



The Bike Sharing potential

The potential for a bike sharing system implementation in medium-large cities in the Netherlands.

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Master's programme in Spatial Planning
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Preface

This document is titled ‘The bike sharing potential,’ on the potential for a bike sharing system implementation in medium-large cities in the Netherlands. As a typical Dutchman, I have always used the bike a lot. With that, I have always experienced the many benefits of biking on fitness and the limited space that bikes occupy in the city. My own interest in the use of bikes and my experiences with shared bike promotional work last year ensured that I wanted to do research on this subject.

This thesis has been written to fulfill the graduation requirements of the Master’s programme in Spatial Planning, with a specialisation in Urban and Regional Mobility, at the Radboud University Nijmegen. In the last six months, I was investigating and writing this thesis on bike sharing.

The problem statement and the corresponding research questions of my thesis have been drawn up together with my supervisor, Frits Verhees. At first, the subject was broad and unspecific. However, after a feedback conversation with Frits Verhees, I saw the importance of specifying the subject and its relevance for increasingly crowded medium-large cities, in which I have always lived myself. For that, and many more forms of good advice, I want to thank my supervisor. I have always appreciated the productive feedback moments.

Finally, I want to thank my friends and family and in particular my girlfriend that supported me during this research project.

I have gained a lot of knowledge during my programme in Spatial Planning and I also experienced writing this final thesis as enormously instructive. Hopefully you will also benefit from reading my thesis in terms of knowledge.

Pol Jansen.



Summary

Due to the pressure on the largest cities in the Netherlands and a housing shortage, the medium-large cities become wanted. There is a growing amount of people moving to these cities and an increasing pressure on the housing market. As a result, the total use of cars in the medium-large cities also keeps increasing (Kennisinstituut voor Mobiliteitsbeleid, 2010). These shifts inflict problems in terms of more congestion, less accessibility and a negative influence on activities in and surrounding the cities (Mingardo, 2008).

The concept of bike sharing, as part of a smart mobility system, can offer an alternative to car use that reduces the amount of cars in city centres and the overall pressure on the mobility network. Commuters and other car drivers can park their cars on city edges and take the bike for a healthy and clean first- and last-mile trip.

The objective of this research was to gain an understanding of the potential implementation of bike sharing systems in medium-large cities, by investigating travel behaviour and the preference of travelers. Subsequently, this contributes to the future aim of improving spatial design and land use. In order to achieve this research aim, the following problem statement has been formulated; *How should a bike sharing system, for a first- and last mile use, be set up to meet the potential demand, and what could be the spatial effects for medium-large cities in the Netherlands?*

Before the investigation, a literature research on relevant theories and an expert interview have been done to set the theoretical foundation.

This research will be methodically supported by a survey on the preferences of car users on the use of shared bikes in different situations and individual characteristics of shared bikes and park & ride locations.

By conducting this research, the current unfamiliarity of shared bikes is observed once again. The results show a potential demand, however. The outcome of this research shows that in a situation where travel time or travel price becomes more advantageous, there is an increasing amount of car users that indicate that they want to use shared bikes often. If both benefits in time and price are becoming more advantageous than in the current state of affairs, this potential group grows considerably. It is, in other words, necessary to create a situation in which time and price are reduced, in order to create a successful bike sharing system. The potential costs of a shared bike are determined by the difference in parking costs between the park & ride and the city center and the petrol savings.

When it comes to the reimbursement of car use, the results show the negative aspect of this concept for bike sharing. The more a traveler is reimbursed in terms of travel costs and parking costs, the less a traveler makes use of public transport. This indicates the comfort of reimbursement and the needlessness of multimodal transport if reimbursement is obtained. This result indicates a considerable influence of employers, who could boost the use of bike sharing if this use as an alternative to car reimbursement is promoted.

By setting up a bike sharing system at park & ride locations alongside other locations, that system could serve multiple societal goals. Thereafter, the volume and flexibility for users increases, thereby increasing the potential use and the chance of succeeding.

The direct spatial effects of the use of shared bikes instead of cars for the first- and last-mile include a reduction of urban congestion, an increased health and physical fitness



for users and a positive influence on accessibility, thereby impacting the land use and spatial quality.

The generalization of the results is limited by the fact that specific numbers on the total amount of car users that enter and leave the city center of the medium-sized cities do not exist. The population could therefore not be precisely determined. This must be taken into account when interpreting and analyzing the results.



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1. Introduction

1.1 Problem statement

In addition to the traditionally popular cities of Amsterdam, Utrecht and The Hague, medium-large cities are increasingly popular among house hunters in the Netherlands. Due to the lack of available housing in the biggest cities, people flock to other popular residential locations. Besides this shift towards medium-large cities, the average purchase price further increased.

The pressure on the housing market, particularly in the four major cities of the Randstad, ensures that the municipalities that are easily accessible, and are in the immediate vicinity, benefit from this with a growth in population. This means an increasing number of people that move to medium-large cities. Especially the cities along important traffic arteries that connect with the Randstad (Bouwfonds Property Development, 2017). For the city of Breda there is a minimum expected population growth of 2.4% between 2018 and 2050, which means a growth of approximately 5000 inhabitants (Gemeente Breda, 2019). For the city of Nijmegen, the minimum expected population growth between 2015 and 2030 is 5.6%, which means a growth of approximately 9500 inhabitants (Gemeente Nijmegen, 2015).

A growth of the population, however, leads to an increased number of car and traffic users and with that more mobility on roads in and around the cities (Kennisinstituut voor Mobiliteitsbeleid, 2010). This increase in car use and congestion leads to the fact that accessibility in inner cities reduces, which negatively influences the economic activities in cities (Mingardo, 2008). Furthermore, the inner cities are also becoming less attractive for car use in terms of parking. Around three-quarters of the Dutch medium-large cities have increased the parking fees by at least 10 percent since 2000. The available area of parking spaces with paid parking has also been expanded by at least 10 percent, meaning that the amount of unpaid parking places decreases (Harms, Bertolini & Brommelstroet, 2016).

This problem is accompanied with a growing awareness of the issue and a shift towards the more accessible and environmentally friendly benefits that smart mobility could achieve (Rabl & De Nazelle, 2012). Thereafter, this awareness, the relative growth of paid parking places and a growth in the price of car fuel predicts an uncertain future for car traffic and the daily dependence on cars in medium-large cities (Newman & Kenworthy, 2011).

Bike sharing can be a way to improve the accessibility of cities, and to help flow out the different transport modes available in cities. An advantage of bike sharing is the improved connectivity to other modes of transit due to the first mile/last mile solution bike sharing helps solve. One can easily take the car to a cheap and large parking space on urban edges, serving as mobility hubs, and take the shared bike for the first/last mile. It also helps decrease personal vehicle trips, because more persons can use the same vehicle (DeMaio, 2009).

For the users of public transport in the Netherlands there already is the availability of the OV-fiets, which gives public transport users the possibility to continue their journey by making use of the shared bicycles. The OV-fiets is a mobility addition that greatly increases the range of train stations. Besides, the use of the OV-fiets is still strongly increasing in the Netherlands (Kickert, 2010).



By commuting by bicycle, advantages for both the commuters and for society are generated. Commuting is a significant aspect of societal travel behaviour. This is mainly because of the fact that commuting contributes to reaching the daily career locations and therefore economic well-doing. In the Netherlands, commuting covers about 20% of the number of trips, in a mostly fixed and disproportionately time and place. Commuting by bicycle can therefore majorly impact the reduction of congestion (Heinen, Van Wee & Maat, 2010).

Car drivers and car using commuters experience the problem of congested cities to an even greater extent than public transport users, and with that, in most cases, lack the possibility to continue the car-journey by making use of a shared bike system.

1.2 Research aim and questions

The objective of this research is to gain an understanding of the potential implementation of bike sharing systems in medium-large cities in the Netherlands, by investigating travel behaviour and the preference of travelers. Subsequently, this understanding contributes to the aim of improving spatial design and land use, which complement accessibility and travel behaviour in and around the city.

In order to achieve this research aim, the following problem statement has been formulated; *How should a bike sharing system, for a first- and last mile use, be set up to meet the potential demand, and what could be the spatial effects for medium-large cities in the Netherlands?*

In order to answer the problem statement, three sub-questions have been composed:

- How should a bike sharing system be spatially set up to match and complement (smart) travel behaviour?

The first sub question describes the spatial set up of the bike sharing system, regarding the location within the city and the design of the accommodation.

- What are the view and preferences on using shared bikes as a smart mobility service?

The second sub question analyses the view and preferences of car users on the use of shared bikes as well as the current familiarity and the role of users within the smart mobility service.

- To what extent and how could a bike sharing system spatially affect increasingly crowded medium-large cities?

The third sub question continues on the potential use of shared bikes within medium-large cities and describes the spatial effects of a bike sharing system for the city and the surroundings.



1.3 Relevance

The relevance of this research can be explained by the problem statement described above. In this section, the scientific and societal relevance are further elaborated on.

The results of this research can be handed over towards municipal governments of urban areas or private organisations interested in working with bike sharing.

1.3.1 Scientific relevance

Recently, a reasonable amount of research has been written about bike sharing. The future role of smart bike sharing systems and smart mobility in urban mobility is investigated (DeMaio, 2009; Midgley, 2009; Benevolo, C., Dameri, R. P., & D'Auria, B., 2016). Also, the modeling and design of a bike sharing system is investigated (Contardo, C., Morency, C., & Rousseau, L., 2012).

There are, however, no hard answers to the question when and how people in medium-large cities in the Netherlands will use bike sharing and what this potential use might mean for the urban areas in which the system will be functionable in the future. By investigating to what extent and in what ways Dutch residents of urban areas are prepared to use shared bicycle systems, their preferences, and in what way the urban area can adapt and benefit from bike sharing, this research contributes to the scientific relevance.

A lot of research is still needed on the potentially important role that bike sharing can have in an urban smart mobility service. Mainly because of the possibilities for bike sharing to fill in an important and sustainable first- and last mile solution.

It can also be seen as a link in Mobility as a Service. Mobility as a Service, or MaaS, is a popular trend and a promising development for the future.

Thereafter, this research is scientifically relevant because of a lack of research into commuting by bicycle. While the research and research population are not entirely focused on commuters and commuting by bicycle, this will play a significant role in the investigation. Studies have been conducted on general bicycle use and commuting in general. Besides the shared bicycle aspect, the aspect of commuting by bicycle is a fairly new understanding in research.

1.3.2 Societal relevance

In addition to the traditionally popular cities of Amsterdam, Utrecht and The Hague, medium-large cities are experiencing an increased pressure on road use and the housing market (Bouwfonds Property Development, 2017). This growth of the population and pressure on road use mainly leads to an increased number of car and traffic users (Kennisinstituut voor Mobiliteitsbeleid, 2010).

Besides that, the pressure on public transport, and the need from travelers to get from door to door in a desirable way will also continue. By investigating insights on the behavioural and spatial aspects in medium-large cities, this survey is societal relevant. It assists in simplifying a possible transition towards bike sharing systems and can help support the reduction of congestion and keeping inner cities attractive. By adapting a



desirable bike sharing service, medium-large inner cities could be enclosed by parking lots, functioning as mobility hubs accompanied by a bike sharing station, in order to remain livable, attractive, healthy and accessible by bike.

Thereafter, the user side of a new innovation in smart mobility and their preferences should not be underexposed. It is important to engage citizens in planning and setting up smart mobility (Siegele, 2012), therefore making it societal relevant to investigate their view and preferences on the use and potential design of a shared biking system.

The social use of research into bike sharing potential is not to set up a system, but to facilitate a sustainable bike sharing system that involves the interests and preferences of the consumer, or user, in order to achieve long-term success.



1.4 Research model

To clarify the relationship between the various steps of this research, it is important to design a research model. The research model schematically shows the different phases of this research, in order to visualise the goal of this research (Verschuren, Doorewaard & Mellion, 2010).



2. Literature review and theoretical framework

The conceptual framework lists theories and concepts that relate to the subject of this research and that are important for the creation of a framework for the research.

Subsequently, a conceptual model will be formed on the basis of the useful theories and concepts that are listed above.

2.1 Bike sharing

At distances up to approximately 15 kilometers, the bike is a cheap, healthy and sustainable modality. Bike sharing systems allow people to rent a bike at one of the many automatic rental stations scattered around the city and make use of this modality. After the use for a short journey, the bikes are returned at any possible location or station in the city (Raviv, Tzur & Forma, 2013).

According to the definition of Maartens (2017), a shared bike used in a bike sharing system can be defined as a bike for collective use.

Nowadays, an increasing number of cities around the world organise and plan such systems in order to encourage their citizens to use bicycles as an environmentally sustainable and socially equitable mode of transportation. Thereafter, the use of shared bikes is a good complement to other modes of transit systems in and around the city (Raviv et al. 2013).

The main characteristics that divide bike sharing from traditional biking rental services are, according to Midgley (2009), the fact that they can be rented at one location and either returned there or at another location; they provide quick and easy access; they have diverse business models; they make use of applied technology and they are often designed as part of the public transport system.

According to DeMaio (2009), three generations of bike sharing systems exist. The first generation. The 1st generation of bike sharing programs began in Amsterdam, in 1965, with the Witte Fietsen, or White Bikes (DeMaio, 2009). Ordinary bikes, painted white, were provided for public use. One could find a bike, use it to ride to the desired destination, and leave it for the next user. However, bikes were vandalised and thrown into the canals and the program lasted only a few days. A second generation bike sharing program was established in 1991 in Farsø and Grenå, Denmark, and in 1993 in Nakskov, Denmark (Nielse, 1993). These were small and local programs, with no more than 30 shared bikes. Two years later, in 1995, the first large-scale second generation bike sharing program was launched in Copenhagen. The so called City Bikes had many improvements over the previous generation, including bike stations and a functionable coin deposit with the intention of utilitarian use.

Although the City Bikes were formalized and organised citywide, the system still experienced theft due to the anonymity of the user. This led to the emergence of a new generation of bike sharing with an improved customer tracking. The first third generation bike sharing program was Bikeabout in 1996, established at the Portsmouth University in England. University students could use a magnetic stripe card to rent a bike. The following third generation bike sharing systems were improved with a variety of smart technological improvements, including electronic bike locks, telecommunication systems, smart cards, mobile phone access, and on-board computers (DeMaio, 2009). The two main ways of



locking and unlocking the shared bikes differ in the way the user has to gain access to an internet connection. In the first way, bikes are unlocked by making use of a smartcard. This way is generally combined with a docking station and an electronic bike stand. The second way relies on an internet connection and functions with an automated lock on the bike itself, forcing the bike users to use a smartphone for the entry code via an application (Midgley, 2011).

These characteristics, in combination with the preferred implication of the research population, will determine the preferred bike sharing system.

Future-proof bike sharing systems, also referred to as the fourth generation of bike sharing systems, include even more technological innovations. Innovations that self-evidently mean the future of cycling include electric bikes, smartphone real time availability applications and the use of electronically displayed parking-zones within cities instead of docking stations (Haverman, 2019). Thereafter, built-in GPS systems are used to track down bikes in real-time to prevent theft and analyse data within the travelling network to improve rebalancing and traffic flow. With bicycle rebalancing is referred to the reestablishment of the number of bikes at the locations in which quantities of bikes are desired. This rebalancing is mainly operated by a fleet of vehicles that transport the bikes (Pal & Zhang, 2017).

2.2 Smart Mobility

Mobility is defined as the ability to move from one place to another (Farber and Marino, 2017). Besides that, accessibility relates to the role of land-use and transport systems in society. To define this complex concept, it is about the extent to which land-use and transport systems enable individuals or groups of individuals to reach activities or destinations by means of a (combination of) transport mode(s) (Geurs et al, 2004).

Especially in and around cities, in the midst of increasing crowds, mobility problems can occur and accessibility can be low.

By using new technologies, like intelligent traffic lights to lower stopping times and improving the flow of traffic, and sharing and exchanging information about realtime accessibility gaps, travelers can bypass those gaps or chose other types of transport modes. Therefore activities can be reached more easily. Alternatively, a smart mobility system can cause that someone doesn't even need to reach those activities, for example when someone can also use technology and practice the activity at home.

Smart mobility focuses on improving and optimizing the mobility infrastructure in a city. On the one hand the smart mobility concept is about new technologies and ways to improve the existing mobility and the flow. On the other hand it is about the consumers, the civilians that are using the transport and mobility modes, and the way information is exchanged between them. Smart mobility can be an approach to the question of how the (inner) city can at the same time remain livable, attractive, healthy and accessible (Papa & Lauwers, 2015).

Bike sharing is an example of smart mobility. Bike sharing is a form of consumer-centric smart mobility. It is therefore designed for the people, who are recognized to have a key role in the “functioning” of this smart city system. In consumer-centric smart mobility, people are



seen as the end-consumers of a mobility service. These services are reflecting the individual needs of people. Consumer-centric applications aim at optimizing consumer's mobility behaviour through information technology systems (Papa & Lauwers, 2015)

The successfulness of smart mobility is determined by the quality of the planning and urban space, participation of the users of a smart mobility system and a willingness to change and adapt to a new system. It is important to engage citizens in planning and setting up smart mobility (Siegele, 2012).

2.3 Use of shared bikes in transport network

After looking at the conceptual definition of bike sharing and the characteristics of the smart mobility principle, it is important to investigate how (shared) bikes are used in the transport network. For the theoretical delineation of this use, we look at multimodal transport, the development of bike use in modal split and the first- and last-mile within travel networks.

2.3.1 Multimodal transport

In this research, multimodal transport is defined according to the definition of Van Nes (2002). This study refers to multimodal transport as the phenomena of using more than one transport service or modes for making a trip, being combinations of private transport and public transport services or combinations of public transport services (Van Nes, 2002).

A mode might be defined by vehicle type or by transport function. The part of the trip where a single mode is used is called a leg. Multimodal transport requires for the traveller to transfer between different transport services, being either private or public transport services. Figure 1 shows examples of trips, where (a) and (b) are examples of unimodal trips, and (c) an example of a multimodal transport trip. The point where travelers transfer to another mode of transport is denoted by the bold T.

A shared bike can be used as a mode in a unimodal trip. However, in this research we focus on the use of bike sharing systems as a solution for the first and last mile and mainly in combination with the use of a car.

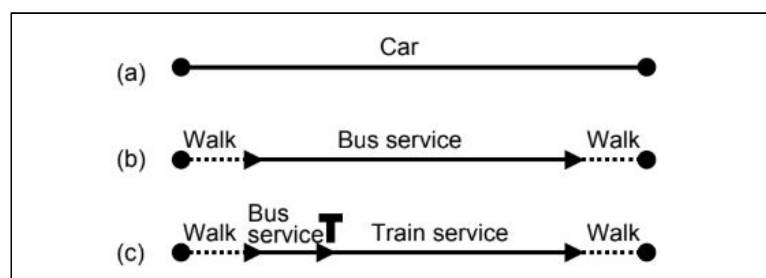


Figure 1 - Examples of unimodal trips (a, b) and a multimodal trip (c) (the transfer point is denoted by the bold T) (Van Nes, 2002).



2.3.2 Modal split

In this section of the chapter, the development of the modal split is described. The modal split changes because travelers on the one hand exchange one mode of transport for another in a certain period and on the other hand because journeys with a certain mode of transport have a drop in demand or a new demand.

