0.025641
bss1.price	-0.480384	-0.230769	-0.230769	1	0.480384	0.589744	-0.230769	-0.435897	0.025641
bss2.type	-1	-0.160128	-0.160128	0.480384	1	0.480384	-0.160128	0.480384	-0.160128
bss2.access	-0.480384	-0.435897	-0.025641	0.589744	0.480384	1	-0.641026	-0.025641	0.025641
bss2.egress	0.160128	0.794872	-0.435897	-0.230769	-0.160128	-0.641026	1	-0.230769	0.025641
bss2.price	-0.480384	-0.230769	0.384615	-0.435897	0.480384	-0.025641	-0.230769	1	0.025641
Block	0.160128	0.025641	0.025641	0.025641	-0.160128	0.025641	0.025641	0.025641	1

Table 12: Resulting D-efficient design for the pilot SC experiment as constructed by Ngene

Table 13: MNL probabilities and utilities as estimated	y Ngene for the	D-efficient design shown in	Table 12
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MNL probabilities			
Choice situation		bss1	bss2
	1	0.721115	0.278885
	2	0.507499	0.492501
	3	0.492501	0.507499
	4	0.2227	0.7773
	5	0.358933	0.641067
	6	0.492501	0.507499
	7	0.415809	0.584191
	8	0.7773	0.2227
MNL utilities			
Choice situation		bss1	bss2
1 2 3 4 5	1	0.17	-0.78
	2	0.32	0.29
	3	-0.32	-0.29
	4	-2.03	-0.78
	5	-0.29	0.29
	6	-0.32	-0.29
	7	-0.17	0.17
	8	-0.17	-1.42

14. APPENDIX D: COMPANY PROFILES

The web survey has been distributed at one large employer and three small employers.

The large employer is Strukton Rail. Their goal is to make rail transport a competitive option by offering attractive rail solutions. They do so by providing ground breaking solutions in the field of rail infrastructure and rolling stock. The company operates on an international basis and have long-term operations in the Netherlands, Sweden, Denmark, Belgium, France, Italy, Germany and Australia.

They have a variety of offices in the Netherlands located near urban regions, for example in Utrecht, near Rotterdam, 's Hertogenbosch, Eindhoven, Nijmegen, Amersfoort and Enschede. They have 1900 employees in the Netherlands, which were all contacted through the web survey. As the company is focussed on rail solutions, employees are stimulated to make use of public transportation. However, due to people having to travel all over the country, many employees are provided with a lease car, making travelling by car very attractive.

The smaller employers are part of the Concordis Group: Forseti, Mobycon and Mobycon People. These small companies work on the field of transport, traffic and mobility and provide a variety of services in this field such as consultancy and detachment of employees. Approximately 60 people are employed by the Concordis Group. Especially Mobycon is focused on stimulating the use of sustainable modes which makes the employees more likely to be open to using a shared bicycle system.

15. APPENDIX E: DATA CLEANING

428 people have opened the web survey. The respondents that stopped filling in the survey before finishing the choice experiment have been removed from the data set.

15.1 TRIP DISTANCES

Next the reported distances by car users were checked against the addresses that were provided by the respondents using google maps. The distances were updated if the google maps information provided a very different result from what the respondent had indicated.

Next I checked odd distances for respondents that filled in they use an electric or regular bicycle. No respondents used an electric or regular bicycle for odd distances (>15km).

Next I checked odd distances for respondents that filled in they walk. No respondents walked for odd distances (>5km).

Next I checked odd distances for respondents that filled in they use the bus / tram / metro. One respondents used the bus / tram / metro for odd distances (>20km). This person travels all over the country and therefore has no stable commuting trip. The distance is set at NA.

Next I checked odd distances for respondents that filled in they use the train. No respondents used the train for odd distances (>100km). All respondents have been checked that used the train for distances =>50km.

15.2 TRANSPORT CHOICES

In the previous steps I realized some respondents have not understood how to fill in the first two questions properly. It seems that some respondents have filled in their preferences from 1 = highest preference to 4 = lowest preference. This is unfortunate. In this section I aim to identify these respondents based on the order of their transport choices, the distances that have been written down, and the home and work address information.

Some rules that possibly prove the question was misunderstood:

- Illogical transport choice order. For example: Car > Bicycle > Train seems unrealistic.
- Although three transport choices have been selected, the corresponding distances are not filled in.
- Although three transport choices have been selected, the corresponding distances are exactly or almost the same
- Distance of first transport choice is equal to commuting distance according to home and work addresses.
- Unrealistic distances for distance transport 2, 3 and 4. (Distance transport 1 has already been checked).

Depending on which of the rules stated above is applicable the transport choices are manually updated to match the trip distances, based on the transport choice which was filled in for the first column which is expected to have their highest preference.

15.3 HABIT

For the variable 'habit', the option 'other' could be selected and further explanation could be given. In case these explanation could be tied to one of the options presented for the question the answers would be filled in, otherwise they would be left blank.