Figure 2, set up by Jonkeren, Wüst & de Haas (2019) from the Kennisinstituut voor Mobiliteitsbeleid (KiM), displays the shifts in modal split share, in percentage points, per distance class for the 2005 to 2015 period. For medium-distance journeys, the share of cars, both by the driver and by the passenger, has fallen by around 2.5 percentage points for large and medium-large cities in general. For journeys over long distances, the share of the car-as-driver group remained practically the same. This distance class does, however, concern a large proportion of all journeys over long distances, with almost 50%. The share of bicycles has increased in all distance classes, the most (3.5 percentage points) in the class for typical bicycle distances, which is between 1 and 7 kilometers. The increase in the bicycle share of around 1.5 percentage points in the longest distance class is also noteworthy, because the bicycle share in 2005 was still only 10 percent (Jonkeren et al. 2019).

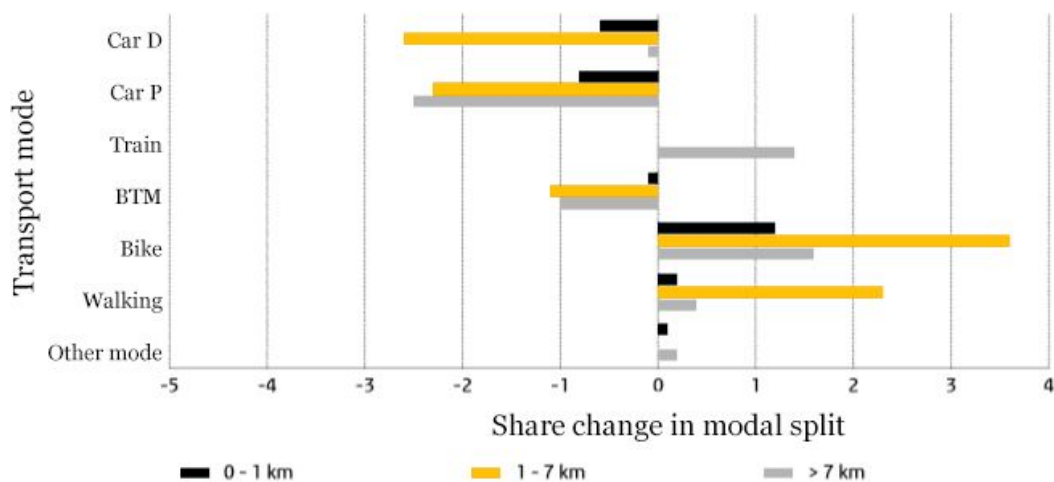


Figure 2 - Modal split change (based on movements) in percentages, between 2005-2015, in large and medium-large cities in the Netherlands (Jonkeren et al. 2019)



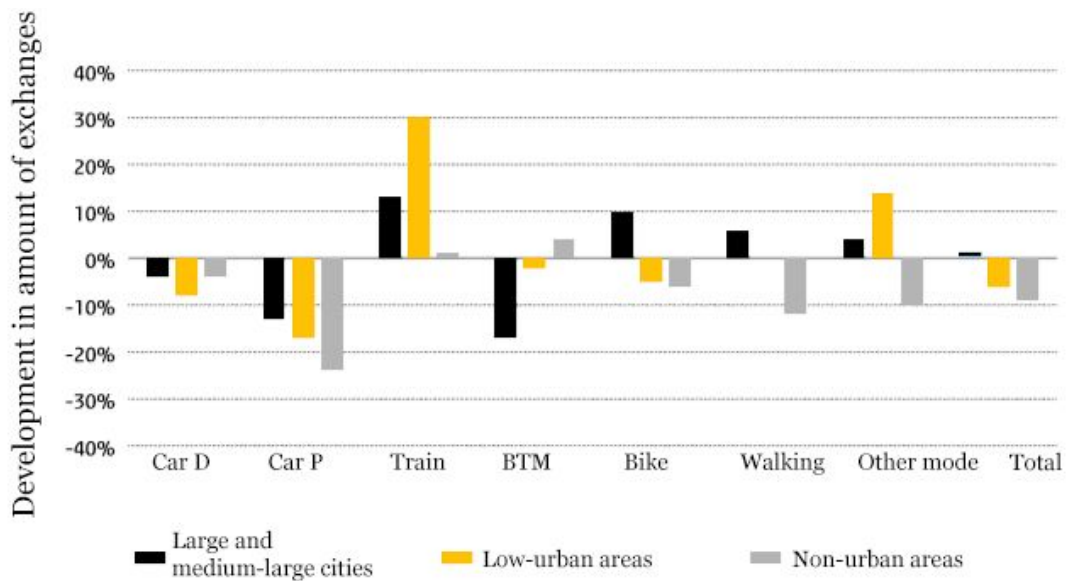


Figure 3 - Development from 2005-2015 in amount of exchanges per inhabitant per year by mode of transport, relative to 2005, nationally in the Netherlands (Jonkeren et al. 2019)

Figure 3 shows the development in amount of exchanges per inhabitant per year by mode of transport from 2005-2015, in comparison with 2005, per degree of urbanity. In general, in the Netherlands the number of exchanges or journeys per inhabitant per year have changed to the same extent in the metropolitan and low-urban Netherlands. For the use of bikes in the transport network, it is clearly visible that in large and medium-large cities bikes are used 10% more from 2005-2015 in amount of exchanges.

The share of bicycles in the modal split has increased in all types of areas, but especially in the large and medium-large cities in the medium-distance segment ranging from 1 to 7 kilometers. At this segment, the car has lost share.

Both figure 2 and figure 3 indicate the growing importance and use of bikes, and the willingness and acceptance of the use of bikes that is already growing in the metropolitan areas of the Netherlands, approximately in the past ten years.

2.3.3 First last mile

The first mile can be defined as the distance people have to cover from or towards their home or workplace towards or from the nearest transport hub (Wang & Odoni, 2014). This is also the definition of first- and last-mile that is applied in this research.

The first- and last-mile, coupled with public transit services can potentially provide cost-effective and sustainable door-to-door transportation (Chong et al. 2011).

An example of a situation where shared bikes are already successfully used as a first- and last-mile solution in the Netherlands, is the OV-fiets sharing system. The addition of the OV-fiets at train stations helped improve the accessibility of train stations as it gave people that traveled with the public transport another alternative for the first- and last-mile.

In this research, the use of shared bikes is investigated, where the bike is used as a first- and last-mile solution in a multimodal transport trip for car users.



2.4 Travel behaviour

There is a shift from the Dutch government towards a growing amount of behavioral change and the involvement of citizens in mobility issues. In a participatory society, in which citizens are actively involved in issues, citizens are expected to take responsibility and initiatives (BIN NL, 2017).

According to Pearmain, Swanson, Kroes & Bradley (1990), travel behaviour is influenced by observable and non-observable elements. Figure 4 shows the process underlying the behaviour of travel. Especially the non-observable elements of behaviour are adjustable, whereas observable elements as *Availability of alternatives* are changed by strategic physical applications in the transport system. The figure shows that preferences and the integration and design of the transport system amidst alternatives are important in travel behaviour.

Bike sharing, as a smart mobility system, won't succeed if, besides the quality of planning, participation and willingness are not achieved. This emphasizes the importance of engaging and involving citizens in planning for travel (Siegele, 2012). At present, there is a growing awareness of the need to change our transportation habits by reducing our use of cars, which can smooth a shift in travel behaviour (Rabl & De Nazelle, 2012).

For the research population, the most important conflict in alternatives is the use of bike versus the use of car in transport, because these are the two means of transport which they theoretically can use.

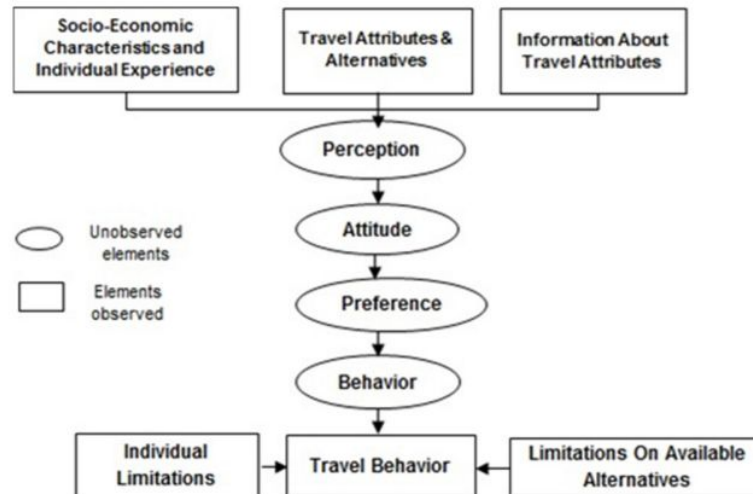


Figure 4 - Components of consumers travel behaviour (Pearmain, Swanson, Kroes, & Bradley, 1991).

2.4.1 Bicycle use

The use of a bicycle over other transport modes has many benefits, both for the individual bike users as for society as a whole. First of all, biking is a healthy form of transport. By making use of bikes, society can reach many benefits over other transport modes, concerning health advantages. Moreover, in and around cities, the use of bikes can be faster than other transport modes. Especially because cyclists can avoid traffic jams (Olde Kalter, 2007). In



the Netherlands, this speed benefit can be underlined by the large-scale presence of specific biking lanes. For the society as a whole, bicycle use over other transport modes benefits the environmental sustainability, because the lack of direct emissions and noise from bikes. Disadvantages of biking include the difficulty of taking loads with you during travel, a physical effort that is needed to travel, dependence on the weather (Heinen, Van Wee & Maat, 2010).

The Netherlands has the highest level of bicycle use within the industrialized world. More than 27% of all trips are made by bicycle, a figure that has been relatively stable over the last decades. Medium-large cities, in particular, show high levels of bicycle ridership, with some reporting a bicycle share of trips exceeding 35% (Martens, 2007).

Besides the highest level of bicycle ridership, medium-large cities also have the highest total bicycle share. This share is in all probability a result of the shorter distances of the destinations involved than in large cities (Rietveld and Daniel, 2004).

In the study of Hunt & Abraham (2007), various attributes related to bicycle use and personal characteristics have been investigated. Their most important conclusions are the negative effects of longer trip lengths on the attractiveness to use a bike, the preference for a separated bike lane instead of mixed road use and the positive effects of a safe parking place on the attractiveness to use a bike.

Heinen, Van Wee & Maat (2010) have cataloged the determinants of bicycle use and addressed the factors related to bicycle use, shown in figure 5.

The factors related to bicycle use can be divided in two sections, policy-influenced and non-policy influenced factors. The policy-influenced factors are split up in physical infrastructure factors, factors with a non-physical context and individual characteristics.

Policy-influenced	Non policy-influenced
Physical infrastructure	-Hilliness
-Urban form (trip distance, density, mixture of functions)	-Weather / Climate (wind, rain, temperature)
-Cycling infrastructure	-Seasons
-Design of infrastructure (continuity, number of stops, cyclist priority, etc.)	-Gender
-Bicycle parking	-Age
-Bicycle sharing system	-Income
Non-physical context	-Employment status
-Social norms	-Household structure
-Costs (of both cycling and its alternatives)	
-Safety (both perceived and actual)	
-Giving cyclists protection in law	
-Education (training cyclists, informing car-users, etc.)	
Individual characteristics	
-Bicycle and car ownership	
-Frequency of physical activity	
-Level of education	
-Attitudes	
-Deeply held environmental beliefs	
-Habits	
-Identity	

Figure 5 - Overview of factors related to bicycle use (Heinen, Van Wee, & Maat, 2010).



2.4.2 Car use

The research by Sted (2005) on car use in the Netherlands revealed that car use by commuters is strongly related to symbolic and affective motives, and to a lesser extent to an instrumental, mean of transport motive. No differences were discovered between the frequent and infrequent drivers in this investigation on car use. This result implies that the functional use of car traffic is most strongly related to non-instrumental motives. In other words, for composing policies it is important to consider the social and affective motives of car use.

Thereafter, car users tend to find personal space and a desire for control over the transport experience important. Drivers want to have control, in order to overcome potential barriers on a trip. Car users that switched to other modes of travel like public transport needed a clear strategy, with which they remained some sort of control over their trip. This control is mentioned on smart mobility aspects of smart travel and ICT technologies to control trips (Gardner & Abraham, 2007). These aspects, regarding frequency and attitude, can be compared with the individual characteristics context factor of bike-use.

Car users also want to minimize physical effort, time and distance (Sted, 2005). These aspects can be compared with the physical infrastructure context factor of bike-use.

A negative aspect of car use is the *dead time*, in which a driver can't do anything productive during a trip. Also, the cost is an important factor to car use, as most car users don't see the full cost per trip and only highlight fuel costs. By giving more insight on the per-trip costs of car use in comparison with other modes of transport, a better overview could be given (Gardner & Abraham, 2007). These aspects, regarding social norms and costs, can be compared with the non-physical context factor of bike-use.

2.4.3 Keuzereiziger

Keuzereizigers, or choice-travelers, are for the first time defined by the Ministry of Transport, Public Works and Water Management (1981), as travelers that can chose to travel their whole trip per car, per public transport, or a combination of both modes.

According to the definition above, the keuze reiziger seems to be an easily recognizable traveler. However, most of the time this is not the case. The emphasis was mainly on the use of transport modes, and not on the perception of choice, personal attitude and travel behaviour.

For this research, the keuzereiziger is split in three distinguishable groups, investigated by Tertoolen (2003). The first group includes potential travelers, which are irregular public transport passengers and who use public transport less than once every four weeks. They need the public transport but don't make use of it, mainly because they have a car.

The second group includes frequent travelers. The frequent travelers use public transport once every four weeks to once a week and who make use of the public transport often and also have a car.



The third group includes very frequent travelers, which travel at least once a week with public transport and also have a car (Tertoolen, 2003).

It is important to point out that the number of keuzereizigers has grown from 26% of the total amount of travelers in 1991 to 45% in 2002, emphasizing that an increasing number of travelers has the opportunity to make a choice in their preferred travel modes (Stienstra, 2002).

2.5 Pressure on medium-large cities

Medium-large cities in the Netherlands are defined as cities with a total population number between 50.000 and 200.000 (Uunk, 2002; G32, 2011). Sometimes more generally referred to as cities with a total population number below 200.000 (Meijers, 2015). In this research, however, medium-large cities along important traffic arteries that are connected to the Randstad will be investigated. The pressure on these cities is becoming higher, as will be explained further in this paragraph. Examples of medium-large cities along those traffic arteries in the Netherlands are Apeldoorn, Arnhem, Nijmegen and Breda.

In addition to the traditionally popular cities of Amsterdam, Utrecht and The Hague, medium-large cities are increasingly popular among house hunters. As stated, due to the lack of available housing in the big cities, people flock to other popular residential locations. Thereafter, the average purchase price further increased.

Nijmegen and Breda are among the ten most desirable residential locations in the Netherlands. The pressure on the housing market, particularly in the four major cities of the Randstad, ensures that the municipalities that are easily accessible, and are in the immediate vicinity, benefit from this with a high score on the housing market heatmap (Bouwfonds Property Development, 2017).

The figure below shows a heatmap of the Dutch housing market in 2017, where the score indicates a combination of market volume and the household development to 2025. Nijmegen and Breda are both part of the highest scoring municipalities. The heatmap shows that there is an increasing pressure on cities such as Nijmegen and cities in the Brabantse stedenrij. The outliers in the southern Netherlands are large cities such as Breda. The role of infrastructure for the added value of a residential region is striking. All promising and high scoring municipalities are connected by important traffic arteries (Bouwfonds Property Development, 2017).



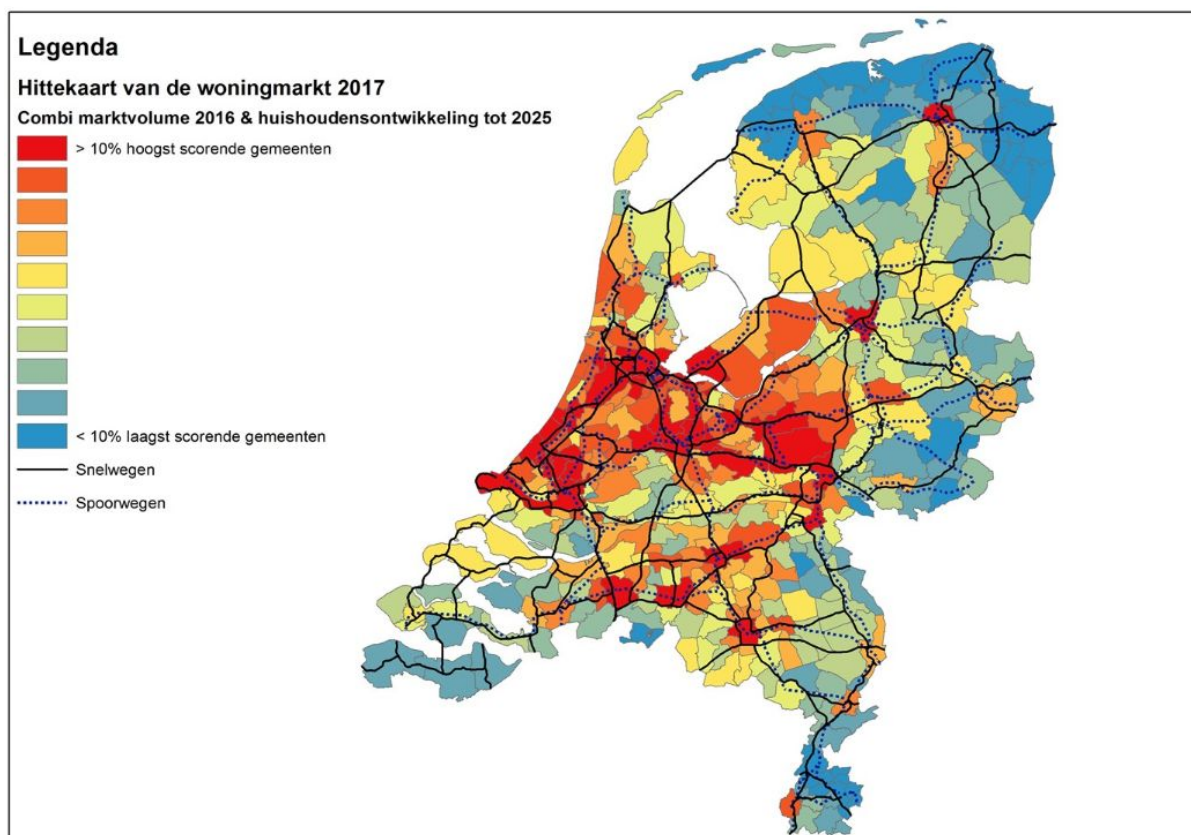


Figure 6 - Heatmap of housing market 2017 (Bouwfonds Property Development, 2017).

The population growth and the pressure on the Dutch road network are inextricably linked. Population growth leads to greater pressure on the roads, especially in the Randstad and the surrounding medium-large cities. In the city of Breda, car use will estimateably increase by a maximum of 9 percent between 2010 and 2030, because of population growth alone. Together with other factors, car use in Breda will estimateably rise by almost 46 percent between 2010 and 2030 (Kennisinstituut voor Mobiliteitsbeleid, 2010).

2.6 Land use

The problems caused by busy roads and the continued intensification of city-centre land use are a form of negative externality. They impose disbenefits on other land users. Disbenefits which, by giving another use to the land, could be solved (Pacione, 2009).

The definition of land use differs for different spatial scales. A local, for instance at the level of a municipality, urban, regional, national and even international scale. However, on all scales land use influences the transport options that are made available. Transport land use can be seen as a traffic system considering both the infrastructure side and the mobility side in terms of geography of trips, length, average number of trips, different transport modes and the relationships between the modes. Land use influences the different characteristics of the transport system, mostly in terms of accessibility to jobs, services and customers.

Subsequently, the accessibility determines the spatial development and therefore the



land use (Wegener & Fürst, 1999). The table below summarizes the definition of land use and describes *the land use and transport system interaction*, as addressed by Wegener and Fürst (1999). It is based on the interaction between land use, activities, transport system and accessibility (Figure 7).

Land Use	The distribution of land uses, such as residential, industrial or commercial, over the urban area determines the locations of human activities such as living, working, shopping, education or leisure.
Activities	The distribution of human activities in space requires spatial interactions or transport services that leads to trips in the traffic system to overcome the distance between the locations of activities.
Transport system	The distribution of infrastructure in the transport system creates opportunities for spatial interactions and can be measured as accessibility.
Accessibility	The distribution of accessibility in space co-determines location decisions and so results in changes of the land-use system.

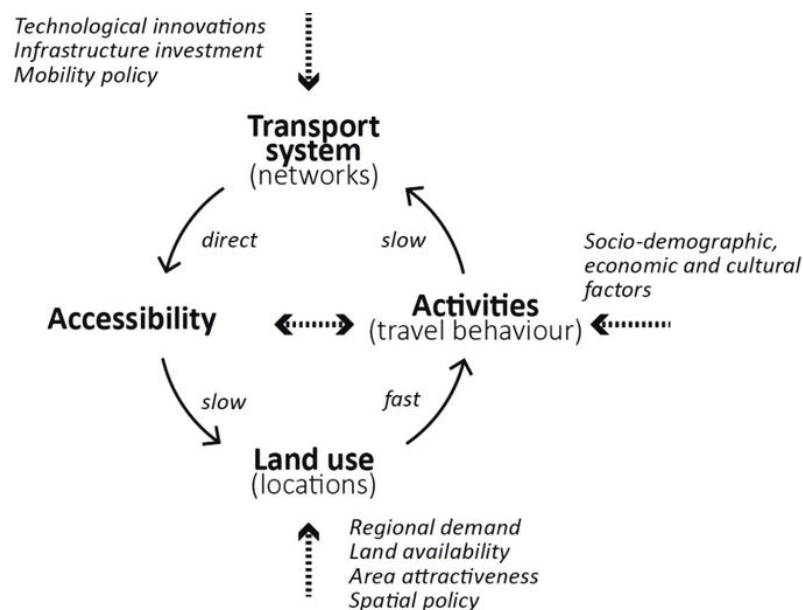


Figure 7 - Transport land-use feedback cycle (Wegener & Fürst, 1999).

The addition of shared bikes in the total of transport modes that can be used to enter the inner city, besides the car and the different public transport options, also improves the accessibility of the city. Accessible cities in which people can optimize their career chances are successful cities. The improvement of accessibility determines land use and helps thereby also improve this optimization and therefore indirectly makes a city more successful (Marlet & van den Berg, 2009).



2.6.1 Mobility Hubs

The land use and attractiveness of the location directly affect the activities and the travel behaviour, and subsequently affect the accessibility of an area, as described in the section above (Wegener & Fürst, 1999).

For the implementation of shared bikes at park & ride locations, it is therefore important to emphasize on attractiveness. Mobility hubs are places where different travel modes within a transportation network connect, complemented with amenities, in order to maximize first-mile last mile connectivity (Urban Design Studio, 2016). For the implementation of a bike sharing system, safety and convenience are momentous. Travelers need to be able to reach bike stations easily, so in order to increase accessibility stations must be properly sited (Urban Design Studio, 2016).

Food facilities and temporary shops and kiosks can enhance the first- and last-mile connection for the users of the mobility hub. Retail and groceries can be provided on location or within walking or biking distance. Thereafter these facilities can provide opportunities for travelers to meet and interact with each other, making it more attractive to use the hub and the mobility and non-mobility related facilities (Urban Design Studio, 2016).

2.6.2 Parking infrastructure

All bikes, on average, take up the same amount of space. The difference in the space that is used for a bike sharing system is therefore mainly caused by the way in which the parking infrastructure is set up. For the way of unlocking the shared bikes by making use of a smartcard, a docking station and an electronic bike stand are needed. The docking stations take up a vast amount of space at different locations within the inner city and along the edges of the city (Midgley, 2011). The second way that relies on an automated lock on the bike itself, takes up clearly less space that is needed for the parking infrastructure.

A docking station is also ten times as expensive as a electronic shared bike, even without the costs for installation, laying of cables and maintenance. By making use of only electronic bikes, without docking stations, money and space are saved (Haverman, 2019).

The OV-fiets and Mobike are both very similar bike sharing systems in the way the parking of the shared bikes within this system is regulated. Both systems exclude the docking stations and give the user the freedom to park their bike wherever they want, as long as the regular parking rules for bike users are followed. The Mobike bikes use an electronic lock, ensuring all the technologies are within the bike itself. These technologies include electronically displaying parking-zones, or operation zones, in which the bike can be parked (Haverman, 2019). This way, the parking infrastructure is set up online, rather than on actual space.

Bike sharing systems with a more online- rather than physical spatial implementation are referred to as free-floating bike systems (Pal & Zhang, 2017). A first difference between the free-floating bike systems and the more traditional docking stations involves the saving of startup costs, by avoiding the construction of expensive docking poles and stations. With



free-floating bike systems, bike theft is prevented because of smart management, in which bikes are tracked in real-time with the built-in GPS in the shared bikes (Pal & Zhang, 2017).

2.7 Theoretical model

The theoretical model forms the foundation of the research and the starting point of the research design. Based on the literature research and the set up of the theoretical framework, a theoretical model is developed. The model shows the relationships of expected impact between the central concepts around the use of bike sharing.

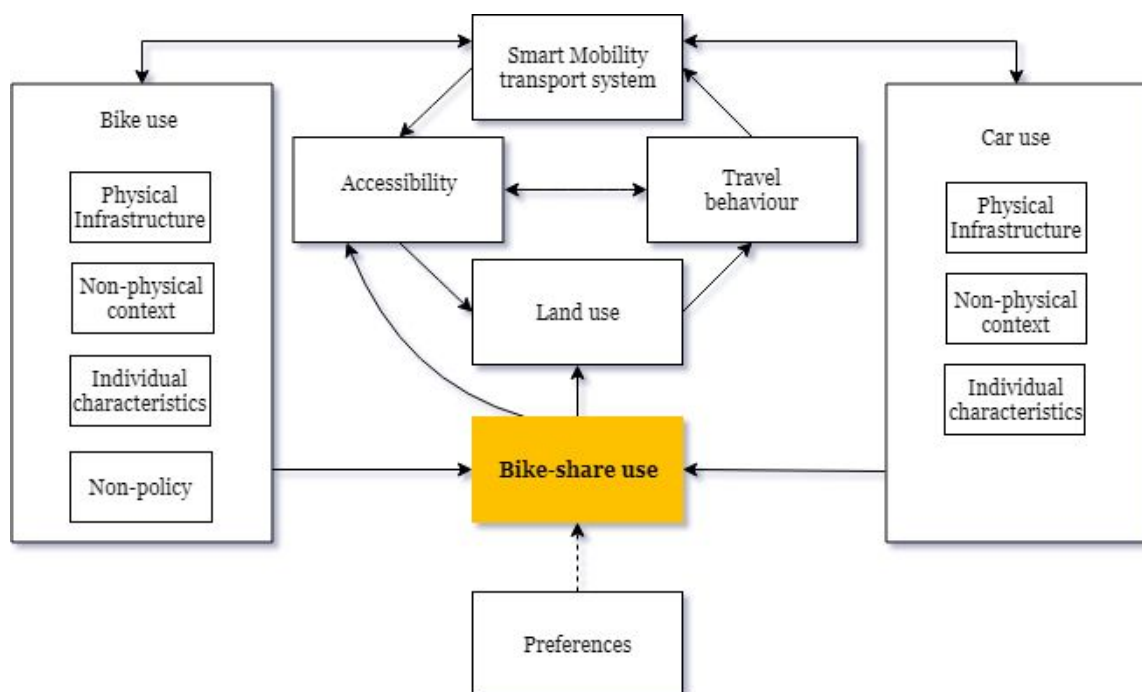
The consideration or choice to use a bike, thereafter, directly affects, and is affected by, the choice to use a car as first- and last-mile option, both directly condition the bike share use.

As the theoretical framework showed, attributes for potential bike use is divided in four factors, complemented with the preferences and personal characteristics. These factors influence, and are influenced by, the way the Smart Mobility transport system is designed and set up.

The transport land-use feedback loop ensures that the transport system directly influences the accessibility, which influences the land use and travel behaviour. Subsequently, the land use and area attractiveness influences the travel behaviour once again, leading to an influence of the transport system.

Accessibility and land use are directly influenced by the use of bike sharing systems, which changes the flow of traffic and the spatial policies in and around the city centre, the urban edge and park & ride locations.

The preference of travelers and its influence on the use of bike sharing is investigated in this research, as is the additional effect from bike share use on spatial land use and accessibility.



3. Methodology

3.1 Research strategy

In this chapter, the methodology used for answering the sub- and main research questions will be described. This section will discuss the design and the used research methods.

The research is exploratory, oriented on achieving new insights in the concept of bike sharing and to better understand solutions for the stated research problem. This research is also based on an open-ended main research question. Because of this, the research is exploratory (Farthing, 2016). However, already published studies and literature will form the basis for the emergence of this research and its societal relevance.

Given the purpose of the research, it will be descriptive. This descriptive purpose will be realized by including a survey to enquire new information and verities (Kothari, 2004). The research in general aims at finding a solution for an immediate problem that plays a role in contemporary planning culture. It also aims at directly linking relevant theories in a more practical approach. Therefore, the research can be defined as an applied or application-oriented research (Kothari, 2004). However, the research concerns human behaviour and preferences and is done to be able to make generalisations about human behaviour, and is therefore even more an example of a fundamental research (Kothari, 2004). Although it seeks to link theories and find knowledge that can help find a solution for a societal problem, the results of this research won't directly and practically solve this immediate problem. This research is therefore better described as a fundamental research focussed on finding a solution for a societal problem, framed by the general problem statement of the research.

Furthermore, the research philosophy in regard to this investigation will be assessed. Thereafter the research population and the case selection are described. With the description of the population and the case selection, questions about the shape and nature of this study and the researched phenomena are answered.

3.1.1 Research Philosophy

An important aspect of research is describing the philosophy, as it leads to a further thinking about the research and can lead to a better understanding and use of the appropriate methodology (Holden & Lynch, 2004).

The major research perspectives or paradigms can be classified somewhere in the framework between positivism, post positivism, critical theory and constructivism. The two outermost perspectives can be more evident and extreme than post positivism and critical theory. According to Holden & Lynch (2004), these outermost perspectives can be delimiting and restricting.

By choosing to work with an intermediate philosophy approach, researchers are allowed to match the philosophy, methodology and the research problem (Holden & Lynch, 2004). This research will take a pragmatic and post positivist approach, together with the application of quantitative surveys and expert conversations.



Post positivism arose from the ways of thinking of the positivism paradigm. Positivism is based on quantifiable observations that can be analyzed through statistical methods. By applying a post positivist paradigm, with subsequent a modified objectivist perspective, the results of this research will be defined as probably true. It is important to remain critical and evaluative in terms of the obtained analysis and results (Guba & Lincoln, 1994). The aim of a post positivist paradigm is to gain explanation, with which the researcher can explain, predict and control the phenomena. For post positivism, progress is build by explaining and controlling the phenomena better and better over time. By making use of the knowledge of previously conducted research and by pursuing validity in this research as much as possible, this research assists in the progression of the explanation and understanding (Guba & Lincoln, 1994).

Within this paradigm, there exists a common rational structure to which all questions of difference can be referred for resolution (Guba & Lincoln, 1994, p. 115). This research, just like other investigations that are prepared within a post positivist paradigm, endeavors to gain knowledge in the form of non falsified and probable facts and laws (Guba & Lincoln, 1994).

3.1.2 Research Population

This paragraph describes the research population, also referred to as the sample for this study. A representative sample is important to determine to what extent the potential of using shared bikes in medium-large cities can be generalized.

In addition, it is of importance to gather a heterogeneous sample. When different personal characteristics are represented, an assessment can be made of the statistical relationship between factors and the effect of personal preferences and characteristics.

The population is the segment of reality that is used in the research by the researcher (Verschuren, Doorewaard & Mellion, 2010).

The OV-fiets is a countrywide bike sharing system, operated by ProRail. In the Netherlands, citizens can rent these shared bikes from and to more than fifty Dutch train stations for a daily fee (DeMaio & Gifford, 2004). The OV-fiets demonstrates that a bike sharing system in the Netherlands is indeed possible and functionable. It is the public transport counterpart of bike sharing in the Netherlands.

This research will instead focus on bike sharing among other modes of transport. The population to be investigated will consist of car users that are not yet using a shared bike system as the norm for the first and last mile in and out urban areas. The focus will mainly be on commuters with a business oriented car use, but other car users that enter and leave urban areas per car will also be included in the investigation to include a large number of people and prevent exclusion, wherein it should be noted that all car users impact the congestion and emissions in city centres.

In summary, the research population for this research will consist of road users that enter medium-large cities by car, and thereby impact the congestion and additional effects on environment and liveability in and around cities.



3.1.3 Case selection

Case selection is a task of the researcher, that ranks as the primary task before the collection of data. By choosing a case, the researcher frames the subject and draws an agenda for studying the selected cases. An important point of attention is the representativeness in case selection (Seawright & Gerring, 2008).

The chosen research population will be investigated quantitatively, as the population consists of a wide range of road users. For the quantitative research method, embodied by the survey, two medium-large cities in the Netherlands will function as research cases. Medium-large cities are increasingly popular among house hunters in the Netherlands, and a growing number of people flock to medium-large cities instead of the traditionally popular cities in the Randstad. This shift is mainly caused by the lack of available housing in the biggest Dutch cities and the pressure on the housing market. Medium-large cities among important traffic arteries that are accessible from the Randstad, especially experience a growth in population (Bouwfonds Property Development, 2017).

The cities in which respondents will be surveyed, are Nijmegen and Breda. Both of these cities are ranked among the ten most desirable residential locations in the Netherlands and are situated along important traffic arteries. Both Breda and Nijmegen are medium-large cities, and are therefore relevant within the case selection.

The cities will serve as an example for medium-large cities in the Netherlands. By including both Nijmegen and Breda as cities in which respondents are investigated, a larger sample of respondents can be collected on multiple different locations.

These two cities, who belong to the medium-large cities in the Netherlands, are part of the highest scoring municipalities in the Netherlands in terms of market volume and the household development to 2025 (Bouwfonds Property Development, 2017).

Thereafter, as described, car use in Breda will estimate increase by a maximum of 9 percent between 2010 and 2030, because of population growth. Together with other factors, car use in Breda will estimate rise by almost 46 percent of the current situation between 2010 and 2030 (Kennisinstituut voor Mobiliteitsbeleid, 2010).

The case cities are especially vulnerable for the impact of road users, as this amount will consequently rise for both cities.

The selected case cities of Nijmegen and Breda are, besides the factors on representativeness described above, also chosen because the limited time for this investigation and their proximity in terms of travel time. The cities are chosen to represent medium-large cities in the Netherlands and will serve as examples for medium-large cities among important traffic arteries.



3.2 Research methods

In this section, the research methods are described, with which answers are drawn up in line with the sub-questions of this research. In chronological order, the data collection, data analysis and the stated preference used for this research are explained.

3.2.1 Data collection

For the exploratory investigation on the view on using shared bike, a quantitative research method will be applied. The research is based on the measurement of quantity or amount. The description by Aliaga and Gunderson (2002) on quantitative research is used to define this method of research in this investigation. They define quantitative research as ‘explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics).’

This method is chosen in order to obtain as much insights and opinions as possible in a short time. The willingness to adapt to a bike sharing system and the opportunities this creates for an urban area are phenomena that can be expressed in terms of quantity, making it possible to investigate this quantitatively (Kothari, 2004). The quantitative research method can help indicate the size and importance of the decisions taken in a survey and therefore assist in clearly outlining the behavior of people (Boezeman, 2016).

This quantitative method will be put into practice by making use of a survey, applied on the research population described above. This research population will serve as the sample. The survey is a commonly used research method, that makes it possible to collect a large amount of data in an efficient way. This is mainly because of the wide range of road users that form the research population and the nature of the research, which seeks to find new insights and personal preferences. Survey research is particularly suited for this research, as it enables the canvassing of opinions and feelings about this particular issue (Muijs, 2010). The survey is used to predict and explain travel behaviour among the population. The survey research is well suited to this particular research, as it wants to analyse and describe the relationships between variables occurring in particular real-life contexts and the correlation between the variables (Muijs, 2010).

This research will be conducted by making use of personal surveys and a link to an online-survey. The link to the online questionnaire was, where possible, handed over on a card (appendix C). The data was collected both digitally and on location in order to obtain the largest possible sample (appendix D). Personal surveys on location enable a researcher to gain more personal and complex information, and the link to online-surveys will make it more easy to gain a larger amount of information in a short amount of time (McClave, Benson, Sincich, & Knypstra, 2014).

Thereafter, further literature research is going to be used in order to collect a just amount of knowledge on the design of bike sharing systems. The theoretical framework and the conceptual model resulting from it are formed on the basis of the useful theories and concepts regarding the subject of this investigation. This framework and the conceptual model are used during the data collection to remain on the right path towards answering to



the research questions. In a way, the data collection has already been started during the process of setting up the theoretical framework.

For the third sub-question, the results of the large-scale survey are combined with an expert interview. This conversation has been conducted in order to further zoom in on the spatial effects of bike sharing systems in medium-large cities. This expert interview, that took place early in the research process, has mainly been planned to improve the basic knowledge on the subject and formed the preliminary research for the researcher.

The interview type that has been chosen for data collection is a semi-structured interview (appendix E). This type of format is the most widely used. Semi-structured interview are most of the time organised around a set of predetermined questions with an open-end. Besides these predetermined questions, other spontaneous questions emerge during the conversation between the interviewer and the interviewee (DiCicco-Bloom & Crabtree, 2006).

3.2.2 Stated Preference

Researching the overcoming of the first -and last mile problem with a bike sharing system could be done by doing stated preference research. Stated preference methods refer to techniques which use the statements of individual respondents, which can be useful for research into travel behaviour (Bos, Van Der Heijden, Molin & Timmermans, 2004). With this method, the usefulness and preferences of influencing factors can be investigated and ranked. Respondents can state their preferences, chosen within a set of situations on the setup and use of the bike sharing system.

In this research, the stated preference method is limited to a set of imaginary situations in contrast to the current state of affairs in regard to transport. For section C of the research questionnaire (appendix A), a situation is sketched in which a shared bicycle system is present at a park & ride location on the outskirts of the city. Thereafter, questions are stated about the preference for the travel time, travel price and other personal characteristics. In this situation, respondents select to park the car at the park & ride location and complete the last part of the journey with a shared bike. Afterwards, their preference in regard to the choice for either the shared bike or the car is surveyed for the different situations.

After the surveying of preferences regarding the choice for shared bikes in different situations, there is an option for respondents to give alternative reasons how the personal choice for either the use or the non-use of shared bikes is determined. The survey research also investigates the specified preference on the shared bike and the design and setting of park & ride locations for the potential set up of bike sharing systems.