15.4 INFLUENCE

For the variable 'influence', the option 'other' could be selected and further explanation could be given. If possible the answers were changed into one of the provided options in the web survey based on the explanation given by the respondents.

15.5 TRAVEL ALLOWANCE

Respondents could answer which allowances they could receive from their employer. Here I will check whether respondents have said yes to 'no travel allowance' and also said yes to allowances such as 'compensation for use of a car', 'compensation for use of PT', 'bicycle mileage allowance'.

Respondents could also choose the category 'Other allowance'. A lot of respondents choose this column and reported a variety of travel allowances, mostly focused around the fact that people are provided with a lease car.

15.6 YEAR OF BIRTH

It was checked whether respondents filled in a year of birth which is unrealistic: <1950 and >1997. Such cases were then changed into the average age of the sample. Only one case was found to match these criteria.

The same approach was taken regarding the other personal characteristics in order to remove NAs from the dataset. These characteristics include the monthly net household income, educational background, and gender.

16. APPENDIX F: RESPONDENT SAMPLE CHARACTERISTICS

Below several characteristics of the respondent sample have been visualized, namely the distribution of age, income levels and the educational background. In addition, bar charts are presented for several user characteristics that have been studied.



Distribution of income levels in the respondent sample





LBO

MULO

MMS

HBS

MAVO



VMBO

Highest completed educational level

мво

HAVO

vwo

нво

University/WO I will not say
16.1 CURRENT COMMUTING MODE CHOICE(S)



16.2 FAVOURITE / PREFERRED MODE OF TRANSPORT



16.3 INFLUENCE FROM THE WORK PLACE



16.4 KNOWLEDGE OF VEHICLE SHARING SYSTEMS

Degree of familiarity with the PT-bicycle



Degree of familiarity with car sharing services



Degree of familiarity with urban bike sharing services



17. APPENDIX G: MNL MODEL RESULTS AND INTERPRETATION

Table 14 shows the results of the MNL model estimation.

Versiable	$C_{p} dim r$	11	0 ac officient	t males a
	Couing	Unit	<i>p</i> coefficient	t-value
Bike sharing constant*	-	-	0.4680	0.80
Bicycle type	Electric = 1 Traditional = -1	-	-0.9950	-2.55
Access time*	-	Minutes	-0.04730	-1.22
Egress time*	-	Minutes	-0.01470	-0.44
Trip cost	-	Euro / km	-2.7400	-5.88
DistanceA (linear component)	10km = 1 6km = 0 2km = -1	Kilometre	-0.8990	-2.52
DistanceB (non-linear component)	10km = 0 6km = 1 2km = -1	Kilometre	0.8240	2.29
Type / Access*	-	Minutes	0.05230	1.48
Type / Egress	-	Minutes	0.07010	2.07
Type / Trip cost*	-	Euro / km	-0.5420	-1.31
DistanceA / Type	-	-	0.1460	2.78
DistanceA / Access*	-	Minutes	0.05530	1.46
DistanceA / Egress*	-	Minutes	0.04900	1.41
DistanceA / Trip cost*	-	Euro / km	0.06230	0.13
DistanceB / Type	-	-	0.1540	2.90
DistanceB / Access	-	Minutes	-0.07720	-2.02
DistanceB / Egress*	-	Minutes	-0.04740	-1.36
DistanceB / Trip cost	-	Euro / km	-0.9440	-2.01
Gender	Female = 0 Male = 1	-	0.4370	3.45
Age	-	Years	0.01260	2.40
Age / Type	-	-	0.009720	3.27
Income	Income categories (1 = lowest, 8 = highest)	Euro / month	0.01150	0.39
Education	Low = 0 Medium = 1 High = 2	-	-0.6250	-7.02
Habit: Car*	-	-	-0.3370	-1.78
Habit: Public transportation	-	-	-0.5270	-2.09
Habit: Bicycle*	-	-	0.2100	1.03
Influence: Car*	-	-	0.2220	1.85
Influence: Public transportation*	-	-	0.06630	0.37
Influence: Bicycle	-	-	0.8690	3.86
Knowledge: PT-bicycle	Not familiar = 0 Familiar, but no user = 1 Infrequent user = 2 Frequent user = 3	-	0.2240	2.50
Knowledge: Urban bike sharing	Not familiar = 0 Familiar, but no user = 1 Infrequent user = 2 Frequent user = 3	-	0.1920	1.98