3.2.3 Data analysis

After the data collection has been finished, the data will be analysed. In this research and the analysis of respondents and correlation, frequency data is used. Frequency data involves the counting of how many people fall into a particular category (Foster, Barkus & Yavorsky, 2006).

The quantitative data will be stored online by making use of Qualtrics. This website collects all the survey answers and is reachable and easily displayed on every electronic device. Thereafter, it is possible to design the look and exterior of the survey with Qualtrics, in order to improve and professionalize the survey.

For the mathematical equations and quantitative data analysis, the SPSS software will be used. After the data is stored online via Qualtrics, the data is entered manually into the SPSS software. SPSS is used to link questions and data, connect subgroups in the population and analyse the collected data to graphically visualise and obtain useful knowledge and results (Muijs, 2010). For the results on individual characteristics, a multiple response analysis is used. This analysis is chosen to give respondents the possibility to enter multiple responses, in order to get a clearer and more valid analysis of the individual characteristics.

This research makes use of the correlation measure, which determines the strength of the linear relationship between two quantitative variables. For the analysis of correlation in SPSS, scale measures are applied. All results of correlation are significant with a probability of exceeding of $<0,001$.

For the analysis of the stated preference situations, descriptive statistics and crosstabs are used in order to determine the view and preference of respondents from different population groups and the dependence of personal characteristics.



3.3 Research validity and reliability

For a correct measurement in quantitative research, the research validity and reliability are important concepts. In the following paragraphs, the validity and the reliability of the research are described.

3.3.1 Interval validity

Validity refers to the question; am I measuring what I want to measure? Validity is about measuring the right factors and not measuring factors that can't be measured quantitatively. A research can have sophisticated results, but still needs to be valid in order to be meaningful (Muijs, 2010). Quantitative research attempts to deal with both 'internal and 'external' generalisations, referring to these as 'internal validity' and 'external validity' respectively (Maxwell, 1992, p. 294).

Internal validity refers to whether a research is influenced by the researcher, and to whether the rules are strictly followed during the research. For the strict following of the rules, it is very important to accurately record which steps have been taken.

The research results need to be related to the researched phenomena and not with other unthought-of factors or influences. Within quantitative research, causality is therefore substantially important. The test must be causal in order to be valid or of use at all (Winter, 2000).

By conducting a literature study on the different relevant theories and concepts, this research tries to be as valid as possible, in order to obtain legit and correct results. Research data and sources are also included and the outline of the survey is added in the appendix (appendix A).

Before the survey, an introduction to the research topic was given. This introduction stated that the questionnaire was about the travel behavior and preferences of travelers with regard to shared bikes, and that the survey was used for the investigation on the impact and potential use of shared bikes. This brief introduction changed the mindset of uninformed respondents and raised the measurement of the right factors.

3.3.2 External validity

The external validity of a research is the extent to which the results can be applied and generalised to other populations (Winter, 2000). The results of the research need to be representative for the entire population, in order to be externally valid (Vennix, 2011).

By using a large amount of scientific sources, the results of this research are drawn upon and linked to universal assumptions. Furthermore, representativeness is reached by using a representative and adequate research population.

The survey was filled in by a total of 149 respondents, both on location and via the online survey option. This group of respondents in general has a number of things in common, namely the access to a driver's license and the fact that they are adults above the age of 18.



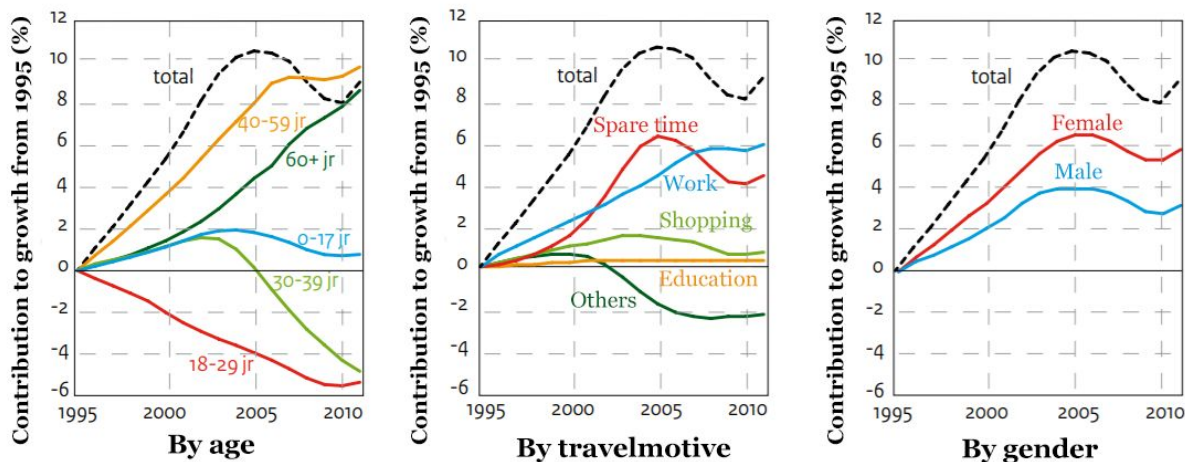


Figure 8 - Contribution of various segments (age, travelmotive, gender) to the development of the car, expressed as a growth percentage compared to the total car use in 1995 (Kennisinstituut voor Mobiliteitsbeleid, 2011).

The most commonly used social variables to explain mobility in urban areas include age, gender, education and household composition (Jonkeren, Wüst & de Haas, 2019). In this research, these commonly used variables are therefore included. The descriptive statistics regarding age, gender, main car use motive, highest level of education and household composition are shown in the pie charts in the figures below.

The analysis regarding age, shows that the largest group of respondents is between the age of 41 and 65 (53%). This amount is in line with the contribution of age to the development of car use from 1996, as shown in figure 8. The age groups between 40-59 years and 60+ are the largest contributors to the growth of car use. Commuting to work among seniors is starting to increase after 2005, especially among men, as a result of measures that encourage longer working hours (Kennisinstituut voor Mobiliteitsbeleid, 2011). The respondents in the age group of 65+ is relatively small, mainly because of the car-commuters are retired from age 65 and up. Thereafter, a major disadvantage of online questionnaires is that perception is still relatively low, and elder people can be excluded due to technophobia (Muijs, 2010).

The age group between 18-29 years is, according to the Kennisinstituut voor Mobiliteitsbeleid (2011), the group that contributes to decline of car use the most. However, this group covers a quarter (26%) of the respondents of this research. One reason could be the increase in the possession of a driver's license, which occurred the most among young people. Other reasons could be the relatively large amount of respondents that are surveyed in the inner city, as young people use the car mostly for social contacts and spare time and leisure activity (Kennisinstituut voor Mobiliteitsbeleid, 2011).

The statistics regarding gender are in the first instance less representative. A total of 68 percent of respondents are male, the others are female. However, according to an investigation on car use and gender in the Netherlands, about 61% of the fathers and 52% of the mothers use the car as their primary transport mode (Schwanen, 2011). Also, given the statistics on persons in possession of a car, stated by the CBS, male car possession is 64% and female car possession is 37% (Centraal Bureau Statistiek, 2017). Considering these numbers, the statistics for this research are representative. Car use is still greater among the



male Dutch population, however there is a change underway. For women, this is partly due to an increase in labor participation, which has led to a shift towards car use. (Kennisinstituut voor Mobiliteitsbeleid, 2017).

The main car use motive among respondents of this research is work, followed by spare time and leisure activities, as shown in figure 13. These motives are also the main contributors to development of the car from 1995, expressed as growth percentage, according to the Kennisinstituut voor Mobiliteitsbeleid (2011). Shopping also contributes towards the development of the car. The motive of shopping is also mentioned by 4 separate respondents.

The highest level of education, university or HBO, is overrepresented among respondents, with a total of 73% of respondents. Possible reasons for this high number include the fact that a high level of education has a positive influence on car ownership and use (Scheiner & Holz-Rau, 2013).

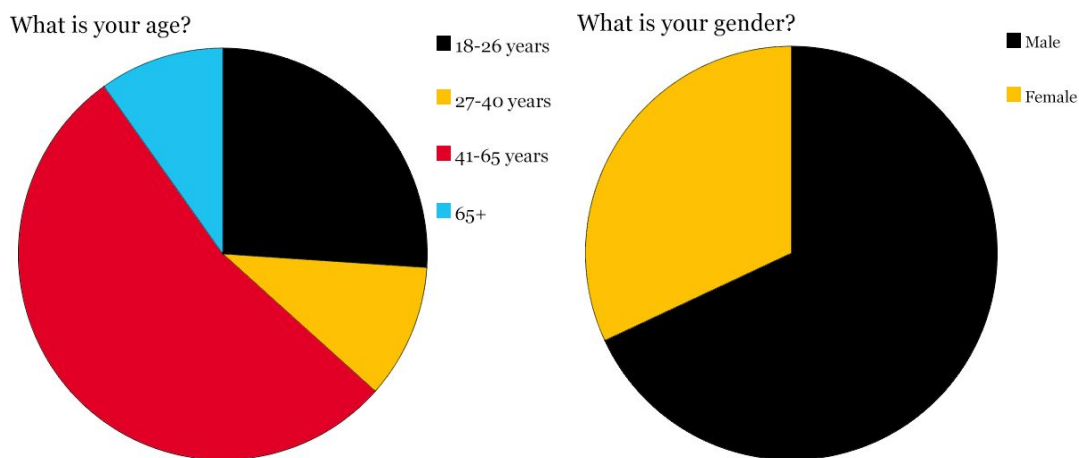


Figure 9 - (left) Pie chart analysis of age among respondents
Figure 10 - (right) Pie chart analysis of gender among respondents

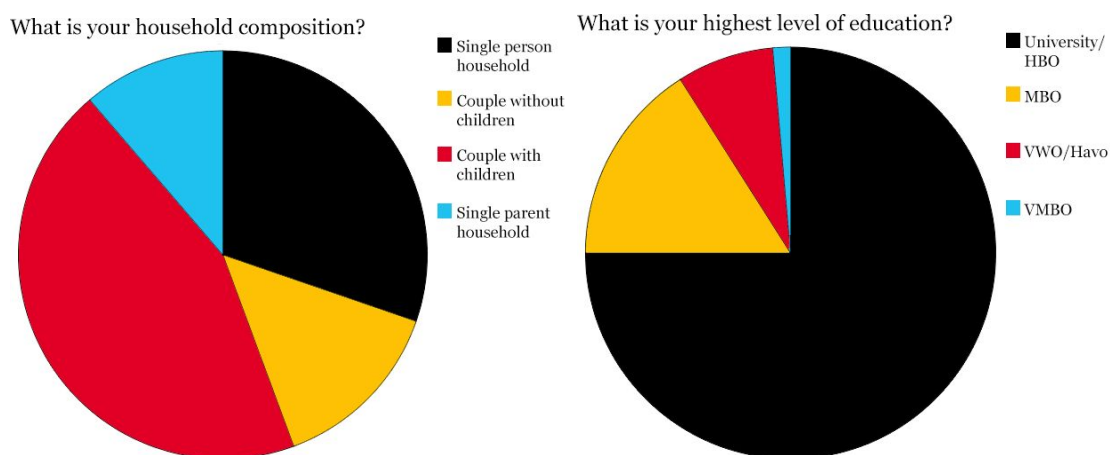


Figure 11 - (left) Pie chart analysis of household composition among respondents
Figure 12 - (right) Pie chart analysis of level of education among respondents



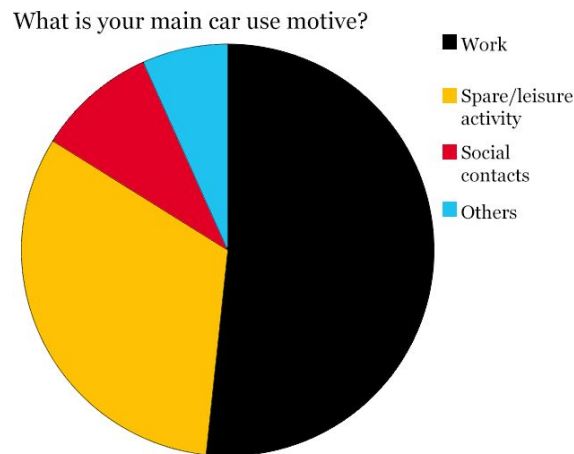


Figure 13 - Pie chart analysis of main car use motives among respondents

3.3.3 Reliability

Reliability can be defined as the extent to which results are consistent over time. A reliable research uses an accurate representation of the total population for the data collection. If the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable (Joppe, 2000, p. 1). In short, the reliability is about the possibility of repetition and redoing the same research (Vennix, 2011).

The research populations response will be obtained in two relevant medium-large cities, and both on location and via online-surveys, in order to gain as much extended response and improve the reliability (McClave et al. 2014).

Thereafter, this research and the different kinds of data collection, including the literature research, an expert interview and the survey, are described as accurate as possible in the methodology chapter of this research. The collected data achieved from the interview and the survey are openly obtainable after approval of the author and the Radboud University. This means that repetition is possible, provided that the different steps and methodology are accurately observed.

Furthermore, to prevent possible errors in the way in which the population is made up, the respondents are surveyed on a variety of relevant parking locations. Also, the data and personal information of respondents is kept anonymous.



4. Research results

The chapter of research results contains the results and analysis of the collected data, with the aim of answering and understanding the research questions. In order to get answers to the first subquestion, in section 4.1, the spatial set up will be described on the basis of the analysis of the survey data and the literature research. Second, in section 4.2, the individual characteristics of respondents will be analysed, as well as the view and preferences on using shared bikes as a smart mobility service, in order to get answers to the second subquestion. Finally, in section 4.3, the spatial effects of a bike sharing system will be addressed following the analysis of the literature research, survey data and the expert interview, thereby answering to the third subquestion.

4.1 Smart mobility applied in the built environment

In order to understand the travel behaviour in and around cities, it is important to first of all focus on the way smart mobility is or should be applied in the built environment. The question that is relevant is how a bike sharing system should be spatially set up to match and complement (smart) travel behaviour. In this part of the results, an answer to this first sub-question is formed. This answer will narrow the scope of this research and describe which spatial features are important towards the use of shared bikes.

Car drivers and car using commuters experience the problem of congested cities, and, in most cases, lack the possibility to continue the car-journey by making use of a shared bike system or alternative transport mode. When alternatives for car travelling aren't available, there won't emerge a change in current car use. To feed back towards a bike sharing system implementation, it is important to focus on the location and spatial set up of a bike sharing system to match with the preferred travel behaviour and to complement and increase smart and sustainable travel behaviour.

4.1.1 Location

A bike sharing system should be located in such a way that travel distance and time will be as short as possible. As stated in the research by Heinen, Van Wee & Maat (2010), distance is an important aspect of a person's choice to either cycle or use other transport modes. Distance, in this statement, is defined as either the distance that commuters have to cover or the distance between the different activities. Distance is a part of the physical infrastructure factor towards bicycle use, and can be influenced by policies and the transformation of the physical infrastructure (Heinen, Van Wee & Maat, 2010).

A shorter distance to work and other activities can be the result of a bicycle-friendly infrastructure that is separated from other infrastructural facilities. Shorter distances will decrease the amount of time and physical exertion that are required for a bicycle trip. Shortening the distance of a travel trip will therefore be a way to promote the use of bikes on this trip, as the physical exertion and time of travel are significant factors towards whether or not to select the bicycle (Heinen, Van Wee & Maat, 2010).



The importance of travel distance can also be explained on the basis of the relationship between city size and the share of transport modes. In the Netherlands, medium-large cities have the highest bicycle share. This share is most presumably a result of the shorter distances of the activities and destinations involved than in large cities (Rietveld and Daniel, 2004).

For the survey, respondents were presented with a scenario in which a shared bike system was available at a parking location on the outskirts of the city. In this scenario, travelers were given the opportunity to choose to park the car at the parking location and complete the last part of their journey with a shared bicycle. This scenario was followed by questions about preferences on travel time, travel price and other characteristics and the influence of these attributes on the choice of travel mode.



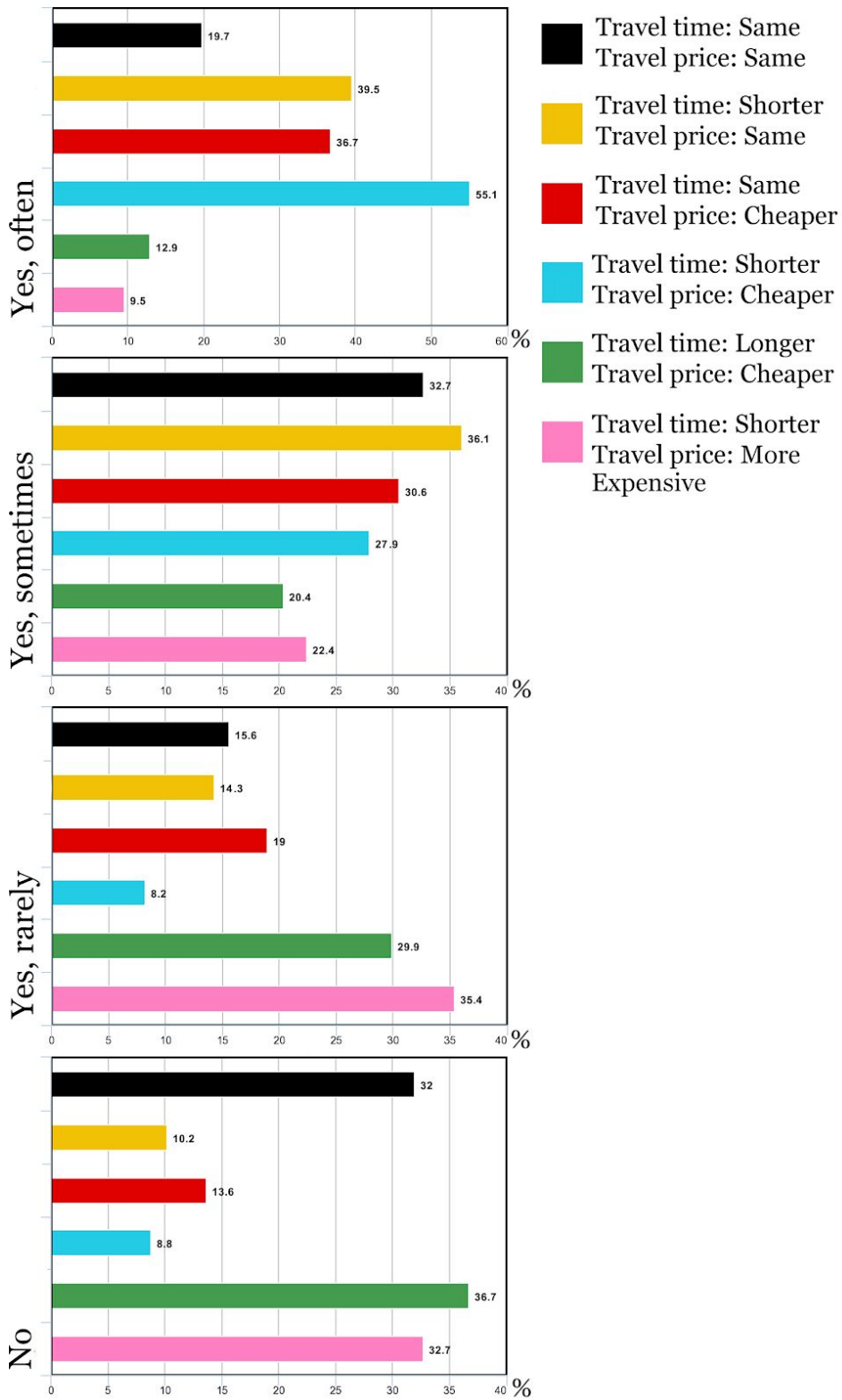


Figure 14 - Shared bike-use preferences regarding travel time and travel price



After establishing a bike sharing system, six possible situations will arise. If a situation is created for travelers in which the travel time and travel price stay the same, more than half of the respondents confirm that they would complete the last part of their journey with a shared bicycle sometimes or even often (figure 14). With *the same*, is meant the existing state of affairs in the situation where the journey is fully completed by car. The figure shows that when either travel time or travel price becomes more advantageous for the traveler, there is an increase in the amount of travelers that indicates that they want to use the shared bikes often, as expected. As explained earlier, distance is an important aspect of a person's choice to either cycle or use other transport modes (Heinen, Van Wee & Maat, 2010).