Table 14: MNL model results, Log likelihood = -2265, adjusted ρ^2 = 0.106

Knowledge:	Not familiar = 0	-	-0.2420	-1.99
Car sharing	Familiar, but no user = 1			
	Infrequent user = 2			
	Frequent user = 3			
Travel allowance: Car*	-	-	-0.1220	-1.16
Travel allowance:	-	-	0.1060	0.99
Public transportation*				
Travel allowance: Bicycle	-	-	-0.9300	-4.73
Preference for privately owned	Strongly agree = 4	-	-0.2200	-5.53
bicycle over shared bicycle	Somewhat agree = 3			
	Neutral = 2			
	Somewhat disagree = 1			
	Strongly disagree = 0			
Perceived attractiveness of	Strongly agree = 3	-	0.2540	9.13
shared bicycle when the	Somewhat agree = 1			
privately owned bicycle is not	Neutral = 0			
available	Somewhat agree = -1			
	Strongly agree = -3			
Model fit				
Log likelihood = -2265				
Adjusted ρ^2 = 0.106				
* ~				

* Significance level of 5%

Over half of the estimated effects are significant and almost all of these are of the expected sign. The results show that the trip cost and interaction effects with trip cost along with influence towards the use of a bicycle and the available travel allowance for bicycle use appear to be the most important attributes influencing the commuters' bike share mode choice, as they contribute the most to the utility (parameter * average attribute level). The parameter estimates for education, the perceived attractiveness of a shared bicycle, the preference for the privately owned bicycle and again the parameter estimate for the trip cost are most accurately measured, shown by their high t-values. The fact that the trip cost parameters are the most important in the commuters' bike share mode choice is not a surprise as it was to be expected that commuters' mainly base their choice on the trip costs and this effect is possibly amplified by the fact that people are not used to having to pay for a bicycle, therefore they strongly reject high trip costs. Other attributes such as the influence from the employer towards promoting the use of a bicycle for the commuting trip as well as being able to make use of a bicycle focused travel allowance seem secondary attributes which determine the bike share mode choice. Because of the non-significance of some of the main effects, the access and egress time seem not to be as relevant in the commuters' bike share mode choice as expected. As there are significant interaction effects with regards to access and egress time some information is available on these aspects. It is found that people are willing to walk further after having used an electric bicycle and people dislike a certain access time more when the trip distance with the shared bicycle increases (up to 6km). However these effects are quite weak.

With regards to the other main effects, it is found that the traditional bicycle is always preferred over the electric bicycle even for longer distances. Although it was expected that the Dutch commuter has a preference towards the traditional bicycle as the electric bicycle has a negative image in the Netherlands, it was expected that for longer distances the electric bicycle would become the preferred type of bicycle. This effect further emphasizes the negative image of the electric bicycle and the preference of Dutch commuters for the simple, traditional bicycle which they are used to using. The utility for the electric and the traditional bicycle for different trip distances is shown in Figure X alongside the utility of trip distance itself. This graph shows that commuters are open towards using a shared bicycle for trips up to 8 kilometres, after which the utility of trip distance becomes negative.



Utility for different trip distances in km

As stated earlier, the parameter estimate for trip cost strongly influences the bike share mode choice. In addition, people value a certain trip cost more negatively when the trip distance with the shared bicycle increases (up to 6km).

With regards to the user characteristics estimated in this MNL model, it is found that males are generally more accepting of the idea of using a shared bicycle than women are. In addition, the interest in using an (electric) shared bicycle increases with age. A peculiar effect is shown by the parameter estimate for education. Higher education levels show a relatively strong negative effect on the bike share mode choice. However, the sign of this parameter was expected to be positive as highly educated people are generally more focused on using sustainable modalities than people with low levels of education. It is possible that this parameter is a proxy for a different effect that relates to educational levels which is not included in the model, which would explain the negative sign. Possible explanations could be that highly educated people more often own a lease car and therefore are less likely to be interested in using a shared bicycle. Although vehicle availability data is not available, the data on the used modalities does not support this theory. It remains unclear what type of effect causes the negative sign of the education parameter.

Most of the user characteristics on habit, influence, knowledge and available travel allowances are not significant. The ones that are significant show that people who prefer to use public transportation to travel to work value the shared bicycle slightly more negatively. This is unexpected as the shared bicycle is generally seen as a very suitable addition to public transportation and could therefore be interesting to the people using public transportation to travel. It is possible however that especially because these people already prefer using public transportation they have found in their daily travels that a shared bicycle does not have an added value for them as they are already happy with the current options for their first and last mile. A similar effect is seen from people who (are able to) receive a travel allowance for bicycle usage, as these people are less likely to be interested in a shared bicycle. This is probably because these people already make use of their own bicycle to travel to work and therefore a shared bicycle is of no added value. These effects indicate that when people are already happy with their current commuting trip, a new type of modality (in this case a shared bicycle) does not provide the added value to them to try a different setup of commuting trip. Habit has always been a problem with regards to wanting to change people's mode choice behaviour. Furthermore, commuters that feel like the employer and / or colleagues push them towards using a bicycle for their commuting trip are more open towards making use of a shared bicycle. An increase in familiarity and use of either an urban bike sharing service or the PT-bicycle leads to an increase in the valuation of a shared bicycle, while an increase in familiarity and use of car sharing services leads to a decrease in valuation.