There is a significant and strong (0.762 out of 1) positive correlation between the respondents that want to use a shared bike if the travel time is shorter and price remains the same and respondents that want to use a shared bike if the travel distance remains the same and price is cheaper than in the car-only state of affairs. This correlation is significant at the 0.01 level. In other words, if a respondent indicates to use shared bikes because of distance benefits, one also indicates to use shared bikes because of price benefits. This correlation therefore indicates that there is a group that can be encouraged to use the shared bike, by whatever advantage the system can deliver.

In a situation where both travel time and travel price become more advantageous for the traveler, shown graphically by the blue bar in figure 14, the travel time will be shorter than the existing state of affairs and the total travel price that a traveler has to pay for the journey will be cheaper. There is a strong incentive for users to travel with shared bikes. In this situation, only 13 (9%) respondents indicated that they still won't use shared bikes as travel mode from the parking location to the end of the journey and vice versa.

In case that one of the attributes of the journey becomes more advantageous, and the other attribute counteracts the traveler, the results are quite similar for both situations. With a longer travel time, but a cheaper travel price, two thirds of the respondents (67%) indicate that they do not want to use shared bikes, or only rarely. With a more expensive travel price, but a shorter travel time, this number remains almost identical (68%). These results show that, for the preferred use of shared bikes and in a situation where only travel time and travel price are estimated to be important, travel time and travel price are just as important. Given the results, at least one of both travel time and travel price needs to be more beneficial for the traveler than in the car-only situation, in order to create a solid demand.

The use of shared bikes can ensure that fewer cars and public buses have to drive, which will lead to less road congestion and therefore improved spatial quality of inner cities. For the biggest switch towards the use of shared bikes, and with that the biggest improvement in congestion and rural spatial quality, the parking locations with available bikes should be located as close to the city center as possible. The distance, and with that also the travel time, will hereby be short.

This conclusion, however, leads to three possible problematic contradictions. In the built environment, for one thing, this means that the location will likely be more expensive. On average, the establishment of a parking location on the edge of cities will be less expensive than within cities. In addition to the establishment, also the supervision and maintenance of the parking location and the bike sharing system.



Second, by settling park & ride locations as close to the city center as possible and reducing travel time, the advantages of the use of bikes will become less effective. Cars have to drive further into the cities, and benefits in terms of less road use, congestion, emissions and accessibility of the inner city will therefore diminish.

Finally, a bike sharing system on a location as close to the city center as possible will result in a situation in which the car will most likely be cheaper to use than the bike. If the distance from the parking location to the city center is reduced, the parking costs and petrol price would differ less with the costs for parking and petrol if one would complete the entire journey by car. The cost of land around the edge of cities is generally cheaper than in the inner city, and with that the parking on a park & ride at these locations.

This last dilemma regarding travel distance can be compared to the influence of transport costs on the sales price as explained by Johann Heinrich von Thünen (Atzema, Lambooy, Rietbergen, & Wever, 2002). Closer to the city center, measured in absolute distance, means higher value and cost of the land (Atzema et al. 2002). If a bike sharing location is further away in terms of distance, more profit is gained in comparison with the car-only situation. The costs for parking and petrol price for the mobility user will be lower there, and the costs for maintaining the park & ride location will lower for the public or private party responsible for the location further away from the center. The profit, or difference in total costs, consisting of the difference in parking costs and petrol price, decreases when distance decreases. Because parking in and driving to the center is more expensive than at the area surrounding it.

Determine the location

By parking the car at a parking location on the edge of the city, there can be a profit achieved concerning the difference in parking costs and a saving of petrol costs. The extra costs consist of the rent of a shared bike. This formula determines the price that shared bikes can cost, and can be calculated for possible locations in medium-large cities.

$$\textit{Profit} = \text{difference in parking costs} + \text{petrol savings} - \text{shared bike rent price}$$

To the question if they would opt for a shared bike if their new parking costs on a park & ride with a shared bicycle system would halve in comparison with their current parking costs, a total of 36 respondents (24%) said yes. If the travel time would be the same or shorter in this situation, the number of respondents that indicated to opt for shared bikes increased to 100 (68%).

For the determination of a location for the shared bikes, a positive coherence exists between profit and distance. By lowering the distance towards the city center, the profit will decline and the environmental and congestion benefits will diminish. Therefore, strategic locations have to be designated, from where people can quickly and safely reach the inner city for reasons other than being close to the inner city already, and by creating an optimal cycling infrastructure.



4.1.2 Spatial design

Spatial design is an important aspect of smart mobility. The way space is designed and filled can help maximize the first- and last-mile connectivity and influences the choices made in a multi-model transportation network (Urban Design Studio, 2016).

The growing number of people that moves to medium-large cities in the Netherlands, together with the overall population growth, leads to a growing number of car users and total mobility (Kennisinstituut voor Mobiliteitsbeleid, 2010). This shift towards more congested and heavier used roads in and around the cities causes a decline of accessibility in cities (Mingardo, 2008). Accessibility is, as said, about the extent to which land-use and transport systems enable the reaching of activities and destinations by means of a (combination of) transport mode(s) (Geurs et al, 2004). It is therefore important to promote travelling that enables reaching activities and ensures the roads to be less crowded and congested, when striving towards a growth of economic activities.

For smart mobility, it is important to keep in mind that cities and the built environment cannot be adapted to all changes that cities generate. To maintain a future-proof environment, flexible adjustments to the living environment must be deployed. The future-proof built environment, including smart mobility, is about adopting towards uncertainty. Thereafter, an attractive placing of multiple transport modes together will be more future-proof than a car oriented planning where the dependency on cars makes a compulsory or voluntary change towards another transport modes harder (Harbers & Snellen, 2016). The future-proof implementation of transport modes within the built environment should lead to more flexibility. People that travel should experience this flexibility in order to attend activities in ways that suits them best, and thereby increasing sustainability goals and a reduction of road congestion (Harbers & Snellen, 2016).

A bike sharing system must therefore be designed to make the shared bikes easily accessible. The location from which you can get the bikes should not form a first barrier in the choice towards smart mobility. This results in the implementation of a mobility hub, in order to connect different mobility modes. In a mobility hub, the bicycle parking should be located near the location where cars are parked, and as visible as possible to the mobility hub users in order to attract and bring attention to everyone (Urban Design Studio, 2016). In terms of the use of space, it is also important to create an area with a high number of shared bikes. Locations with a higher number of bikes are generate more trips and a higher overall use of the bikes. By having a high number of bikes in the first place, there is an increase in the chances for potential users in finding an available bike (El-Assi, Mahmoud & Habib, 2017).

Considering the results of the survey, different attributes of the park & ride location and bike sharing system are more important than others. Figure 15 gives an overview of the view and preferences on the spatial attributes of a park & ride location for the accomodation of a bike sharing system.

The proximity of a bike freeway, as part of the cycling infrastructure, belongs to the physical infrastructure in the overview of factors related to bicycle use by Heinen, Van Wee, & Maat (2010). Despite the obvious advantages that a bike freeway gives in comparison with



a bike lane on a normal road that is shared with other road users, the proximity to a bike freeway isn't a decisively important factor according to the respondents. Although the largest group of respondents (40%) finds this a fairly important factor, there is 42% that thinks location along a bike freeway is not very important or not important at all.

This high number could be explained by the fact that the bike freeway is a relatively new concept, introduced in the Netherlands in 2006. Thereafter, the effect of bicycle freeways on traffic congestion is not yet known. Only after potential positive results in scientific research and media, the general public will probably really start to appreciate the freeways.

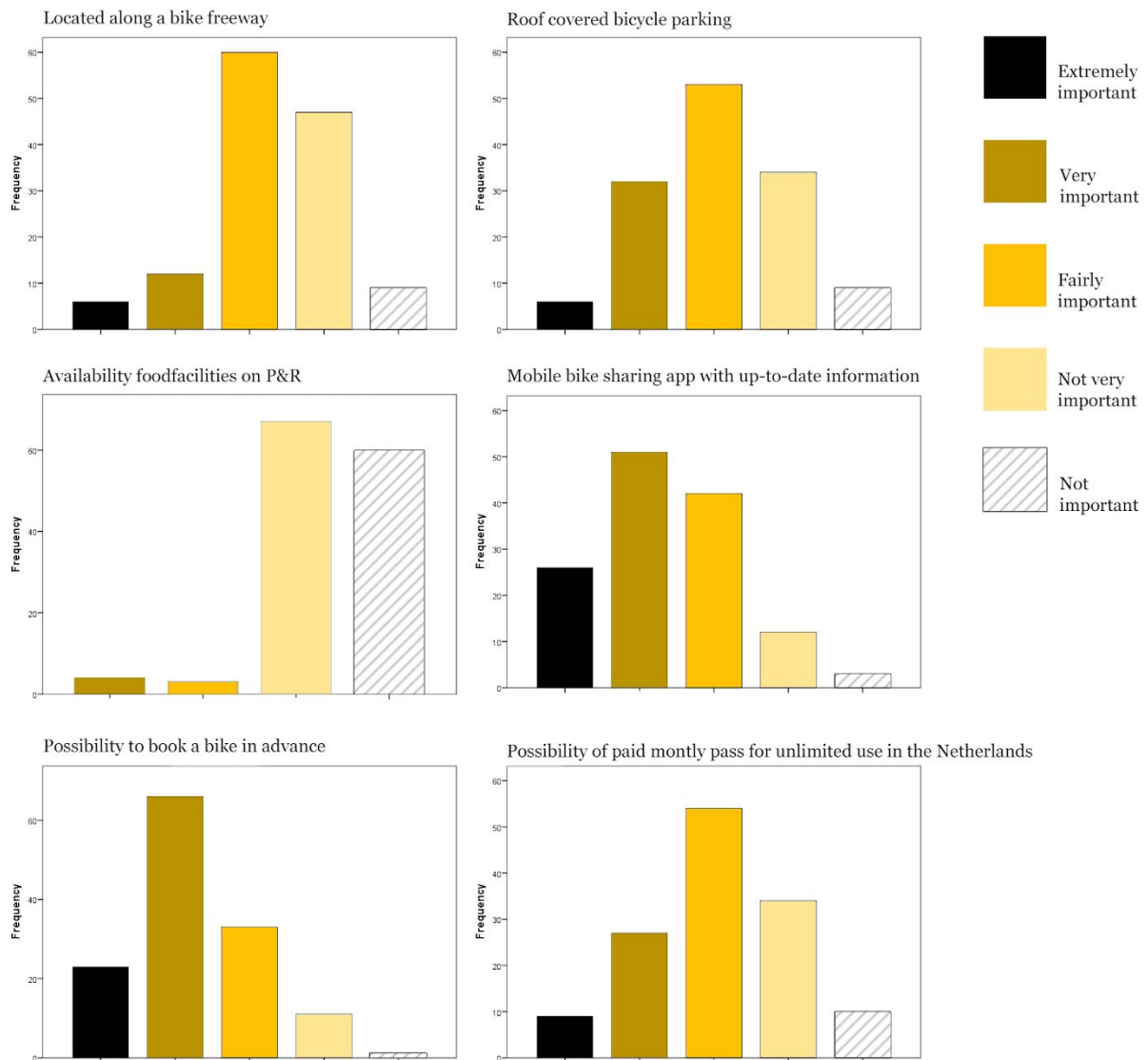


Figure 15 - Frequency with which location and bike-use factors are assessed on a five-point scale

Food facilities and alternative non-transport related facilities can create meeting points for travelers and improve the attractiveness of the parking location. What emerges from the answers is the fact that the mobility hubs do not necessarily have to feature food facilities, as the availability of these facilities has been largely assessed as not or not very important. This result is further clarified by the fact that a lot of respondents that were surveyed at park &



ride locations indicated to be in a hurry. However, a handful of respondents indicated that they used their car mostly for grocery shopping. An attractive hub with food facilities could generate interest and attractiveness. By combining the park & ride location with shared bikes and food facilities or a supermarket, you also affect this group of travelers who no longer have to enter the city center by car for doing groceries.

The interpretation of the space in terms of technology is an important aspect of the spatial design. The most recent technology to unlock shared bikes functions with an automated lock on the bike itself, forcing the bike users to use a smartphone for the entry code via an application (Midgley, 2011). This unlocking system makes sure that users can unlock their bikes without having to include the setup and maintenance of docking stations and electronic bike stands. Regarding the parking infrastructure, the results are in favor of a system without docking stations, like for example the Mobike system currently active in the cities of Rotterdam, Den Haag en Delft. By making use of only electronic bikes, without docking stations, money and space are saved (Haverman, 2019), and 67% of the survey respondents indicated that the possibility to park bikes at every legal parking space is an extremely important or very important aspect of the use of shared bikes. This advantage would not be delivered by making use of location-specific docking stations.

For the spatial design, this means that an on-site WiFi connection would be a major improvement for convenience. The fact that the user is open to the use of technology is confirmed by the answers given to the statement as to whether a mobile app is important. In this case, the mobile app was focused on sharing real time information. As many as 77 respondents (58%) indicated that a mobile bike sharing app is extremely or very important. Also, 89 respondents (66%) indicated that the possibility to book a shared bike in advance is extremely or very important. This function can be added to the technology already available in the newest shared bikes, by incorporating advanced information technologies (IT) for bicycle reservations (Shaheen & Guzman, 2011). To build on the successful development of hi-tech innovations, a public WiFi access should be designated on the shared parking spaces that gives the smart mobility innovations more support and that stimulates the attraction of more users. In addition, by making a public WiFi at the parking spaces, the use of shared bikes as part of Mobility as a Service is fostered. Public WiFi ensures an open access to internet in order to use MaaS and other travel-related applications.

Other factors that have been indicated in the survey include the availability of sanitation, the pairing with a bus system in times of bad weather, an information point for people that are less familiar with technology, safety at the parking location including barriers and clear directions to the center and to where you can and may park the bikes.



4.2 View and preferences on shared bike use

For a new innovation to be implemented and used successfully, it is important to focus on the potential consumers. Smart mobility is about the consumers that are using and traveling with the different transport modes. The new technologies and innovative exchange of information can not be successfully implemented without the approval and understanding of its potential consumers (Haverman, 2019; Papa & Lauwers, 2015).

Besides the understanding of the way in which new systems are supposed to be used, users should also feel that the systems can provide benefits. New innovations, as the implementation of shared bike systems at parking places in and around cities, should tend towards fulfilling an individual interest for the user as well as a societal interest. If these two interests align, a situation exists in which the individual interest equals the societal interest (Haverman, 2019). Consumers can be encouraged to make use of new innovations by giving individual interests such as convenience and low costs. If the innovation also ensures societal interests, for example sustainability improvements and a improved accessibility, this leads towards a higher chance of successful implementation (Haverman, 2019). In this chapter, the potential consumers and their individual interests are described. This is done by investigating the view and preferences on using shared bikes as a smart mobility service in medium-large cities in the Netherlands.

4.2.1 Familiarity

A shared bike system is a new way to travel from one point to another. The use of bikes that work with a variety of technological improvements, like electronic bike locks, smart cards and mobile phone access, only emerged at the beginning of the 21th century (DeMaio, 2009). For the users, an entire new system within a multimodal trip can be overwhelming. There is still a lot of ignorance and a lack of general awareness concerning bike sharing systems in a multimodal trip.

According to this research, almost exactly half of the road users surveyed were unfamiliar with bike sharing systems. This unfamiliarity with shared bike systems in general appears to be true for every age group.

Although this research focuses entirely on medium-large cities as a whole, and not on the differences between the two cities, it is good to mention that there is no statistically significant difference in the familiarity of shared bikes between the two cities

Among male respondents, more than half indicated that they were already familiar with bike sharing systems. What stands out here is the fact that this number was significantly lower among female respondents, of which only a third indicated familiarity. This difference is straightened out again after the question whether people sometimes use the shared bike for a trip to work or the city center. This question was answered with No by 120 respondents (81%), and of the respondents that answered Yes, there were 25 (17%) that indicated using shared bikes only rarely. Among male respondents, 78 (80%) answered No and 19 (19%) indicated Yes, but rarely. Among female respondents, 37 (80%) answered No and 6 (13%) indicated Yes, rarely.



The findings above indicate a current state in which there is still a lot of unfamiliarity with shared bikes, both among male and female respondents. Besides that, the vast majority of road users surveyed said they never used shared bikes for a trip to work or the inner city or only very rarely.

The will and ability to travel with a different transport mode is reflected in the answer to the question whether respondents sometimes use public transport to work or the city center. Only a third never travels by public transport, and a quarter of the respondents makes use of the public transport often. Besides the data from the survey, this result has also been observed at park & ride locations where respondents make use of bus trips regularly, for example at the P&R Noord at Nijmegen Lent. In a certain sense, people are therefore prepared to switch to public transport on a large scale, whether this shift takes place occasionally or often. There is still much to be gained here, because the shared bikes can ensure that fewer buses have to drive, which will lead to less road congestion and therefore improved spatial quality of inner cities.

The results also display the impact of the reimbursement of car use. The reimbursement of car use negatively correlates with the use of public transport modes. This correlation is significant at the 0.01 level. The more a traveler is reimbursed in terms of travel costs and parking costs, the less a traveler makes use of public transport. This indicates the comfort of reimbursement and the needlessness of multimodal transport if reimbursement is obtained. The reimbursement of car use, in addition, positively correlates with the will to use shared bikes if travel time is shorter and travel price is more expensive. This correlation is also significant at the 0.01 level. Because of accustomation to reimbursement, comfort is in all probability more important to this group than price.

4.2.2 Individual characteristics

In the previous chapter on the location of a shared bike system within the built environment, the importance of travel time and travel price was described. Although both aspects of the trip do not differ much in terms of importance, both travel time and travel price have shown to be incentives that can theoretically cause road users to make a shift towards shared bikes. According to the overview of factors related to bicycle use, by Heinen, Van Wee & Maat (2010), the additional policy-influenced factor that may affect bicycle use is the factor of individual characteristics.

For the results on individual characteristics, a multiple response analysis is used. First, the group of respondents that feels the least positive about the use of shared bikes is analysed. This group has most often indicated that they did not want to use the bicycles under certain conditions regarding travel time and price. In the analysis on individual characteristics, personal and physical reasons are important factors against shared bike-use among respondents. A total of 22 respondents (15% of cases) has personal or physical reasons against the use of shared bikes. Users traveling with a heavy workload or suitcases indicate that using a bike isn't possible or at least not encouraging. There is in addition also a group of users that won't use the shared bikes because of physical complaints and or old age.