Lastly the parameter estimates on the preference for the privately owned bicycle compared to a shared bicycle and the perceived attractiveness of a shared bicycle when the privately owned bicycle is not available are both significant. The estimates show that people who strongly prefer to use their own bicycle over a shared bicycle are less open towards using a shared bicycle compared to people to whom it does not matter whether they are using their own bicycle or a shared bicycle. In addition, people who do not find the shared bicycle an attractive mode choice when the privately owned bicycle is not available are less interested in using a shared bicycle. These effects are of course as expected, however it is interesting to see that these parameters have quite a strong effect on the bike share mode choice, indicating that the general perception of using a shared bicycle is an important factor in determining the bike share mode choice.

18. APPENDIX H: WEB SURVEY

On the following pages the web survey is shown as it was distributed amongst the respondent sample (in Dutch).



Welkom bij deze enquête!

De Technische Universiteit Delft voert in samenwerking met adviesbureau Mobycon een onderzoek uit naar de wijze waarop deelfietsen een rol kunnen krijgen in de mobiliteit. We kijken in het bijzonder naar woon-werkverkeer en zakelijke ritten.

We stellen het op prijs als u een bijdrage wilt leveren aan dit onderzoek door deze enquête in te vullen. We willen ook graag dat u meedoet als u niet bekend bent met deelsystemen, of als u bij voorkeur gebruik maakt van de auto of uw eigen fiets.

In deze enquête brengen we eerst uw huidige woon-werkreis in kaart, waarna we uw mening zullen vragen over deelfietsen. Vervolgens bekijken we of de deelfiets in uw woon-werk of zakelijke ritten een kansrijk vervoermiddel kan zijn. De enquête zal eindigen met enkele persoonlijke vragen.

Het invullen van de enquête duurt maximaal 12 minuten. De enquête is volledig anoniem.

Namens de TU Delft en Mobycon willen wij u hartelijk danken voor uw medewerking.

Bij vragen of problemen kunt op contact opnemen met: h.vanheijningen@mobycon.nl

12%



Van welk vervoermiddel of vervoermiddelen maakt u normaal gesproken gebruik wanneer u van uw woning naar uw werk reist?

(Indien u meerdere werklocaties hebt, vul de vervoermiddelen in voor uw reis vanaf uw woning naar uw meest bezochte werklocatie)

(Wandelen wordt niet als vervoermiddel gerekend, tenzij u rechtstreeks vanaf uw woning naar uw werk wandelt.) (Wanneer u eventueel overstapt op een andere trein, vult u slechts één keer trein in.)

Voorbeeld 1: Jan, woonachtig in Tilburg, fietst naar het treinstation, daar pakt hij de trein richting Utrecht Centraal (stapt over in 's-Hertogenbosch) en vanaf Utrecht Centraal reist Jan per bus naar zijn meest bezochte werklocatie --> Vervoermiddel 1 = fiets, vervoermiddel 2 = trein, vervoermiddel 3 = bus.

Voorbeeld 2: Eric, woonachtig in Utrecht, fietst rechtstreeks naar zijn werk --> Vervoermiddel 1 = fiets.

	Vervoermiddel 1	Vervoermiddel 2	Vervoermiddel 3	Vervoermiddel 4
Keuze:		\$	¢	\$

Hoeveel kilometer legt u (ongeveer) af met de hierboven aangegeven vervoermiddelen wanneer u van uw woning naar uw werk reist?

(Indien u meerdere werklocaties hebt, vul de afstanden in voor uw reis vanaf uw woning naar uw meest bezochte werklocatie)

Afstand afgelegd in km met vervoermiddel 1

Afstand afgelegd in km met vervoermiddel 2

Afstand afgelegd in km met vervoermiddel 3

Afstand afgelegd in km met vervoermiddel 4

Welk van de onderstaande vervoermiddelen zou u omschrijven als uw favoriete vervoermiddel? (ongeacht welke vervoermiddelen u tot uw beschikking hebt)

Met welk vervoermiddel verwachten uw collega's / werkgever dat u naar uw werk reist?



Welk van de onderstaande reiskostenvergoeding(en) kunt u van uw werkgever ontvangen voor uw <u>woon-</u> werk reis? (*U kunt meerdere opties aankruisen*)

Geen reiskostenvergoeding

Vergoeding voor het gebruik van de auto

Vergoeding voor het gebruiken van het OV

Fietskilometervergoeding

Andere vergoeding, namelijk:

Reist u naast uw normale woon-werk reis wel eens naar een andere locatie voor werk gerelateerde afspraken (hierna: <u>zakelijke reizen</u>), en zo ja hoe vaak? (*bijvoorbeeld naar andere bedrijven, instellingen, of bijeenkomsten*)

\$

Bent u bekend met de onderstaande 'gedeelde' vervoermiddelen, en zo ja in welke mate gebruikt u deze vervoermiddelen voor uw <u>woon-werk en zakelijke reizen</u>? (*de vervoermiddelen staan onder deze vraag afgebeeld*)

	Nee, niet mee bekend	Ja, maar ik maak er nooit gebruik van	Ja, ik heb er een enkele keer gebruik van gemaakt	Ja, ik maak hier regelmatig gebruik van
OV-fiets (te vinden bij NS stations)	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Deelauto (bijvoorbeeld Greenwheels of MyWheels)	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Stedelijke deelfiets (bijvoorbeeld de GoBike in Utrecht)	\bigcirc	\bigcirc	\bigcirc	\bigcirc



Deelauto (voorbeeld: MyWheels)

OV-Fiets

Deelfiets (voorbeeld: GoBike)





Op de volgende pagina wordt uw mening gevraagd over het gebruiken van deelfietsen voor uw woon-werk of overige zakelijke reizen. Wij vragen u uw mening te baseren op de onderstaande beschrijving van een deelfiets(systeem).

Het deelfietssysteem

- Een organisatie (deelfietsbedrijf of gemeente) biedt fietsen aan, waarvoor zij zorg dragen, verspreid over een regio.
- Een deelfiets kan opgehaald worden bij een deelfietsstation, zoals weergeven is in de foto hieronder. Dit kan een elektrische of traditionele fiets zijn.
- U meldt zich aan bij de terminal (zie rechts in de foto) en kunt vervolgens één van de fietsen meenemen.
- Aan het einde van de rit kunt u uw deelfiets parkeren bij een deelfietsstation in de buurt van uw bestemming.
- Deelfietsstations zijn te vinden bij onder andere OV-stops, P+R locaties, kantoren, woonwijken, de binnenstad, enzovoorts. U kunt de deelfiets dus overal ophalen.
- U betaalt een bepaald bedrag per kilometer voor het gebruiken van de deelfiets

Dit deelfietssysteem is op dit moment nog in ontwikkeling, en is dus nog niet te vinden in Nederland.

Voorbeeld deelfietsstation met terminal



38%



In welke mate bent u het eens met de volgende stellingen over het gebruiken van een deelfiets (zoals deze op de vorige pagina aan u is voorgesteld) voor <u>woon-werk en zakelijke reizen</u>?

	Zeer mee oneens	Enigszins mee oneens	Niet mee eens / niet mee oneens	Enigszins mee eens	Zeer mee eens
Ik fiets liever op mijn eigen fiets dan op een deelfiets	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
De deelfiets is een aantrekkelijk vervoermiddel wanneer mijn eigen fiets niet aanwezig is	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik kan mijn <u>werkadres</u> gemakkelijker bereiken als ik een deelfiets combineer met, of gebruik in plaats van mijn huidige vervoerswijze	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik kan <u>zakelijke afspraken</u> gemakkelijker bereiken als ik een deelfiets combineer met, of gebruik in plaats van huidige vervoerswijze	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
De deelfiets is aantrekkelijk omdat ik alleen hoef te betalen per kilometer	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik vind het geen probleem om de deelfiets altijd terug te brengen naar de startlocatie van mijn reis	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc

Als u een deelfiets zou gebruiken voor uw <u>woon-werk</u> of overige <u>zakelijke</u> reizen, voor welk van de onderstaande reisopties zou u de deelfiets dan het liefst gebruiken? (*u kunt meerdere reisopties aankruisen per type reis*)

	Op mijn woon-werk reis zou de deelfiets het interessantst zijn voor	Voor overige zakelijke reizen zou de deelfiets het interessantst zijn voor
Gehele reis van deur tot deur		
Rit naar bus / metro / tram stop		
Rit naar treinstation		
Rit vanaf P+R locatie		
Rit vanaf bus / metro / tram stop		
Rit vanaf treinstation		

In hoeverre bent u het eens met de volgende stelling?

"Ik zou graag een deelfiets willen gebruiken voor (een deel van) de reis naar de onderstaande activiteiten of bestemmingen."

(Hierbij kunt u aannemen dat de deelfiets voor u gemakkelijk te bereiken is en altijd beschikbaar is)

			Niet mee		
	Zeer mee	Enigszins mee	eens / niet	Enigszins mee	Zeer mee
	oneens	oneens	mee oneens	eens	eens
Woon-werk reis	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Zakelijke reizen	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Bezoek aan vrienden of familie	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Winkelen	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Sport, hobby of verenigingsactiviteiten	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Bezoek van culturele / toeristische attracties	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Buitenrecreatie (zoals steden- of strandbezoek)	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc

46%



Let op! Het is belangrijk dat u de onderstaande informatie doorneemt voordat u verder gaat met de enquête.

Vanaf de volgende pagina wordt u een 8 keer gevraagd uw voorkeur aan te geven tussen twee verschillende deelfietsen met net andere eigenschappen.