This group of users shouldn't be included in the group of potential shared bike users, as there always will be a group of travelers that will ignore the use of bikes because of these physical reasons.

Non policy-influenced factors regarding the weather are, as seen in figure 16, noteworthy or significant. Bad weather and cycling in the dark negatively related with bike use. Although these factors are part of non policy-influenced factors, actively promoting the use of shared bikes, for example by employers, can take away barriers and ensure more bike-use (Heinen, Van Wee & Maat, 2010).

Other reasons against the use of shared bikes that were mentioned, included the preference for walking instead of biking and the preference for buses, which goes hand in hand with the influences of bad weather and darkness.

	N	Percent
Personal or physical reasons	22	12,6
Don't feel like cycling due to bad weather	28	16,1
Don't feel like cycling in the dark	6	3,4
Other reasons	18	10,3
Not applicable	100	57,5
Total	174	100

Figure 16 - Frequency of factors against bike-use other than travel time and travel price

Factors that are analysed in favor of using shared bikes, besides the possible incentives regarding travel time and travel price, have been investigated as well. Figure 17 shows the frequency of factors for bike-use other than travel time and travel price mentioned in the survey. The results display the importance of exercise, environmental reasons, parking difficulty and the congestion in city centers. All four factors in favor of using shared bikes instead of the car are indicated by at least 55 respondents (38% of cases). These numbers match with the expected influence of these factors considering this research problem statement. The input among *other reasons* shows factors as; you see more of the city on your bike, cycling creates a sustainability image and cycling is fun.



	N	Percent
Nice to exercise	55	20,2
Environmental reasons	62	22,8
Difficulty with parking in the city	56	20,6
Crowded city centers	66	24,3
Other reasons	15	5,5
Not applicable	18	6,6
Total	272	100

Figure 17 - Frequency of factors for bike-use other than travel time and travel price

Besides the way in which location and bike-use factors are assessed, the results also display an assessment of the characteristics of a shared bike. For the view and preferences on using shared bikes as a smart mobility service, the characteristics of the bike itself can be influential as well. Figure 18 gives an overview of the assessment of the characteristics of shared bikes.

According to the literature, a location with a high number of shared bikes generates more trips and a higher overall use of the bikes than a location with a limited number of shared bikes. By having a high number of bikes in the first place, there is an increase in the chances for potential users in finding an available bike (El-Assi, Mahmoud & Habib, 2017). This knowledge matches the importance of the high number of available shared bikes according to the results. A total of 46 respondents (34%) indicates that this factor is extremely important, and 49 respondents (37%) indicates that this factor is very important. Only 2 respondents feel this factor is not very important.



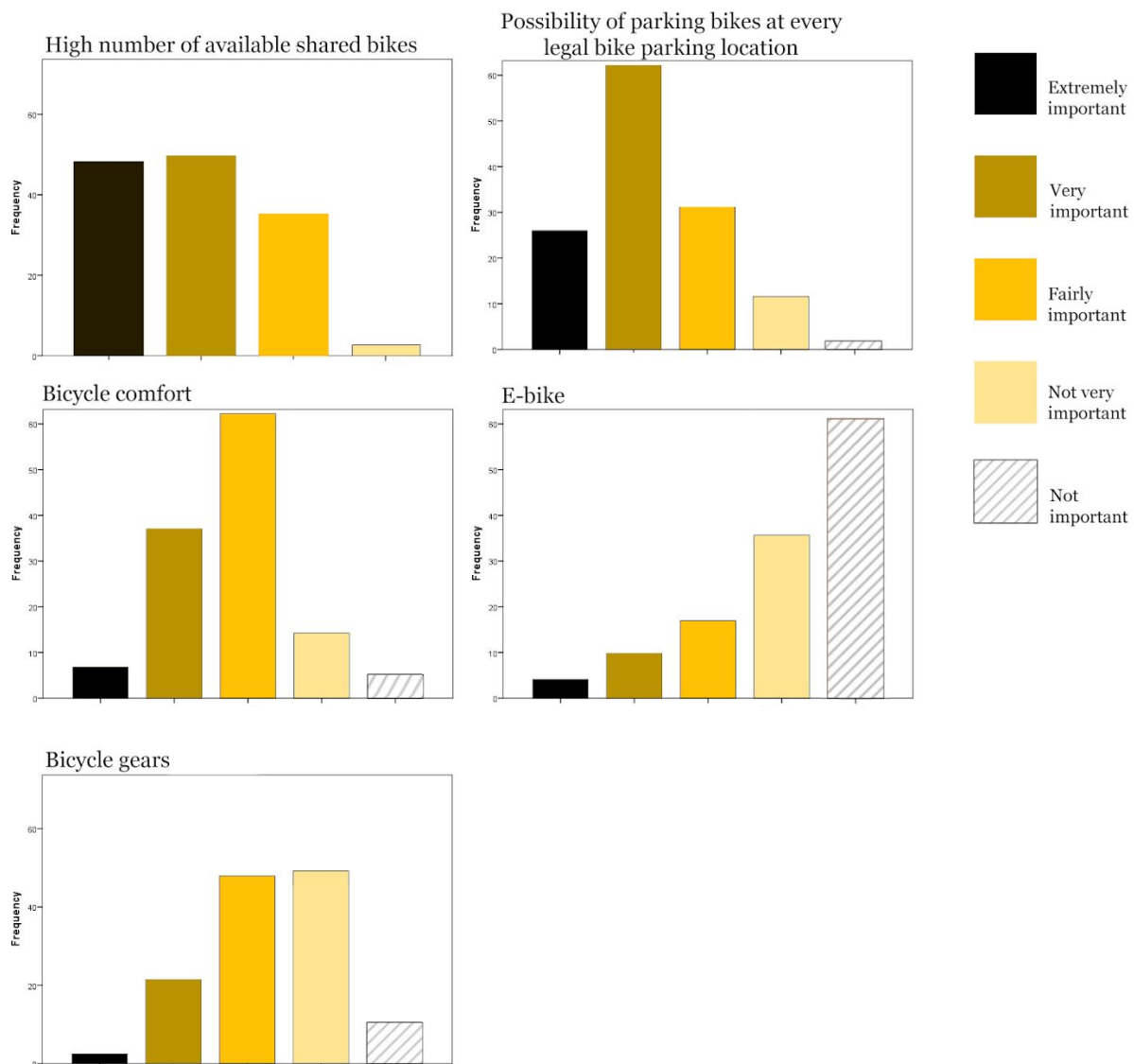


Figure 18 - Frequency with which bicycle factors are assessed on a five-point scale

The next factor is about the possibility of parking bikes at every legal bike parking location. This is the manner in which the Mobike principle is already operating in the Dutch cities of Rotterdam, Den Haag and Delft. Instead of different docks that are located throughout the city, users can park their bike at every legal bike parking location within an electronically displayed area in and around the city (Haverman, 2019). Two thirds of the respondents (67%) feels that this possibility is an extremely or very important factor. The advantage of commuting by bike for this system is the fact that the users will use bikes from the parking location to the office, and return to the same parking location later to hand in the bikes again. This first- and last-mile trip will ensure that there isn't much work needed for returning and re-dividing of bikes along the city because the use of bikes will be regular and from and to the same location on a daily basis. The results may also indicate that commuting respondents appreciate the value of parking at every location in a city, and therefore using the bikes for shorter trips during office hours.

A comparison between the results on bicycle factors and the main reason for car use among respondents revealed that people whose main reason for car use is maintaining social



contact all appreciate the value of parking at every location in a city. For this group of respondents, whose destination might often change, docking stations that are fixed in terms of space may be restrictive.

The results of the technical characteristics of bikes reveal that those factors are less important. The E-bike is part of the new innovations that are developed within the fourth generation of bike sharing systems. The introduction of E-bikes is likely to be the most significant in terms of attractiveness, as it costs less effort and one can cover further distances in the same time (Midgley, 2011). However, the results display that 77% of the respondents rate E-bikes as not very important or not important. This result positively correlates with the factor *Nice to exercise*, because many of the respondents that like to exercise rate the E-bike less positively.

The factors of bike gears and bicycle comfort are rated rather neutral, with few very positive or very negative respondents. Bike comfort is a requirement that is expected.

Other factors that have been indicated in the survey include the availability of a repairstation, adjustable saddle height, close to the bus for an easy switch to other transport modes, a 24/7 possibility to hand in shared bikes and enough space to hand in and store bikes.

4.2.3 Bike sharing within a sharing economy

The previous paragraphs have been a description of the view and preferences on bike sharing and the most important aspects of the parking location and the shared bikes itself. In this paragraph, the results are displayed that suggest the position of the bike sharing concept within a sharing economy.

In most cases, working employees receive a salary from the employers that they work for. Besides the salary, other ways of payout are possible. In addition to the salary, employees can namely receive fringe benefits, also defined as emoluments. The difference between fringe benefits, or emoluments, and the salary payout is the difference in payment form. Emoluments can be paid out in kind, in forms of payment with goods or service (Barry & Caron, 2015).

One major example of an emolument in the field of mobility is the reimbursement of car use. In the paragraph on familiarity, it was already described that the reimbursement of car use in terms of travel costs and parking costs negatively correlates with the use of public transport modes. There was also a significant and positive correlation between the respondents that are reimbursed and respondents that want to use a shared bike if the travel time is shorter but price is more expensive. The benefit of reimbursement, handed out by employers, ensures that comfort is more important to this group than price.

Thereafter, respondents that indicate to use shared bikes if their new parking costs on a park & ride would halve in comparison with their current parking costs positively correlate with the use of shared bikes if travel time is shorter. This correlation is significant at the 0.01 level. This is the case for all situations with shorter travel times, indicating that travelers with halved parking costs in comparison with the current situation would still be more inclined to use shared bikes sometimes or often than people with no parking costs at all. This correlation emphasizes the fact that the benefit of reimbursement ensures that comfort is more



important to this group than price, and that reimbursement negatively correlates with the use of shared bikes.

In other words, to promote bike sharing and the benefits that it incites for the environment and the liveability of urban areas, a worthy alternative must be provided to the reimbursement of travel costs and parking costs. In a situation where employers give the costs for the use of shared bikes as an emolument to their employees, the use of bike sharing is actively offered at the work floor. A less fierce transition for the employers could be a changing arrangement in which employees can change their emolument from a shared bike subscription to a reimbursement of car use per specified time.

The results display that 88% of the respondents that use the car mostly for work don't use the shared bike to get to the office or the inner city. In a situation in which the car is parked at a park & ride and the last mile is travelled by bike without a change in travel time and travel price with the current situation, the results show that 60% of the commuting respondents is considering biking rarely, sometimes or often. In the position of bike sharing within a sharing economy, there is therefore a major role for employers.



4.3 Spatial effects of a bike sharing system

After the analysis of the results of the spatial set up of bike sharing systems and the view and preferences on the use of shared bikes, the spatial effects of a bike sharing system will be analysed. For a useful answer to the main question, it is important to describe the way in which a bike sharing system could affect the increasingly crowded medium-large cities in terms of space.

Every single mobility user that switches from a car to a shared bike for entering and leaving the inner city, contributes to spatial effects and the improvement of accessibility, air quality and parking pressure of the city.

Thereafter, bike sharing systems itself have various spatial consequences for the city and the surroundings. For the implementation of a shared bicycle system, provisions must be made and facilities have to be constructed that influence the space that is available in the city and the spatial quality of a place. Shared bike use also brings about a change in mobility behavior and modal split, which indirectly impacts the way in which urban space is filled in. This section of the research results focuses on the spatial effects of a bike sharing system.

4.3.1 Accommodation of shared bikes

The spatial effects of bike sharing systems begin with the accommodation of shared bikes, concerning the collection- and delivery-locations of the shared bikes and the underlying network in which it functions. The way in which the accommodation is arranged has an impact on the use of space.

For all types of bikes, the same amount of space is required for parking. The difference in required parking space is caused by the way the bike sharing system is set up. In terms of necessary space and spatial quality, traditional docking stations for shared bikes are not desirable. For a bike docking station, the required space for parking grows. Thereafter, the construction of docking stations can cause significant problems in historic and overbuilt cities in the Netherlands. The space for a docking station cannot be filled in for other purposes. To create a network, shared bicycle stations must be fitted into existing urban areas where there is hardly any space. Also, the practical necessities of laying cables, digging, the connection to electronic networks and applying for construction permits are costly and work against the implementation of docking stations.

The technology makes it nowadays possible to set up bike sharing systems without the use of docking stations. The technology for renting the bike is built in the bike itself, instead of in the docking station. This technological implementation includes electronically displayed parking-zones, or operation zones, in which the bike can be parked (Haverman, 2019). This way, the parking infrastructure is set up online, rather than on actual space, as with free-floating bike sharing. However, systems without docking stations still involve various spatial challenges (Pal & Zhang, 2017). Free-floating bike sharing ensures that less space is needed for the accommodation of shared bikes, by avoiding the construction of docking stations.

What is often the case for the implementation and accommodation of a bike sharing system on a park & ride location, is the set up of a separate system. On a park & ride location,



next to the car parking, a handful of bicycles or bicycle lockers are placed. These bikes are shared within a micro-system, in which travelers can use the bikes and subsequently return them in the evening after work or after a day out in the city (Haverman, 2019). This micro-system is quite expensive. The operating costs for a bike sharing system include maintenance, staff, distribution, insurance, office space, website hosting and maintenance, construction costs, storage facilities and the docking station electricity charges, among other things (Midgley, 2011, p. 12).

However, if an already existing sharing system is in operation, the addition of the shared bikes on park & ride locations can be a more flexible and less costly practice. The addition of the shared bikes on park & ride locations can be added to the extension of the existing system, and will mainly consist of adding extra supply. This can be done by adding the park & ride locations in a system that is already linked to multiple societal goals, for example, the campus, hospitals, train stations, hotels and museums. This gives the bike sharing system more volume and a higher chance of succeeding. This way, a more integral approach is used in which multiple facets and reasons behind the use of shared bikes are combined. This is mainly the cause if the park & ride locations are added within a free-floating bike sharing system without docking stations (Haverman, 2019).

Thereafter, free-floating bike sharing gives the opportunity to park directly at the final destination, instead of at the closest docking station. Free-floating systems allow the hiring and returning of bikes very close to the demanded destination, without being forced to pass by a docking station before or after the ride (Caggiani, Camporeale & Ottomanelli, 2017). This ensures more flexibility and in a way ensures less road use by the shared bikes because of this flexibility.

However, because of potential nuisance, the system needs to be regulated and controlled strictly. The free-floating system can be regulated by applying virtual docks, which indicate a parking location or zone without the use of physical and expensive docking stations. The virtual docks can help lower parking problems, but in potential there are newer technologies that have to be looked forward to (Haverman, 2019).

Regarding the accommodation of shared bikes at workplaces, this application can ensure a shift towards bicycle use. The provision of bike parking at workplaces may lead to a modal shift from car use to bike use (Wardman, Tight & Page, 2007). So not only can employers play a role in the encouragement of shared bike use by implementing a change in policy, as described in section 4.2.3 of the results, employers can also influence bike use by setting up or improving the bike parking accommodation at the workplace.

4.3.2 Spatial effects of bicycle parking

In the Netherlands, major challenges are going on in terms of parking capacity. There is less and less space for parking, and the available parking spaces with paid parking have been expanded by at least 10 percent (Harms et al. 2016).

At train stations, the OV-fiets bikes are advanced in terms of space in comparison with standard owned bikes. Some people still use bikes in more than one city, instead of shared bikes. These bikes occupy a significant part of the bicycle parking capacity of the stations and sometimes even the surrounding area. The second bike of a commuter at a



station is parked for approximately 3,5 days, while shared bikes are much more flexible and used in a quick paced manner (Haverman, 2019). With the use of shared bikes at park & ride locations surrounding cities, the space in cities is even less occupied. After using the bikes, they are even stalled outside the city on these locations. As the results of the survey display, the largest part of respondents uses the car for work related motives. This group will return at the park & ride location daily, needing no space in the inner city for the rest of the day and in the weekends.

The first section of the results on travel time and travel price showed a general openness to the use of shared bikes from park & ride locations. The shift from parking cars towards the parking of bikes in the city center generates spatial effects. First of all, the land requirements for automobile parking in square metres is approximately 30 times as large as for bike parking (Replogle & Purcells, 1992). Thereafter, a shift towards shared bikes instead of cars will generate a profit in operating costs per space. The operating costs per space for automobile parking are approximately 3 times as costly in comparison with the operating costs for bike parking (Replogle & Purcells, 1992).

Besides the shift from automobile parking to bike parking, a section of the parking space can be scaled back. In medium-large cities in the Netherlands, where space is becoming increasingly scarce, this can provide major benefits. The scaled back areas can be replaced by green space for play, social interaction and an increase and improvement of the urban green space. Furthermore, less parking of cars in the city center reduces the heat island effects and the pollution of water from oil-contamination into the nearby urban streams and rivers. A final spatial effect of less car parking is a reduction in the amount of impervious surface. Less impervious surface means in addition a recharge of groundwater (Cervero & Sullivan, 2011).

Parking space in city centers can be scaled back to free up space for urban green purposes and to relieve the parking pressure in the center, and thereby compensating with the construction of parking locations at areas surrounding the city.



Spatial effect analysis in a practical example for Breda

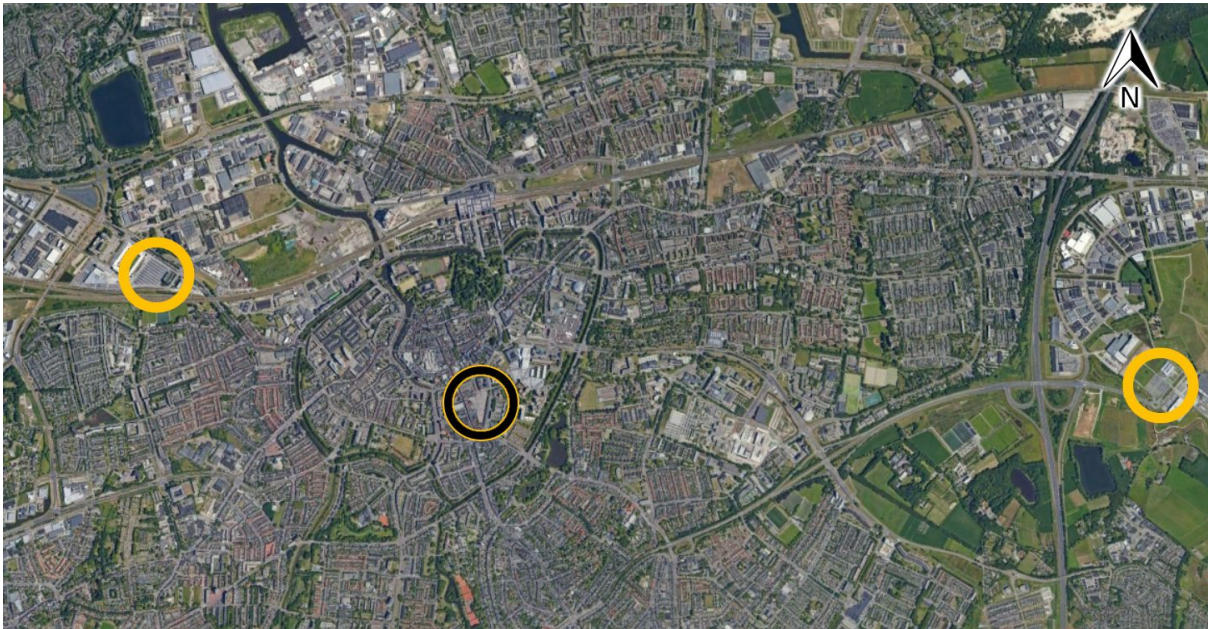


Image 1 - Parking locations Breda (P5 left, Mols Parking centre, Breepark right)

For the determination of this analysis, observations have been performed on the size of the location and the connection to the highway. For Breda, the parking location P5 and the newly constructed parking location of Breepark are both locations outside the city center (image 1). These locations can be complemented with a bike sharing system for the possibility of frequent commuting. A direct spatial effect could be the redesigning of the Mols Parking location, in the city center, filled in with urban green space.