Bij het beantwoorden van deze vragen moet u zich voorstellen dat u vanaf huis op weg bent naar uw werk en u op een bepaald punt op uw reis de keuze krijgt om verder te reizen met deelfiets 1 of deelfiets 2. De afstand die u met de deelfiets tijdens deze fictieve reis gaat afleggen verschilt en wordt weergegeven bij elke vraag.

De twee deelfietsen worden beschreven aan de hand van de volgende eigenschappen:

- Type deelfiets: Een traditionele óf een elektrische fiets;
- **Toegangstijd fiets**: Het <u>aantal minuten lopen naar het deelfietsstation</u> waar u de fiets kunt ophalen;
- **Toegangstijd bestemming**: Het <u>aantal minuten lopen naar uw bestemming</u> vanaf waar u de fiets heeft geparkeerd;
- Ritprijs: De prijs in euro's voor een enkele rit met een deelfiets.
 - Let op! Als u normaal voor uw woon-werk reis een reisvergoeding ontvangt, geldt deze ook voor het gebruiken van een deelfiets. Houdt hier dus rekening mee bij het beantwoorden van deze enquête: de prijs van de deelfiets zou u dus niet zelf hoeven te betalen.

Zie hieronder een visualisatie van hoe elke reis aan u wordt gepresenteerd.





Rit uitleg

Het deel van de <u>woon-werk reis</u> wat u af zal leggen met de deelfiets is **10 kilometer**.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	4 minuten	7 minuten
Toegangstijd bestemming:	1 minuut	4 minuten
Ritprijs:	€3.00	€1.50

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

De door mij gekozen deelfiets

Een ander vervoermiddel

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 6 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	1 minuten	7 minuten
Toegangstijd bestemming:	7 minuten	1 minuut
Ritprijs:	€1,80	€0,-

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

- De door mij gekozen deelfiets
- Een ander vervoermiddel

Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 6 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	7 minuten	4 minuten
Toegangstijd bestemming:	4 minuten	7 minuten
Ritprijs:	€0,-	€0,90

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

- Deelfiets 1
- Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

De door mij gekozen deelfiets

) Een ander vervoermiddel

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 10 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	4 minuten	1 minuten
Toegangstijd bestemming:	7 minuten	4 minuten
Ritprijs:	€0,-	€3,00

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

- De door mij gekozen deelfiets
- Een ander vervoermiddel

Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 2 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	4 minuten	7 minuten
Toegangstijd bestemming:	4 minuten	1 minuut
Ritprijs:	€0,30	€0,60

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

- Deelfiets 1
- Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

De door mij gekozen deelfiets

) Een ander vervoermiddel

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 6 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	7 minuten	4 minuten
Toegangstijd bestemming:	4 minuten	7 minuten
Ritprijs:	€1,80	€0,90

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

- De door mij gekozen deelfiets
- Een ander vervoermiddel

Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 2 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	7 minuten	1 minuut
Toegangstijd bestemming:	1 minuut	7 minuten
Ritprijs:	€0,30	€0,-

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

- Deelfiets 1
- Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

De door mij gekozen deelfiets

) Een ander vervoermiddel

Het deel van de <u>woon-werk reis</u> wat u af zal leggen met de deelfiets is **2 kilometer** lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	1 minuten	4 minuten
Toegangstijd bestemming:	7 minuten	4 minuten
Ritprijs:	€0,30	€0,60

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

De door mij gekozen deelfiets

Een ander vervoermiddel

77%



Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 2 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	1 minuut	7 minuten
Toegangstijd bestemming:	7 minuten	1 minuut
Ritprijs:	€0,60	€0,-

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

- Deelfiets 1
- Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

- 🔵 De door mij gekozen deelfiets
- Een ander vervoermiddel

Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 10 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	1 minuut	4 minuten
Toegangstijd bestemming:	7 minuten	4 minuten
Ritprijs:	€1,50	€3,00

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
O De door mij gekozen deelfiets			
Een ander vervoermiddel			
Rit uitleg			
Het deel van de <u>woon-werk re</u>	<u>eis</u> wat u af zal le	ggen met de deelfiets is 6 kilometer lang.	
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Traditioneel	Elektrisch	
Toegangstijd fiets:	4 minuten	7 minuten	
Toegangstijd bestemming:	1 minuut	4 minuten	
Ritprijs:	€1,80	€0,90	
Welk van de beschreven deelf	ietsen heeft uw	voorkeur voor deze rit?	
O Deelfiets 1			
 Deelfiets 2 			
\bigcirc			
Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
De door mij gekozen deelfiet	S		
Een ander vervoermiddel			
Dituitlog			
Het deel van de <u>woon-werk re</u>	eis wat u af zal le	ggen met de deelfiets is 10 kilometer lang.	
		- 10	
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Traditioneel	Elektrisch	
Toegangstijd fiets:	4 minuten	7 minuten	

Toegangstijd bestemming:4 minuten1 minutenRitprijs:€1,50€3,00

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
De door mij gekozen deelfiets			
Een ander vervoermiddel			
Rit uitleg			
Het deel van de <u>woon-werk re</u>	eis wat u af zal le	eggen met de deelfiets is 2 kilometer lang.	
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Traditioneel	Elektrisch	
Toegangstijd fiets:	7 minuten	4 minuten	
Toegangstijd bestemming:	4 minuten	7 minuten	
Ritprijs:	€0,60	€0,30	
Welk van de beschreven deelf	ietsen heeft uw	voorkeur voor deze rit?	
O Deelfiets 1			
O Deelfiets 2			
Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
O De door mij gekozen deelfiets	5		
Een ander vervoermiddel			
Rit uitleg			
Het deel van de <u>woon-werk re</u>	eis wat u af zal le	eggen met de deelfiets is 2 kilometer lang.	
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Elektrisch	Traditioneel	
Toegangstijd fiets:	7 minuten	4 minuten	
Toegangstijd bestemming:	4 minuten	7 minuten	

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

€0,-

€0,30

Deelfiets 1

Ritprijs:

Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
De door mij gekozen deelfiets			
Een ander vervoermiddel			
D ¹ . 1.1			
Kit uitleg Het deel van de woon-werk re	eis wat 11 af zal le	eggen met de deelfiets is 6 kilometer lang.	
	<u></u> wat a ai 2ai ie		
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Elektrisch	Traditioneel	
Toegangstijd fiets:	4 minuten	1 minuut	
Toegangstijd bestemming:	7 minuten	4 minuten	
Ritprijs:	€0,-	€1,80	
Welk van de beschreven deelf	ietsen heeft uw	voorkeur voor deze rit?	
Deelfiets 1			
O Deelfiets 2			
Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?	
Oe door mij gekozen deelfiet	S		
Een ander vervoermiddel			
Rit uitleg	11		
Het deel van de <u>woon-werk re</u>	<u>eis</u> wat u af zal le	ggen met de deelfiets is 10 kilometer lang.	
	Deelfiets 1	Deelfiets 2	
Type deelfiets:	Elektrisch	Traditioneel	
Toegangstijd fiets:	7 minuten	1 minuut	
Toegangstijd bestemming:	1 minuut	7 minuten	

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

€1,50

€0,-

Deelfiets 1

Ritprijs:

Welk vervoermiddel heeft uw voorkeur voor deze rit?	
De door mij gekozen deelfiets	
Een ander vervoermiddel	
	7796
	,,,,,



Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 6 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Elektrisch	Traditioneel
Toegangstijd fiets:	7 minuten	1 minuut
Toegangstijd bestemming:	1 minuut	7 minuten
Ritprijs:	€0,90	€0,-

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

- Deelfiets 1
- Deelfiets 2

Welk vervoermiddel heeft uw voorkeur voor deze rit?

- De door mij gekozen deelfiets
- Een ander vervoermiddel

Rit uitleg

Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 10 kilometer lang.

	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	7 minuten	4 minuten
Toegangstijd bestemming:	4 minuten	7 minuten
Ritprijs:	€3,00	€1,50

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?
O De door mij gekozen deelfiet	S	
Een ander vervoermiddel		
Pit uitlog		
Het deel van de <u>woon-werk re</u>	<u>eis</u> wat u af zal le	eggen met de deelfiets is 2 kilometer lang.
Type dealfiets.	Deelfiets 1	Deelnets 2
Toegangstiid fiets:	4 minuten	
Toegangstijd hestemming	7 minuten	4 minuten
Rithrije	fo_	fo 60
	00,	
Welk van de beschreven deel	fietsen heeft uw	voorkeur voor deze rit?
Deelfiets 1		
Deelfiets 2		
Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?
🔵 De door mij gekozen deelfiet	s	
Een ander vervoermiddel		
\bigcirc		
Rit uitleg		
Het deel van de <u>woon-werk re</u>	<u>eis</u> wat u af zal le	eggen met de deelfiets is 6 kilometer lang.
	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	4 minuten	7 minuten
Toegangstijd bestemming:	4 minuten	1 minuten

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

€0,90

€1,80

Deelfiets 1

Ritprijs:

Welk vervoermiddel heeft uw voorkeur voor deze rit? De door mij gekozen deelfiets Een ander vervoermiddel **Rit uitleg** Het deel van de <u>woon-werk reis</u> wat u af zal leggen met de deelfiets is **2 kilometer** lang. Deelfiets 1 **Deelfiets 2** Type deelfiets: Traditioneel Elektrisch **Toegangstijd fiets:** 4 minuten 7 minuten Toegangstijd bestemming: 1 minuut 4 minuut **Ritprijs:** €0,60 €0,30 Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit? Deelfiets 1 Deelfiets 2 Welk vervoermiddel heeft uw voorkeur voor deze rit? De door mij gekozen deelfiets Een ander vervoermiddel **Rit uitleg** Het deel van de woon-werk reis wat u af zal leggen met de deelfiets is 10 kilometer lang. **Deelfiets 1 Deelfiets 2** Type deelfiets: Elektrisch Traditioneel Toegangstijd fiets: 7 minuten 4 minuten