Given the results in section 4.1.1 on location, it can be analyzed whether a profitable system can be set up. The following is an analysis on travel time and travel price in a practical example for Breda.

The travel time and price need to be at least equal to the travel time and price of a car-only situation and there needs to be a connection to existing locations. The parking space of Breepark, located along the national highway A27, currently has free parking facilities. The travel time by bike from Breepark to Mols Parking in the city center is 16 minutes (Google, 2019 a), which means a round trip travel time of 32 minutes. It should be mentioned here that with a free-floating system a biker can directly travel to their destination and save time. The parking space of Mols Parking currently has a hourly parking tariff of €2,-. The travel time by car from the A27 highway exit by Breepark to Mols Parking is 10 minutes (Google, 2019 b), which means a round trip travel time of 20 minutes.

The results display that a bike sharing system in this situation can be advantageous in terms of costs of travel, even without calculating the difference in petrol use, if a shared bike can be rented for less than €2,- per hour. In terms of travel time, the car-only user will save 12 minutes in total. However, this amount will be lower if a free-floating system is in use in which the shared bike user will save time by directly parking at the final destination(s).



Spatial effect analysis in a practical example for Nijmegen

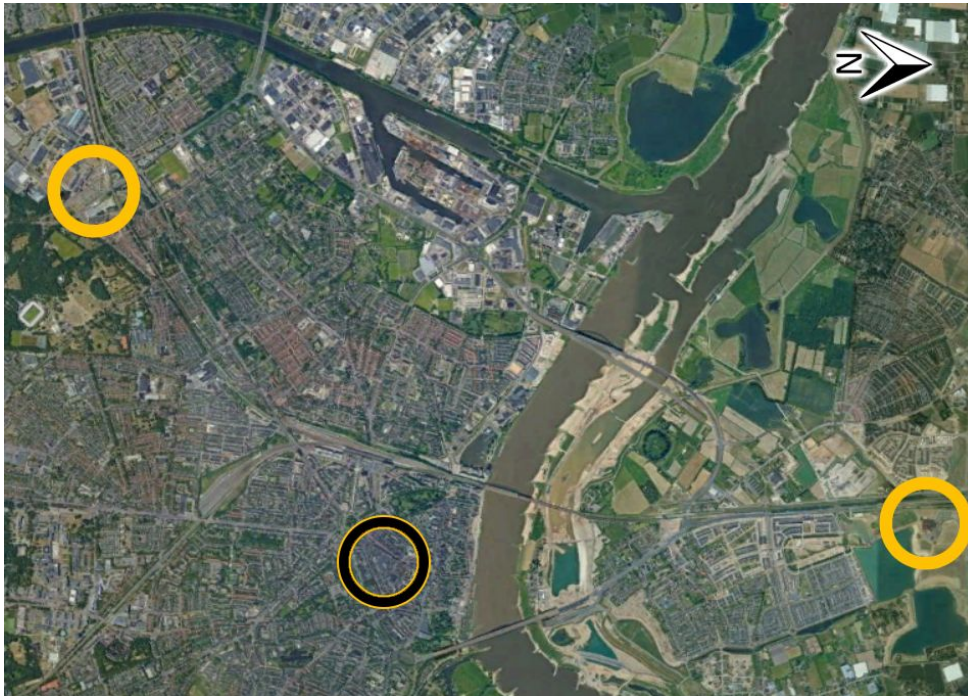


Image 2 - Parking locations Nijmegen (Dukenburg left, Molenpoort centre, P&R Noord Lent right)

For Nijmegen, the parking location Dukenburg and the parking location of P&R Noord Lent can be complemented with a bike sharing system for the possibility of frequent commuting (image 2). A potential spatial effect could be the redesigning of the upper part of the Molenpoort location, in the city center, filled in with urban green space on top of the parking roof. Given the results in section 4.1.1 on location, it can be analyzed whether a profitable system can be set up. The following is an analysis on travel time and travel price in a practical example for Nijmegen.

The parking space of P&R Noord Lent, located along the provincial highway N325, currently has a daily parking facility tariff of €3,50. It is possible to lower the costs by purchasing a monthly parking subscription. The travel time by bike from P&R Noord Lent to Molenpoort parking in the city center is 20 minutes (Google, 2019 c), which means a round trip travel time of 40 minutes. It should be mentioned here that with a free-floating system a biker can directly travel to their destination and save time. The parking space of Molenpoort currently has a hourly parking tariff of €2,50. The travel time by car from the N325 highway exit by P&R Noord Lent to Molenpoort is 16 minutes (Google, 2019 d), which means a round trip travel time of 32 minutes.

The results display that a bike sharing system in this situation in Nijmegen can be advantageous in terms of costs of travel, even without calculating the difference in petrol use, if a shared bike can be rented for less than approximately €2,50 per hour. In terms of travel time, the car-only user will save 8 minutes in total for the first- and last-mile trip to the city center. However, this amount will be lower if a free-floating system is in use in which the shared bike user will save time by directly parking at the final destination(s).



4.3.3 Shift in modal split

If car use decreases, this ensures that more space is created for other ways of space occupancy . This can have positive effects on the spatial quality and the experience value of a place. A shift in modal split towards the use of shared bikes influences the reduction of road use and an improvement of accessibility. Table 1 displays additional benefits of this development (Victoria Transport Policy Institute, 2014).

Shift in modal split benefit	Description
Reduced congestion	Bike use reduces congestion and traffic delays, because of a reduced road use. Associated costs are therefore also lowered
Environmental protection	There is a reduction in the pollution of air, water and noise. Also a reduction of wildlife crashes and environment damage
Health and physical fitness	By an increased amount of daily biking, and an overall growth of the physical activity, benefits for health and physical fitness are generated

Table 1 - Shift in modal split benefits (Victoria Transport Policy Institute, 2014)

Besides the reduction of car use, the shift towards shared bikes for the first- and last-mile can also ensure that there is a reduction of inner city bus and tram use. In the Netherlands, the bike is already a frequently selected option. For car-commuters and people that visit inner cities by car that park at the park & ride locations, the remainder of the trips can be covered by bike if the shared bike system was chosen. Thereafter, a bus is very expensive in production, maintenance and taxation (Haverman, 2019).

For Breda, the shift towards bike use has already had spatial effects, which can be seen spatially in the transformation of the Boschstraat in the city center into a bicycle-priority street and the broadening and renewal of the bicycle lanes through the Ginnekenweg, which give the bicycle more space and safety. With a further shift in modal split for the first- and last-mile, additional investments in the infrastructure can be made. Infrastructure investments can directly affect the accessibility and attractiveness of bicycle use (Wegener & Fürst, 1999).

4.3.4 Bike use and placelessness

Although the effects of the feeling of being connected with certain places are not entirely related to spatial effects, they can influence the way in which a space is used and experienced.

The argument of enjoying biking and experience the nature and the environment of cities is mentioned in the results of this survey research, accompanied by the reason that exercising is nice. The choice for a transport mode also creates placelessness, which refers to the declining feeling of belonging and identification with a certain place. Cresswell (2015)



also refers to this decline as the end of place. The location where someone is going is less important than the act and style of going (Cresswell, 2015, p. 76). By using the shared bike to get in a city, travelers connect with the surrounding landscape and experience the location. In a speeded-up world, the use of bikes instead of cars or public transport may counteract placelessness and lets travelers experience the places in-between their starting and final destination (Cresswell, 2015). By the experience of a sense of place, a place will also transform into a meaningful location that people can be attached to in one way or another (Agnew, 1987).

Finally, the environmental bike use motives and the sustainability appearance of biking also strengthen the sense of belonging. Travelers with these motives are actively choosing to improve the situation for the space around them, instead of polluting by car use.



5. Conclusion

The purpose of this research was to analyse and gain knowledge on the potential use and effects of shared bikes and to answer the main question; *How should a bike sharing system, for a first- and last mile use, be set up to meet the potential demand, and what could be the spatial effects for medium-large cities in the Netherlands?*

This research first looked at the location and spatial set up of a bike sharing system. The implementation needs to match with the preferred travel behaviour and increase the potential for smart and sustainable travel behaviour.

With the use of a research questionnaire, the preference of travelers on travel time and travel price is surveyed. The respondents involved were presented with different scenarios in which a bike sharing system was present at a parking location on the outskirts of the city, followed by questions about the willingness to use shared bikes. With this survey, the influence of different attributes on the choice of travel mode is measured. Research has shown that in a situation where travel time or travel price becomes more advantageous, the amount of travelers that indicates that they want to use the shared bikes often increases. If both time and price become more advantageous, this group of travelers grows considerably. To create a thriving bike sharing system, it is therefore necessary to try to reduce both time and price compared to car traffic.

The significant positive correlation between respondents that want to use shared bikes if travel time is shorter and price remains the same and respondents that want to use shared bikes if travel time remains the same and price is cheaper shows that there is a group that will use the shared bikes if an advantage is given.

Travel time and travel price are strong factors regarding shared bike use, as only 13 (9%) respondents won't consider shared bikes if both time and price decrease in comparison with the current state of affairs. Furthermore, research has shown that at least one of both travel time and travel price needs to be advantageous for travelers, in order to create a solid demand. The formula that arises for the potential price of shared bikes is; $Profit = \text{difference in parking costs} + \text{petrol savings} - \text{shared bike rent price}$.

The most important findings of this research regarding spatial design are that the technology and system design is in the first instance more important than the overall spatial design of park & ride locations in the form of mobility hubs. Furthermore, it can be concluded that there is an overall openness to technology and the use of mobile apps and technology inside bikes to further improve the use of the shared bike system. These factors were rated as important among the surveyed population.

Research on the view and preferences has shown that a current state exists in which there is still much unfamiliarity with shared bikes. This is true for male and female respondents in medium-large cities. Thereafter, the vast majority of car-users said they never used a shared bike for a trip to work or the inner city or only very rarely. Car-users are, however, prepared to switch to public transport on a large scale, which shows the willingness to make use of a multimodal transport trip. This was shown by both the survey data and personal observations.

What is further proved is the impact of reimbursement of car use. The more a traveler



is reimbursed in terms of travel costs and parking costs, the less a traveler makes use of public transport. This indicates the comfort of reimbursement and the needlessness of multimodal transport if reimbursement is obtained.

Aspects of the shared bikes that are notable are first of all a high amount of available bikes and the possibility to park bikes at every possible location, like in a free-floating system for example.

The spatial effects of a bike sharing system have been researched. For the implementation and accommodation of a bike sharing system on a park & ride location, a set up of a separate system is costly and is accompanied by a lot of costs for a single micro-system. By appending the park & ride spots to an existing system of shared bikes that serves multiple societal goals, the operation can be a more flexible and less costly practice. Thereafter, more volume and a higher chance of succeeding are established.

The direct spatial effects include a reduction of congestion, improved health and physical fitness and a positive influence on the urban accessibility, thereby impacting the land use and spatial quality.

Finally, the factor of enjoying biking and experience the nature and the environment of cities is shown to be mentioned in the results of the survey. Biking instead of car-use improves the sense of place in increasingly crowded medium-large cities and strengthens a sense of belonging because of the motives on sustainability.



6. Recommendations

The results and research conclusions of this research have provided new knowledge in the field of shared bike systems. This section of the thesis will describe recommendations for policy and practice, in which an analysis is made on what needs to be done in order for a bike sharing system to be successful. Finally, recommendations for further investigations into this topic are put together in section 6.2.

6.1 Recommendation for policy and practice

In this section, recommendations for future policy and practice are made which correspond to the research.

- Municipalities are recommended to investigate the possibilities of **offering a bike sharing system** at park & ride locations surrounding the city. This is interesting for both the municipality and the travelers. The implementation of shared bike systems at parking places in and around cities should always tend towards fulfilling the individual interest of the traveler as well as a societal interest for society and the municipality. If these two interests align, a situation exists in which the individual interest equals the societal interest (Haverman, 2019). On the one hand, it increases the freedom of choice for travelers, on the other hand it decreases congestion, road-use in the city center and it potentially offers the possibility of replanning urban parking space into urban green spaces, which is interesting for both the municipality as well as for the travelers. For the municipality, it is recommended to use this overview of conditions that are derived from the research results;
 - Travel time for users should preferably be shorter, partly through adequate infrastructure and the time saving of a free-floating system
 - Travel costs for users should preferably be lower, due to the possibility of lower parking costs and a saving on petrol price
 - Create a mobile app with up-to-date information, as most respondents (58%) indicated that a mobile bike sharing app is extremely or very important
 - Ensure a large possible quantity of bikes and the possibility to park shared bicycle at any legal bicycle parking place, as the results show the importance of these aspects for travelers
 - The research results display a current state in which there is still much unfamiliarity with shared bikes. Promotion and small scale or temporary offers for users are needed to increase familiarity



- There is a serious **responsibility for employers** in workplaces where commuters are employed. Instead of only granting a reimbursement for parking costs or a reimbursement per kilometer, employers should encourage bike sharing by granting shared bike subscriptions as an emolument. In other words, to promote bike sharing and the benefits that it incites for the environment and the liveability of urban areas, a worthy alternative must be provided to the reimbursement of car-use. If employers give the costs for the use of shared bikes as an emolument to their employees, the use of bike sharing is actively offered at the work floor. Thereafter, an adequate bike parking accommodation needs to be available for commuters which encourages the use of bikes. This is another recommendation for employers.

- It is recommended to reach **collectivity among employers and the municipal government** for the accommodation of shared bicycles and the active promotion thereof for commuters and people who want to use the parking facilities in the city center.

- It is recommended for municipalities where one or more smaller bike sharing initiatives are emerging, to merge as much as possible. By **appending park & ride spots to other or existing systems** of shared bikes, the system can be a more flexible and less costly practice. Thereafter, more volume and a higher chance of succeeding are established if there are more societal goals in the bike sharing system besides the park & ride location, for example hospitals, cultural destinations or a campus.

6.2 Recommendation for further investigations

This section includes recommendations for further studies and the development of theory. Because of the descriptive purpose of this research, a wide range of aspects has been investigated. However, there are limitations caused by a relatively small research sample and an approach that was not so much focussed on the differences between demographic groups but more on a general description of the problem statement.

It is recommended that a less time-bound and more large scale research with an exploratory purpose, roughly the same approach and research methods is conducted on a sample of car users that exceeds the size of the current research sample many times. Since this current research has shown that bike sharing on park & ride locations has potential, it would be societally and scientifically relevant to research the way a bike sharing system should be set up and what the spatial effects for a certain area could be on a large scale and feedback to the results of this study.

Another relevant follow-up study should be conducted that aims at analysing the current and potential role of employers in the emergence of bike sharing and smart mobility



initiatives that affect spatial quality and liveability. It is recommended that, having regard to the results of this study which clearly show that employers can and would play a major role, a case-study is done. This case-study with a descriptive purpose focuses on employers that include shared bikes within their emoluments and the impacts on the use and the familiarity of shared bikes this case or these cases have.

Despite the fact that minors are not so much part of car users, it is scientifically interesting to investigate to what extent this group is open to shared cycling. The results of this research indicate that the group between the age of 18-26 indicated to often use shared bikes if time is shorter and price remains the same (49%) and if time remains the same and price is cheaper (51%). From this, it is very likely that there is a potential willingness for minors to make use of shared bikes. In addition, it is also socially relevant because shared cycling can be used by a new generation, in which a wave of new smart mobility initiatives originate such as flexible transportation services, the MaaS concept and the sharing society.

It is also advisable that further investigation is conducted into several issues concerning the parking of shared bikes and the effects on parking pressure. If bike users with a second bike in a city would use a shared bike instead of a second bike, a lot of possible positive spatial effects could be gained including freeing up space.

A relevant follow-up study that could contribute to the development of practice could be a qualitative study in which policy makers that are currently working with bike sharing initiatives are interviewed on their method and preferences, in order to construct an overview of opportunities and pitfalls that arise during this initiation.

With the rise of the exclusion of cars from city centers and the guaranteed rise of initiatives such as Mobike in the Netherlands, more experiences will be added. A final recommendation for further studies is a qualitative research based on the initiatives and experiences that municipalities will gain in the coming years in the field of bicycle sharing systems to further improve the knowledge and to keep the bike sharing guidance up-to-date.



7 Discussion

In this research, I have collected data and analysed results in order to gain knowledge on the way a bike sharing system, for a first- and last mile use, should be set up, what the view and preferences on this bike sharing system are and on the spatial effects for medium-large cities in the Netherlands. What follows is a discussion on the research conclusion and an evaluation of the research process and the investigation.

Bike sharing, if successfully implemented and presented, offers a lot of benefits for a city and its surroundings. The growing pressure on medium-large cities has to be dealt with, and besides the repulsion of cars in city centers and the rise of new public transport initiatives, bike sharing as an alternative for cars has to at least be seriously considered by medium-large municipal governments.

Car commuters and day trippers, according to the results of this research, are willing to use shared bikes. Certainly in a system in which the bike sharing at park & ride locations offers more volume, instead of being a micro system of its own, it has the potential to be a worthy alternative transportation mode. The results also show that there is not a specific group of customers. For car commuters, it can offer a healthy variety. For day trippers, the use of bikes could give more flexibility, in order to attend different inner city activities in ways that suits them best.

7.1 Reflection

According to Groen (2011), to reflect is to consciously think about your own actions in order to increase your further actions and your professionalism. In this section, my own theoretical and methodological reflection will be written down to give an overview of my actions and to be able to learn more from it by reflecting on it once again.

For this research, as much scientific literature and different theories have been used in the literature research to form a solid foundation and a useful theoretical framework. In this literature research, however, I could have delved deeper in the available research on foreign uses of bike sharing systems. This has ensured that the foundation for this study mainly consists of domestic literature and the expert interview. The theoretical foundation of this research is therefore less broad than in other studies.

The generalization of the thesis is about the extent to which statements are tested precisely according to all conditions, so that they are valid in other situations and for other researchers. In order to critically reflect on the limits of my own research, I have to say that the sample of this research is adequate but not large enough to assume a very small margin of error. This is due to the time-bound character of the thesis and my choice to initially conduct personal surveys on location.

Thereafter, the generalization of the results and the determination of the population is complicated by the fact that there are no verified, specific numbers on the total amount of car users that, in any way, enter and leave the city center of the medium-sized cities. There are investigations on movements in and around specific roadways, but these say little to nothing about the precise population. Generalisation has been attempted to achieve,



however, by collecting in multiple cities at specific locations. Reflecting backwards, it would both improve and facilitate further research by determining the specific number related to the population as a whole before determining an interesting problem statement.

This research was concerned with human behaviour and the exploration of generalisations about human behaviour and preferences, making it a fundamental research. A limit of this research is that it isn't directly aimed at discovering solutions for immediate problems that a society or an organisation is dealing with. A similar research focusing more on one specific location or organization could offer direct guidance on how to improve or implement a shared cycling system there.

The situations that are used in this research to investigate preferences on travel time and travel price are can be experienced as abstract, and may for some respondents not be directly linked to reality. The reader must take into account that this study and the results are based on findings that may be more promising than reality. On the other hand, the results and the conversations conducted during the survey do indicate that there is willingness and a demand for it.

For the data collection at parking locations across the medium-large cities, it applies that it is more useful to collect and survey respondents in the morning rush than it is to collect in the evening rush, as many car users are in a hurry to get home after a day at work or the inner city. I was able to give a lot of car users the survey card, but in the morning I had more successful sessions leading to more response.

Another reflection concerning the methodology and data collection of this research is about the analysis program of Qualtrics. It is possible to directly link this program to the SPSS software, in order to automatically fill in the data from one program to the other. However, I wasn't able to perform this link because my account was not associated with the Radboud University. I therefore had to single handedly insert all data myself. In future situations, I will therefore ensure that my account is authorized before performing the survey research.

Finally I want to conclude with the fact that I have always greatly appreciated the feedback of my supervisor during the writing of this research and his involvement during the initial phase of research. Reflecting backwards, I often needed a helping hand and constructive criticism to complete this research, but in the end I learned a lot from this in terms of performing an investigation and in collaborating with a supervisor.



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Appendix A

Appendix A includes the original survey questionnaire, which is used for this research. The survey questionnaire was originally formulated in Dutch, to make it useful for the investigated respondents in the Netherlands.



Mijn naam is Pol Jansen, student Mobiliteit aan de Radboud Universiteit.

Door groeiende steden en toenemende mobiliteit, wordt er de laatste jaren steeds meer aandacht besteed aan de vraag hoe we onze steden schoon, leefbaar én bereikbaar kunnen houden. Deelfietsen kunnen daarvoor een belangrijke schakel worden in die groeiende steden. Deze vragenlijst gaat over het reisgedrag en de voorkeur van reizigers wat betreft deelfietsen, en zal door mij gebruikt worden om de impact en potentie van deelfietsen te onderzoeken.

De reacties zullen anoniem en vertrouwelijk worden bijgehouden.
Het invullen duurt ongeveer 5 minuten, alvast enorm bedankt!

Hoe vaak gebruikt u een auto?

Dagelijks

Wekelijks

Minder dan 1 keer per week

Wat is de voornaamste reden voor uw autogebruik?

Werk

Vrijtijdsbesteding

Sociale contacten onderhouden

Anders, namelijk



In hoeverre worden de kosten voor dit autogebruik vergoed?

Volledige vergoeding reiskosten

Vergoeding parkeerkosten

Vergoeding per kilometer

Geen vergoeding

Bent u bekend met deelfietsystemen?

Ja

Nee

Maakt u weleens gebruik van een deelfiets naar uw werk of de binnenstad?

Ja, vaak

Ja, af en toe

Ja, heel soms

Nee

Maakt u weleens gebruik van het openbaar vervoer naar uw werk of de binnenstad?

Ja, vaak

Ja, af en toe

Ja, heel soms

Nee



Voor sectie C van de vragenlijst geldt dat er een deelfietsensysteem aanwezig is op een park&ride locatie aan de rand van de stad. Hieronder volgen vragen over uw voorkeur voor de tijd, prijs en overige karakteristieken.

U kunt er in deze situatie voor kiezen uw auto te parkeren op de park&ride en het laatste stukje van uw reis af te leggen met een deelfiets.

Zou u dit doen, als;

	Ja, vaak	Ja, af en toe	Ja, heel soms	Nee
Totale reistijd; gelijk Reiskosten; gelijk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Totale reistijd; korter Reiskosten; gelijk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Totale reistijd; gelijk Reiskosten; goedkoper	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Totale reistijd; korter Reiskosten; goedkoper	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Totale reistijd; langer Reiskosten; goedkoper	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Totale reistijd; korter Reiskosten; duurder	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Indien u 2 of meer keer Nee hebt beantwoord in de tabel, wat zijn hiervoor naast reistijd en reiskosten de voornaamste redenen? (Meerdere antwoorden mogelijk)

Persoonlijke of lichamelijke redenen

Geen zin door slechte weersomstandigheden te fietsen

Geen zin door het donker te fietsen

Andere reden, namelijk

N.v.t.



Indien u 2 of meer keer Ja hebt beantwoord in de tabel, wat zijn hiervoor naast reistijd en reiskosten de voornaamste redenen? (Meerdere antwoorden mogelijk)

Fijn om te sporten

Milieuredenen

Moeite met parkeren

Drukke in de binnenstad

Andere reden, namelijk

N.v.t.

Als uw nieuwe parkeerkosten op een park&ride met deelfietsystemen zouden halveren t.o.v uw huidige parkeerkosten, zou u dan voor een deelfiets kiezen?

Ja

Ja, mits gelijke of kortere reistijd

Nee

Ik heb geen huidige parkeerkosten



Op een vijfpuntsschaal, hoe beoordeelt u de volgende kenmerken van een deelfiets voor het gebruik ervan?

Grote hoeveelheid aanwezig	<input type="text"/>
De mogelijkheid tot het stallen van fiets op elke legale fietsparkeerplek	<input type="text"/>
Versnellingen	<input type="text"/>
Comfort van fiets	<input type="text"/>
Elektrische fiets	<input type="text"/>

Zijn er nog andere kenmerken die u belangrijk vindt voor het gebruik van een deelfiets?

Op een vijfpuntsschaal, hoe beoordeelt u de volgende kenmerken van een park&ride met deelfietsen voor het gebruik ervan?

Gelegen langs een snelfietspad	<input type="text"/>
Overdekte fietsenstalling	<input type="text"/>
Aanwezigheid etensvoorziening op park&ride	<input type="text"/>
Mobiele deelfietsysteem app met up-to-date informatie	<input type="text"/>
Mogelijkheid tot vooraf reserveren fiets	<input type="text"/>
Mogelijkheid betaalde maandpas voor onbeperkt fietsen in Nederland	<input type="text"/>

Zijn er nog andere kenmerken die u belangrijk vindt voor een park&ride met deelfietsen?

Wat is uw geslacht

<input type="radio"/> Man	<input type="radio"/> Vrouw
---------------------------	-----------------------------

Wat is uw leeftijd?

<input type="radio"/> 18-26 jaar
<input type="radio"/> 27-40 jaar
<input type="radio"/> 41-65 jaar
<input type="radio"/> 65+



Wat is uw hoogst genoten opleiding?

Universiteit/HBO

MBO

VWO/Havo

VMBO

Basisonderwijs

Wat is uw huishoudsamenstelling?

Eenpersoonshuishouden

Paar zonder kinderen

Paar met kinderen

Eenoudergezin

Radboud Universiteit 

Bedankt voor uw tijd om aan deze enquête deel te nemen.
Uw antwoord is geregistreerd.



Appendix B

Appendix B includes the survey questionnaire that has been translated into English.

a Introduction

My name is Pol Jansen, student Mobility at the Radboud University.

Due to growing cities and increasing mobility, more and more attention has been paid in recent years to the question of how we can keep our cities clean, liveable and accessible. Shared bicycles can therefore become an important link in those growing cities. This questionnaire is about the travel behavior and preferences of travelers with regard to sharing bikes, and will be used by me to investigate the impact and potential of sharing bikes.

The responses will be kept anonymously and confidentially.
Filling in takes about 5 minutes, thanks in advance!

b Investigation of travel data

- How often do you use a car?
 - Daily
 - Weekly
 - Less than once a week

- What is the main reason for your car use?
 - Work
 - Leisure activity
 - Maintaining social contacts
 - Otherwise, namely.....

- To what extent are the costs for this car-use reimbursed?
 - Full reimbursement of travel expenses
 - Reimbursement of parking costs
 - Reimbursement per kilometer
 - No compensation

- Are you familiar with sharing bicycle systems?
 - Yes
 - No

- Do you ever use a sharing bicycle to work or to the city center?
 - Yes, often
 - Yes, occasionally
 - Yes, sometimes
 - No



- Do you ever use public transport to work or the city center?
 - Yes, often
 - Yes, occasionally
 - Yes, sometimes
 - No

c Preferences bike sharing system

For section C of the questionnaire, a shared bicycle system is present at a park & ride location on the outskirts of the city. In this situation you can choose to park your car at the park & ride location and complete the last part of your journey with a shared bicycle.

Below are questions about your personal preference on the time, price and other characteristics.

	Yes, often	Yes, sometimes	Yes, rarely	No
Total travel time; equal Travel costs; equal				
Total travel time; shorter Travel costs; equal				
Total travel time; equal Travel costs; cheaper				
Total travel time; shorter Travel costs; cheaper				
Total travel time; longer Travel costs; cheaper				
Total travel time; shorter Travel costs; more expensive				

- If you answered No 2 or more times to the previous question, what are the main reasons for this in addition to travel time and travel costs? (Multiple answers possible)
 - Personal or physical reasons
 - Don't feel like cycling due to bad weather
 - Don't feel like cycling through the darkness
 - Other reason, namely
 - Not applicable



- If you answered Yes 2 or more times to the previous question, what are the main reasons for this in addition to travel time and travel costs? (Multiple answers possible)
 - Fancy exercising
 - Environmental reasons
 - Difficulty with parking
 - Crowdedness in the city center
 - Other reason, namely
 - Not applicable

- If your new parking costs on a park & ride with partial bicycle system would halve by your current parking costs, would you opt for a partial bicycle?
 - Yes
 - Yes, provided that the travel time is the same or shorter
 - No
 - I have no current parking costs

d Assessment of the characteristics of a partial bicycle

- On a five-point scale, how do you assess the following characteristics of a shared bike for its use?
 - Large quantity available
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important

 - The possibility to park your bicycle at any legal bicycle parking place
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important

 - Bicycle gears
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important

 - Bicycle comfort
 - Extremely important
 - Very important
 - Fairly important



- Not very important
- Not important
- E-bike
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
- Are there other characteristics that you think are important for the use of a shared bike?
 - _____
- On a five-point scale, how do you assess the following characteristics of a park & ride location with bike sharing system for its use?
 - Located along a bike freeway
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
 - Roof covered bicycle parking
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
 - Possibility to book a bike in advance
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
 - Possibility of paid monthly pass for unlimited use in the Netherlands
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
 - Mobile bike app with up-to-date information
 - Extremely important
 - Very important



- Fairly important
- Not very important
- Not important
- Availability of food facilities on the P&R location
 - Extremely important
 - Very important
 - Fairly important
 - Not very important
 - Not important
- Are there other characteristics that you think are important for the characteristics of a park & ride location?
- _____

e General personal data important for the investigation

- What is your gender?
 - man
 - Woman
- What is your age?
 - 18-26
 - 27-40
 - 41-65
 - 65+
- What is your highest level of education?
 - University / HBO
 - MBO
 - VWO
 - Havo
 - VMBO
 - Primary education
 - I prefer to give no answer
- What is your household composition?
 - Single-person household
 - Couple without children
 - Couple with children
 - Single parent family



Appendix C

Radboud Universiteit



bit.ly/Deelfiets

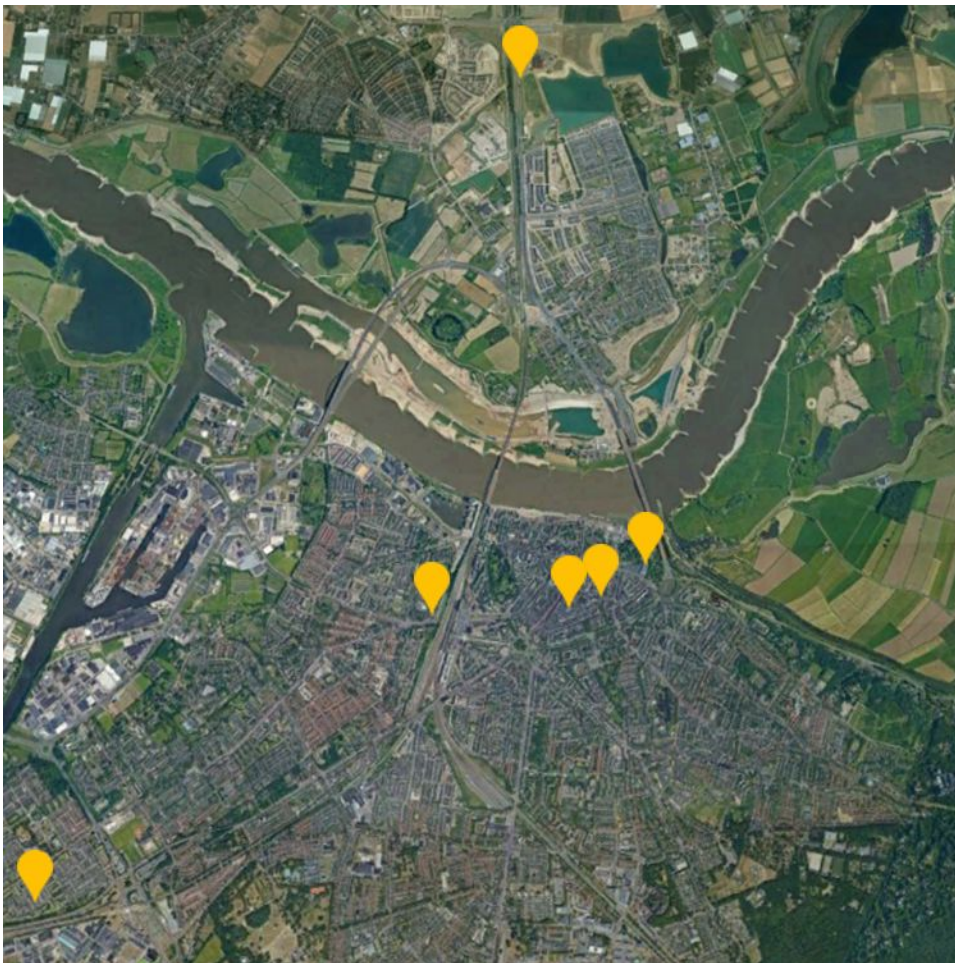
Bedankt voor uw tijd om aan deze enquête deel te nemen.



Appendix D

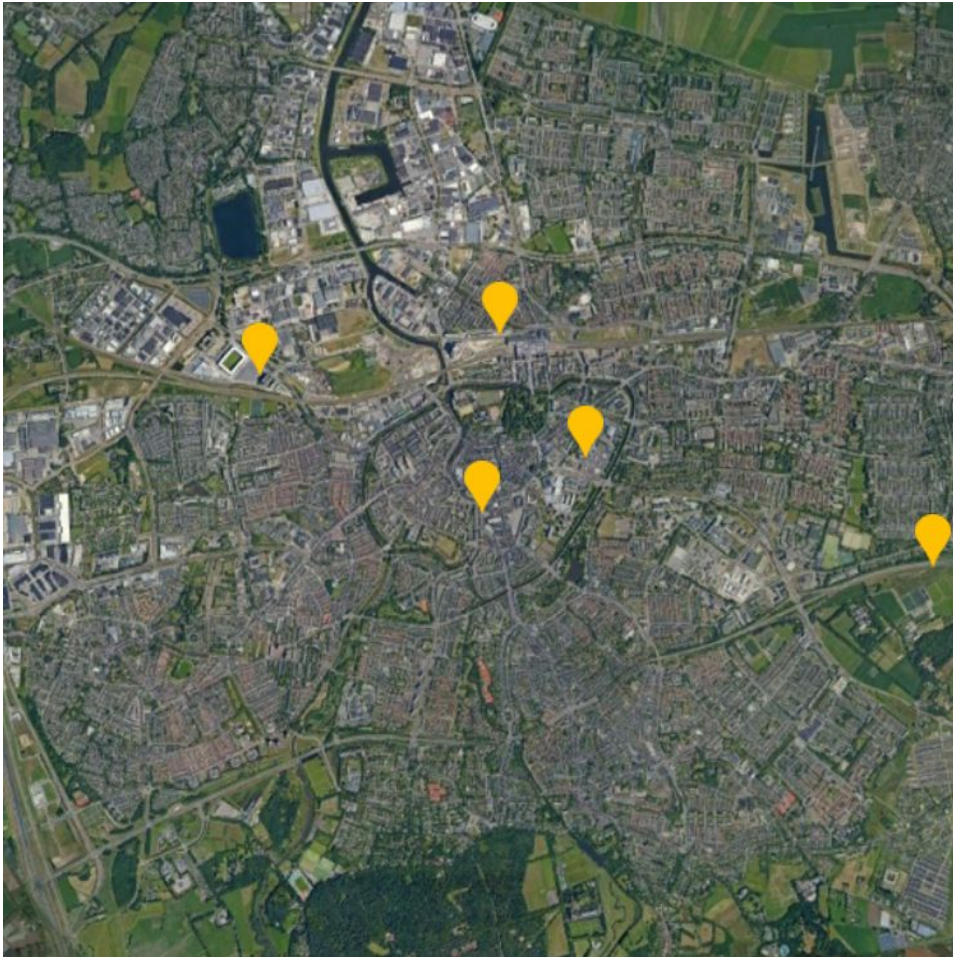
Appendix D contains a list and maps of Nijmegen and Breda with locations where respondents were questioned and/or observations were made.

- **Nijmegen**
 - P+R Eerste Oude Heselaan
 - P+R Noord Lent
 - Marienburg
 - Molenpoort parking
 - Kelfkensbos
 - Dukenburg



- **Breda**

- P+R Spoorgebied
- Turfschip parking
- Breepark
- P5 NAC
- ParkBee Markendaalseweg



Appendix E

Interview guide semi-structured interview

- I. De cijfers over het gebruik van de OV-fiets en de ervaringen laat zien dat een deelfietssysteem in Nederland zeer mogelijk en functioneerbaar is. Wat was de gedachte achter het oprichten van de OV-fiets?

- II. Wat is het succes achter de OV-fiets in Nederland?

- III. (Denk je dat dit succes van de OV-fiets andere deelfietssystemen verruimt of juist beperkt?)

- IV. Klopt het dat je er mede voor gezorgd hebt dat Mobike naar NL kwam? Wat was de gedachte achter het naar NL halen van Mobike?

- V. Mobike wordt nu toegepast in Rotterdam, Den Haag en Delft. In hoeverre denk je dat het Mobike concept ook in middelgrote steden buiten de Randstad zou kunnen worden toegepast?

- VI. Mobike en de OV-fiets hebben beide het voordeel dat er niet veel ruimtelijke effecten hoeven worden toegepast te worden in de stad. Wat zijn hier de voordelen van denk je, in tegenstelling tot een systeem met veel stations bijvoorbeeld?



- VII. Een tegenhanger van het OV is het gebruik van de auto, waarna je op je bestemming ook geen fiets ter beschikking hebt, bijvoorbeeld op park&rides aan stadsranden, met als populatie vooral forenzen en dagjesmensen. In hoeverre zie je op deze locaties deelfiets potentie?
- VIII. De deelfiets in Nederland voorziet nu voornamelijk een first- en last-mile oplossing. In hoeverre zie je deze functie nog verder uitbreiden voor de deelfiets?
- IX. Denk je dat het wenselijk is dat de fiets een nog grotere rol gaat spelen?
- X. Met het oog op ruimtelijke veranderingen. Wat moet er denk je nog veranderen voor de deelfiets een stadsbus of tram vervangen?