Toegangstijd bestemming:4 minuten7 minutenRitprijs: \pounds 0,- \pounds 1,50

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Welk vervoermiddel heeft uw	voorkeur voor d	leze rit?
De door mij gekozen deelfiets	5	
Een ander vervoermiddel		
Rit uitleg		
Het deel van de <u>woon-werk re</u>	<u>is</u> wat u af zal le	ggen met de deelfiets is 10 kilometer lang.
	Dealfiate 1	Dealfiata a
Type deelfiets:	Elektrisch	Traditioneel
Toegangstiid fiets:	1 minuut	7 minuten
Toegangstijd bestemming:	7 minuten	1 minuten
Ritprijs:	€3,00	€o,-
Welk van de beschreven deelf	ietsen heeft uw	voorkeur voor deze rit?
Deelfiets 1		
Deelfiets 2		
TAT-11		
	voorkeur voor c	
De door mij gekozen deelfiets	5	
Een ander vervoermiddel		
Rit uitleg		
Het deel van de <u>woon-werk re</u>	<u>is</u> wat u af zal le	ggen met de deelfiets is 6 kilometer lang.
	Deelfiets 1	Deelfiets 2
Type deelfiets:	Traditioneel	Elektrisch
Toegangstijd fiets:	1 minuten	4 minuten
Toegangstijd bestemming:	7 minuten	4 minuten

 Ritprijs:
 €0,90
 €1,80

Welk van de beschreven deelfietsen heeft uw voorkeur voor deze rit?

Deelfiets 1

Welk vervoermiddel heeft uw voorkeur voor deze rit?	
O De door mij gekozen deelfiets	
Een ander vervoermiddel	
	7796
	_ //~



Naast bedrijven of stichtingen die deelfietsen aanbieden en hiervoor zorg dragen, kunnen individuen ook met elkaar hun eigen fietsen delen. Hieronder kunt u kort aangeven wat uw mening hierover is.

In welke mate bent u het eens met de volgende stellingen over privé of "peer-to-peer" fietsdelen?

	Zeer mee oneens	Enigszins mee oneens	Niet mee oneens / niet mee eens	Enigszins mee eens	Zeer mee eens
Ik stel graag mijn eigen fiets ter beschikking als peer-to-peer deelfiets wanneer ik deze zelf niet nodig heb	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik gebruik liever een deelfiets die ter beschikking is gesteld door een bedrijf of stichting dan een fiets van een ander persoon	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik gebruik graag een peer-to-peer deelfiets voor (een deel van) mijn woon-werkreis	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Ik gebruik graag een peer-to-peer deelfiets voor (een deel van) mijn zakelijke ritten	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc

85%

Wat kan een deelfiets betekenen voor werknemers?
Om een beter beeld te krijgen van de eigenschappen van de respondenten wordt u aanvullend een aantal vragen gesteld. Deze informatie wordt strikt anoniem verwerkt en alleen gebruikt voor wetenschappelijke doeleinden.
Wat is uw geslacht?
🔘 Man
Vrouw
In welk jaar bent u geboren?
Wat is uw hoogst voltooide opleiding?
Wat is het netto inkomen van uw huishouden per maand? (exclusief het inkomen van uw kinderen) Wat is uw huidige beroepsstatus?
Welke vorm heeft uw dienstverband?
Wat voor beroep heeft u?
92%



Om een compleet beeld te krijgen van uw reispatronen willen wij u vriendelijk verzoeken de onderstaande vraag te beantwoorden. De informatie wordt strikt anoniem verzameld en alleen gebruikt voor wetenschappelijke doeleinden.

Wat is uw woonadres?

Postcode woonadres (zescijferig)

Wat is uw meest bezochte werkadres?

Postcode meest bezochte werklocatie (zescijferig)

Indien postcode onbekend: Straatnaam

Indien postcode onbekend: Plaats

Indien u meerdere werklocaties heeft die u regelmatig bezoekt (minimaal 1 keer per week), dan kunt u hieronder het werkadres van uw tweede en derde werklocatie achterlaten.

Wat is het werkadres van uw tweede werklocatie?

Postcode tweede werklocatie (zescijferig)

Indien postcode onbekend: Straatnaam

Indien postcode onbekend: Plaats

Wat is het werkadres van uw derde werklocatie?

Postcode derde werklocatie (zescijferig)	
Indien postcode onbekend: Straatnaam	
Indien postcode onbekend: Plaats	

100%

Wat kan een deelfiets betekenen voor werknemers?
E-mailadres:
Wilt u op de hoogte worden gesteld over de resultaten van dit onderzoek? (Zo ja, vul hierboven uw e- mailadres in)
🔵 Ja
○ Nee
Vragen en/of opmerkingen: