Delft University of Technology

Potential for Sustainable Mode Usage Amongst Car Users in Mid-sized Cities

A case study in The Hague, the Netherlands

Master Thesis

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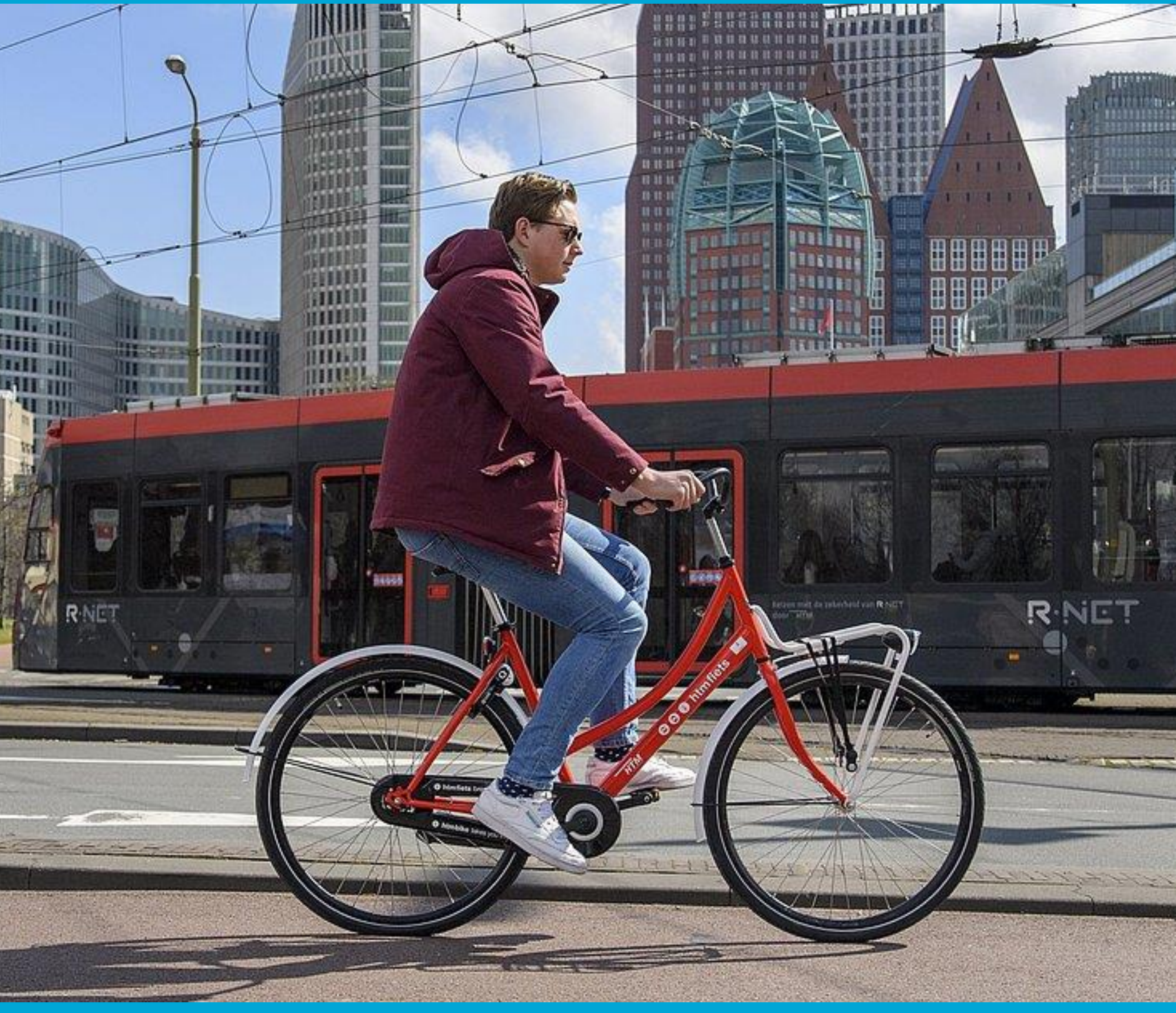

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Potential for Sustainable Mode Usage Amongst Car Users in Mid-Sized Cities

A case study in The Hague, the Netherlands

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by

B.M. (Babette) Limburg BSc.

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Abstract

Cities are growing worldwide, which leads to an increase in trips in urban areas. In Europe, more than half of the trips are made by car, while car takes most space of all modalities. Of all modalities car has the highest CO_2 emissions. The high number of trips by car within cities lead to challenges related to the accessibility, livability, and sustainability of cities. Sustainable mode alternatives in this research are the bicycle, shared bicycle, and urban public transport which have potential for being an attractive alternative on short trips (<5 kilometer). Therefore, this study researches factors that influence car users' mode choice towards those three sustainable modes, for stand-alone trips with trip purpose shopping. Through a stated preference survey amongst car drivers in a Dutch mid-sized city (N=360), preferences are gathered with respect to the mode choice. A panel mixed logit model with error component and interaction variables is used for the analysis of the stated preference data. The factors with most impact on mode choice are (shared) bicycle travel time, bicycle parking costs, shared bicycle availability, public transport travel costs, and public transport in-vehicle crowdedness. The non-mode factor with most impact is attitude towards tram, which is negatively correlated to car frequency. Car users tend to switch towards public transport, so a guaranteed seat in public transport, a more positive attitude towards public transport and higher car parking costs can achieve the switch. The switch towards bicycle can be made if the bicycle travel time is lower than currently.

Keywords: mode choice, car users, sustainable, stand-alone trips, stated preference, discrete choice modelling

I. Introduction

Worldwide, urban areas are growing. The growing number of inhabitants in urban areas puts pressure on the transportation infrastructure, as the transport demand grows quicker than the transport supply. This results in challenges for urban areas to keep the areas accessible, livable, and sustainable. Of all modalities, car is the least sustainable modality with the highest CO_2 emissions per passenger-kilometer (Milieu Centraal, 2017). Besides the impact on the environment, car use influences urban space, road safety and health in a negative way (Vandecasteele et al., 2019).

Within Europe, 56% of the most frequent trips undertaken is made by car (Fiorello et al., 2016). In the Netherlands is this share 53%. In urban areas in the Netherlands, the car share varies from 31% in Amsterdam to 52% in Eindhoven (KiM, 2019). Dutch cities are developing programs which create more space for pedestrians, cyclists, and public transport. For these interventions, it is valuable to get more knowledge on factors that trigger car users to switch away from car towards sustainable modes.

Car driving is found attractive because it is convenient, fast, gives individual freedom, and cars bring the traveler close to its destination (Batty et al., 2015; Beirão & Cabral, 2007; Corpuz, 2007; Kang et al., 2019). Three sustainable alternatives for car are considered in this research: bicycle, shared bicycle, and public transport. Bicycle could be a good alternative for car trips because it is comfortable, flexible, and time saving (Heinen et al., 2010). Shared bicycles are in general used mostly for short distances, and one-way trips (Bachand-Marleau et al., 2012), and are a substitute for car in 2% to 21% of the cities (Fishman, 2016). In this study, both bicycles and shared bicycles are considered since bicycle users also use shared bicycles (Bachand-Marleau et al., 2012). Besides, about 22% of the Dutch modal split for most frequent trips is bicycle (Fiorello et al., 2016), and Dutch people own on average 1.4 bicycles per person (Harms & Kansen, 2018). Therefore, including bicycle is a good representation of reality. The last mode in this research is public transport as it could bring car users close to its destination in the city centre as well, and both bus and tram are a more sustainable alternative for car.

Of all Randstad provinces in the Netherlands, Zuid-Holland has the highest total car share (47.5%). The Hague is a mid-sized city in Zuid-Holland, which has a total car share of 41% (KiM, 2019). Within The Hague, 20.7% of all trips are undertaken with trip purpose 'shopping' (CBS, 2020d), of which 47.8% is undertaken by car. The trip purpose in this research will therefore be shopping. More specifically, as more than half of the visits to The Hague city centre are inhabitants of The Hague (Gemeente Den Haag, 2018), the focus will be on trips to the city centre.

The combination of bicycle, shared bicycle, public transport, and car in a research is new. Especially for trip purpose shopping, for stand-alone trips in a mid-sized city. This research will fill that research gap. Another research gap that will be filled is the shared bicycle reliability. Shared bicycle can be seen as form of public transport, as it should meet the same minimum requirements according to the pyramid of traveler desires from Peek and van Hagen (2002): reliability, speed, and ease of use. van Marsbergen (2019) found that certainty of an available shared bicycle could lead to more shared bicycle usage. However, van Marsbergen (2019) did not quantify this availability. Therefore will the second filled research gap in this research be the quantification of the shared bicycle reliability.

The research question that is answered by this research is: *Which factors influence the usage of private bicycle, shared bicycle, and urban public transport (bus and tram) for stand-alone trips of car users in a mid-sized city with trip purpose shopping, and what measures could increase the potential usage of these sustainable modes?*

This research question will be answered through a couple of stages, of which the method will be explained in section 2. In section 3, the results will be presented followed by the model application on The Hague context in section 4. The research will be concluded and discussed in section 5, which is followed by recommendations in section 6.

II. Methods

A. Choice experiment

For the identification of trade-offs by car users, a survey has been designed. The survey consists of two parts. The first part is a stated preference (SP) choice experiment. Stated preference allows the respondent to make multiple hypothetical choices, which can include new alternatives (Molin, 2018a). Furthermore, by using SP the correlation amongst attributes can be controlled, so less respondents are needed. The main drawback of SP is that due to the hypothetical choices it is uncertain whether users would make the same choices in real life as well (Train, 2003).

The mode alternatives which are included in this research are bicycle, shared bicycle, urban public transport, and car. In literature was searched for factors that make car users switch to all three other sustainable modes: bicycle, shared bicycle, and urban public transport (bus and tram). The switch towards (shared) bicycle is influenced by trip purpose, where car users are likely to switch towards shared bicycle for commuting (Politis et al., 2020), but shopping was not part of this research. Besides travel time and travel costs influence the switch. Here, the mode with shorter travel time affects the mode choice (Halldórsdóttir et al., 2011). For travel costs has been found that especially for short trips (<25 minutes), switching is likely when the costs of their current mode increases (Politis et al., 2020). Switching from car towards public transport is mainly influenced by frequency, service reliability, convenience, and the public transport mode (Beirão & Cabral, 2007; Corpuz, 2007; de Witte et al., 2013; Kang et al., 2019; Redman et al., 2013).

The included attributes are driving time, walking time, crowdedness, mode type, costs, availability, and frequency. The reasoning for choosing these attributes is as follows. Table 1 shows which attributes are part of each of the alternatives, including the attribute levels. Travel time is included as it is in general influences mode choice (de Dios Ortúzar & Willumsen, 2011), and time saving is possibly influential on switching towards sustainable modes (Heinen, Maat, & van Wee, 2011). Travel time consists in this study of the sum of driving time and walking time. Driving time is in-vehicle time, and walking time is the total of walking time at the home-end and activity-end of the trip.

Travel costs have an effect on choosing one mode over the other (Halldórsdóttir et al., 2011; Politis et al., 2020; Redman et al., 2013), as well as car parking costs at the destination influence mode choice (Hamre et al., 2014; de Witte et al., 2013). The third included alternative is crowdedness, which for public transport is in-vehicle crowdedness. Car users value individual freedom and comfort (Beirão & Cabral, 2007; Hagman, 2003). A part of comfort is in-vehicle crowdedness (Haywood et al., 2017), so therefore it is valuable to include in-vehicle crowdedness as part of the choice set.

The fourth attribute is mode type, which is part of shared bicycle and public transport. For shared bicycle this is a 'regular' shared bicycle, and an electric shared bicycle. Public transport modes are bus and tram, which are both included because frequent car users like switching to bus, while frequent cyclists rather switch towards tram (Bunschoten et al., 2013). For bicycle and car, the respondent has to keep in mind their own bicycle and car.

The last two included attributes are availability of the shared bicycle and the frequency of public transport. Availability in this case relates to the reliability of the service, which is proven to be an issue (van Marsbergen, 2019). Therefore, the reliability is quantified in this research. Lastly, frequency is included as car is valued because of its flexibility. It is therefore expected to have influence on the mode choice.

With the four alternatives and seven attributes are twelve choice sets generated via a bayesian efficient design in Ngene (ChoiceMetrics, 2018). The used prior values are from previous Dutch context researches (Arendsen, 2019; Arentze & Molin, 2013; Bunschoten et al., 2013), and through the results of a pilot survey in Dutch cities (N=86).

The second part of the survey consists of socio-demographics, amongst which gender, age, education level, household type and size. In addition is asked for travel frequencies of the included modes, as well as frequency of going to the city centre, and statements of the five included modes in this research. The statements reflect the respondents' attitude towards each of the modes.

The research consists of two scenarios, which differ in distance. Both scenarios have the context of a trip from home towards the city centre of The Hague with trip purpose shopping. Scenario 1 has distance 2.5 kilometer, and scenario 2 5 kilometer. In the results of this paper, the focus will be on scenario 2 only: 5 kilometer to the city centre.

B. Survey and sample

The survey has been conducted amongst car owners in The Hague, Rijswijk and Leidschendam-Voorburg, The Netherlands. The respondents were gathered via Panelclix, an online panel (PanelClix, 2021). The respondents could participate in the survey when they lived in The Hague, Rijswijk, and Leidschendam-Voorburg. Furthermore, the respondents should have a driver license, own a car, and own a bicycle. Total of 360 responses are gathered, of which 174 useful responses are gathered in scenario 2: 5 kilometer to the city centre. Within the sample is age group 18 to 27 years old underrepresented, while 41+ years old are overrepresented. Furthermore, the level of education is a higher than in in both Dutch and The Hague population.

Table 1: Attributes and their levels per alternative

		Bicycle	Shared bicycle	Public transport	Car
Driving time	2,5 km	8, 10, 12 min	8, 10, 12 min	6, 8, 10 min	6, 8, 10 min
	5 km	17, 20, 23 min	17, 20, 23 min	12, 15, 18 min	12, 15, 18 min
Walking time		1 min (= 100 m) 3 min (= 250 m) 5 min (= 400 m)	3 min (= 250 m) 5 min (= 400 m) 7 min (= 550 m)	3 min (= 250 m) 6 min (= 500 m) 9 min (= 750 m)	1 min (= 100 m) 4 min (= 350 m) 7 min (= 600 m)
Crowdedness		1, 3, 5 min parking search time	-	Quiet Not quiet/not busy Busy	1, 3, 5 min parking search time
Mode type		Own bicycle	Shared bike Shared e-bike	Bus Tram	Own car
Costs		0, 1, 2 euro	0, 1, 2 euro	1, 2, 3 euro	3, 6, 9 euro
Availability		-	1-2 available 3+ available Booked	-	-
Frequency		-	-	Every 5, 10, 15 min	-

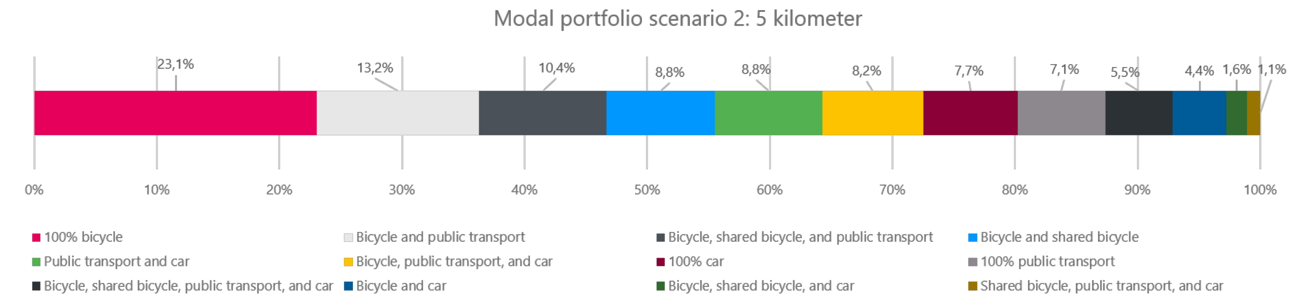

Figure 1: Modal portfolio scenario 2: 5 kilometer

Household types 'alone, kids' and 'together, kids' are overrepresented, while household types 'alone, no kids' is underrepresented. The bicycle and car modes which are kept in mind by the respondents are regular bicycles (78.7%), and diesel or gasoline cars (71.6%).

Figure 1 shows the modal portfolio of the choice sets. The modal portfolio gives insight in the chosen alternatives and its variation among all respondents. 23.1% of the respondents chose bicycle in all choices. This is followed by the combination of (shared) bicycle and public transport. 37.7% of the respondents chose at least once for the car alternative. 62.1% of the respondents varied in mode choice.

C. Model specification

The analysis of the choice sets results is done using four model estimation methods: a multinomial logit (MNL) model, a panel mixed logit (ML) model, a panel ML model with error component (EC), and panel ML model with EC and interaction variables. These models are run using Pandas Biogeme (Bierlaire, 2020). The panel ML model corrects for the MNL model assumption where each choice set is seen as a new individual. The error component is added to correct for common characteristics which are not captured in the attributes. The interaction variables consist of a combination of significant socio-demographics, mode frequencies and mode attitudes.

III. Results

A. Discrete choice model

Step by step, the MNL model is extended. First by a panel mixed logit model, followed by a panel mixed logit model with error component. In the last model, interaction variables are added. The panel mixed logit model with error component on bicycle with interaction variables is the best fitting model according to the Likelihood Ratio Test (LRS). This model fitted better than the model without interaction variables ($\chi^2(11) = 358.390, p < 0.001$), and is therefore used in the remainder of the research.

B. Model interpretation

Table 2 shows the results of the final model. All three alternative specific constants are positive and significant (p<0.05), so bicycle, shared bicycle and public transport are valued more positively than car. Furthermore, for the three sustainable modes is travel costs significant. The driving time for bicycle and shared bicycle have more impact on the utility than the in-vehicle time for public transport and car. So, for making the bicycle and shared bicycle alternatives more attractive the travel time should be lower than for public transport and car. For shared bicycle, three or more bicycles available at the drop zone has a more positive utility than the reference ('booked').

Table 2: Parameter values panel ML with EC bicycle and interactions scenario 5 kilometer
* = significant at p<0.05 level, ** = significant at p<0.10 level

Beta	**Value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC				
Bicycle	6.650	1.680	3.950	0.000*
Shared bicycle	3.850	1.510	2.550	0.011*
Public transport	2.680	0.518	5.170	0.000*
Generic				
Crowdedness	0.009	0.030	0.307	0.759
Travel costs	-0.624	0.147	-4.240	0.000*
Travel time	-0.031	0.036	-0.848	0.396
Walking time	0.080	0.050	1.590	0.111
Bicycle				
Travel time bicycle	-0.214	0.065	-3.310	0.001*
Shared bicycle				
1-2 bicycles available	0.363	0.268	1.360	0.175
3+ bicycles available	0.625	0.235	2.660	0.008*
Mode type (electric SB)	0.041	0.259	0.157	0.875
Travel time shared bicycle	-0.179	0.080	-2.240	0.025*
Walking time shared bicycle	-0.163	0.134	-1.220	0.222
Public transport				
Not quiet/not busy	-0.650	0.277	-2.350	0.019*
Busy	-0.507	0.170	-2.990	0.003*
Frequency PT	-0.035	0.020	-1.790	0.073**
Mode type (tram)	0.174	0.154	1.130	0.260
Car				
Parking costs car	0.028	0.061	0.461	0.645
Interactions				
*Age group 41-64 years * travel costs*	0.334	0.155	2.150	0.031*
*Age group 65+ years * travel costs*	0.721	0.188	3.840	0.000*
Negative attitude tram	-3.320	0.829	4.010	0.000*
Positive attitude tram	1.380	0.636	2.160	0.031*
Monthly frequency car in city	0.839	0.587	1.430	0.153
<5 days per year frequency car in city	1.590	0.794	2.000	0.046*
*Monthly frequency city centre * parking costs car*	-0.362	0.083	-4.370	0.000*
*<5 days per year frequency city centre * parking costs car*	-0.427	0.154	-2.770	0.006*
Monthly cycling frequency	-0.911	0.681	-1.340	0.181
<5 days per year cycling frequency bicycle	-1.070	0.629	-1.710	0.088**
*Cars in household * walking time*	-0.077	0.040	-1.920	0.055**
Sigmas				
Bicycle	4.780	0.618	7.730	0.000*
Panel	2.350	0.447	5.260	0.000*

The in-vehicle crowdedness for public transport is valued most positively when ‘quiet’ (guaranteed seating place), than ‘not quiet/not busy’, and ‘busy’. For shared bicycle and public transport mode types are car users indifferent.

The interaction variables show that both age groups 41-64 years and 65+ years old are more sensitive to travel costs than age group 18-40 years (reference). A negative attitude towards tram has a big negative impact on the three non-car alternatives. For a positive attitude towards tram is the opposite found. The frequencies have as reference weekly trips. Less frequent car drivers (<5 days per year) in the city value the three sustainable modes more positively than weekly car drivers. Frequent city centre visitors are less sensitive to the car parking costs than infrequent city centre visitors. People who cycle on a yearly basis value the three sustainable modes more negatively than weekly cyclists. Lastly, the number of cars in household has impact on the walking time: more cars in household leads to a lower valuation of walking time.

The two sigmas in the model are bicycle and panel, which are both significant and positive. This shows there are common characteristics between bicycle and shared bicycle, which are not captured in the attributes (Chorus, 2018d). Also, a panel effect is present, which corrects for the correlations between each individual response.

C. Effect of attitude towards modes

A couple of correlations have been found between mode frequency and mode attitude. Firstly, tram attitude is correlated to bus (r(358)=0.606, p<0.001), and shared bicycle (r(358)=0.197, p<0.001). This shows that the found relation of attitude towards tram in the final discrete choice model holds for as well the attitude towards bus and the attitude towards shared bicycle. Tram attitude is also positively correlated to bus frequency (r(358)=0.282, p<0.001) and tram frequency (r(358)=0.498, p<0.001). This shows that a change in tram attitude from negative towards positive leads to a higher bus and tram frequency. This could be the case for car users especially, as total car frequency is negatively correlated to bus attitude (r(358)=0.089, p=0.091).

Shared bicycle frequency has a positive correlation with bus frequency (r(358)=0.142, p=0.007) and tram frequency (r(358)=0.093, p=0.079), so public transport users use shared bicycles more often. Car drivers have a negative correlation with the shared bicycle attitude (r(358)=-0.122, p=0.020), while shared bicycle frequency is positively correlated to shared bicycle attitude (r(358)=0.431, p<0.001).

These correlations show that car drivers have a negative attitude towards other modalities, and do not often use the other modalities. However, a positive attitude towards the sustainable modes has a positive correlation to the use frequency. So, by changing the attitude of car users towards the sustainable modes, an increase in use frequency of the sustainable modes can be achieved.

IV. Model application

The model results are applied on The Hague context. In The Hague, a couple of goals are set in the mobility transition which should be reached in 2040 (van Asten, 2019). The first goal is to have efficient mobility, the second goal is to have sustainable mobility without emissions, and the last goal is to have affordable mobility. Through means these goals should be reached. The model results are applied on the means, to see how the mobility transition goals can be reached in The Hague.

Within the first goal are three means: lower the high car parking demand, providing quick public transport, and good bicycle parking facilities. The factor in this research that can lower the car parking demand is car parking costs. For trips to the city centre will an increase of car parking costs from €4/hour to €6/hour lead to a car share decrease of 30.2% monthly (M) city centre visitors and 36.8% '<5 days per year' (Y) visitors. Instead, these visitors travel by bicycle (M and Y: +1.7%), and public transport (M: +15.8%; Y: +16.0%).

The second mean is to increase the public transport speed. This can be done in two ways. First one is to lower the walking time, and the second one is to increase the frequency. In one minute walking time is about 100 meters covered, for every reduced minute of walking time, an increase in public transport share of 3.7% is achieved, which results in a car decrease of 1.3%.

Currently in The Hague, most of the lines have a frequency of 4 or 6 per hour, so every 15 minutes or every 10 minutes. Increasing frequency from 4 to 6 times per hour leads to an increase of 8.1% public transport share, and a car share decrease of 2.9%. Increasing the frequency from 6 to 8 times per hour leads to an increase in public transport use of 4%, and a car decrease of 2.0%. So, the effect from 4 to 6 times per hour is bigger than another improvement from 6 to 8 times per hour.

In the third mean, bicycle parking facilities should become more attrctive. Two factors in this study that relate to bicycle parking are walking time and bicycle parking costs. Bicycle walking time in this study varied between 1 and 5 minutes. The decrease in bicycle share is 1.1% due to increase in walking time from 1 to 5 minutes. On the contrary have bicycle parking costs a big effect on the bicycle share. Currently, most bicycle parking is free. Every €0.50 more fee leads to a 2.5% loss in bicycle share. So, to stimulate bicycle use by improving bicycle parking, the parking should stay free of charge.

In the second goal, the mobility should be without emissions. The factors with most impact on the switch from car to one of the three sustainable modes are the bicycle and shared bicycle driving time, public transport in-vehicle crowdedness and public transport travel costs. The average cycling time for 5 kilometer is 20 minutes (average speed: 15 km/h (Fietsersbond, 2019)). If the cycling time can be improved by one minute (new average speed: 15.8 km/h), the bicycle share increases with 3.5%. The car share decreases by 2.0% due to this change. If for shared bicycle this same improvement can be made from 20 minutes to 19 minutes, the share increases by 17.1%. However, this change does not influence car share. For in-vehicle crowdedness is the impact as follows. The difference between 'quiet' public transport vehicles where a seating can be guaranteed, and 'not quiet/not busy' vehicles where a seat is uncertain makes a big difference in public transport share (31%), and car share (13.1%). Here, public transport share increases when 'quiet', while the car share is higher when the in-vehicle crowdedness is 'not quiet/not busy'.

Changes in public transport travel costs could contribute to the second goal as well, by means of making it cheaper. The current travel costs for public transport for 5 kilometer are about €1.75 (HTM, n.d.-c). A decrease of public travel costs to €1.50 leads to an increase in public transport share of 2.9%, while at the same time the car share decreases with 1.5%. An even further decrease of travel costs from €1.75 to €1.25 leads to an increase in public transport share of 5.8%. By this change, car share decreases with 2.6%.

In the third and last goal of the mobility transition program, mobility should be affordable. One of the ways of reaching that goal is to make use of shared mobilities, in this case the shared bicycle. When looking at the shared bicycle in this study, the shared bicycle becomes more attractive in a couple of ways. The first one is by lower travel costs for shared bicycle. In The Hague, the current fee is €1.00 per 30 minutes (HTM, n.d.-a). Lowering these costs by €0.50 leads to an increase of shared bicycle usage of 11.4%. Furthermore, the availability of the shared bicycle - and thus the reliability of the service - influences the shared bicycle share. Having 3+ shared bicycles available at the drop zone instead of 1-2 available bicycles leads to an increase of 25.7% in usage. In both cases, mostly bicycle users switch towards shared bicycle and are car users hardly influenced by the changes in shared bicycle attributes.

Combining all factors mentioned above, the car modal share can be potentially reduced by 45.6%. Car users mainly switch towards public transport of which the modal share is potentially increases by 46%.

V. Conclusion and discussion

Car use in cities leads to several challenges with respect the environment and livability, as urban areas keep on growing worldwide. This research identified factors that influence the usage of sustainable modes amongst car users (N=360) for short stand-alone trips to the city centre with trip purpose shopping. The three sustainable modes in this research are bicycle, shared bicycle, and urban public transport being bus and tram. Both mode specific and socio-demographic characteristics factors influence this mode choice.

The mode specific factors with most impact on mode choice are travel time, travel costs, public transport in-vehicle crowdedness. Previous research found that shared bicycle travel time is valued more negatively than bicycle and car travel time (Arendsen, 2019; Halldórsdóttir et al., 2011). Here, bicycle time was valued more negatively than shared bicycle travel time, but both were valued more negatively than car travel time. This could be due to the specific response group of car users in this research.

Travel costs for all three sustainable modes are valued more negatively than travel costs for car, which is in line with the findings by Arendsen (2019) and Halldórsdóttir et al. (2011).

For public transport, usage is influenced by speed, and comfort (Beirão & Cabral, 2007; Peek & van Hagen, 2002; van Hagen & van Oort, 2019). In this research has frequency impact on the mode usage, which relates directly to waiting time, and thus speed of the trip. In-vehicle time was not found significant. In relation to comfort was found found that in-vehicle crowdedness has a big effect on the public transport usage. Guaranteed seating places are preferred over standing.

Other than mode specific factors is the impact of attitude towards tram. As this has a positive correlation with attitude towards bus, bus frequency and tram frequency. On the other hand, attitude towards bus is negatively correlated with car frequency. So, the negative attitude has much impact on mode choice. Furthermore, frequent car drivers, city centre visitors and infrequent cyclists have the highest car share.

The research gap regarding shared bicycle reliability has been filled here as well. The availability of 3+ available bicycles at the drop zone is preferred over 1-2 available bicycles. A higher availability leads to a higher reliability and thus to a higher shared bicycle usage.

This research was conducted in a mid-sized city in The Netherlands: The Hague. The model application was done in this context as well. It is expected that these results can be generalized to other Dutch cities as well because The Hague is out of the five biggest cities in The Netherlands in the middle with car share within the city. Furthermore, the bicycle frequency in the sample is similar to the average Dutch cycling sample. Generalization to other European countries could be done under a couple of conditions. The Netherlands has a higher cycling frequency than the average in the European Union: 28% of the Dutch population cycles a couple of days per week, which is 11 percentage points higher than in the European Union (European Commission, 2013). Furthermore has the Netherlands a high quality cycling infrastructure, flat terrain, mild climate, lots of bicycle parking facilities, and short travel distances within cities (Heinen et al., 2010; Schepers et al., 2017). The Dutch public transport share is relatively low to compared to other European countries (Fiorello et al., 2016). Therefore, these differences should be kept in mind when applying the results on other European countries.

VI. Recommendations

For the switch from car towards sustainable modes is the following recommended, recommendations are made for policy and research.

For policy, a couple of recommendations can be made in relation to the mobility transition plan in The Hague. Lowering the car parking demand can be reached by increasing the car parking costs from €4.00/hour to €6.00/hour, which has most effect on infrequent (monthly or less) city centre visitors. For the switch towards mobility without emissions, a guaranteed seating place in public transport has most effect on the switch towards public transport. Besides, a higher public transport frequency attracts car users. For bicycle parking facilities, the bicycle parking costs have most effect on the bicycle share. For the highest bicycle share, it is best to offer the bicycle parking facilities for free. Walking time towards the bicycle parking facilities in the city centre has a low effect on the bicycle share. Lastly, for making shared modalities attractive the following is recommended for shared bicycle. The availability of the shared bicycles is valued mostly when more (3+) shared bicycles are available at the shared bicycle drop zone. This is followed by shared bicycle travel costs.

In further research could be focused on a couple of topics. Firstly, this research focused on stand-alone trips towards the city centre. Regardless of the statement that for the trip homewards the characteristics would be the same, it is recommended to research the mode choices for the return trip as well. In addition, tour-trips are recommended to research because car has the flexibility of going everywhere easily, but the trade-offs for tour trips are not yet clear.

What is not yet clear either is the reasons behind the negative attitude towards bus and tram usage. As a negative attitude towards bus and tram usage is correlated to a high car share, it is valuable to get to know the reasons behind this negative attitude in order to be able to act on those factors.

The last recommendation for further research is to include other sustainable alternatives, such as shared mopeds, shared scooters. Those shared modalities are different than bicycle, and could be quicker and thus more attractive to car users.

VII. Acknowledgements

This research was conducted in cooperation with Goudappel, Smart Public Transport Lab, Delft University of Technology, and HTM.

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Chapter 1

Introduction

Urban areas are growing worldwide. 55% of the world population is living in urban areas, while the United Nation expects this number to increase to 68% by 2050 (United Nations Department of Economic and Social Affairs, 2018). Currently, 74% of the population is living in urban areas in Europe. This is more than world wide. The increase of inhabitants puts pressure on the transportation infrastructure as the transport demand grows quicker than the transport supply. As a consequence, congestion occurs and travel times go up in peak-hours mainly (Rodrigue, 2020). It has become a challenge for cities to remain accessible, livable, and sustainable.

Within Europe, 56% of the most frequent trips is undertaken by car (Fiorello et al., 2016). Of all modalities, car is the least sustainable modality as car has the highest CO_2 emissions per passenger-kilometer (Institute for Sensible Transport, 2018; Milieu Centraal, 2017). In addition, car needs most space per occupant compared to all other modalities (Figure 1.1). Besides the big impact of high car usage on the environment and urban space, road safety and health are influenced in a negative way by the high car share (Vandecasteele et al., 2019).

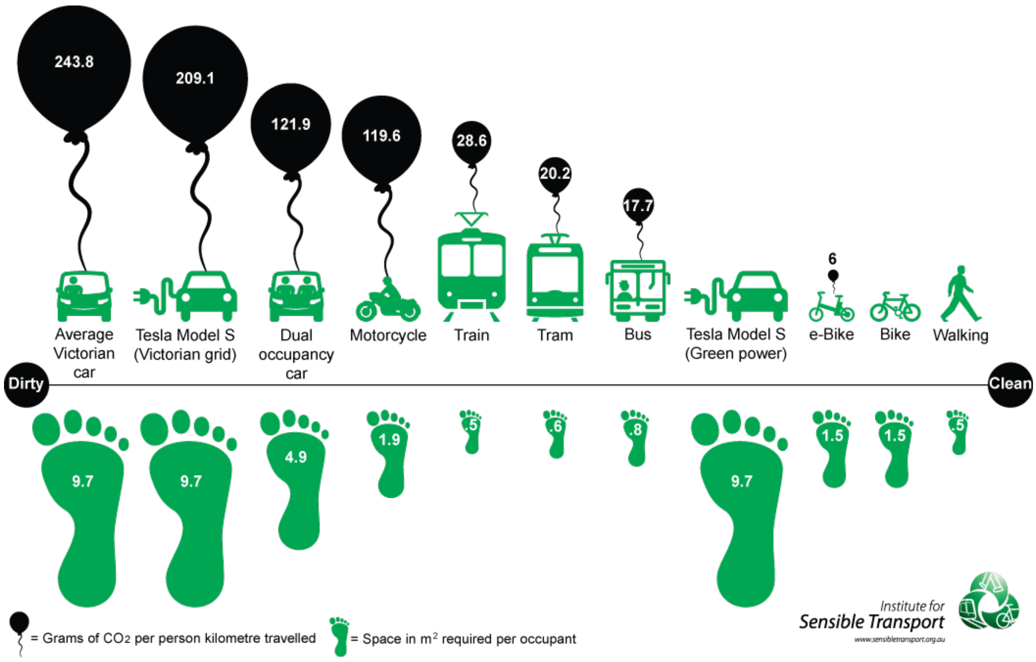


Figure 1.1: CO_2 emissions and space usage per mode (Institute for Sensible Transport, 2018)

In order to cope with challenges that come along with the high number of car trips and increasing transport demand in cities, innovative ways of transportation are searched for. Since urban trips mainly are made over short distances, active modes such as walking and cycling can play a vital role in urban mobility (Rodrigue, 2020). Two studies, co-financed by the European Union, show that cycling in cities will be an important step towards livable and more sustainable cities (Civitas, 2016; Dekoster & Schollaert, 1999). This is confirmed by the positive numbers in on both CO_2 emissions and required space for cycling (Institute for Sensible Transport, 2018). Urban public transport, bus and tram have an even lower space requirement per occupant than bicycle (Figure 1.1). For public transport lies the challenge in both decentralized urban areas and the city centres. The decentralized urban areas are expensive and difficult to serve by public transport (Rodrigue, 2020), but integrating bicycles as access or egress mode with high frequent and high speed public transport services offers opportunities for those decentralized urban areas (Brand et al., 2017).

The current modal split of the five big cities in the Netherlands is visualised in Figure 1.2. The total car use in, to, and from those cities varies from 31% in Amsterdam to 52% in Eindhoven. This is slightly lower than the 53% car share on Dutch national level (Fiorello et al., 2016). This shows that the car is the dominant modality in all these five big cities. All five cities are developing programs to become more sustainable, better accessible, and remain livable (Gemeente Amsterdam, 2020; Gemeente Eindhoven, 2019; Gemeente Rotterdam, 2020; Gemeente Utrecht, 2019; van Asten, 2019). This is amongst other things done by means of distributing space more equally based on the usage of different modes. More space is made for pedestrians, cyclists and public transport. This is done to reach the same end, namely increasing the use of sustainable modes and making the cities more livable.

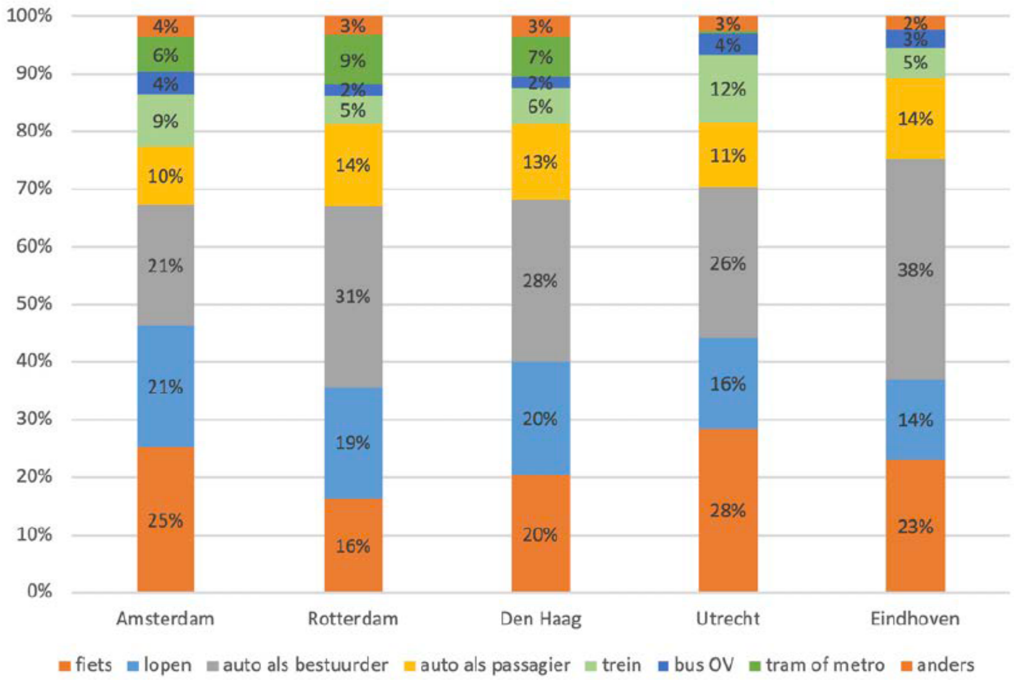


Figure 1.2: Modal split in, to, and from five big cities in the Netherlands, where *orange* = bicycle, *blue* = walking, *grey* = car as driver, *yellow* = car as passenger, *light green* = train, *dark blue* = bus, *dark green* = tram or metro, *orange* = other. Image from: KiM (2019)

Figure 1.2 does not show the proportion of shared modalities. Over the last couple of years, several shared modalities such as shared bicycles, shared scooters, and shared cars are introduced. The concept of shared bicycles was introduced for the first time in Amsterdam in 1965 (DeMaio, 2009). The next shared bicycle concept that came available in the Netherlands is the OV-fiets, which is available at train stations and can be used at the activity end of a trip (Jansen, 2019). Besides the OV-fiets, other free floating or shared bicycles with drop zones has been introduced (Shen et al., 2018), which makes it possible to use the shared bicycle in an access or stand-alone trip as well. The shared scooters are introduced in 2017 (VerkeersNet, 2017). The shared scooter allows users to make stand-alone trips in a shorter amount of time than the shared bicycle. However, the prompt introduction of the shared scooters have a negative effect on the livability in cities, as the scooters can be parked everywhere (Geneste, 2019). The shared cars are the third kind of shared modality, which has become more popular over the last couple of years (CROW, 2020). The effect of shared cars on the driven kilometers differs per car driver, for some drivers there is a decrease of 15 to 20% in kilometers per year, while for other drivers the car use increased as substitute of bicycle or public transport (Autodelen, 2020).

1.1 Problem description and scope

Given the previous knowledge about cities that improve its sustainability and accessibility by distributing space more equally based on the usage of different modes, the car will get less space compared to the current situation. At the same time, pedestrians, cyclists, and public transport will relatively get more space in cities. Therefore, it will become more attractive to use these modes of transport instead of the car. However, this will not be achieved over one night as mode choice has a repetitive nature (H. Aarts, 1996). Currently, trips between 1 and 7 kilometers in big cities is has car a modal share of 32% in the Netherlands (KiM, 2019). The car share increases quickly when the trip distance increases (Gemeente Den Haag, 2016). Therefore, this research will focus on gaining insights in factors that are valued as important by car users for switching towards sustainable modes. These insights are valuable input for the mobility transition plans, where these insights can be used for motivating car users to use sustainable modes.

The sustainable modes in this research will be (shared) bicycle, and urban public transport being bus and tram. This is in line with the mobility transition plans of the Dutch big cities where the focus shifts from car towards those sustainable modes. For shared mobility, this study will focus on shared bicycles because the shared bicycle occupies least space like the regular bicycle (Institute for Sensible Transport, 2018). Shared scooters will not be part of this study because they have a negative effect on the livability of cities. Shared cars will not be considered either because this study focuses on lowering car use for short trips in cities. Bus and tram take even less space per occupant than bicycle, and is a sustainable alternative to car (Redman et al., 2013). Therefore, these two urban public transport modes are part of the research as well.

Trips with the highest share have trip purposes work, shopping including grocery shopping, and for going out, sports, and hobbies Figure 1.3. Trip purpose *to and from work* has the highest car share, followed by shopping (CBS, 2020d). Many previous researched focuses on work or commuting as trip purpose (e.g. Halldórsdóttir et al. (2011); Hróbjartsson (2019); Ma et al. (2020); Tran et al. (2015)). Shopping has an average daily trip share of 20%, of which car is the main modality (Figure 1.3). The average trip distance per day for trip purpose shopping is 3.13 kilometer (CBS, 2020d). So, shopping trips are mainly on the short distances in which car share is almost 50%. Therefore, the trip purpose in this research is shopping, including grocery shopping.

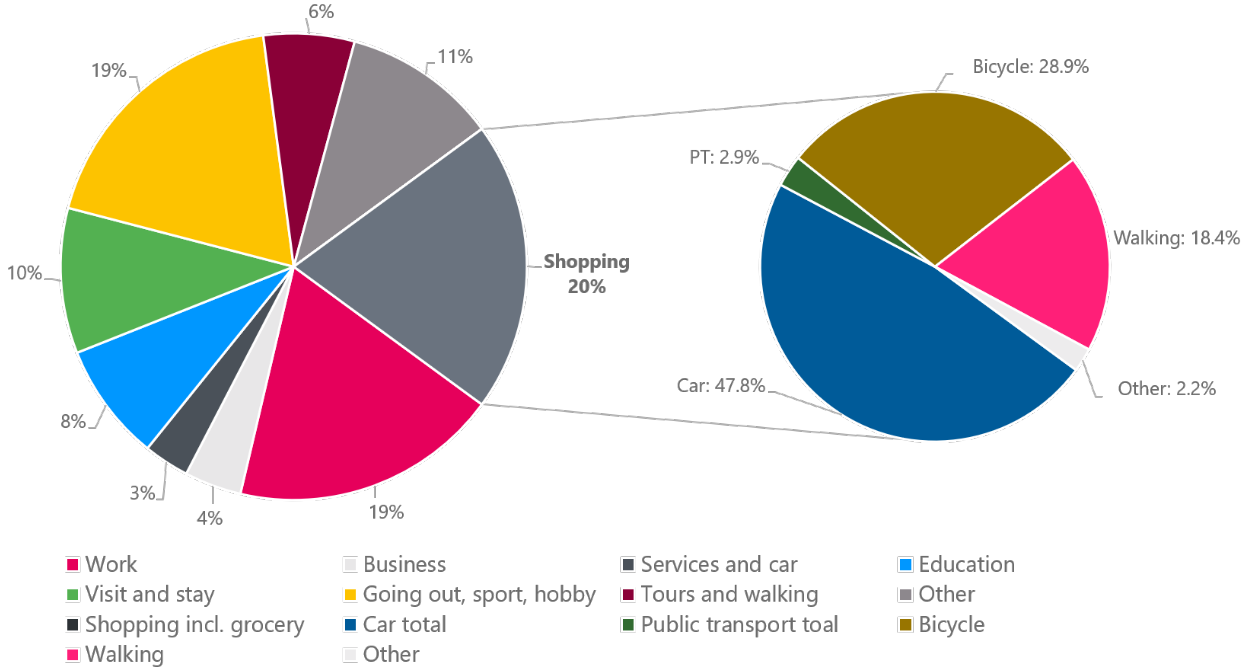


Figure 1.3: Average daily share for trip purpose in The Netherlands, and modal share for trip purpose shopping (CBS, 2020d)

The focus in this study will be on short (<5 km), stand-alone trips within a mid-sized city (+/- 500.000 inhabitants) in the Netherlands. Stand-alone trips in this research are trips within the city, and are in itself thus not access or egress trips to metro/light-rail/train for multi-modal transport. Given the goal to decrease the car use on the short trips in the cities, the focus will be on car users in this study. Although several mode choice researches were conducted previously in literature (e.g. Ton et al. (2019); Ma et al. (2020); Majumdar and Mitra (2013)), specifically the choice between private bicycles, shared bicycles, urban public transport (bus and tram), and car for stand-alone trips in a mid-sized city has not been researched yet. In particular, the factors influencing the mode choice of car users towards one of the previously mentioned sustainable modes will be researched and is an addition to literature.

Figure 1.4 presents a visualisation of the kind of trips taken into account. This is the private bicycle, shared bicycle, public transport (bus and tram), and car. For all modes is access and egress necessary, which consists of walking only. The shared bicycle is a back-to-many shared bicycle variant, where bicycles can be picked up and dropped off in drop zones. There are thus no physical docking stations.

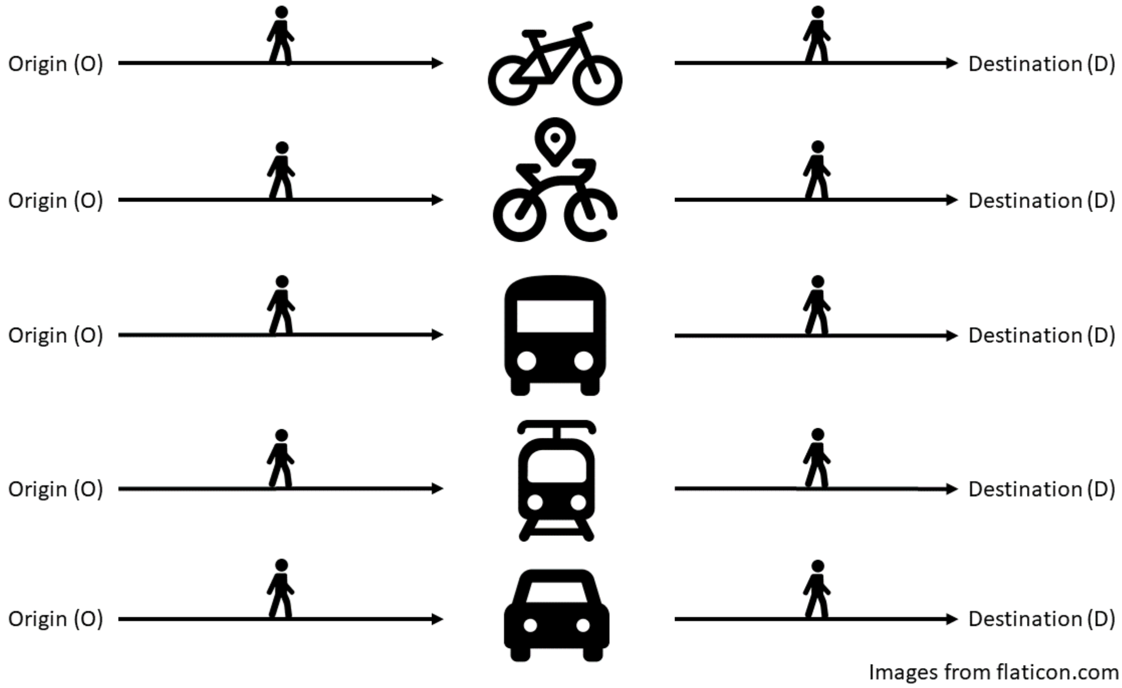


Figure 1.4: Modes in this research: bicycle, shared bicycle, bus, tram and car.
Trip type in this research: stand-alone trips.

1.2 Research objective and research questions

The objective of this research is to gain insight in explaining variables of switching from car towards sustainable modes in a mid-sized city, for trip purpose shopping. In particular switching towards privately owned bicycle, shared bicycle, or bus and tram (urban public transport). This research aims at an integrated analysis on factors that determine the mode choice for switching towards sustainable modes.

In line with the scope of this research is the research question that will be answered in this study:

Which factors influence the usage of private bicycle, shared bicycle, and urban public transport (bus and tram) for stand-alone trips of car users in a mid-sized city with trip purpose shopping, and what measures could increase the potential usage of these sustainable modes?

The main research question is going to be answered by means of a couple of sub-questions:

1. Which factors theoretically influence the mode choice of bicycle, shared bicycle, urban public transport (bus and tram), and car?
2. Which of the theoretical factors from sub-question 1 are most influential and measurable?
3. What is the actual influence of the selected factors in sub-question 2 on mode choice for a stand-alone trip in a mid-sized city?
4. What is the potential use of the private bicycle, shared bicycle, tram and bus?
5. What measures could be taken to extend the potential usage of the sustainable modes?

Research question one and two will be answered through literature study, where factors are identified which proved to have impact on the mode choice and switching towards the sustainable modes. By means of a stated preference survey, the influence of the selected factors is identified. The stated preference results will be used for calculating the potential usage of the sustainable modes. The potential usage here is the difference between the current situation and the situation where the influential factors are implemented. Lastly, through a case study, the results will be applied on the mobility transition plans. The Dutch mid-sized city in the case study will be The Hague.

1.3 Scientific and societal relevance

In terms of scientific relevance, the contribution will be to gain insights in switching from car towards sustainable modes in urban areas, for stand-alone trips with trip purpose shopping. In particular, the addition of shared bicycle in the mode choice set is new in research. In addition, the effect of shared bicycle reliability, i.e. its availability at drop zones, on mode choice is not quantified in literature yet. In this research the quantification of the availability will therefore be done, as an addition to literature.

The results of this research can contribute societally as well. Based on this research, advice can be given to public transport operators, municipalities, and policy makers about making urban areas more sustainable, livable, and accessible while cities are continuously growing. This is an addition to the mobility transition plans of the cities. As the case study will be conducted in The Hague, its public transport operator HTM can identify its potential users. Furthermore, HTM can improve their public transport network, including their shared bicycles service *'HTM Fiets'*.

1.4 Thesis outline

The outline of this thesis is as follows. First, in Chapter 2, the methodologies which will be used are described. This is followed by an extended literature research in Chapter 3. In Chapter 4, the survey design is explained. The survey results are devided in two chapters. Chapter 5 contains the descriptive statistic analysis, and Chapter 6 contains the discrete choice model results. The case study of The Hague is conducted in Chapter 7. The report will end with conclusions in Chapter 8 and a discussion which includes recommendations in Chapter 9.

Chapter 2

Research methodology

This chapter describes the research methodology. The methods described in this chapter will help answering the main research question. At first, the literature study will be introduced in Section 2.1. The literature review helps answering the first two sub-questions. The main methodology of this research will be a stated preference choice experiment, which will be introduced in Section 2.2. The stated preference survey is used to answer research question 3. The gathered stated preference data will be analyzed using various models (Section 2.3). The last part of this research consists of a case study, which is introduced in Section 2.4. In the case study, the results will be applied on the Dutch mid-sized city The Hague.

2.1 Literature review

The first step in this research is a literature review conducted in Chapter 3. The literature review enables answering research question 1 and 2. The purpose of this literature review is mainly to identify the state-of-the-art, and to be able to answer the first two sub-questions. The literature review will therefore focus on travel behavior research in general first. This will be followed by factors for the usage of the four modes in this research: bicycle, shared bicycle, public transport, and car. These mode choice factors will be followed by the identification of factors for modal shift from car towards bicycle, shared bicycle and public transport. Literature will be found through a couple of online databases. Amongst others, Google Scholar, Scopus, Worldcat Discovery TU Delft, and Science Direct are used. Keywords which are used in the search of literature is amongst others 'mode choice', 'modal shift', mode 'usage factors' of bicycle, shared bicycle, bus, tram, and car, 'travel behavior', 'choice behavior', 'stated preference'. Keywords are combined using boolean operators. In addition is the snowballing technique used.

2.2 Stated preference choice experiment

The literature review forms the basis for a stated preference choice experiment. This experiment will be carried out by means of a survey. This section will describe the steps for the stated preference survey. At first, the reason for stated preference data is argued in Subsection 2.2.1. This is followed by Subsection 2.2.2, where the theory behind choice experiment designs and the design type used in this research will be explained.

2.2.1 Stated preference data

Choice observation data can be collected in two ways: via revealed preference and stated preference. These two types of choice data gathering will be evaluated in this section, after which a choice is made for the type of data gathering in this study. Choice observation data will be collected, as trade-offs cannot be asked for directly. This has a couple of reasons (Chorus, 2018a). Firstly, people do not know their trade-offs while making choices. Secondly, people hesitate in many cases to give their true trade-offs. Lastly, judgement is more susceptible to bias than choices. The remainder of this section focuses on the two types of data collection.

Revealed preference

Revealed preference (RP) data contains people's actual choices (Train, 2003). This is its biggest advantage, but it is suitable for forecasting choices if the choice alternatives and market conditions do not change much (Molin, 2018a), and for alternatives and attributes which currently exist or have existed historically (Train, 2003). This shows already one of the limitations of RP data: revealed preference cannot be used for new alternatives or for testing new attributes (Molin, 2018a). Besides, the choice set of which respondents choose is unknown, as only the chosen alternative is given. Another limitation is multicollinearity (Molin, 2018a). Furthermore, for RP are many respondents required, as there is only one choice per respondent. This is expensive as many respondents are needed. Lastly, there may be insufficient variation in the data, which makes important factors important to detect with the revealed preference data (Train, 2003).

Stated preference

To obtain stated preference (SP) data, a questionnaire with choice experiments is designed which is presented to respondents (Train, 2003). In this questionnaire, the researcher constructs choice sets and the respondent is asked which option one would choose in the real world. The constructed options can include hypothetical alternatives, such as non-existing alternatives, new attributes, and levels outside the current value range (Molin, 2018a). SP also allows the researcher to make as much variation as appropriate (Train, 2003). Moreover, experimental design allows to control the correlation amongst attributes, which enables avoiding multicollinearity. Lastly, respondents make multiple choices (opposed to RP), so smaller samples are needed for reliable estimates (Molin, 2018a). All of the aforementioned advantages of SP are solutions to the limitations of RP. Nevertheless, the main drawback of SP is the hypothetical choices respondents need to make. It is not sure whether people would make the same choice in a real life decision as well (Molin, 2018a; Train, 2003). This is caused by a couple of things: respondents do not feel the consequences of the choice, respondents have perfect information which is not the case in real life, and the new alternatives are not experienced yet (Molin, 2018a).

In this study, stated preference data will be obtained by creating a survey with choice experiments. In line with the goal of this research, to identify factors for switching away from car use, choices will be constructed to identify the car users'trade-offs. The design of the stated preference survey will be explained in Chapter 4.

2.2.2 Choice experiment design

Choice experiments consist of several parts. These parts will first be elaborated on, followed by the actual construction of the choice sets.

Alternatives, attributes and attribute levels

To obtain the stated preference data, choice sets need to be generated. Choice sets consist of three parts: alternatives, attributes, and attribute levels. Choice sets are the set of alternatives which is presented to the respondent (Train, 2003). The choice sets at least should have three characteristics according to Train (2003). First, they must be mutually exclusive. Second, all possible alternatives should be included, so it should be exhaustive. Lastly, the number of alternatives should be finite.

Attributes are the characteristics of the alternatives. Attributes should describe the context of the alternative, in order to prevent the respondents from making assumptions. Also, attributes that are relevant for policy or design should be selected (Molin, 2018a). Besides these characteristics of the attributes, the number of attributes cannot be too high (de Dios Ortúzar & Willumsen, 2011) because then it may be that respondents simplify their choices by focusing on a smaller number of attributes, or answer at random (Carson et al., 1994; Sælensminde, 1999).

The last part of a choice set is the attribute level. Levels are typically limited to 2 to 4 levels (Molin, 2018a). Three and four level attributes result in polynomial curves, and allows for linearity testing, so have the preference. In all cases, the ranges should be wide (Molin, 2018a). Wide ranges allow all levels to fit in, it increases validity, and reliability. Validity is increased because a wider range makes interpolation possible, which is more reliable than extrapolation. Reliability can be increased by a wider range, because it will create smaller standard errors. In all cases, all combinations of all attribute values should make sense. These requirements are kept in mind while designing the attribute levels for this survey.

Experimental design construction

The number of choice sets, and the choice set design, depend on all of the previously mentioned items: the number of alternatives, the number of attributes, and the number of attribute levels. There are four design types that can be considered (ChoiceMetrics, 2018): *full factorial designs*, *fractional factorial designs*, *efficient designs*, and *bayesian efficient designs*. Full factorial designs have all possible different choice situations, for which fractional factorial designs are the solution if all different choice situations are too much. The fractional factorial designs consist of a subset of the full factorial designs. Of the full factorial designs, the orthogonal designs are the most popular, as those minimize correlations between attribute levels (ChoiceMetrics, 2018). Furthermore, the standard error of the attributes is minimized, which results in reliable parameters (Molin, 2018b). With increasing number of alternatives and attributes, the number of choice sets increases as well. The downside of orthogonal designs is that it may result in dominant alternatives, which cannot be removed from the design because that will result in correlations within the alternatives.

(Bayesian) efficient designs are used to avoid dominance by balancing the utilities of alternatives in choice sets, but that requires prior knowledge on attributes. Based on the prior knowledge (applied in the model as 'priors'), the efficient design maximizes information about trade-offs, while minimizing the standard errors of parameters (Molin, 2018c). In general, compared to orthogonal designs require efficient designs less choice sets (ChoiceMetrics, 2018). The difference between efficient designs and bayesian designs is that instead of the fixed priors in efficient designs, the priors are considered as random parameters (ChoiceMetrics, 2018). That results in more stable designs.

All these types of designs can be generated by Ngene, which is software that generates experimental designs which are used in stated choice experiments (ChoiceMetrics, 2018). Ngene can generate the designs for a couple of efficiency measures: d-efficient, a-efficient, s-efficient, b-efficient, and wtp-efficient. The d-, a-, and s-efficient designs optimize for the sample size, b-efficient for utility balance, and wtp for the willingness to pay (ChoiceMetrics, 2018). The d-optimality criterion is the optimal design criterion according to literature (Carson et al., 1994), so the d-efficiency measure will be used while generating designs in Ngene.

In this study, the used alternatives, attributes, and attribute levels are elaborated on in the survey design in Chapter 4. The experimental design construction will be determined in Chapter 4 as well, as it depends on the number of alternatives, attributes, and attribute levels, which will be specified in the survey design.

2.2.3 Conclusion stated preference choice experiment

In this study, stated preference data will be obtained by creating a survey with choice experiments. In line with the goal of this research, to identify factors for switching away from car use, choices will be constructed to identify the car users' trade-offs. The design of the stated preference survey will be explained in Chapter 4, where the alternatives, attributes and attribute levels will be defined. The experimental design will be made using Ngene. For the pilot survey a non-bayesian efficient design will be made, because not all prior values are known in literature. For the final survey design a bayesian efficient design is made, using the pilot survey outcomes as prior values.

2.3 Discrete choice modelling

Choice models are a key pillar on which transport models and policies are built in most developed countries, because transportation and its effects are all about choices (Chorus, 2018a). Within discrete choice modelling, first are people's choices observed by - in this case - a stated preference survey. With the choice data, the preferences and trade-offs are inferred. Based on the trade-offs, future choices are predicted (Chorus, 2018b). This section will focus first on the model types available for the analysis of the choice set data in Subsection 2.3.1, followed by model performance measures in Subsection 2.3.2. Subsection 2.3.4 concludes on the models that will be used in this research.

2.3.1 Model types

One of the most-used decision rule for discrete choice models is the Random Utility Maximization (RUM) theory, which is based on the utility maximization assumption (Ben-Akiva & Bierlaire, 1999; Train, 2003). RUM is based on three main pillars: revealed preference axiom, probabilistic decision making, and multi-attribute consumer theory (Chorus, 2018a). Within the RUM theory, the utility is composed of a systematic part V and a random part ε, for alternative i (Equation 2.1). The systematic part V is the observed part of the utility function, which consists of the - to be estimated - tastes β and attribute values x_i of all alternatives m. The random part ε captures all unobserved utility for each alternative. Alternative i is chosen if the utility of alternative i is bigger than the utility of alternative j (Equation 2.2) (Train, 2003).

$$U_i = V_i + \varepsilon_i = \sum_m \beta_m \times x_{im} + \varepsilon_i \tag{2.1}$$

$$P_i = \text{Prob}(U_i > U_j,\ \forall j \neq i) \tag{2.2}$$

$$P_i = \text{Prob}(U_i - U_j > 0,\ \forall j \neq i) \tag{2.3}$$

$$P_i = \text{Prob}(\varepsilon_j - \varepsilon_i > V_i - V_j,\ \forall j \neq i) \tag{2.4}$$

As Equation 2.3 shows, RUM is about the utility *difference* that makes respondents choose - in this case - either alternative i or j. This utility difference is still the case if the utilities are decomposed into its systematic (V) and random (ε) part (Equation 2.4). The βs can be estimated using the program PandasBiogeme (Bierlaire, 2020), in which the upcoming model types will be analysed.

Multinomial Logit model

The multinomial logit (MNL) model is the simplest and most widely used discrete choice model (de Dios Ortúzar & Willumsen, 2011). In the MNL model, the random part ε of Equation 2.1 is independently identically distributed (iid) Extreme Value Type I across alternatives, choice situations, and individuals (Chorus, 2018a; Train, 2003). This leads to a closed form choice probability formulation in Equation 2.5. The numerator consists of the exponential value of the observed utility part of the *chosen* alternative by respondent n. The denominator consists of the sum of exponential observed utility parts of the *non-chosen* alternatives in choice set J for respondent n.

$$P(in) = \frac{\exp(V_{in})}{\sum_{j=1}^{J} \exp(V_{jn})} = \frac{\exp(\sum_m \beta_{mn} \times x_{imn})}{\sum_{j=1}^{J} \exp(\sum_m \beta_{mn} \times x_{jmn})} \tag{2.5}$$

There are three aspects why using an MNL model may cause trouble (Chorus, 2018c; Train, 2003). The first possible trouble is when one or more subsets of alternatives share common factors which are not captured in the observed utility. Given the iid assumption in an MNL model, it is assumed there are no correlations between subsets of alternatives. When alternatives share common factors, there are correlations and the iid assumption is not valid anymore. This also happens with the second possible trouble: not all variation in utility may be captured in the observed part of the utility function (V). As a result, the remaining part that determines the utility ends up in the unobserved part of the utility function: the error term ε. The third possible trouble, the MNL model does not capture for variations across individuals as MNL is not able to capture that one respondent fills in multiple choice sets. Despite of these drawbacks, MNL is still a widely used model. In this study, the MNL model will be used as first estimation of the results from the stated preference study.

Mixed Multinomial Logit model

Mixed Multinomial Logit (MMNL) models, also familiar as Mixed Logit (ML) models, are more used than MNL models nowadays, amongst others because ML is able to cope with the previously mentioned drawbacks of the MNL model (Chorus, 2018c). Moreover, the ML model is flexible and can approximate any random utility model (Mcfadden & Train, 2000). It has become popular since simulations became more common to use, as simulations enabled to vary explanatory variables over decision makers rather than over the market as a whole (Train, 2003). While in MNL the random error ε is independently identically distributed (iid), MMNL is able to cope with common characteristics of different alternatives. MMNL does that by the so-called mixed logit error component model. In the mixed logit error component model, an additional error component is added to alternatives with common characteristics which are not captured in attributes (Train, 2003). A second form of MMNL models is a random coefficient mixed logit model, where a distribution for coefficients is specified by the researcher (Train, 2003). This distribution can vary in tastes for different decision makers. The third and last possible MMNL model is a panel model. Panel effects correct for the MNL assumption where each choice set is seen as a new individual. ML panel enables correcting for that assumption, by considering correlations within each respondent instead. A model which corrects for panel effects only is called a *panel model*.

This research uses a combination of the panel model and error component mixed logit model. Further referred to as panel mixed logit model with error component. Equation 2.6 shows the ML equation which is the integral of the log probability $L_{in}(\beta)$ and a $f(\beta)$ density function, over parameters β (Train, 2003). The density function $f(\beta)$ and the log probability $L_{in}(\beta)$ depend on parameters β. Within the log probability $L_{in}(\beta)$ is $V_{in}(\beta)$ the observed utility of alternative i for respondent n.

$$P_{in} = \int L_i n(\beta) f(\beta) d\beta \tag{2.6}$$

$$\text{where: } L_{in}(\beta) = \frac{\exp(V_{in}(\beta))}{\sum_{j=1}^{J} \exp(V_{jn}(\beta))}$$

2.3.2 Goodness of fit

The *likelihood ratio index* is used often in discrete choice models (Train, 2003). This index is a measure for how well the model fits the data, which has a range from 0 (very poor model) to 1 (perfectly fit). Equation 2.7 shows the likelihood ratio index equation, which is also known as McFadden's rho-square (ρ^2) (Hauser, 1978; McFadden, 1973).

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \tag{2.7}$$

Where:

ρ^2	= McFadden's rho-square
$LL(\hat{\beta})$	= Final log-likelihood; log likelihood of the tested model
$LL(0)$	= Null log-likelihood; log likelihood when all estimated betas would be zero

Besides the likelihood ratio test are a couple of statistical tests which enables comparing model fit across models: Likelihood Ratio Statistic (LRS) (Chorus, 2018a), Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Kuha, 2004; Schwarz, 1978), and Ben-Akiva and Swait test (Chorus, 2018d). The main difference between the four is that LRS (Equation 2.8) can compare models with comparable structures, and enables comparing two models of which one is a simplification of the other. AIC (Equation 2.9) and BIC (Equation 2.10) can both be used to compare completely different model structures (Ton, 2020). Ben-Akiva and Swait test (Equation 2.11) can compare two models with the same number of parameters, and can be used combined with the AIC and BIC test.

$$LRS = -2 \times (LL_A - LL_B) \tag{2.8}$$

$$AIC = -2 \times LL + 2 \times K \tag{2.9}$$

$$BIC = -2 \times LL + K \times \ln N \tag{2.10}$$

$$p = NormSDistr(-\sqrt{2 * N * ln(J) * (LL(model1) - LL(model2))/LL(0)}) \tag{2.11}$$

Where:

LL	= Log-likelihood
k	= Number of parameters to be estimated
N	= Number of observations
NormSDist (x)	= probability that draw from standard normal is smaller than x
J	= Number of alternatives in choice set

Both AIC and BIC criteria have the aim of identifying good models. Using AIC and BIC together for model selection criteria is recommended, as both criteria can fail when used as a single model fit estimator. When both criteria agree on the best model, it ensures robustness of the chosen model (Kuha, 2004). Therefore, both criteria will be used to identify the best model fit in this study. AIC and BIC will be used in combination with LRS in case of similar models with different number of parameters, and in combination with Ben-Akiva and Swait test in case of different models with the same number of parameters.

2.3.3 Modal split

With the final estimated discrete choice model results, modal split will be calculated. Modal split can be used to calculate the effect of changes in attribute levels on mode choice. The modal split calculation will be done by using Equation 2.6. For calculating the modal split for a panel mixed logit model with error component, simulations are needed as well (Train, 2003). For modal split, pseudo Monte Carlo simulation will be used, where pseudo draws from a normal distribution are drawn. Halton draws will be used, as those are *intelligent* draws (Chorus, 2018c). The modal split calculations will be done using PandasBiogeme (Bierlaire, 2020).

Besides the modal split from the current and maximum potential situation, significant parameters will be gradually changed in value, from the minimum to the maximum attribute level value. Due to this gradual change, the impact of a change in attribute value on the modal split becomes visible. By means of these outcomes, conclusions can be drawn on factors which have most influence on modal shift.

2.3.4 Conclusion discrete choice modelling

A stated preference survey will be designed, which will be analysed with the multinomial logit model at first. Given the limitations of the MNL model, a panel model will be applied next, which has the main purpose of identifying a possible panel effect. Furthermore, a panel mixed logit model with error component will be estimated. Error components will be added to alternatives with common characteristics, of which the best fitting model will be chosen. The goodness-of-fit criteria LRS will be used as a start to see the difference between the MNL model and panel model, as well as for the differences between the panel model and panel mixed logit model with error components. Simultaneously, the AIC and BIC criteria will be used for determining the best model. With the best fitting model, modal split will be estimated lastly for calculating the maximum potential of interventions.

2.4 Case study: identifying potential usage of sustainable modes

The survey will be conducted in a specific context: The Hague, a Dutch mid-sized city. The focus in both the survey and the case study will therefore be on The Hague specifically. This enables identifying the potential usage of sustainable modes amongst car users in various parts of the city. It furthermore enables advice to HTM, The Hague public transport operator, and The Hague municipality. This section argues first why a case study can be used as research methodology (Subsection 2.4.1). Thereafter, an introduction is given on the steps that will be undertaken in the case study to identify the potential usage of sustainable modes, and how that potential usage can be extended.

2.4.1 Case study as research methodology

The case study, as defined by Yin (1994), is "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used*". In other words, defined by Zainal (2007), "*case studies explore and investigate contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships*". The focus of this case study is a specific context in terms of geographical area: The Hague, which is a Dutch mid-sized city of about 545.000 inhabitants in 2020 (Gemeente Den Haag, 2020).

Case study is a scientific research method, because "*it allows finding answers to questions with good evidence and good reasoning, which can be done in various ways*", and a case study is one of those ways (Thomas, 2015). The case study offers results for Dutch mid-sized cities regarding the factors that influence the shift from car usage to sustainable modes in this research, and specifically for Dutch mid-sized cities the results can be used for policies. Generalization of case study results is a draw-back of doing a case study, as it is a single context (Thomas, 2015; Yin, 1994).

The case study research methodology consists of four stages according to Yin (1994): (1) Design the case study, (2) Conduct the case study, (3) Analyze the case study evidence, and (4) Develop the conclusions, recommendations and implications.

2.4.2 Conclusion case study

For The Hague situation, in-depth analysis on modal split change will be done. The goal of this case study is two-fold: identifying the potential usage of sustainable modes, as well as gaining insight in the factors that most influence the modal shift towards sustainable modes. These goals will be achieved by applying the model results on the mobility transition plans by The Hague municipality (van Asten, 2019). The case study will be conducted in Chapter 7.

2.5 Conclusion

The first methodology step is literature review which will be conducted in Chapter 3. The literature review will answer research question 1 and 2. The literature outcomes are theoretical factors of mode choice and modal shift, which will be used as a basis for the stated preference survey design that will be made in Chapter 4. The results of the stated preference survey will be analysed in Chapter 6, by using the panel mixed logit model with error components in PandasBiogeme (Bierlaire, 2020). The outcomes of the discrete choice model will answer research question 3. The last two research questions will be answered through a case study in Chapter 7 on the mid-sized city The Hague, the Netherlands. The case study answers research question 4 and 5.

Chapter 3

Literature review

This chapter contains a literature review. This review starts in Section 3.1 with literature on travel behavior research in general. The goal of this literature review is two-fold. The first goal is to find factors which influence the mode choice of bicycle, shared bicycle, urban public transport, and car. This enables answering the first research question. The second goal is to find factors that influence the switch towards these sustainable modes, which will be done in Section 3.3. The output of this chapter will used as basis for the stated preference survey design.

3.1 Travel behavior research

People who travel from an origin to a destination, make a couple of decisions before undertaking the trip. The four-stage model of McNally (2008) shows that those steps are: trip generation, trip distribution, mode choice, and route choice. The focus in this research is mode choice, because choosing (another) mode is what is meant by switching from car to private bicycle, shared bicycle, or urban public transport. To identify the reasons for switching or not switching away from car usage, the underlying factors should be identified. In general, factors influencing mode choice can be classified into three categories: characteristics of the trip maker, characteristics of the journey, and characteristics of the transport facility (the mode) (de Dios Ortúzar & Willumsen, 2011). These factors are the underlying explaining variables of choosing a mode. People evaluate the advantages and disadvantages of mode alternatives, under the trip circumstances, and based on those factors. Based on the weight of the pros and cons, the mode decision is made (H. Aarts, 1996). An overview of the factors according to de Dios Ortúzar and Willumsen (2011) is given in Table 3.1.

Table 3.1: Influencing factors of mode choice (de Dios Ortúzar & Willumsen, 2011)

Trip maker characteristics	**Journey characteristics**	**Transport facility characteristics**
Car availability and/or ownership	Trip purpose	Travel time components
Having a driving license	Time of day	Monetary cost components
Household structure	Trip alone or with others	Parking availability and costs
Income		Reliability of travel time
Residential density		Frequency
		Comfort and convenience
		Safety, protection, security
		Demands of driving task

Factors from the three categories in Table 3.1 are often taken into account in other literature. The factors of the first category (trip maker characteristics) are mostly asked for in socio-demographic variables, in surveys. Car availability influences the choice for both bicycle and public transport, such that by having a car available, bicycle and public transport use is lower compared to when a car is unavailable (M. J. Aarts, Mathijssen, van Oers, & Schuit, 2013; Corpuz, 2007; de Witte et al., 2013; Heinen, Maat, & van Wee, 2013; Rietveld & Daniel, 2004).

For repetitive trips, the mode choice decision is not made based on the aforementioned trip characteristics, because mode choice has a repetitive nature (H. Aarts, 1996). Its repetitiveness has an impact on future mode choices, because once a mode is chosen for a certain trip, it is very likely that the same mode is chosen the next time as well. The more often the same mode is used for a certain trip, the stronger the habit becomes for that particular mode. As a result of that, the intention to choose another mode becomes way lower, so the chance on other mode choice behavior decreases as well (H. Aarts, 1996). The presence of habits in mode choice results in people not changing modes, but as the initial choice was made for car over private bicycle, shared bicycle, or urban public transport, the car had more advantages compared the other modes. Therefore, the underlying factors for choosing those modes should be identified, such that changes can be made to make (one of) the sustainable modes more beneficial over the car alternative.

This study is not the first in researching mode choice of car, (shared) bicycle and (urban) public transport. Therefore, the remainder of this literature review will evaluate the knowledge (gaps) on the individual modes first, followed by the knowledge on switching from car to one of the three sustainable modes.

3.2 Mode usage factors

For all modes in this research, factors for mode usage is searched for. Firstly, the factors for private bicycle usage is searched for, followed by the factors for shared bicycle, public transport, and car.

3.2.1 Factors for private bicycles usage

The Netherlands can be considered as a cycling country: the cycling level is higher compared to other countries such as the UK and USA (Pucher & Buehler, 2008). Starting with the average bicycle occupancy, which is 1.4 bicycles per person in The Netherlands (Harms & Kansen, 2018). On average, the Dutch cycle more than 880 kilometers per person per year, divided over 250 to 300 trips (Fietsersbond, 2019). In comparison to other countries in Europe, 43% of the Dutch population cycles daily and 28% cycles a few times per week, which is respectively 31 and 11 percentage points higher than the European Union average (European Commission, 2013). A couple of differences can be identified of countries with high cycling levels compared to countries with low cycling levels. One of the differences that in the first women cycle as often as men, while in the latter men cycle more often (Garrard, 2003; Pucher & Buehler, 2008). Also, being young increases the likelihood of cycling (Table 3.2). Income and education have contradictory results on the likelihood of cycling in low(er) cycling level countries (Muñoz et al., 2016), while in the Netherlands cycling is evenly distributed across all income groups, and for all ages (Pucher & Buehler, 2008). Research towards cycling is done in different countries worldwide, mainly in the UK, USA, Canada and Australia (Pucher & Buehler, 2008). Looking at the couple aforementioned differences of countries with high and low cycling levels, those researches can be used partly, but cannot be generalized to the Dutch context as the Dutch cycling conditions differ from other countries. The Netherlands has high quality bicycle infrastructure, flat terrain, a mild climate, lots of bicycle parking facilities, and short travel distances within cities (Heinen et al., 2010; Schepers et al., 2017). Therefore, this part of the literature review will focus on the Dutch context mainly.

Table 3.2: Socio-economic and household cycling characteristic variables of Dutch studies in Muñoz et al. (2016); adapted table, * reference = university, ** reference = living with both parents; x = not significant, + = significant positive effect, - = significant negative effect

	Gender (male)	Age (young)	Income	Level of studies *	Family type **	Car availability	Bicycle availability	Transit availability
Rietveld and Daniel (2004)		+	x			-		
Bruijn et al. (2005)	-	-		+	+			
Engbers and Hendriksen (2010)	x	x	x	x				
Heinen et al. (2011)								
Heinen et al. (2013)	x	+				-	+	+
M. J. Aarts et al. (2013)	x	+				-		

A part of Table 3.2 focuses on the availability of other modes. The availability of other modes has different effects on bicycle usage. Bicycle availability influences the use of private bicycles positively (Heinen et al., 2011), as without the availability, one cannot use the bicycle. Car availability influences the use of bicycles the other way around: when a household has one or multiple cars available, bicycles are used less often (M. J. Aarts et al., 2013; Heinen et al., 2013; Rietveld & Daniel, 2004). Public transport availability within 500 meters has a positive effect on bicycle usage, however stimulating public transport and bicycle usage simultaneously has a significant ($p<0.01$) negative effect on bicycle usage (Heinen et al., 2013).

Besides the availability of other modes, the intention and attitude both have a positive effect on bicycle usage (Bruijn et al., 2005; Heinen et al., 2013). Attitudes are influential for the mode choice decision of cycling as a commuter (Heinen et al., 2011): comfort, flexibility and time-saving are seen as direct benefits of cycling. Those benefits are experienced the same in short distances (< 5km), medium distances (5-10 km) and longer distances (>10 km). Regardless of the benefits at all three distance classes, trip distance generally influences the bicycle usage negatively (M. J. Aarts et al., 2013; Engbers & Hendriksen, 2010; Heinen et al., 2013). This finding supports the scope of this research, which takes trips up to 5 kilometers into account. The last influencing factor is bicycle parking. Private bicycles are in the Netherlands usually parked nearby one's home or in someone's shed. This makes it an easy accessible mode. Being certain of bicycle parking at the destination side influences bicycle use positively (Heinen et al., 2013).

3.2.2 Factors for shared bicycle usage

The first shared bicycles were introduced in 1965 in Amsterdam, the Netherlands. These shared bicycles could be used for free, and left behind anywhere in the city (DeMaio, 2009). This first generation ended shortly after its introduction, because of high bicycle theft. The second generation came up in 1991, in Denmark. This time, the bicycles could be picked up at a station using a coin deposit (DeMaio, 2009). The second generation faced theft of the bicycles as well, so it did not survive either. The third generation started in 1996, and resulted in worldwide programs for shared bicycles in several cities of the USA and Europe (Shaheen & Guzman, 2011). This generation makes use of mobile phones and smart cards for picking up and dropping off bicycles, and for locating and reserving the bicycles (Shaheen & Guzman, 2011). A Dutch example of a shared bicycle system is OV-fiets (Figure 3.1). The fourth generation is smarter and more advanced than the third generation. The main difference is that the fourth generation does not need docking stations anymore, but can be considered as free floating, or it makes use of drop zones (Shen et al., 2018). Two Dutch examples of the fourth generation shared bicycle is Mobike (Figure 3.1) and HTM Fiets (HTM, n.d.-b).

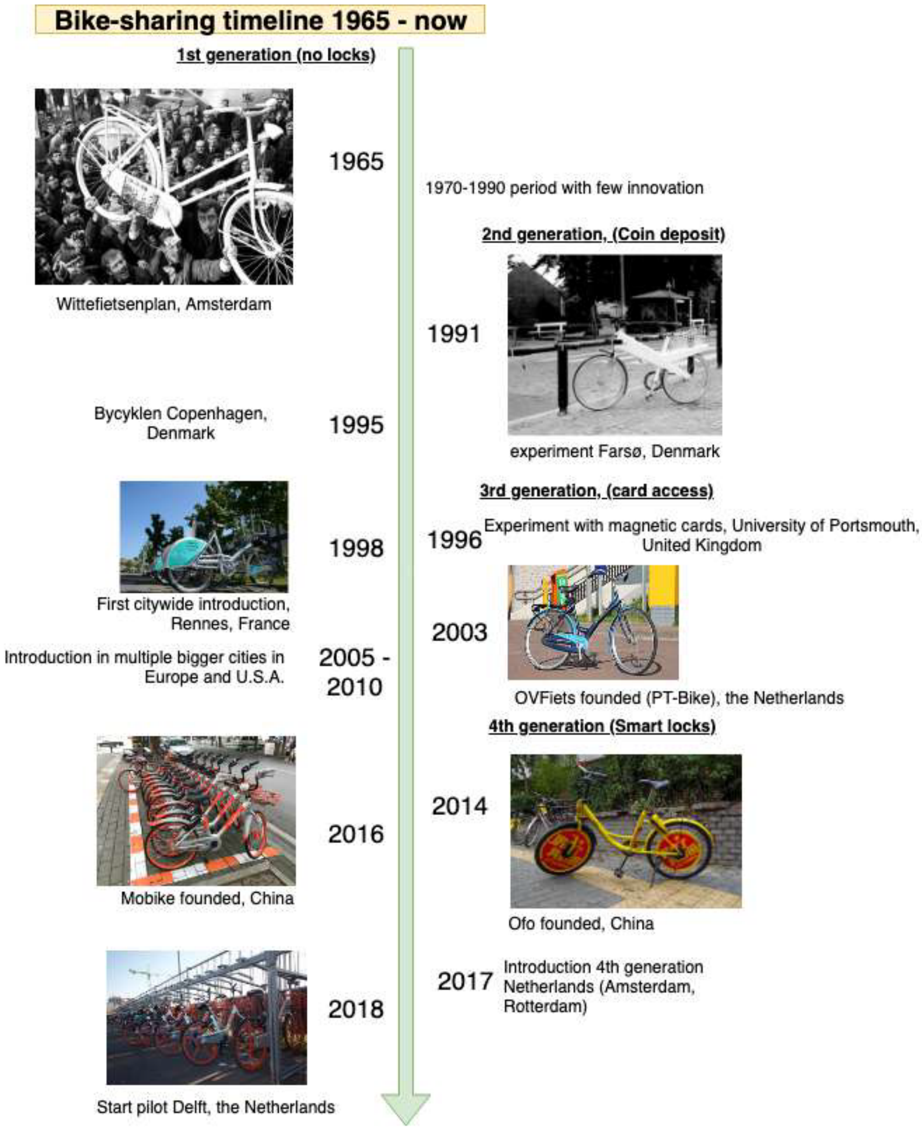


Figure 3.1: Shared bicycle timeline from Boor (2019)

In general, four types of shared bicycles can be classified into four quadrants as can be seen in Figure 3.2. The quadrants here are based on the trip type and whether the shared bicycle has a station (van Waes et al., 2018). The shared bicycle systems without a station are called 'free-floating' shared bicycles, which means there are no physical docking-stations for the shared bicycles. Although there are no physical docking-stations in the station-less variant, there are shared bicycle operators which work with geographical zones. In those zones, also known as *drop zones*, the bicycles can be picked up and dropped off. An addition to Figure 3.2 is for the fourth quadrant: HTM Fiets, the shared bicycle from the public transport operator in The Hague which was introduced in May 2019 (HTM, n.d.-b).

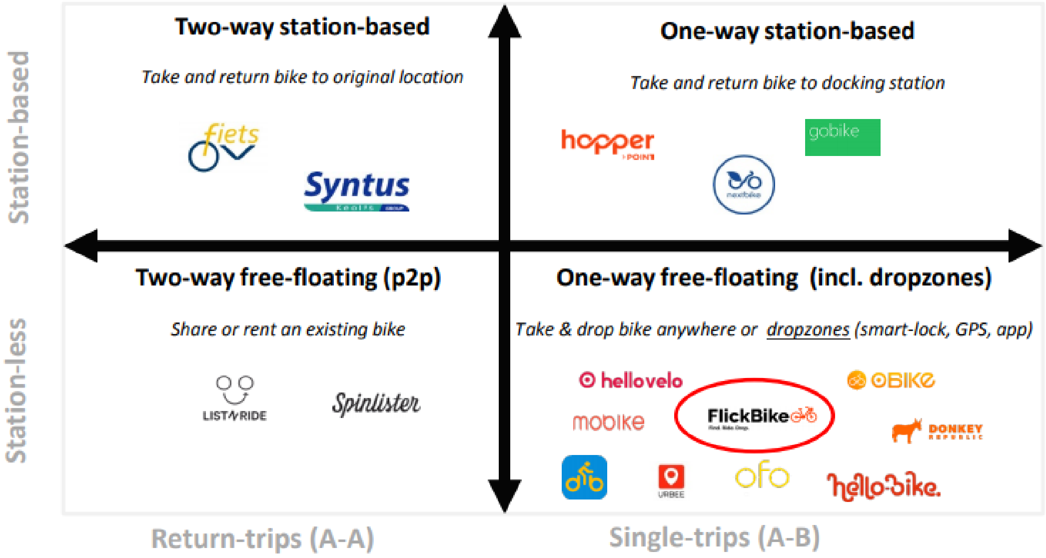


Figure 3.2: Shared bicycle types overview by van Waes et al. (2018)

Since the beginning of the 21st century, research has been done about shared bicycles. Factors of using shared bicycles were revealed, and more knowledge about the consequential modal shift has been gained. Knowledge of both will be collected here, because it will form a basis for the survey, and will reveal knowledge gaps.

Bike sharing is mostly used because it is convenient (Fishman, Washington, & Haworth, 2013). Generally speaking, convenient means *"suitable for your purposes and needs and causing the least difficulty"* and *"near or easy to get to or use"* (Cambridge Dictionary, n.d.). Although Fishman et al. (2013) does not specify the meaning of convenient, one of his ways to measure convenience is by the distance between home and the closest docking station. This is a reliable predictor for shared bicycle usage (Fishman, Washington, & Haworth, 2014). Other motivations for bike sharing are getting around easier, faster and shorter (Fishman, 2016). Benefits of shared bicycle usage according to Hróbjartsson (2019) are improved health, increased transportation choice and convenience, reduced travel time and cost, and improved travel experience.

Shared bicycles seem to be used mostly for short distances, and one-way trips (Bachand-Marleau et al., 2012). This finding fits within the scope of this study: trips with a maximum of 5 kilometers in a mid-sized city. A couple of studies show that shared bicycle trips vary between 2.4 and 4.4 kilometer, and vary in trip time from 14 to 22 minutes (Fishman et al., 2014; Jensen, Rouquier, Ovtracht, & Robardet, 2010; Zhang & Mi, 2018). As the distances of the shared bicycles are short, it is not surprising that the proximity of residential addresses to the pick-up point of shared bicycles has a powerful influence on the use of the shared bicycle program (Fishman et al., 2013). Within the body of literature, the distance to docking stations differs between 250 meters (Fuller et al., 2011), 300 meters (Faghih-Imani & Eluru, 2015), and 500 meters (Bachand-Marleau et al., 2012). Having a drop zone closer to ones home and destination is one of the reasons found by van Marsbergen (2019) to use HTM Fiets more often. Drop zones which are located close to facilities, business areas and around public transport nodes seem to be used mostly (van Marsbergen, 2019). Earlier studies contradict each other about the effect of more drop zones of the use of the shared bicycle systems, so it cannot be said with certainty whether more drop zones will attract more users (de Chardon, Caruso, & Thomas, 2017; Zhang, Thomas, Brussel, & van Maarseveen, 2016).

Other than convenience, trip distance, and distance to docking station, a couple of other factors are mentioned in literature. The usage costs of shared bicycles are proven to be lower compared to public transport and car (Shen et al., 2018), however the costs of the shared bicycle system have a large effect on the attractiveness (van Heijningen, 2016). Moreover, in terms of costs is found that a cost-free period of 30 minutes results in a spread of bicycle usage within the 30 minutes, a sharp peak at 6 minutes, and a sharp decline just before 30 minutes (Jurdak, 2013). Besides paying for every single trip, subscription systems are reviewed. It appears that long-term subscriptions are mainly used by commuters, while the short-term subscriptions trip purposes are more varied and for more occasional trips (Hróbjartsson, 2019; Tran et al., 2015). Frade and Ribeiro (2015) indicate different commonly used subscription systems. Short-term subscriptions are normally 1-day, 3-day or 7-day tickets, while long-term subscriptions are monthly or annual.

The reliability in terms of availability of the bicycles at docking stations has only been found once in literature. van Marsbergen (2019) found that one of the reasons to use HTM Fiets more often is certainty of a shared bicycle being available. In public transport, service reliability is one of the travelers' dissatisfiers (Peek & van Hagen, 2002). This is related to the bicycle unavailability, the travel time of the trip increases directly, because the traveller should look for another alternative. Here, another alternative could be other docking station or another mode. Therefore, it is important that this service reliability is in place for shared bicycles as well.

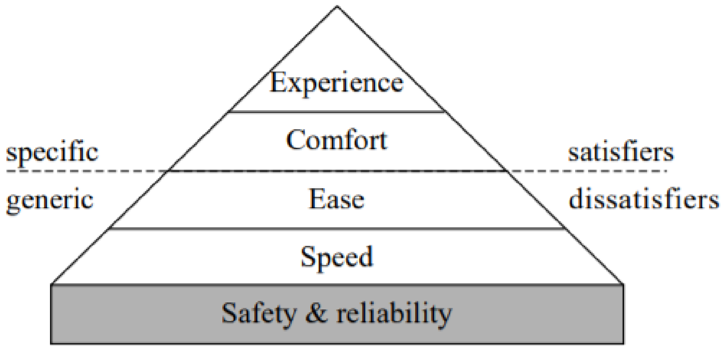


Figure 3.3: Pyramid of traveler desires, image from Peek and van Hagen (2002)

As mentioned in Subsection 3.2.1, the availability of other modes influenced bicycle use. The availability of other modes does have influence on the shared bicycle use as well. People who have a private bicycle available, make use of shared bicycles as well (Bachand-Marleau et al., 2012). The availability of bicycles in the Netherlands is on average 1.4 bicycles per person (Harms & Kansen, 2018).

3.2.3 Factors for public transport usage

This section contains a review of public transport factors which are influential on the public transport use. Starting with the pyramid of travel desires as showed in Figure 3.3, which is applicable on public transport (Peek & van Hagen, 2002). As can be seen in the pyramid (Figure 3.3), there are two types of factors: satisfiers and dissatisfiers. Satisifers are experience and comfort. Dissatisfiers are ease (convenience), speed, and safety and reliability. The dissatisfiers are a minimum requirement for the quality of public transport, otherwise travelers avoid the service (Peek & van Hagen, 2002). The satisfiers on the other side are extra services, which make the service more attractive.

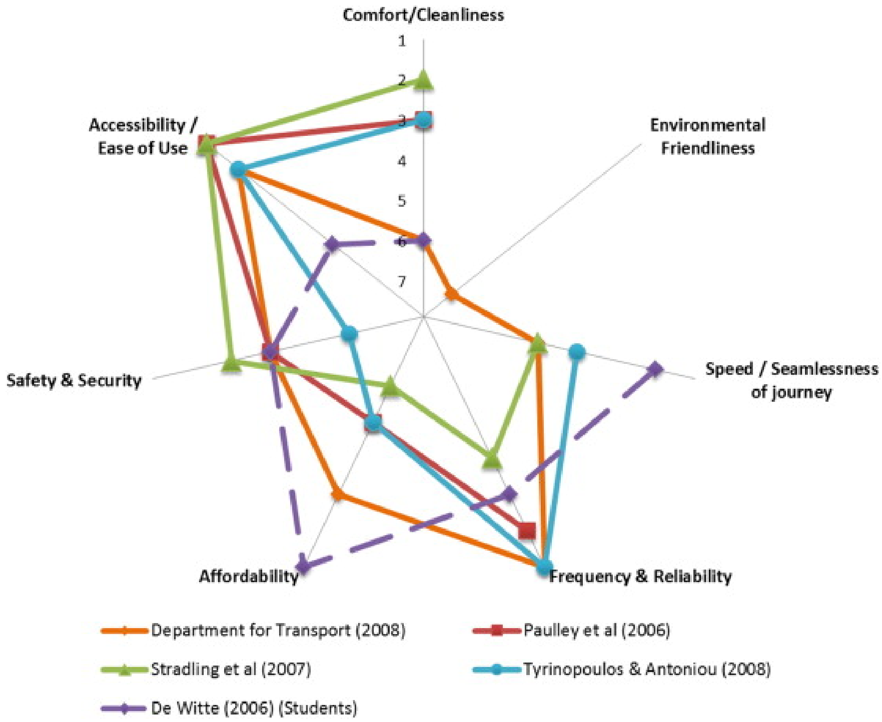


Figure 3.4: Pull factors for Public Transport according to five studies, 1 = most important attribute, 7 = least important attribute. Image from Batty et al. (2015)

Later studies confirm the findings of Peek and van Hagen (2002). Starting from the bottom of the pyramid in Figure 3.3 with safety and reliability. Figure 3.4 shows the importance of the safety and security attribute. Public transport should be safe and secure enough, as well at the stop, as in the service itself (Batty et al., 2015). Reliability has different definitions: the service being on time (Beirão & Cabral, 2007), the service meeting the expected service quality (being: waiting, travel time and comfort) (van Oort, 2011), and the ability of passengers to rely on the service (Batty et al., 2015). Beirão and Cabral (2007) find that unreliability is seen as a disadvantage of public transport, and Batty et al. (2015) shows the importance of the reliability attribute as well (Figure 3.4).

Speed is the next factor. Speed is directly related to all aspects of travel time as the time budget of passengers is scarce (Beirão & Cabral, 2007; van Hagen & van Oort, 2019). Higher public transport times reduce the use of public transport (de Vasconcellos, 2005), and in general travel time has a negative effect on customer satisfaction (Beirão & Cabral, 2007). So, the factor speed is an important attribute, which is also shown by Figure 3.4. Travel time consists of several components: access/egress time, waiting time, in-vehicle time, and transfer time (Figure 3.5). Access and egress time is directly related to the public transport network design: designs with high line and stop densities minimize access and egress time (van Nes, 2020), however high stop densities influence the in-vehicle time negatively. Besides the negative effect on in-vehicle time, continuously decreasing access distances to public transport stops do not lead to higher public transport use (Corpuz, 2007). Access distances in literature differ; optimized stop spacing for both user and operator leads to an optimal stop spacing between 650 and 700 meters (van Nes, 2020), but walking distances to a bus stop should not be higher than 400 meters (Boulange et al., 2017). As last part of travel time, waiting time is a direct effect of the frequency of the service, and is evaluated as an important attribute, like reliability in Figure 3.4 (Batty et al., 2015).

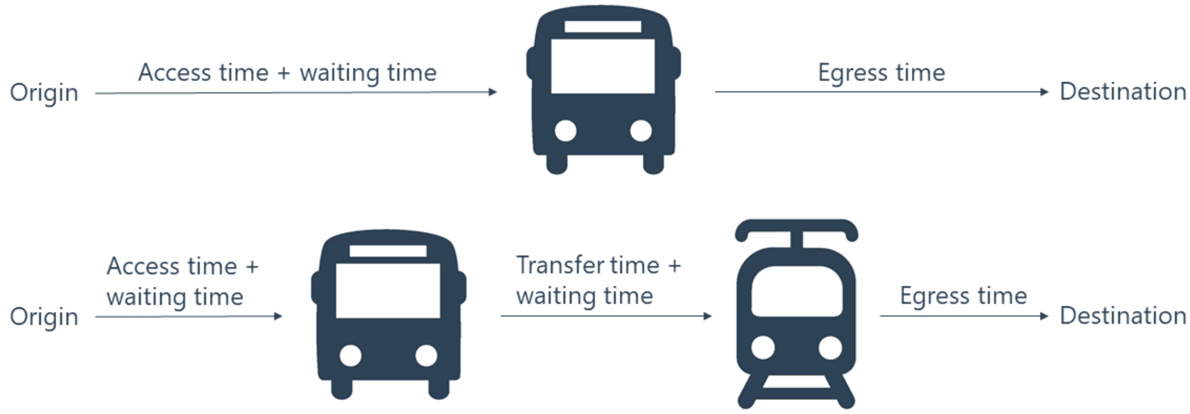


Figure 3.5: Trip chain without and with transfer. Vehicles indicate the in-vehicle time;
own image with icons from flaticon.com

The third, and last dissatisfier, from the Peek and van Hagen (2002) pyramid in Figure 3.3 is ease (of use), also known as convenience. There are different definitions of convenience in public transport: not stressful (Corpuz, 2007), boarding, in-bus crowd, bus steps and chair convenience (Gebeyehu & Takano, 2007), and short access time, convenient transfer, and clear information of bus stop on route (Chen & Li, 2017). Batty et al. (2015) shows in Figure 3.4 that ease of use is in the same category of accessibility, which is both valued as an important attribute for choosing public transport. In this study, convenience will therefore be defined the same as in the shared bicycle category, as the accessibility of a bus or tram (i.e. (short) access time).

The three dissatisfiers of public transport are now discussed. The two satisfiers comfort and experience are left. Comfort is the level of passenger wellbeing in as well the vehicle as at the stop (van Oort, 2011). Comfort is in literature defined as probability of finding a seat, crowdedness in the vehicle, seating comfort, and clean vehicles (Fellesson & Friman, 2008; İmre & Çelebi, 2017; van Oort, 2011). Comfort is in different countries valued as important quality aspect of public transport (Fellesson & Friman, 2008), which is in line with the pyramid of traveler desires from Peek and van Hagen (2002).

The travel experience is the second satisfier in the pyramid from Peek and van Hagen (2002), and is defined as the experience while waiting and transferring to other modes. Judgments towards public transport, such as the quality of the service, cost, travel time and punctuality influence the experience (Olsson, Friman, Pareigis, & Edvardsson, 2012).

3.2.4 Factors for car usage

Car use is attractive because of its convenience, speed, comfort and individual freedom (Beirão & Cabral, 2007; Batty et al., 2015; Corpuz, 2007; Kang et al., 2019). Trips by car are seen as convenient because three aspects are comfortable: no waiting time, a trip can made whenever one wants to, and the car brings the traveler close to its destination (Corpuz, 2007). The flexibility of cars, in terms of going everywhere at any time, is also valued by car users (Batty et al., 2015; Kang et al., 2019). Next to these perceived advantages is car availability in the household very influential on the mode choice, and the amount of cars per driver in a household increases the probability of choosing car for travel instead of other modes (de Witte et al., 2013). Parking availability at the activity-end of the trip also impacts mode choice for car. Guaranteed (free) parking space at work stimulates people to take the car (de Witte et al., 2013; Hamre et al., 2014). Especially in highly dense areas, the availability of car parking influences the modal choice (Kajita, Toi, Chishaki, & Matsuoka, 2004). The reduction of parking spaces in cities make car trips in cities unattractive (Batty et al., 2015; Hagman, 2003).

In short trips (<8 km) trip purpose seems to influence the car use most (Mackett, 2003). The reasons for the three trip purposes in this study are further elaborated on: work, shopping, and recreational trips. For trip purpose work, the two mostly given reasons for usage is that the car is needed at work and because the user is short on time. For shopping, the most given reason is because of heavy goods, and because it is a long way. For the recreational purpose, the reasons differ: carrying heavy goods, lift to family, long way, convenience and further trip are mentioned most often. In short, the most given arguments for car use in short trips according to Mackett (2003) are: carrying heavy goods, being short on time, convenience, and distance.

3.3 Modal shift

For all modes, factors that influence mode choice are identified. This section focuses on literature which gives insight on switching towards (shared) bicycle in Subsection 3.3.1, and switching towards public transport in Subsection 3.3.2.

3.3.1 Switching towards (shared) bicycle

In cities, most shared bicycle users come from public transport and walking, followed by car (Fishman et al., 2013; Murphy & Usher, 2015). The substitution percentage of cars by shared bicycles differs per city, ranging from 2% to 21% in the cities reviewed by Fishman (2016) (Figure 3.6). Figure 3.7 shows a bit lower substitute, as if HTM Fiets was not available, only 4.2% of the shared bicycle users would shift towards car. Figure 3.8 shows the same result compared to Fishman (2016) (Figure 3.6): a decrease in car usage due to the introduction of all three shared bicycle systems: Mobike, OV-fiets and Swapfiets (Ma et al., 2019).

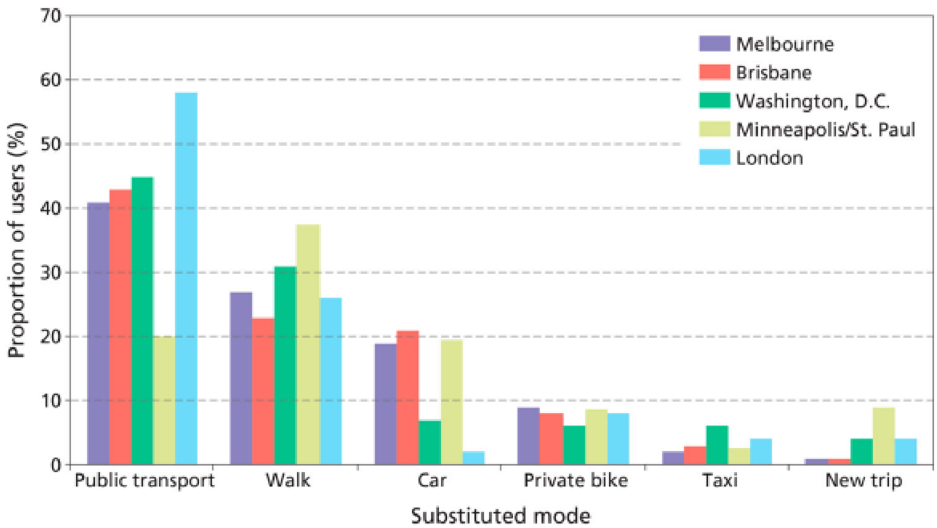


Figure 3.6: Shared bicycle replacements; image from: Fishman (2016)

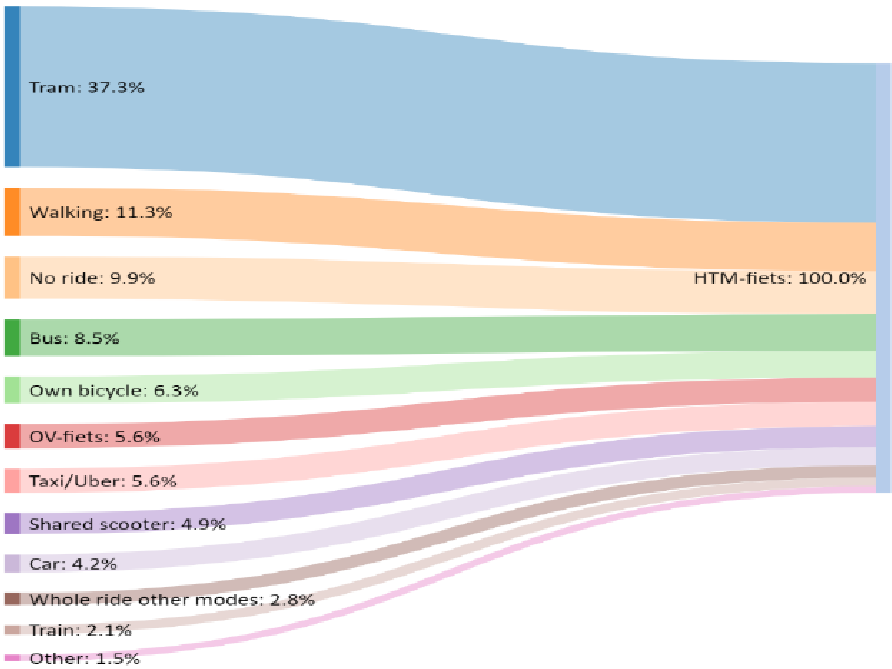


Figure 3.7: Modes used if HTM Fiets was unavailable, image from: van Marsbergen (2019)

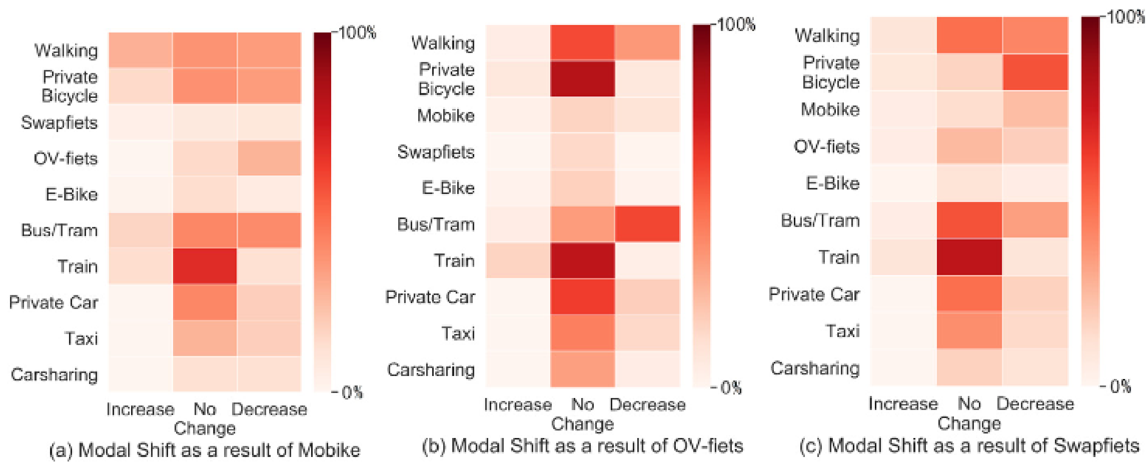


Figure 3.8: Modal shift as a result of three shared bicycle types in Delft, The Netherlands, image from: Ma et al. (2019)

There are a couple reasons that cause the modal shift from car to (shared) bicycles in cities. The purpose and frequency of the trips determine the willingness of bicycle sharing system usage (Politis et al., 2020). For both short (<25 min) and long (>25 min) trips, car users are less likely to use the shared bicycle for entertainment trips, while commuters are more likely to do so. In terms of frequency, daily trips and infrequent trips (3-5 times a month), are more likely to change towards shared bicycles than trips undertaken 3-5 times a week.

Costs of the alternative option and travel time are also factors that influence the choice for shared bicycle over car (Halldórsdóttir et al., 2011; Politis et al., 2020). The cost of the shared bicycle influences the car users' mode choice, higher costs for the shared bicycle influences the usage of the shared bicycle harshly in a negative way (Politis et al., 2020). Travel time has a significant negative effect on both bicycle and car use, of which the effect of travel time is stronger for shared bicycle (Halldórsdóttir et al., 2011). This shows that for longer trip duration car is more attractive than shared bicycle. This is in line with the finding in Ma et al. (2019), where two-third of the respondents was willing to shift from car to shared bicycles for short trips (<2 km).

Last effect that was found to be influential for switching towards (shared) bicycles is the car parking availability, at as well the origin and destination side (de Witte et al., 2013). When car parking is unavailable, alternative modes are used to get to one's activity. The effect of payed parking over free parking facilities is such that the probability of cycling increases when parking is payed (Hamre et al., 2014).

3.3.2 Switching towards public transport

Factors that make car users switch towards public transport are partly different and show some similarities with shifting towards (shared) bicycles. The similarities are the effect of parking facilities availability, and the influence of travel time and travel costs on mode choice. The unavailability of parking facilities, and the availability of payed parking facilities have a negative impact on car use. Both types of parking regulations make public transport and (shared) bicycles more attractive (Batty et al., 2015; Beirão & Cabral, 2007; de Witte et al., 2013; Hamre et al., 2014; Hagman, 2003). Shorter travel time, and lower or even free public transport influence the switch towards public transport in a positive way (Redman et al., 2013).

Other factors that make public transport more attractive to car users are the service frequency, reliability, convenience, and public transport mode (Beirão & Cabral, 2007; Corpuz, 2007; de Witte et al., 2013; Kang et al., 2019; Redman et al., 2013). The service frequency should be high, which is in line with the finding that freedom, flexibility and independence are both factors that car users value in car usage (Batty et al., 2015; Corpuz, 2007; de Witte et al., 2013; Kang et al., 2019). Service reliability definition according to Beirão and Cabral (2007) is that the public transport service is on time, such that the passengers do not have to be uncertain about the time the service will arrive. When the reliability is valued low, the car users will switch back to their car. Convenience has a positive effect on intention to switch, with convenience meaning adequate personal space, and having control over the trip movement (Kang et al., 2019). The latter is in line with the reliability of the trip. The last factor which is important to realize is that when car users switch towards public transport, they have a preference for bus over tram, while more frequent cyclists would choose tram over bus (Bunschoten et al., 2013).

3.4 Conclusion

The main reasons for car usage are convenience, speed, no waiting time, comfort, individual freedom, and being able to arrive close to one's destination (Figure 3.9). Convenience for car users is defined as having no waiting time, being flexible, and having the ability to arrive close to its destination. Besides those factors, households with more cars available have a higher car frequency. Previous studies about switching from car towards (shared) bicycles and public transport show factors influencing the switch, which are visualised in Figure 3.10. For both, the costs, travel time, and car parking availability are influential. What is missing between Figure 3.9 and Figure 3.10 is the following. As shared bicycles can be seen as a form of public transport, the service reliability in terms of having a solid shared bicycle available in the nearest drop zone has probably an effect on the switching. However, that has not been researched yet. Moreover, as in car use comfort is an important factor, what comfort factors will influence the switch towards either shared bicycles and public transport. Convenience is another factor that is overlapping in all four modes in Figure 3.9, but has not been researched for the switch towards (shared) bicycles. As it is important in all four modes, it is expected to have an effect for switching towards (shared) bicycles as well. As convenience is defined as the ease of accessibility to a drop zone, the upcoming research will focus on that definition.

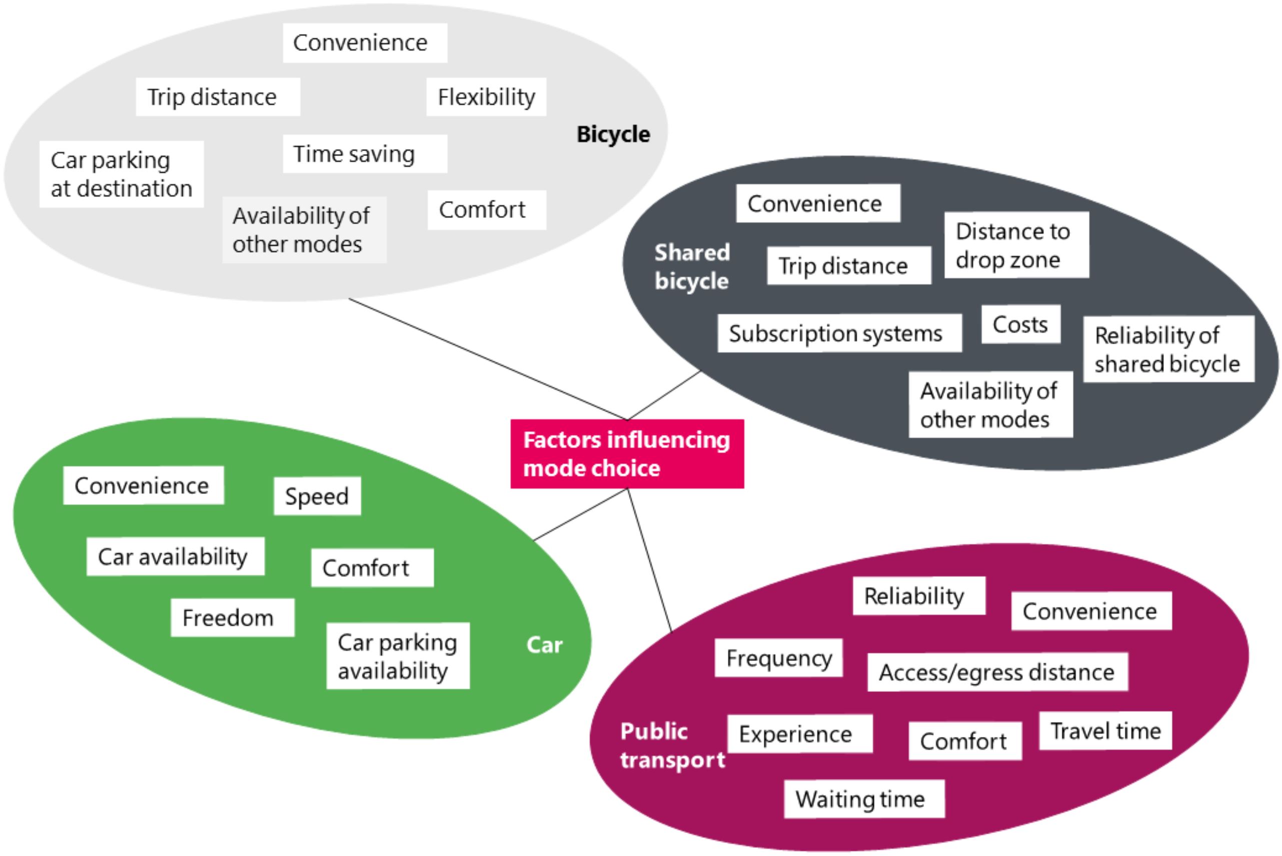


Figure 3.9: Factors influencing mode choice for each mode individually, based on literature review

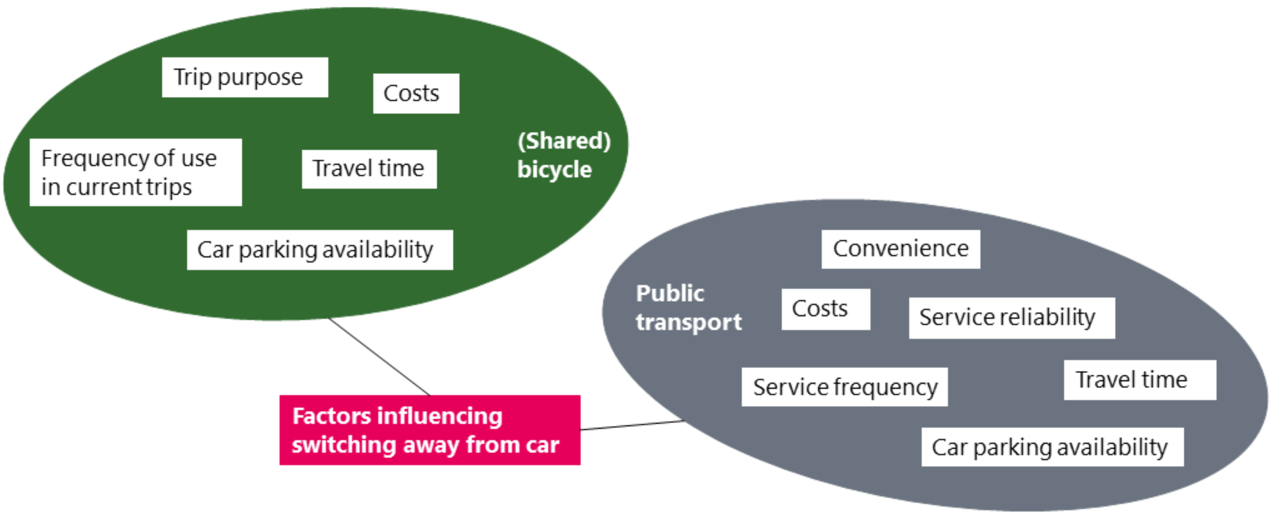


Figure 3.10: Factors influencing the switch from car towards (shared) bicycle and public transport, based on literature review

Chapter 4

Survey Design

This chapter will describe the generation of the initial survey design in Section 4.1, which is tested in a pilot group. The lessons learnt from the pilot survey are used to make improvements for the final survey design in Section 4.2.

4.1 Pilot survey

The generation of stated choice experiments consist of three steps (ChoiceMetrics, 2018). The first step is *model specification* in Subsection 4.1.1, followed by *generation of experimental design* in Subsection 4.1.2. The third and last step in Subsection 4.1.3 is questionnaire construction.

The pilot survey will have of two scenarios: 2.5 kilometer to the city centre, and 5 kilometer to the city centre, which enables the identification differences and similarities of both distance classes. The differences and similarities in the survey design will be discussed in both Subsection 4.1.1 and Subsection 4.1.3.

4.1.1 Model specification

The model specification consists of two main choices which need to be addressed: the alternatives that need to be included, its corresponding attributes, and attribute levels. The last two steps of the model specification consists of choosing the model type, after which the utility functions can be created.

Alternatives

In a stated preference study, choices are presented to respondents. In this study, the choices consist of four alternatives: bicycle, shared bicycle, urban public transport and car. Bicycle, shared bicycle, and urban public transport are three sustainable alternatives for car (Chapter 1). Bicycle could be a good alternative for car trips because it is comfortable, flexible, and time saving (Heinen et al., 2010). Besides, given both the scope of the study of identifying factors to decrease car usage within one's home city and the average number of bicycles of 1.4 in households (Hamre et al., 2014), own bicycles are considered as alternative. Shared bicycles can be seen as a form of public transport (Chapter 3). In general, shared bicycles are used mostly for short distances, and one-way trips (Bachand-Marleau et al., 2012), and are a substitute for car in 2% to 21% of the cities (Fishman, 2016). Both bicycles and shared bicycles are part of the study, as people who own a bicycle also use shared bicycles (Bachand-Marleau et al., 2012). Public transport is part of the research as it could bring car users close to its destination in the city centre as well, and both bus and tram are a more sustainable alternative for car. Public transport consist of two modes: tram and bus. The fourth and last alternative is car, which is included to see the trade-offs compared to car.

Attributes

Attributes are the characteristics of the alternatives. Table 4.1 shows an overview of the included attributes for each alternative. The included attributes are total travel time, (mode) type, costs, availability, frequency and crowdedness. The chosen attributes are based on the literature review in Chapter 3, of which the reasoning behind the choice will be explained in the remainder of this section. As can be seen in Table 4.1, not all attributes are included in each alternative. This has to do with the characteristics of the alternatives: simply not all attributes are relevant for every alternative.

Table 4.1: Overview of alternatives and their attributes

	Bicycle	Shared bicycle	Public transport	Car
Total travel time	x	x	x	x
Type		x	x	
Costs		x	x	x
Availability		x		
Frequency			x	
Crowdedness			x	x

Total travel time	The time of the whole trip from A to B in minutes.
Type	A further specification of the mode type for *shared bicycle* and *public transport*.
Travel costs	*Shared bicycle and public transport*: the costs of using the service in euros; *Car*: the parking costs at the destination side in euros.
Availability	*Shared bicycle*: the availability of shared bicycles at the nearest drop zone, 10 minutes before departure from home, which have a 90% chance they can be used. If not, one should walk 5 minutes to the next drop zone
Frequency	The time in minutes between two *public transport* services (headway time).
Crowdedness	*Public transport*: Level of crowdedness in the public transport service, in terms of seat availability; *Car*: delay on top of total travel time, as a result of parking search time in minutes.

The chosen attributes aim at describing the trip in a way that the respondent does not imagine characteristics themselves. The choice for total travel time, is twofold. First, speed is part of the pyramid of traveler desires from Peek and van Hagen (2002), which is a minimum requirement for shared bicycle and public transport. For both bicycle and car, the benefits are respectively time-saving (Heinen et al., 2011), and its speed (Batty et al., 2015). Second, it is part of the *transport facility characteristics*, which influence mode choice in general (de Dios Ortúzar & Willumsen, 2011).

The choice for travel costs is also chosen because it is part of the *transport facility characteristics* that influence mode choice (de Dios Ortúzar & Willumsen, 2011). In addition, travel costs influence the choice for shared bicycle over car (Halldórsdóttir et al., 2011; Politis et al., 2020). For public transport, a lower public transport fee influences the switch positively (Redman et al., 2013). Also, parking costs at the destination side were found influential for mode choice (Hamre et al., 2014; de Witte et al., 2013). Therefore, for shared bicycle and public transport, the fares are included as attributes, and for car the parking costs at the destination side.

Mode type is included in the attributes, to be able to test different kinds of shared bicycles and public transport. For HTM, insights in the effect of electric shared bicycles over the regular shared bicycles will be gathered. Furthermore, Bunschoten et al. (2013) found that frequent car users like to switch towards bus, while frequent cyclists rather switch towards tram. Therefore, both bus and tram are included in the model to identify potential differences between the two urban public transport types. Further elaboration on the included mode types will be given in Section 4.1.1.

The fourth included attribute is availability. This one is included in the shared bicycle alternative only. As was concluded in literature (Chapter 3), reliability is one of the dissatisfies according to the pyramid of traveler desires from Peek and van Hagen (2002). This directly relates to availability for shared bicycles. van Marsbergen (2019) concluded that reliability of the shared bicycles was an issue, but she did not quantify the reliability. Therefore, availability of the shared bicycles are included to be able to quantify the reliability of shared bicycles.

The last two attributes that are included in this survey are frequency and crowdedness. Literature shows that car use is attractive because of its convenience, speed, comfort, and individual freedom (Beirão & Cabral, 2007; Batty et al., 2015; Corpuz, 2007; Kang et al., 2019). According to the pyramid of traveler desires from Peek and van Hagen (2002), convenience (ease of use) is a dissatisfier if not included, and comfort is a satisfier when included. Part of comfort is in-vehicle crowdedness (Haywood et al., 2017). Therefore, for the public transport alternative, both frequency and (in-vehicle) crowdedness are included to see if this influences the car users' choice for another sustainable mode. Expected is that these two have an effect on the choice for public transport, because of the characteristics which make car use attractive. Higher frequency leads to more speed and freedom, and a lower in-vehicle crowdedness leads to higher comfort.

The crowdedness attribute is also part of the car alternative. Crowdedness in the car alternative stands for the crowdedness in the car parking spots in parking garages in the city centre. During busy hours, less parking places are available and parking search time goes up. It is known from the literature review (Chapter 3) that parking availability at the destination influences mode choice (de Witte et al., 2013; Kajita et al., 2004), and extra time for finding a parking place in Dutch context was researched by Arentze and Molin (2013) which resulted in a significant effect on mode choice. The respondents in Arentze and Molin (2013) are a national sample of Dutch inhabitants, but not specifically car users in a mid-sized city. Therefore, by including the parking search time, more knowledge will be gathered on Dutch car users in a mid-sized city.

Attribute levels

Attribute levels are the values of the attributes. Table 4.2 gives a complete overview of the attribute levels which are used in the initial survey design. The reasoning behind the attribute levels follows after Table 4.2.

Table 4.2: Attribute levels for scenario 2,5 km and scenario 5 km in initial survey design

		Bicycle	Shared bicycle	Public transport	Car
Total travel time [min]	2,5 km	11, 12, 13	12, 13, 14	11, 13, 15	9, 11, 13
	5 km	21, 22, 23	22, 23, 24	19, 21, 23	18, 20, 22
...of which walking time [min]		1 (= +/-100 m) 3 (= +/-250 m) 5 (= +/-400 m)	3 (= +/-250 m) 5 (= +/-400 m) 7 (= +/-550 m)	3 (= +/-250 m) 6 (= +/-500 m) 9 (= +/-750 m)	1 (= +/-100 m) 4 (= +/-350 m) 7 (= +/-600 m)
Type		Own bicycle	Shared bicycle Shared e-bike	Bus Tram	Own car
Costs [€]		-	0, 1, 2	1, 2, 3	5, 10, 15
Availability		-	1-2 available 3+ available Booked	-	-
Frequency [every X min]		-	-	5, 10, 15	-
Crowdedness		-	-	Quiet Not quiet/not busy Busy	No parking search time Search time, +3 min Search time, +6 min

Starting with the first attribute: total travel time. This is the only attribute that differs in levels for the 2,5 kilometer and 5 kilometer scenarios. In the basis, the average speed of each of the alternatives is used for calculating travel time. The average cycling speed in the Netherlands is 15.8 km/h (Fietsersbond, 2019). In big cities the cycling speed is lower, in Amsterdam and Utrecht the average cycling speed is relatively 14.4 km/h and 14.7 km/h. Therefore, in this study an average speed of 15 km/h is used for calculating the cycling speed. Bus and tram have both an average speed of 15 to 20 km/h in cities (Brogt, 2013). Tram expert Erik Oerlemans from Goudappel advised to work with 18 km/h, so the average speed in this research is set on 18 km/h (Oerlemans, 2020). Lastly, the average speed of cars in The Hague. As can be seen in Figure 4.1, the main roads have an maximum speed of 50 km/h while the neighborhoods all have a maximum speed of 30 km/h. The city centre has a 30 km/h-zone as well. In three big cities in the Netherlands, being Amsterdam, Rotterdam, and The Hague, the car speed is the lowest compared to other places in the Netherlands (PBL, 2012). The travel time for car is calculated via the Google Maps route planner, which is an average speed of 20 km/h.

In *total travel time*, walking time is included. For walking, an average speed of 5 km/h is considered. The walking times are based on walking distances, which can be seen in Table 4.2. For the bicycle is chosen to range the walking time between 100 and 400 meters, as own bicycles can be parked nearby one's house, and close to the destination. For the shared bicycle, currently there is one available within 250 meters from one's house, and are many drop zones available within the city centre. Therefore is chosen to vary with both a higher and lower value, because that allows testing whether the walking distance to drop zones should be higher or lower than in the current situation. For public transport, currently the maximum walking distance from a passenger's home to the stop is 400 meters. Given the stops in the city centre, the middle level is set at 500 meters. The lower and upper level differ with 250 meters from the middle level. Lastly, car distances are based on the walking distance from the Q-Park parking garages in the city centre (Q-Park, 2020), and the walking distance at the origin side of the trip. In the most positive scenario, the walking distance is only 100 meters, and it increases with 250 meters up to the highest level which is 600 meters.

The total travel distance always adds up to 2,5 or 5 kilometers, depending on the scenario. The total travel time is calculated using Equation 4.1.

$$Total\ travel\ time = \frac{scenario\ distance - walking\ distance}{vehicle\ speed} + \frac{walking\ distance}{walking\ speed} \tag{4.1}$$

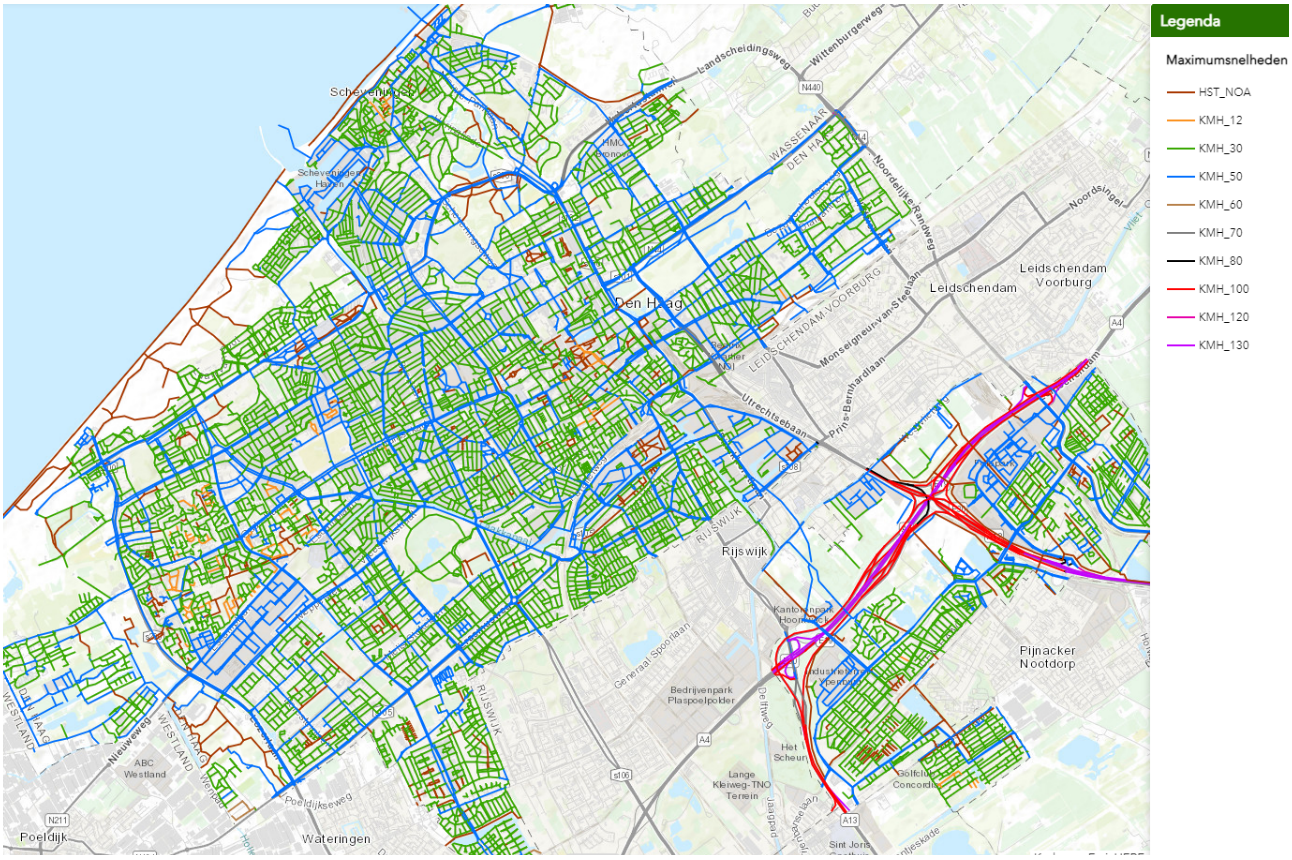


Figure 4.1: Maximum speed overview of The Hague (Dataplatform, 2021), where green is 30 km/h and blue is 50 km/h.

The next attribute is *type*. The attribute levels vary for shared bicycle and public transport only, as for the bicycle and car own vehicles should be kept in mind during the survey. A variation for shared bicycle is made of a regular shared bicycle and an electric shared bicycle. In this thesis period is one shared e-bike available in The Hague (Gemeente Den Haag, 2021), which is a shared e-cargo bike from Cargoroo (Cargoroo, 2021). This is not a regular e-bike, as it has space in front for cargo, and children. However, this is a back-to-one system, so the bicycle should be picked-up and left-off at the same location. This is not the case for the shared e-bike in this study, which is the back-to-many variant using drop zones. For public transport, the choice is made for both bus and tram, as from the literature study in Chapter 3 followed that car drivers and bus passengers have a preference for bus, while cyclists and tram passengers have a preference for tram (Bunschoten et al., 2013). Given the tram bonus, which does exist according to Bunschoten et al. (2013), both modes are part of this study.

Costs is the third attribute. Here, the attribute levels vary for the alternatives shared bicycle, public transport, and car. The HTM shared bicycle, which is used here as reference, costs €1.00 per 30 minutes (HTM, n.d.-a). In the two scenarios, the shared bicycle will not be used longer than 30 minutes, so €1.00 is the middle level. A variation is made with *free* shared bicycles and shared bicycles which will cost €2.00 for the trip. This is not different for the regular shared bicycle and the shared e-bike. For bus and tram, the current tariffs are used as basis (HTM, n.d.-c). The costs vary between €1.00, €2.00 and €3.00 for a single trip.

The costs for car are the costs for the parking garage in the city centre. The parking costs for the Q-Park in The Hague city centre are on average €4.00 per hour (Q-Park, 2020), and parking at the streets of The Hague is on average €4.50 per hour (ANWB, n.d.). Other parking garages around the city centre are from ParkBee and should be booked in advance. ParkBee is cheaper than Q-Park, as the average costs are €2.85 per hour (Parkeren Den Haag, 2021). Given the scenarios for the choice sets, which is 1.5 hours shopping in The Hague city centre, the lowest level is set at €5.00 euros for 1.5 hour. The middle and upper level are built up in steps of 5 euros, where the upper level has a parking tariff of 10 euros per hour. This high parking tariff is chosen to experiment with an incentive of high parking costs.

The frequency attribute is for public transport only. The lowest level is a bus or tram every 15 minutes, which is a frequency of 4 per hour. As it is easier for the respondents to understand minutes, the attributes are shown in minutes. By increasing the frequency per 5 minutes, the frequencies in the survey will be 12 per hour (every 5 minutes), 6 per hour (every 10 minutes), and 4 per hour (every 15 minutes).

For the last attribute, crowdedness, only public transport and car have attribute levels. For public transport, the *HTM crowding indicator* is used (HTM, 2020). The HTM crowding indicator uses a three-point scale: quiet, not quiet/not busy, and busy. When 'quiet', there are many seats available in the vehicle. If 'not quiet/not busy', there are only a couple seats left, but there is a chance they are unavailable when a passenger boards the vehicle. The last category is 'busy', where it is crowded, so an availability of standing places only. Crowdedess for the car is delay which is added to the total travel time. The crowdedness is a consequence of a crowded city centre, and thus busy parking garages. Therefore, levels are varied in 0, 3 and 6 minutes parking search time.

Model type and utility function

The model type for analysis will be, as discussed in Subsection 2.3.1, at first an multinomial logit model. This will later on made more complex by generating a panel mixed logit model. With the MNL model in mind, the utility functions will be constructed for both the MNL and ML panel model. While constructing the utility functions should be considered whether the parameters are generic or alternative, thus mode, specific. Given that the four included alternatives are all different modes, the attributes in the utility functions are made alternative specific.

Equation 4.2 to Equation 4.5 show the utility specifications for the MNL survey design. Within the four utility functions here are two parameters which are dummy-variables. This is the *availability* and *crowdedness* parameter for respectively the shared bicycle and public transport. As those two attributes have three attribute levels, two parameters should be estimated. Attribute *mode* is a dummy variable as well, mode has two attribute levels, so the estimation of one dummy parameter is sufficient.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A \tag{4.2}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{MT_B} \times MT_B + \beta_{TC_B} \times TC_B + \beta_{AV1} \times AV_B1 + \beta_{AV2} \times AV_B2 \tag{4.3}$$

$$U_C = ASC_C + \beta_{TT_C} \times TT_C + \beta_{MT_C} \times MT_C + \beta_{TC_C} \times \beta_{TC_C} + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C \tag{4.4}$$

$$U_D = \beta_{TT_D} \times TT_D + \beta_{TC_D} \times TC_D + \beta_{CR_D} \times CR_D \tag{4.5}$$

Where:

U_i	= utility of alternative i
ASC_i	= Alternative Specific Constant
TT_i	= mode-specific parameter for the variable 'travel time' (TT)
MT_i	= mode-specific parameter for the variable 'mode type' (MT)
TC_i	= mode-specific parameter for the variable 'travel cost' (TC)
AVx_i	= mode-specific parameter for the variable 'availability' (AV), is dummy coded with three attribute levels
FR_i	= mode-specific parameter for the variable 'frequency' (FR)
CRx_i	= mode-specific parameter for the variable 'crowdedness' (CR), is dummy coded in U_C with three attribute levels

4.1.2 Experimental design generation

In this part of the design, the type of design is decided on. An efficient design fits best, which will be argued in the first section. This is followed by the determination of the number of choice sets necessary. As an efficient design requires *priors*, the prior estimates will be elaborated on in the last section.

Type of design and number of choice sets

As described in Section 2.2.2, four designs can be considered: *full factorial designs*, *fractional factorial designs*, *orthogonal design*, *efficient designs*, and *bayesian efficient designs*. This section will determine which of the designs suits best. This design has four alternatives, with a total of 15 parameters (alternative-specific attributes). Of the 15 parameters consist 6 of two attribute levels, and the remaining 9 parameters have three attribute levels. All combinations would result in $2^6 \times 3^9 = 1,259,712$ choice sets. This is impossible to solve. A fractional factorial orthogonal design byNgene generates 36 choice sets, which is too much to ask for one respondent. A solution could be to split the 36 choice sets into three blocks. One respondent could get one of those blocks, but that requires three times more respondents for the pilot survey. However, given the two scenarios, this would be two times three blocks. Therefore, an efficient design will be made.

In an efficient design, the minimum number of choice sets is determined according to Equation 4.6 (Molin, 2018c). For an MNL model, 6 choice sets would do (Equation 4.7), but as a panel model will be estimated as well, a minimum of 7 choice sets is necessary (Equation 4.8). To meet the *attribute level balance* criterion, 12 choice sets will be generated and presented to the respondents.

$$\text{number of choice sets} > \frac{\text{number of parameters}}{\text{number of of alternatives per choice set - 1}} \tag{4.6}$$

$$\text{number of choice sets} > \frac{18}{3} = 6 \tag{4.7}$$

$$\text{number of choice sets} > \frac{21}{3} = 7 \tag{4.8}$$

Prior estimates

For an efficient design, prior parameters are necessary for the design generation. The prior estimates are gathered from various studies Arendsen; Arentze and Molin; Bunschoten et al.. Not all parameters were found in literature, but the found parameters will be elaborated on here. Prior parameters from Arentze and Molin (2013) are used, because this study has a Dutch context in which choice experiments on short-distance trips of 5 kilometer are tested, where choices between bicycle, car, and public transport (bus, tram, local train) were tested. Arendsen (2019) focused on shared mobility services, amongst which the shared bicycle. The choice experiments from Arendsen (2019) were conducted amongst Dutch NS train travellers. The last used study is from Bunschoten et al. (2013), as that study investigated the tram bonus, which is a good prior for the bus/tram dummy in this research.

As all three studies are different and within one study parameter values are relative to each other, priors should be normalized towards one of the studies. This can be done by comparing ratios, such as Value of Time, with another study. In Table 4.3 is the overview of the normalized prior parameters shown, including its original source. The parameter values are normalized towards Arentze and Molin (2013). Unless the majority of the parameters are been found in literature, a couple of parameters have not been found and are thus estimated as a very small prior value with the correct direction. The overview of those values is shown in Table 4.4. The experimental design code and generated choice sets can be found in Section A.1 in Table A.1 and Table A.2.

Table 4.3: Prior values for efficient design in pilot survey

Parameter	Prior	Source
Travel time		
Bicycle	-0.076	(Arentze & Molin, 2013)
Shared bicycle	-0.377	(Arendsen, 2019)
Public transport	-0.058	(Arentze & Molin, 2013)
Car	-0.043	(Arentze & Molin, 2013)
Travel cost		
Shared bicycle	-0.479	(Arendsen, 2019)
Public transport	-0.207	(Arentze & Molin, 2013)
Car	-0.17	(Arentze & Molin, 2013)

Parameter	Prior	Source
Public transport mode type		
Bus (ref)	0	(Bunschoten et al., 2013)
Tram	0.057	(Bunschoten et al., 2013)
Public transport crowdedness		
Seat always (ref)	0	(Arentze & Molin, 2013)
Seat sometimes	-0.337	(Arentze & Molin, 2013)
Seat uncertain	-0.674	(Arentze & Molin, 2013)
Public transport (other)		
PT frequency	-0.014	(Bunschoten et al., 2013)

Table 4.4: Prior values for efficient design in pilot survey, not found in literature

Parameter	Prior value	Source
Shared bicycle mode type		
Shared bicycle (ref)	0	N/A
Electric shared bicycle	0.01	N/A
Availability shared bicycle		
Booked (ref)	0	N/A
3+ available	-0.01	N/A
1-2 available	-0.02	N/A
Car - Other		
Crowdedness car	-0.01	N/A

4.1.3 Questionnaire construction

The pilot survey is conducted among a target group which is as much as possible identical to the The Hague target group. The survey is shared among Goudappel and HTM colleagues, and distributed via LinkedIn and Twitter. In the pilot survey, the first page contained a couple of selection criteria to make sure the correct target group would fill in the survey only. The respondents who were allowed to continue to the survey had to live in a Dutch city which has a tram operating. Furthermore, the respondents should be in the possession of both a driver's licence and a car, as well as a bicycle. If that was the case, they could continue to the survey.

The pilot survey consists of three parts: the introduction (with selection criteria), choice tasks, and socio-demographics. The choice tasks are introduced first, by providing information on the alternatives and attributes. Furthermore, an example choice task is shown to the respondents. Also, two questions are asked about the type of car and bicycle the respondent owns, since their own vehicle should be kept in mind while filling in the choice tasks. The choice sets can be found in Section A.1 in Table A.1 and Table A.2.

The socio-demographics asked for in the pilot survey are:

- Gender
- Year of birth (opt-out option)
- Zipcode-4 (opt-out option)
- Highest finished education
- Current working situation
- Household type
- Household size
- Travel frequency for
  - Bicycle
  - Car within the city
  - Car total
  - Shared bicycle
  - Bus
  - Tram
  - Going to the city centre
- Mostly used modes to the city centre
- Attitudinal statements, I like...
  - driving a car
  - cycling
  - travelling by bus
  - travelling by tram
  - using a shared bicycle

4.1.4 Results pilot survey

The survey has been filled in by a total of N=83 respondents, of which in scenario 1 N=45, and in scenario 2 N=38. A complete overview of the descriptive statistics can be found in Section A.4. The pilot survey has been analysed in a couple of ways, which will be described in this section.

Table 4.5: Chosen alternatives in pilot survey

	Scenario 1: 2.5 km Total choices: 552		**Scenario 2: 5 km Total choices: 456**	
	# chosen	% chosen	# chosen	% chosen
Alternative 1: Bicycle	451	81.7%	380	83.3%
Alternative 2: Shared bicycle	10	1.8%	6	1.3%
Alternative 3: Public transport	61	11.1%	43	9.2%
Alternative 4: Car	30	5.4%	27	5.9%

The choice set analysis of the pilot survey has been done using PythonBiogeme (Bierlaire, 2016). What is remarkable on forehand in both scenarios, that bicycle has the highest share in both scenarios (Table 4.5). Moreover, shared bicycle is in both cases hardly ever chosen as first alternative. This makes sense as almost all respondents answered 'never' when asked for shared bicycle frequency (Figure A.11). At the same time, half of the respondents in both scenarios are undecided in the statement *'I like using a shared bicycle'* (Figure A.16; Figure A.17).

After this analysis, first, an MNL model has been estimated, followed by a panel mixed logit model, of which the Biogeme codes can be found in Section A.2, and the results of both MNL and ML panel models can be found in Section A.3. In these estimated models, a general time and cost parameter has been estimated, since due to the little response the alternative-specific time and cost parameters were unreliable and not significant at a $p<0.05$ level. Although the ML panel model shows significant better goodness-of-fit statistics (Table A.9; Table A.12), given the low share of shared bicycle choices, the shared bicycle alternatives are unreliable, mainly in the 5 kilometer scenario (Table A.14). Therefore, it is better to use the MNL model as basis for the new prior values. The prior values for the final survey design will be as in Table 4.6 and Table 4.7.

Table 4.6: Prior values for the final survey, scenario 1

Parameter	Value MNL	Robust std.err
ASC		
Bicycle	1.04	0.503
Shared bicycle	-2.39	0.727
Public transport	-0.465	0.607
Travel time and cost		
Time	-0.161	0.0521
Cost	-0.174	0.0534
Crowdedness		
Bicycle	-0.0871	0.0826
Car	-0.0871	0.0826
Mode type shared bicycle		
Shared bicycle (ref)	0	N/A
Electric shared bicycle	-0.545	0.821

Parameter	Value MNL	Robust std.err
Availability shared bicycle		
Booked (ref)	0	N/A
3+ available	-0.377	0.963
1-2 available	0.641	0.808
Mode type public transport		
Bus (ref)	0	N/A
Tram	0.395	0.395
Crowdedness public transport		
Seat always (ref)	0	N/A
Seat sometimes	-0.303	0.334
Seat uncertain	-0.370	0.341
Public transport - other		
Frequency	-0.00284	0.0323

Table 4.7: Prior values for the final survey, scenario 2

Parameter	Value MNL	Robust std.err
ASC		
Bicycle	1.73	0.650
Shared bicycle	-2.93	1.05
Public transport	-0.153	0.758
Travel time and cost		
Time	-0.159	0.0567
Cost	-0.173	0.0555
Crowdedness		
Bicycle	-0.0880	0.0861
Car	-0.0880	0.0861
Mode type shared bicycle		
Shared bicycle (ref)	0	N/A
Electric shared bicycle	2.06	1.18

Parameter	Value MNL	Robust std.err
Availability shared bicycle		
Booked (ref)	0	N/A
3+ available	-0.01	N/A
1-2 available	-0.02	N/A
Mode type public transport		
Bus (ref)	0	N/A
Tram	0.220	0.325
Crowdedness public transport		
Seat always (ref)	0	N/A
Seat sometimes	-0.294	0.396
Seat uncertain	-0.158	0.405
Public transport - other		
Frequency	-0.0134	0.0382

4.2 Final survey

This section describes the final survey design. First, the improvements that are being made based on the pilot survey are elaborated on in Subsection 4.2.1. This is followed by a renewed overview of choice set parameters and attribute levels in Subsection 4.2.2. The full survey design can be found in Appendix B.

4.2.1 Improvements of pilot survey

A couple of improvements have been made based on the experiences in the pilot survey. The made improvements will be discussed below, and are implemented in the final survey.

- As the final survey will be about the city centre of The Hague, this is specified instead of saying ‘the city centre of the city you live in’.
- The instruction part of the stated preference part of the survey is improved by adding images about shared bicycles in the extra explanation on shared bicycles. Also, icons are added for each of the alternatives. This may help respondents to read through the instruction more easily.
- A couple of questions have been added to the stated preference part of the survey:
  – At the start of the stated preference part is asked whether respondents are familiar with shared bicycles. If not, they get extra explanation of shared bicycles. This shortens the explanation on shared bicycles for respondents who are already familiar with shared bicycles.
  – As in the pilot survey a lot of respondents did not choose for shared bicycle or public transport, would it be insightful to know why respondents did not. Therefore, a ‘why’-question has been added at the end of the stated preference part of the stated preference part when the respondent did not choose for the shared bicycle and/or public transport: “*You did not choose for the shared bicycle / public transport. Can you tell us why you did not choose the shared bicycle / public transport?*”.

- If respondents did choose for the shared bicycle, it would also be insightful if the respondents normally consider a shared bicycle for their trip as well. If they did not, they are asked why they normally not consider a shared bicycle.

- In the socio-demographics part, the question on the mostly used mode type to the city centre, the option *walking* missed. This was filled in a lot in the ‘other’ category and is therefore added as an extra category in this question.
- Instead of showing the respondents the 2.5 and 5 kilometer distances with the scenarios, the actual distances are removed and replaced with ‘short’ and ‘long’ trips towards the city centre.
- The choice set design has has been improved. The main changes that have been made are these:
  - Instead of total travel time, of which a part was *walking time*, it was unclear if this distinction was clear to the respondents. It could have been that the respondents saw these as complementary items, so the improvement that has been made is to make two time components: driving time and walking time.
  - The parking search time for car was extra time on top of ‘total travel time’, which was not clear to every respondent. Therefore, in combination with the item above, this is a separate time component as well instead of an additional time component.
  - Since bicycle has been chosen so often, probably because it was always free of charge, a parking cost component has been added for the bicycle as well. In the scenario is explained that this is for a guarded bicycle parking spot, and ‘free’ bicycle parking is still one of the attribute levels.
  - Bicycle parking search time has been added as well, since now the bicycle cannot be parked at any place anymore. Instead the cyclist should look for a specific parking location, so that may take extra time as well. This way it is treated the same as car parking search time.
  - The attribute levels of some attributes are improved. Starting with the driving time, which will differ 2 minutes from each other in the 2.5 kilometer scenario, and 3 minutes in the 5 kilometer scenario. By increasing the interval between attribute levels, the trade-offs will become more visible. Furthermore, the parking search time is 1, 3, 5 minutes instead of 0-3-6 minutes. At least 1 minute search time is realistic, so starting from that value and intervals of 2 minutes, one comes at attribute levels of 1, 3, and 5 minutes for parking search time. The last adapted attribute level is parking costs, because car is hardly chosen, probably due to the extreme parking costs. Therefore, the car parking costs are lowered to 3, 6, 9 euros, which is in line with the parking costs in The Hague currently.

4.2.2 Renewed experimental design

The adapted choice set input is visible in Table 4.8, where in green attribute (level) changes are highlighted. This time, the choice sets will be generated using Bayesian efficient design instead of non-Bayesian efficient design. In this design, prior values are from the MNL results of the pilot survey (Table 4.6 and Table 4.7). Still, 12 choice sets can be used in the design. The used Ngene code and generated choice sets can be found in Section B.1. The full Dutch survey is presented in Section B.3.

Table 4.8: Choice set input final survey

		Bicycle	**Shared bicycle**	**Public transport**	**Car**
Driving time	2,5 km	8, 10, 12 min	8, 10, 12 min	6, 8, 10 min	6, 8, 10 min
	5 km	17, 20, 23 min	17, 20, 23 min	12, 15, 18 min	12, 15, 18 min
Walking time		1 min (= 100 m) 3 min (= 250 m) 5 min (= 400 m)	3 min (= 250 m) 5 min (= 400 m) 7 min (= 550 m)	3 min (= 250 m) 6 min (= 500 m) 9 min (= 750 m)	1 min (= 100 m) 4 min (= 350 m) 7 min (= 600 m)
Crowdedness		1, 3, 5 min parking search time	-	Quiet Not quiet/not busy Busy	1, 3, 5 min parking search time
Mode type		Own bicycle	Shared bike Shared e-bike	Bus Tram	Own car
Costs		0, 1, 2 euro	0, 1, 2 euro	1, 2, 3 euro	3, 6, 9 euro
Availability		-	1-2 available 3+ available Booked	-	-
Frequency		-	-	Every 5, 10, 15 min	-

Chapter 5

Descriptive statistics

This chapter will discuss the descriptive statistics of the obtained observations in the final survey. This will start by the data collection in Section 5.1, followed by frequency distribution of the socio-demographic characteristics in the sample and chosen choice set frequencies in Section 5.2. The last part of this chapter, Section 5.3, consists of found relations in the socio-demographics, mode frequency and mode attitudes.

5.1 Data collection

The data is collected using an online panel, called PanelClix (PanelClix, 2021). PanelClix is a Dutch company which is specialized in having online questionnaires completed. Participants in this panel applied to this panel voluntarily and are rewarded with money by filling in surveys. PanelClix is chosen, as they could offer most respondents within the target group of this research: car drivers who own a car and live in The Hague, Rijswijk and Leidschendam-Voorburg, The Netherlands. Furthermore, as the respondents receive a reward, the responses are obtained quickly. Despite the advantages of a big panel and quick response, the quality of the response could be lower than when filled in completely voluntarily.

As this study investigates two different scenarios, more respondents are needed compared to the situation in which there would be only one scenario. Two components determined the number of respondents to fill in the survey. First is looked at the S-estimate of the Ngene choice set design, as the S-estimate determines the minimum number of respondents to obtain a significant result at a 95% confidence level (ChoiceMetrics, 2018). Due to the unknown prior parameters for shared bicycle availability, the S-estimate generated by Ngene in scenario 1 is: 10,791,231 and in scenario 2: 1,332,591. Those numbers are impossible to reach, so the number of respondents used will be the available number of respondents in The Hague (N=260), Rijswijk (N=42) and Leidschendam-Voorburg (N=58) which fit the previously mentioned criteria being having a drivers license, as well as owning a car. This comes to a total of N=360 respondents. This fitted the available budget from Goudappel and the Smart Public Transport Lab of the TU Delft.

Due to the strict selection criteria, which are also part of the survey, PanelClix ensures the specific target group will fill in the survey only. Therefore, four selection questions are asked to the respondents, of which question 4 is added to screen people with bicycle as well, since the choice set requires people to imagine using their own bicycle.

1. Do you live in The Hague, Rijswijk or Leidschendam-Voorburg?
2. Do you have drivers license?
3. Do you own a car?
4. Do you own a bicycle?

A total of 517 respondents attempted to fill in the survey. Of this number, 31 (6.0%) responses clicked on the survey link only but did not proceed to the page with selection criteria questions. 63 (12.2%) respondents did not meet (one of) the selection criteria, while another 63 (12.2%) respondents did either not continue at the choice set page or ended the choice sets before finishing. Those results cannot be used in the survey. As the survey was closed precisely at a complete response rate of 360 respondents, this number is used for the analysis of the survey. Of the 360 respondents, 177 (49.2%) respondents filled out scenario 1: 2.5 kilometer, and 183 (50.8%) respondents got scenario 2: 5 kilometer. As the average time to fill in the survey was 10 minutes, the respondents who were quicker than 5 minutes were filtered out. So the total number of respondents used in the analysis is 167 in scenario 2.5 kilometer, and 174 in scenario 5 kilometer.

5.2 Frequency distribution

In this section, first for gender, age, and education level the frequency distribution is analysed and compared to the Dutch and The Hague population in Subsection 5.2.1. Besides, the current travel frequencies are looked into in Subsection 5.2.2. This is followed by the analysis of the chosen alternatives in the choice sets in Subsection 5.2.4. These analysis are conducted as it gives insights in the sample, and helps the model result interpretation.

5.2.1 Socio-demographics

A couple descriptive statistics are highlighted in this section, to see whether the sample is representative for the Dutch and The Hague population. Table 5.1 shows the ratios of gender, age, education and household type of the sample and the Dutch and The Hague population. A chi-square test will be conducted to test whether the sample significantly differs from the two populations. The chi-square test will be used, as the compared variables are categorical variables, while the test tests for the observed and expected frequencies (Kroesen, 2016). As appears from the chi-square tests on gender, age, education and household type of these four the only parameter which is not different from the population is gender (Table 5.2). In age, the 18-27 population is under represented, while the 41-64 and 65+ age groups are over represented. For education, in the sample, the lower level education is under represented, while the high level education is over represented. The under represented household type is 'alone, no kids', while the type 'together, kids' is over represented. A complete overview of the socio-demographics can be found in Section B.4. The respondents do thus not fully represent the Dutch population, which should be kept in mind during the upcoming model analysis and interpretation.

Table 5.1: Descriptive statistics in sample compared to Dutch and The Hague population (CBS, 2020a, 2020b, 2020c, 2021; Gemeente Den Haag, 2021)

	Respondents		**Population**	
	Count	%	% NL	% The Hague
Gender				
Male	179	49,7%	49.7%	49.7%
Female	180	50,0%	50.3%	50.3%
Other	1	0,3%	-	-
Age				
18-27	13	3,6%	16.8%	17.0%
28-40	85	23,6%	21.4%	25.2%
41-64	179	49,7%	43.0%	43.2%
65+	78	21,7%	18.7%	14.6%
Education				
Lower level education	40	11,1%	25.2%	31.0%
Medium level education	140	38,9%	39.3%	35.0%
High level education	180	50,0%	35.4%	34.0%
Household type				
Alone, no kids	58	16,1%	35.9%	43.9%
Alone, kids	47	13,1%	6.9%	8.5%
Together, no kids	91	25,3%	26.8%	19.2%
Together, kids	164	45,6%	30.5%	28.3%

Table 5.2: Chi-square tests results on gender, age, education, and householdtype

	The Netherlands			**The Hague**		
	Chi-square	df	P-value	Chi-square	df	P-value
Gender	0.004	1	0.951	0.004	1	0.951
Age	44.083	3	<0.001	54.873	3	<0.001
Education level	122.138	2	<0.001	68.339	2	<0.001
Household type	86.190	3	<0.001	116.801	3	<0.001

5.2.2 Mode frequencies and attitudes

The second part of the socio-demographics consisted of questions about respondents' mode frequencies (in the situation before the Covid-19 pandemic) and the respondents' attitude towards the modalities in the stated preference part of the survey. Figure 5.1 shows the mode frequencies of all respondents, where scenario 2.5 kilometer and scenario 5 kilometer is combined as the respondents in both scenarios showed the same pattern (for detailed graphs see Figure B.8 to Figure B.13 in Section B.4).

Two modalities are used most often on a weekly basis: bicycle and car. This is in line with the positive attitude towards bicycle and car in Figure 5.2. The two public transport modes, bus and tram, on the contrary are used respectively 10% and 15% on a weekly basis. The attitude towards bus and tram is mostly neutral, but about 45% shows a negative attitude towards bus usage, while for tram this number is about 30%. This shows that respondents are less negative about tram usage compared to bus usage. The last modality is shared bicycle, which 90% of the respondents uses less than five days per year. This in line with the respondents' attitudes towards shared bicycle, as those are either neutral or negative.

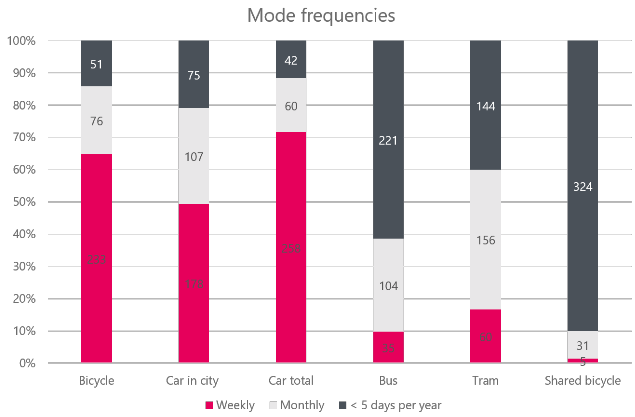


Figure 5.1: Mode frequencies of all respondents

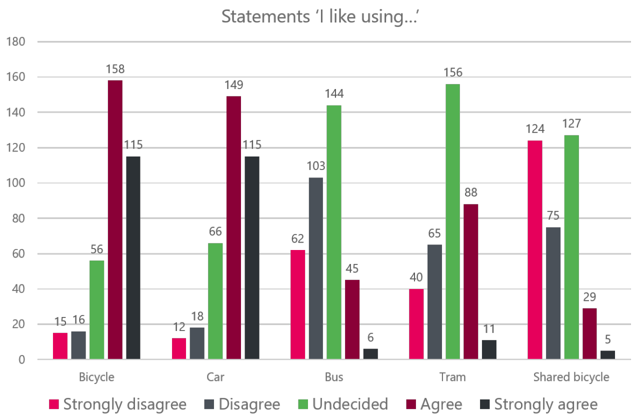


Figure 5.2: Attitudes towards various modes, responses from both scenarios

Table 5.3: Descriptives mode frequencies

Frequency	Mean	Std. dev	N
Bicycle	1.49	.731	360
Car within city	1.71	.789	360
Car total	1.40	.689	360
Bus	2.52	.667	360
Tram	2.23	.717	360
Shared bicycle	2.89	.359	360

Table 5.4: Attitudes towards modes

Attitude	Mean	Std. dev	N
Car	2.65	.629	360
Bicycle	2.67	.627	360
Bus	1.68	.708	360
Tram	1.98	.754	360
Shared bicycle	1.54	.662	360

Between mode frequencies and mode attitudes, a couple of correlations have been found of which a full overview can be found in Section C.19. The correlations which help answering the research question of persuading car users into sustainable modes will be discussed here. For the interpretation of the correlations, the coding schemes should be kept in mind. Frequency coding is as follows: 1 = weekly, 2 = monthly, and 3 = <5 days per year, so a high frequency has the lowest category value. The attitude coding is as follows: 1 = negative; 2 = neutral; 3 = positive attitude.

Car users who drive in the city on a frequent basis, drive more often car over all ($r(358)=0.242$, $p<0.001$). Those same frequent car drivers in the city have a correlation with bicycle, bus and tram attitudes: the higher the car frequency, the lower the attitude towards bicycle ($r(358)=0.097$, $p=0.066$), (bus ($r(358)=0.117$, $p=0.027$) and tram ($r(358)=0.142$, $p=0.007$). Furthermore, for *total* car trips, a higher frequency correlates to a more positive car attitude ($r(358)=-0.145$, $p=0.006$). A higher car frequency has as well a negative on the shared bicycle attitude ($r(358)=0.122$, $p=0.020$), and the bus attitude ($r(358)=0.089$, $p=0.091$). So, frequent car drivers have in general a positive attitude on car, while they have a more negative attitude towards bicycle, bus, tram, and shared bicycle.

For both bus and tram frequencies, the correlations have the same directions. Frequent bus and tram drivers have a positive attitude towards bus, tram, and shared bicycle, while they have a negative attitude towards bicycle (Section C.19). Furthermore, bus frequency is positively correlated to shared bicycle frequency ($r(358)=0.142$, $p=0.007$) and tram frequency ($r(358)=0.609$, $p<0.001$). Bus frequency is on the contrary negatively correlated to cycling frequency ($r(358)=-0.094$, $p=0.084$). Tram frequency is also positively correlated to shared bicycle frequency ($r(358)=0.093$, $p=0.079$).

These correlations show that car drivers have a negative attitude towards other modalities. The other way around: people with a negative attitude towards bicycle, shared bicycle, bus and tram have a higher car frequency. Furthermore, people with positive attitudes towards bicycle, shared bicycle, tram and bus have a higher frequency of those modes as well.

Besides the mode frequencies and attitudes, the current used modalities for traveling to the city centre are asked for as well (Figure 5.3). This knowledge is of interest as it can be used to reflect on the choices made by the respondents in the choice sets. The mode which is used most often for traveling to the city centre is bicycle, followed by tram and car. Bus is used less often, which is in line with the predominantly negative attitude towards bus (Table 5.4). Shared bicycle is hardly ever used for trips towards the city centre, which is not surprising given the earlier low shared bicycle usage frequencies.

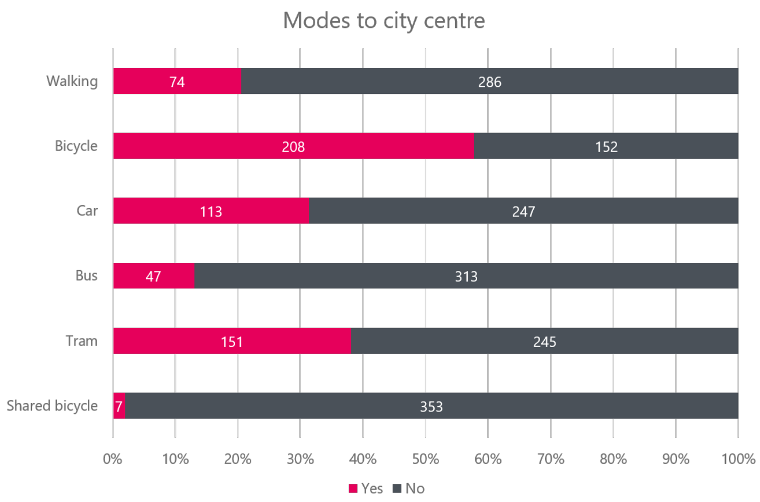


Figure 5.3: Modes currently used to go to the city centre, both scenarios (N=360)

5.2.3 Car and bicycle ownership

The choice set design required people imagining their own car and own bicycle. This section analyzes the car and bicycle types which the respondents filled in and used as their car and bicycle type. 62.5% of all respondents own a private car, and the remainder owns lease cars (Figure 5.4). The bicycles in the sample are mainly regular bicycles: 72.8%, followed by e-bikes (15.0%).

Via the one-way ANOVA test are no differences found between lease and private car ownership groups, and other characteristics such as mode frequencies and mode attitudes. On the contrary, there are differences found in the bicycle ownership groups. Respondents who use a regular bicycle, are younger (average: 46 years old) than electric bicycle users (average: 53 years old) (Table 5.5). Bicycle type has a relation to two mode frequencies: total car driving and shared bicycle frequency. Regular bicycle users drive more often by car than users who use an 'other bicycle'-type ($p<0.05$) (Table 5.6). Furthermore, regular bicycle users have a higher shared bicycle frequency than both electric and *other* bicycle users (Table 5.7). The last frequency difference was found in frequency of going to the city centre, where regular bicycle users go more often to the city centre than both electric and *other* bicycle users (Table 5.8).

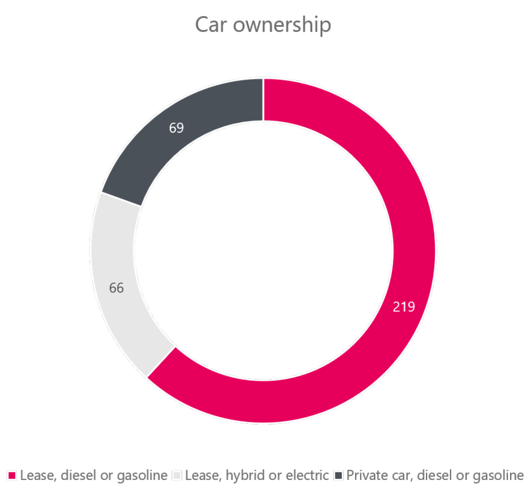


Figure 5.4: Car ownership of all respondents (N=360)

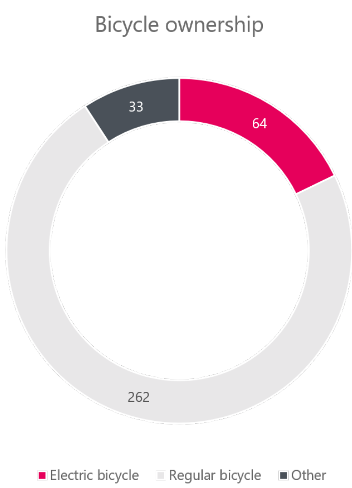


Figure 5.5: Bicycle ownership of all respondents (N=360)

Table 5.5: Average age, for bicycle types (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Bicycle type	**Mean**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	45.81	13.644	59	0.002	0.055
Electric bicycle	53.11	14.790	246	-	1.000
Other bicycle	53.42	13.488	31	-	-

Table 5.6: Average total car frequency, for bicycle types (ONEWAY ANOVA)
Frequency coding: 1 = weekly; 2 = monthly; 3 = <5 days per year

	Frequency: car total			p (post hoc test Bonferroni)	
Bicycle type	**Mean**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	1.30	.667	61	.896	.020
Electric bicycle	1.40	.671	249	-	.054
Other bicycle	1.71	.864	31	-	-

Table 5.7: Average shared bicycle frequency, for bicycle type (ONEWAY ANOVA)
Frequency coding: 1 = weekly; 2 = monthly; 3 = <5 days per year

	Frequency: shared bicycle			p (post hoc test Bonferroni)	
Bicycle type	**Mean**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	2.70	0.587	61	<0.001	0.036
Electric bicycle	2.92	0.281	249	-	1.000
Other bicycle	2.90	0.301	31	-	-

Table 5.8: Average frequency going to the city centre, for bicycle type (ONEWAY ANOVA)
Frequency coding: 1 = weekly; 2 = monthly; 3 = <5 days per year

	Frequency: city centre			p (post hoc test Bonferroni)	
Bicycle type	**Mean**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	1.61	0.690	61	0.009	0.045
Electric bicycle	1.91	0.724	249	-	1.000
Other bicycle	2.00	0.655	31	-	-

5.2.4 Choice set frequencies

Besides the socio-demograhpics, the choice set descriptives can give insightful information as well. Inspired by Alonso-González, van Oort, Cats, and Hoogendoorn (2017), a modal portfolio is generated of which the first part is shown in Figure 5.6 and Figure 5.7. This first graph type gives insights in the chosen alternatives among all respondents, as it is visualized how respondents varied between alternatives. The graph is sorted from highest to lowest percentage respondents with that profile. This first graph type does not show the variation between chosen alternatives, so therefore a second type of graph is made where this variation becomes clear (Figure 5.8 & Figure 5.9).

Figure 5.6 shows that for scenario 2.5 kilometer the two biggest profiles are '100% bicycle' and 'bicycle and shared bicycle'. These two profiles add up to 44.1% of the sample. This reflects the popularity of (shared) bicycle on the short distance 2.5 kilometer to the city centre. The share of profiles containing respectively at least once the choice for bicycle, shared bicycle, public transport and car is 83.1%, 34.5%, 42.9%, and 32.2%. This reflects the popularity of bicycle on this short distance of 2.5 kilometer, followed by public transport, shared bicycle and car. This relatively high shared bicycle outcome is remarkable, given the low share of current used modes to city centre (Figure 5.3). The higher modal share of public transport than car is in line with the current used modes. Besides these total numbers where at least once is chosen for those modalities, there are a part of respondents who did not switch between alternative modalities at all. The share of 100% chosen for the same modality is for bicycle 29.4%, public transport 9.0%, and car 6.2%, which is a total of 44.6% non-varying answers. No respondent chose the shared bicycle for all choice sets.

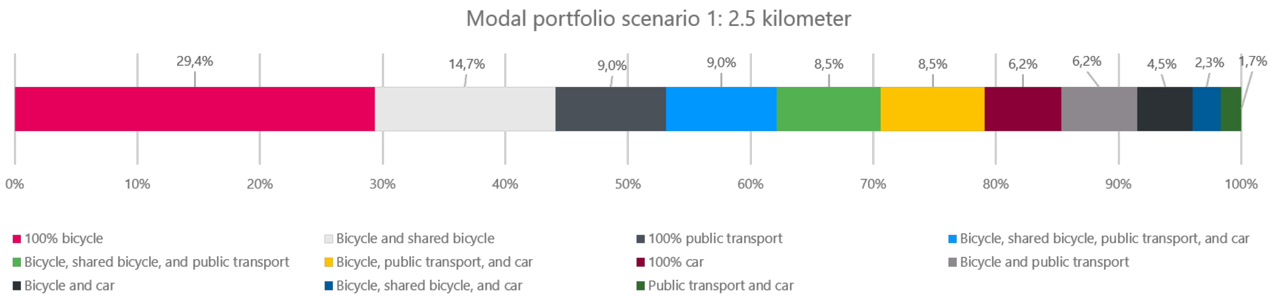


Figure 5.6: Modal portfolio scenario 1: 2.5 kilometer

The modal portfolio of scenario 5 kilometer is visualized in Figure 5.7. Here, similar to scenario 2.5 kilometer, the biggest share of respondents choose for bicycle in all choice sets (23.1%). The share of at least once chosen modes bicycle, shared bicycle, public transport and car is for this scenario respectively 75.2%, 27.4%, 54.3%, and 37.3%. This shows bicycle is most popular, followed by public transport, car and shared bicycle at this longer distance of 5 kilometer to the city centre. These findings are in line with the findings of the current used modes to the city centre as visualized in Figure 5.3. Some respondents did not vary between choices: 23.1% chose bicycle in all choices, 7.1% did so for public transport, and 7.7% for car, which is a total of 37.9% unvaried choice sets answers. The combination bicycle and public transport is most popular after the 100% bicycle response group.

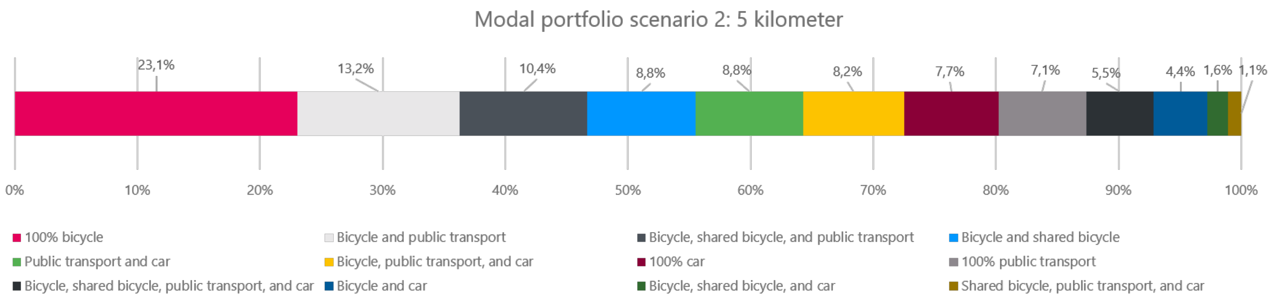
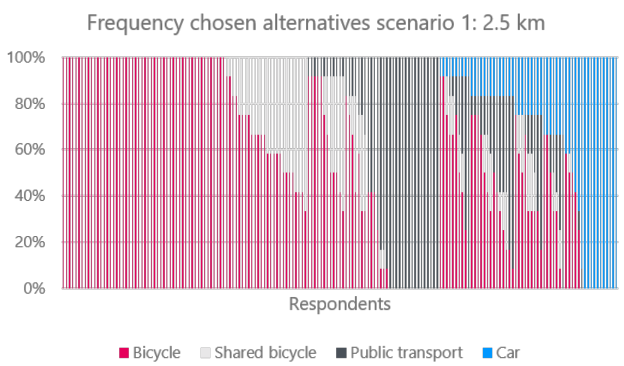


Figure 5.7: Modal portfolio scenario 2: 5 kilometer

The choice frequencies of both scenarios are visualized in Figure 5.8 and Figure 5.9. These graphs are sorted on bicycle share and car share. This visualizes the parts where is chosen for bicycle, public transport and car only in both scenarios. Apart from the parts where is chosen for the single modality bicycle, public transport or car, there is variety of shares in both scenarios, so respondents who varied between modes in the choice sets, seem to have made trade offs.



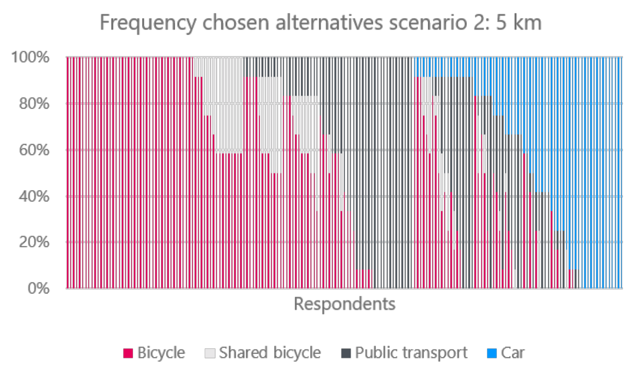


Figure 5.8: Choices per respondent scenario 1: 2.5 kilometer Figure 5.9: Choices per respondent scenario 2: 5 kilometer

The majority of the respondents is undecided about shared bicycles, or has a negative attitude towards the shared bicycle. Since this was already the case in the pilot survey, a question was added to the survey to the respondents who did not choose the shared bicycle in the choice sets. This question asked the reasoning behind not choosing the shared bicycle. The most given reasons is *having my own bicycle available*, followed by *hassle*. 6% of the respondents mentioned having own bicycle and too much hassle both as reasoning. The remainder 26% of the reasons is mainly no interest, being unfamiliar with the concept, dislike sharing, not having a shared bicycle available nearby. It is interesting to dive a bit further in *hassle*, which is actually a psychological barrier which influences peoples good intentions on behavioral change (Vries, Rietkerk, & Kooger, 2020).

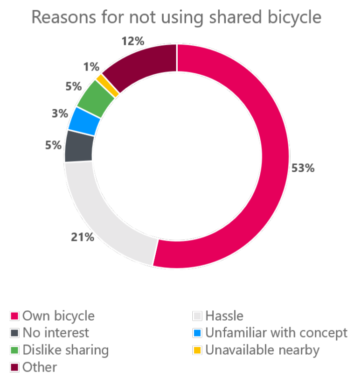


Figure 5.10: Reasons for not using shared bicycle

As Vries et al. (2020) describes, hassle can be a potential source of stress (McLean, 1976), and the way people deal with stress, is by avoiding it (Roth & Cohen, 1986). In the case of shared bicycles, there are a couple of factors mentioned by the respondents which hold them back of using the shared bicycle: no interest, unfamiliar with concept, unavailable nearby. Interventions, inspired by Vries et al. (2020)'s findings, that could help for the last two stages are: providing clear, concise and credible information about the availability of and instructions for the shared bicycle.

5.3 Interaction variables

For all socio-demographic variables, an ONEWAY ANOVA test has been done, followed by a post hoc Bonferroni test to identify differences between different groups in the sample. A full overview and explanation of found relations can be found in Appendix C, where all significant relations are presented. In this section, a couple of relations are highlighted which help identifying the car user who could be willing to switch towards sustainable modes.

Starting with number of cars in households. Households who have 2 cars in their household have a higher car frequency within the city than households with 1 car in their household. This is in line with the fact that households with 2 cars in their household have a more positive attitude towards car driving than households with 1 car in their household. The number of cars in households also have a relation to bus and tram attitude. Respectively have households with 1 car in their household a less negative attitude towards bus, while households with 1 car in their household have a neutral to positive attitude towards tram, both compared to households with 2 cars.

Weekly car drivers are on average younger (average age: 51 years) than car drivers who drive less than five days a year (average age: 56 years). Weekly car drivers have a more negative attitude towards shared bicycles, tram and bus than monthly car drivers. Also, frequent car drivers within the city go more often to the city centre. At the same time, both weekly and monthly city centre visitors have a higher tram frequency than city centre visitors who go less than five days per year.

5.4 Conclusion

The sample does not fully represent the population, as the respondents are on average older, higher educated and have an over-representation of the 'together, kids' household type, and an under-representation of 'alone, no kids' household type. Most of the respondents own a private car (62.5%), and an regular bicycle (72.8%). Furthermore, on average, the respondents have a high bicycle and car frequency (weekly to monthly), while the frequency of bus, tram and shared bicycle is on average monthly to less than five days per year. This is in line with the attitudes towards modes, which is most positive to both car and bicycle. The mode attitude for bus, tram and shared bicycle is on average between negative and neutral.

The descriptive statistics of the choice set frequencies show a big part of (shared) bicycles: 44.1% in scenario 2.5 kilometer, and 31.9% in scenario 5 kilometer. Besides this big bicycle share, both scenarios contain a share of non-varying answers. In scenario 2.5 kilometer this was 44.6% (29.4% bicycle, 9.0% public transport, 6.2% car), and in scenario 5 kilometer 37.9% (23.1% bicycle, 7.1% public transport, 7.7% car). The profiles with varying answers, the answers did vary quite well, so there true trade-offs were made.

Chapter 6

Results discrete choice modelling

The results of the stated preference study will be presented in this chapter. First is explained how the data set is prepared in Section 6.1. This is followed by Section 6.2 which dives into the estimated models, and its results. The model result interpretations are done in Section 6.3.

6.1 Data preparation

Before starting the discrete choice modelling on the stated preference survey data, the data set should be prepared for analysis. At first the data of the both scenarios is separated, because the two scenarios will be analysed apart from each other. As second step, the first and second choices from respondents are separated for each scenario as well. This brings a total of four data sets. The choice set data can be used directly, however the socio-demographics should be re-coded. Re-coding data can be done in two ways: by dummy coding and effects coding. In dummy coding, the utility difference have a reference category, while in effects coding the utility differences have an average utility contribution of 0 (Molin, 2018d). Dummy coding is convenient to use, as the estimated constant is the utility of the reference alternative (Molin, 2018e). There is chosen for two types of coding: for socio-demographics and mode frequencies, dummy coding is used. For mode attitudes, effect coding is used where the 'undecided' is the mean of 0, and the negative attitude is coded as '-1', while the positive attitude is coded as '1'. For age, the age groups 18-27 years and 28-40 years old are combined, because the number of respondents was less than 30 (N<30) for the 18-27 years old category. A complete overview of the dummy and effect coding is shown in Appendix D.

6.2 Model estimation

In this study, four model types are estimated for each scenario: a multinomial logit model (MNL), a panel mixed logit model (ML panel), a panel mixed logit model with error component (ML panel + EC), and a by interactions extended panel mixed logit model with error component (ML panel + EC + interactions). The last three models are ran based on the *first choices* in the choice sets only. The MNL model with second choices only was run, but due to a low model fit (scenario 2.5 kilometer: rho-square = 0.11; scenario 5 kilometer: rho-square = 0.119) was decided not to test the more complex models based on the respondents' second choices.

A complete overview of variables in the first choices' final model is visualised in Table 6.1. The utility functions, parameter values and significance levels are presented in Section E.3. This section explains the steps which are taken from the MNL model to the panel mixed logit with error component bicycle and interaction variables. The MNL model is a model without any simulations, so runs the fastest. Therefore, the MNL model has been used for a three purposes. First, the MNL model has been used to test for linearity in Subsection 6.2.1. Second, the MNL model has been used to to test for the best model with respect to generic and mode-specific parameters (Subsection 6.2.2). As third and last, the interaction variables have been tested on the final MNL model. The MNL models with best modal fit are used in the three other more advanced model types, which leads to the final model (Subsection 6.2.3). Subsection 6.2.4 elaborates on the over-all fitting model, which will be used for the model interpretation.

Table 6.1: Estimated models including estimated parameters

Included parameters in models	Scenario 2.5 kilometer				Scenario 5 kilometer			
	MNL	**ML panel**	**ML panel + EC bicycle**	**ML panel + EC bicycle + interactions**	**MNL**	**ML panel**	**ML panel + EC bicycle**	**ML panel + EC bicycle + interactions**
ASC								
Bicycle	X*	X*	X*	X*	X*	X*	X*	X*
Shared bicycle	X*	X*	X	X*	X*	X*	X*	X*
Public transport	X	X*	X*	X	X**	X*	X*	X*
Generic betas								
β crowdedness (bicycle and car)	X	X*	X	X	X	X	X	X
β travel costs	X*	X*	X*	X*	X*	X*	X*	X*
β driving time (PT and car)	X	X	X	X	X	X	X	X
β walking time (bicycle, PT and car)	X*	X*	X**	X*	X	X	X	X
Bicycle								
β driving time	X*	X*	X*	X*	X*	X*	X*	X*
Shared bicycle								
β driving time	X*	X*	X	X*	X*	X*	X**	X*
β walking time	X*	X*	X*	X*	X*	X*	X**	X
β travel costs	X*	X*	X*	X*	-	-	-	-
β mode type (electric SB)	X	X	X	X	X	X	X	X
β 1-2 bicycles available	X**	X*	X**	X*	X	X	X	X
β 3+ bicycles available	X*	X*	X*	X*	X*	X*	X*	X*
Public transport								
β mode type (tram)	X	X	X	X	X	X	X	X
β frequency	X	X	X	X	X	X	X	X**
β not quiet/not busy	X*	X*	X	X*	X	X*	X	X*
β busy	X**	X*	X	X	X**	X*	X	X*
Car								
β parking costs	X*	X*	X*	X*	X*	X*	X*	X
Sigmas								
σ panel	-	X*	X*	X*	-	X*	X*	X*
Sigma bicycle	-	-	X*	X*	-	-	X*	X*
Interactions								
Number of cars in household	-	-	-	X*	-	-	-	X**
Household type	-	-	-	X*	-	-	-	-
Age	-	-	-	-	-	-	-	X*
Frequency: bicycle	-	-	-	X*	-	-	-	X**
Frequency: city centre	-	-	-	X*	-	-	-	X*
Frequency: car within city	-	-	-	-	-	-	-	X*
Attitude tram	-	-	-	X*	-	-	-	X*
Attitude shared bicycle	-	-	-	X*	-	-	-	-
Attitude car	-	-	-	X	-	-	-	-

Parameters included in model = X; parameter not included in model = -

Significant parameters in green: X (p<0.05); X** (p<0.10)*

6.2.1 Linearity testing

Most of the attributes in the choice sets have three levels, as this allowed for linearity testing (Molin, 2018a). Therefore, a test for linearity will be done to see whether there are non-linear parameters included in this stated preference study. Two types of linearity testing are conducted: adding a quadratic component to the MNL model, and secondly via dummy variables differences between the three levels are tested. The detailed test of linearity is done in Section E.1. Here will the summarised results be discussed.

The tested parameters are parameters which are present in two or all alternatives, and have three attribute levels. These are crowdedness (for bicycle and car), travel cost, travel time, and walking time. In scenario 2.5 kilometer, the quadratic travel time component was significant. In scenario 5 kilometer, the travel cost and travel time quadratic time component was significant in a separate model, but when both were included the travel time component was significant only. In the dummy test, for both scenarios the two travel time components were significant.

The Likelihood Ratio Statistic (LRS) compared the base model (without quadratic components) to the models with quadratic component or dummy variables (Table E.5). The LRS test between the base model and model with quadratic travel time component was significant, while the model with travel time dummy variables was not significantly better than the MNL base model. Therefore, MNL model with quadratic travel time component will be used as base for further analysis.

6.2.2 Final MNL model

In the model estimation, a couple of options are possible with respect to the parameters. First, a model with generic parameters: e.g. one travel cost parameter is estimated for all modes. Second, a model with specific parameters can be estimated, so the travel cost parameter will be mode specific. A hybrid model with partly generic and partly mode specific parameters is the third and last possibility. The main advantage of generic parameters is that given the high number of observations, the generic parameters are very likely to be significant. However, generic parameters do not show the differences between the modalities, which in this case would be insightful to know. Using all mode specific parameters has as downside that the model has a high number of parameters. Also, it could be possible that some of the specific parameters are not significant due to this high number of parameters. Therefore, tests are ran to find a hybrid model in which partly generic and partly mode specific parameters are estimated.

The taken steps to find the best fitting hybrid model are explained here, followed by the result of the best model. A complete overview of the parameter values is given in Section E.2. The test is started with a MNL model containing generic parameters only. One by one, models are ran with specific parameter values, and the quadratic travel time component. As in a couple of cases, the quadratic travel time component was insignificant, the specific parameters are tested on the base MNL model without quadratic travel time component as well. The models without quadratic travel time component had a significantly better model fit than the models with quadratic travel time component. Therefore, the separate significant specific parameter models without quadratic travel time component were combined into one, until significant specific parameters were left. This is called the *hybrid model*. The hybrid model has been used as basis for the more complex model types panel mixed logit, panel mixed logit with error component bicycle, and panel mixed logit with error component bicycle and interaction variables.

6.2.3 Panel mixed logit models

With the final hybrid model, a panel mixed logit model is estimated because a panel mixed logit corrects for the correlations within one respondent. A more advanced panel mixed logit model contains an error component. An error component corrects for similarities which are not captured in the attributes. Therefore, a panel mixed logit model is run with an error component. In this study, three error component types are tested. First, an error component that was tested is ‘own modalities’, so on the bicycle and car component. Second, a ‘public transport’ error component on the shared bicycle and public transport alternative. The last error component is ‘bicycle’, which is added to the bicycle and shared bicycle alternative. Table 6.2 shows the outcomes from the panel mixed logit model, and the models with the three types of error components.

The three error component models are compared to the panel mixed logit model and to each other statistically, to identify the model with the best model fit. The error component models are compared to the panel mixed logit model by an Likelihood Ratio Statistics (LRS) test, while the error component models are compared to each other using the Ben-Akiva and Swait test. From these models, for both scenarios the best fitting model is ML panel + EC bicycle (Table E.13 & Table E.14).

Table 6.2: Comparison of panel mixed logit + error component models

	ML panel		**ML panel + EC own mode**		**ML panel + EC public transport**		**ML panel + EC bicycle**	
	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer
Init. log likelihood	-2778.134	-2894.538	-2778.134	-2894.583	-2778.134	-2894.583	-2778.134	-2894.538
Final log likelihood	-1850.664	-1912.084	-1620.768	-1855.760	-1620.768	-1855.76	-1491.257	-1544.417
Rho square	0.334	0.339	0.417	0.359	0.417	0.359	0.463	0.466
Rho square bar	0.327	0.333	0.409	0.352	0.409	0.352	0.456	0.460
AIC	3741.328	3862.168	3283.536	3751.520	3283.536	3751.520	3024.513	3128.834
BIC	3803.688	3922.190	3349.014	3814.701	3349.014	3814.701	3089.991	3192.015
Number of draws	200	200	200	200	200	200	200	200

The panel mixed model with an error component on bicycle is the model which is used for the last model type: the model that includes interaction variables. The interaction variables consist of socio-demographic variables, mode frequencies and mode attitudes, which were all three asked in the last part of the survey. Before adding the interaction variables to the model, correlations between the interaction variables are tested. Interaction variables with correlations cannot be added to the same model (Table E.21 & Table E.22).

All interactions are one by one tested on the final hybrid MNL model, to identify the significant interactions. This one by one testing is followed by sorting the significant interaction values on t-value, from most robust to least robust parameters. Based on the bottom-up principal, step-wise non-correlated interaction variables are added to the final MNL model where significant variables are kept in the model, and insignificant variables are removed. The result of these iterations is a final MNL model with significant interaction parameters only. The next step taken is to add the significant interaction variables on the panel ML + error component bicycle model. This took a couple of iterations, where again non-significant interaction variables were removed step by step. In scenario 2.5 kilometer, the iterations has been quit when sigma panel became insignificant, so instead the insignificant attitude car parameter is kept in the model. In scenario 5 kilometer, iterations are done until only significant interaction variables was left.

In scenario 2.5 kilometer and scenario 5 kilometer, different interaction variables are significant. In the 2.5 kilometer scenario is significant: number of cars in household, household type, bicycle frequency, going to the city centre frequency, attitude towards tram, and attitude towards shared bicycle. In the 5 kilometer scenario is significant: number of cars in household ($p<0.10$), bicycle frequency ($p<0.10$), frequency going to the city centre, frequency of car driving within the city, and attitude towards tram.

6.2.4 Model fit

Besides the statistical test for the best fitting error component model in Subsection 6.2.3, here the model fit for both scenarios will be significantly tested. As described in Subsection 2.3.2, this is done with the Likelihood Ratio Statistic, as all models are an extended version of each other. As the results in Table 6.4 and Table 6.5 show, all extended models fit better than its less extended predecessor. Therefore can be concluded that the most extended model, being the panel mixed logit model, with bicycle error component and interaction variables, fits the data best. Therefore, the upcoming result interpretation and case study are done with this best fitting model.

Table 6.3: Descriptives all final models, both scenarios

	MNL model		**ML panel**		**ML panel + EC bicycle**		**ML panel + EC bicycle + interaction**	
	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer
Init. log likelihood	-2778.134	-2894.538	-2778.134	-2894.538	-2778.134	-2894.538	-2778.134	-2844.676
Final log likelihood	-2075.165	-2361.003	-1850.664	-1912.084	-1491.257	-1544.417	-1260.039	-1365.222
Rho square	0.253	0.184	0.334	0.339	0.463	0.466	0.546	0.520
Rho square bar	0.246	0.178	0.327	0.333	0.456	0.460	0.526	0.509
AIC	4188.330	4758.007	3741.328	3862.168	3024.513	3128.834	2632.079	2794.444
BIC	4294.785	4859.598	3803.688	3922.190	3089.991	3192.015	2806.687	2889.835
Number of draws	N/A	N/A	200	200	200	200	100	100
Number of parameters	19	18	20	19	21	20	56	31
Number of observations	2004	2088	2004	2088	2004	2088	2004	2052

Table 6.4: LRS test for all models, scenario 2.5 km

Scenario 1: 2.5 kilometer		**LRS**	**df**	**Critical χ^2**
Model 1	**Model 2**			**value**
MNL	ML panel	**449.002**	1	3.841
ML panel	ML panel + EC bicycle	**718.814**	1	3.841
ML panel + EC bicycle	ML panel + EC bicycle + interactions	**462.436**	35	49.802

Table 6.5: LRS test for all models, scenario 5 km

Scenario 2: 5 kilometer		**LRS**	**df**	**Critical χ^2**
Model 1	**Model 2**			**value**
MNL	ML panel	**897.838**	1	3.841
ML panel	ML panel + EC bicycle	**735.334**	1	3.841
ML panel + EC bicycle	ML panel + EC bicycle + interactions	**358.390**	11	19.675

6.3 Interpretation model results

The final model has been determined, so now it is time for the interpretation of the final model. This is done in two steps. First, the parameter interpretation will be done in Subsection 6.3.1. This is followed by the identification of the relative utility contribution in Subsection 6.3.2, which will give insight in the relative importance of the parameters in the model.

6.3.1 Parameter interpretation

The parameter interpretation will first be done for both scenarios separately, followed by identifying the similarities and differences of both scenario outcomes. Both mode parameters and interaction variables are discussed. The tables with all parameter values are presented in the appendices. Scenario 1 in Table E.24, and scenario 2 in Table E.26.

Scenario 1: 2.5 kilometer

All parameters but one have the expected sign. The shared bicycle travel time is positive while it is expected to have a negative sign, and the parameter is significant. Not all generic parameters are significant ($p<0.10$): the parking search time for bicycle and car (crowdedness) is insignificant, and the generic walking time (bicycle, public transport, and car) is not significant either. In the shared bicycle mode, the shared bicycle availability is remarkable. The booked shared bicycle is the reference value. Compared to this reference, 3+ available shared bicycles have a higher disutility value than the option where 1-2 shared bicycles are available. This is expected to be the other way around. For the in-vehicle crowdedness in public transport, the relation is remarkable as well. Here, 'quiet' is the reference attribute, and 'not quiet/busy' has a higher disuitlity than 'busy'. This would be expected the other way around as well. Furthermore, for both shared bicycle mode type (electric shared bicycle) and public transport mode type (tram) is no significant value, so the respondents do not value these mode types differently. Lastly, the public transport frequency is insignificant, meaning the frequency does not matter for this trip length to the city centre.

In the interaction variables, only one variable is insignificant: the attitude towards car. This variable is kept in the model, as otherwise σ_{panel} would become insignificant. Here, the significant or relevant interaction variables will be discussed. Starting with the relation caused by the attitude towards tram. If the relation towards tram is negative, the three sustainable modes become less attractive compared to car. Furthermore, respondents with a negative attitude towards tram value bicycle travel time in a more negative way (higher disutility) than respondents with a neutral attitude towards tram. The same relation holds for the negative attitude towards tram in relation to the shared bicycle walking time. The attitude towards shared bicycle has a relation to travel costs: people with a negative attitude towards shared bicycle are more sensitive to travel costs of bicycle and public transport than people who have a positive attitude towards shared bicycle. Furthermore, people with a negative attitude towards shared bicycle add more disutility to the shared bicycle costs and shared bicycle walking time than respondents who have a neutral attitude of shared bicycle.

With respect to the frequency interactions, respondents who go to the city centre on a yearly basis are more sensitive for car parking costs than weekly city centre visitors. Cycling frequency has an interaction with bicycle travel time and walking time to shared bicycle: the lower the cycling frequency, the more negative the utilities towards bicycle travel time and shared bicycle walking time. The last interaction variable is household type, where the reference is 'alone, no kids'. The interaction with car parking costs is significant for all other household types, where the household types 'alone, no kids', 'together, no kids', and 'together, kids' are less sensitive for car parking costs. As last interaction variable, shared bicycle walking time for 'alone, no kids', while the 'together, no kids' has a higher disutility for the shared bicycle walking time than 'alone, no kids'.

Scenario 2: 5 kilometer

Scenario 5 kilometer does contain three positive significant alternative specific constants. So bicycle, shared bicycle, and public transport start with a positive utility compared to car. One generic parameter is significant: travel costs, which is the generic travel costs for bicycle, shared bicycle and public transport. Although the generic travel time parameter (for public transport and car) is insignificant, the travel time parameter for bicycle and shared bicycle is significant. For the 5 kilometer trip, the 3+ available shared bicycles are preferred over the booked alternative, and an electric shared bicycle does not influence the respondents' choice. In the public transport alternative, the public transport frequency plays a role: higher frequencies are preferred over lower frequencies as lower frequencies cause more disutility. Furthermore, the in-vehicle crowdedness causes disutility, where people have more disutility for the 'not quiet/not busy' vehicle than for the 'busy' vehicle. Car parking costs are insignificant, so does not have an effect.

Nearly all interactions are significant ($p<0.10$).Both the 41 to 64 years old and the 65+ years old groups have less disutility for travel costs than the reference category (18 to 40 years old). Meaning, the two eldest age groups are less sensitive to travel costs than the 18 to 40 years age group. The negative attitude tram adds disutility to bicycle, shared bicycle, and public transport, while positive attitude towards tram adds utility to those three modes. Furthermore, for yearly car drivers within the city, positive utility is added to the three sustainable modes as well, meaning those three sustainable modes are more preferred than car for yearly car drivers. Frequency of going to the city centre has an interaction with car parking costs: the lower the city centre frequency, the more sensitive one becomes for car parking costs. The second-last interaction is with bicycle frequency, where disutility to the three sustainable modes is added when one cycles on a yearly basis. This is in line with the found correlations between mode frequencies and mode attitudes, where a lower bicycle frequency causes a lower bicycle attitude, and a lower bicycle attitude is related to a higher car frequency within the city. Lastly, the number of cars influences the walking time negatively: households with more cars have a higher disutility for the walking time of bicycle, public transport and car walking time.

Similarities scenario 2.5 kilometer and scenario 5 kilometer

In both scenarios, the bicycle and shared bicycle are preferred over car in general, as those alternative specific constants are positive and significant. From the generic parameters, in both scenarios the travel costs are significant and negative. In both cases, the bicycle travel time is significant and negative. The shared bicycle alternative has five corresponding parameters: shared bicycle availability, mode type, travel time, and walking time. In both cases, the shared bicycle mode type is insignificant, meaning that the electric shared bicycle is not more or less preferred than the regular shared bicycle.

In both scenarios, the public transport in-vehicle crowdedness influences the public transport utility. A ‘quiet’ vehicle is in both cases preferred over a ‘not quiet/not busy’ and ‘busy’ vehicle. Furthermore, in both cases the public transport mode type tram (reference is bus) is insignificant. So in both scenarios tram is not preferred over bus.

Overlapping interaction variables are tram attitude, frequency city centre, bicycle frequency, and the number of cars in household. In both sceanrios, attitude towards tram is a general parameter added to the sustainable modes, where in both cases disutility is added to the sustainable modes if one has a negative attitude towards tram. For frequency of going to the city centre, in both scenario this frequency has an interaction with car parking costs, where the relation is: a lower the city centre frequency leads to a higher disutility of car parking costs.

Differences between scenario 2.5 kilometer and scenario 5 kilometer

While in scenario 5 kilometer, the public transport alternative is significant, this is not the case in the scenario 2.5 kilometer. Meaning that in scenario 2.5 kilometer, car and public transport have the same ‘starting value’, while bicycle and shared bicycle start with a positive utility. In the generic parameters, in scenario 2.5 kilometer, walking time (for bicycle, public transport and car) is significant, while in scenario 5 kilometer walking time is insignificant. Generic travel costs are in scenario 5 kilometer higher than in scenario 2.5 kilometer (relative utility contributions: 2.5 km = -0.766; 5 km = -1.248). This is probably because in scenario 5 kilometer the shared bicycle costs are part of the generic parameter. In scenario 2.5 kilometer the shared bicycle costs had a mode-specific parameter.

In the shared bicycle mode is a difference with respect to the availability of the shared bicycles. In scenario 2.5 kilometer, the booked version is preferred over the non-booked availability. In scenario 5 kilometer, 3+ available shared bicycles are most preferred. In the public transport alternative, both scenarios differ in the public transport frequency significance: in scenario 2.5 kilometer, frequency does not influence the public transport utility, while in scenario 5 kilometer the public transport utility is influenced by frequency. The last mode, car, differs in car parking costs: in scenario 2.5 kilometer respondents are sensitive for car parking costs, while in scenario 5 kilometer the car utility is not influenced by car parking costs.

With respect to the interaction variables, there are a couple of differences. For instance, age. Age is only part of the scenario 5 kilometer model. On the contrary, the shared bicycle attitude does not play a role in scenario 5 kilometer, while it has interactions in scenario 2.5 kilometer. Lastly, in the 5 kilometer scenario the frequency of car driving within the city is part of the model, while this is not the case in the 2.5 kilometer scenario.

6.3.2 Utility contribution

The previous section focused on the parameter interpretation. This section will focus on the relative utility contribution of the parameters in the model. This will be done in two stages for both scenarios. The first stage consists of a table which shows the utility contributions and its relative importance. The relative importance is the utility value scaled to the attribute range. The second stage visualizes the utility contribution with graphs, where - amongst others - based on the slope and starting value, the most influential parameters are identified.

Scenario 1: 2.5 kilometer

Table 6.6 shows the utility contributions of scenario 2.5 kilometer, with the utility ranges, and the relative utility importance. The attribute with the highest - and significant - utility importance is car parking costs. The other influential attribute are shared bicycle walking time, shared bicycle driving time, and shared bicycle travel costs. These values have overall the biggest impact on the utility functions. That relation is confirmed by Figure 6.2 and Figure 6.4. The four parameters have the steepest slope due to the high attribute level value and attribute range.

The attitudes towards shared bicycle and tram in Figure 6.5 show that a negative attitude towards tram influences the utility of the sustainable modes very hard compared to the other attributes with interactions. A negative attitude towards shared bicycle influences the shared bicycle travel time most negatively compared to other attitudes. A positive attitude towards shared bicycle influences shared bicycle travel time positively. The other way around, for the attitude towards shared bicycle, shared bicycle travel costs and shared bicycle walking time: negative attitudes influence both costs and time positively, while a positive attitude towards shared bicycle influences costs and time negatively.

Ending with the last two figures of scenario 2.5 kilometer. First, Figure 6.6 presents the frequencies to the city centre and bicycle frequency. People who cycle on a less regular basis (monthly or yearly) value the walking time to shared bicycle more negatively than weekly cyclists. The same weekly cyclists value cycling time less negatively than infrequent cyclists. The last relation of city centre frequency is with car parking costs: infrequent city centre visitors have more disutility for car parking costs than frequent city centre visitors. Last, the household type in Figure 6.7 influences the utility of car parking costs as well. The household type 'alone, no kids' is most sensitive for car parking costs, while household type 'together, with kids' is least sensitive.

Table 6.6: Utility contribution scenario 2.5 kilometer

Beta	**Value**	**Attribute range**	**Utility range** min	max	**Relative importance**
Bicycle driving time	-0,171	4	-1,368	-2,052	-0,684
Bicycle walking time	-0,086	4	-0,086	-0,430	-0,344
Bicycle parking search time	-0,046*	4	-0,046	-0,228	-0,182
Bicycle parking costs	-0,383	2	0,000	-0,766	-0,766
Shared bicycle driving time	0,588	4	4,704	7,056	2,352
Shared bicycle walking time	-0,982	4	-2,946	-6,874	-3,928
Shared bicycle mode type (electric SB)	0,070*	1	0,000	0,070	0,070
Shared bicycle travel costs	-0,983	2	0,000	-1,966	-1,966
1-2 shared bicycles available	-0,449	1	0,000	-0,449	-0,449
3+ shared bicycles available	-0,950	1	0,000	-0,950	-0,950
Public transport driving time	-0,055*	4	-0,332	-0,554	-0,222
Public transport walking time	-0,086	6	-0,258	-0,773	-0,515
Public transport not quiet/not busy	-0,435	1	0,000	-0,435	-0,435
Public transport busy	-0,352*	1	0,000	-0,352	-0,352
Public transport mode type (tram)	-0,125*	1	0,000	-0,125	-0,125
Public transport travel costs	-0,383	2	-0,383	-1,149	-0,766
Public transport frequency	0,021*	10	0,104	0,311	0,207
Car driving time	-0,055*	4	-0,332	-0,554	-0,222
Car walking time	-0,086	4	-0,086	-0,601	-0,515
Car parking search time	-0,046*	4	-0,046	-0,228	-0,182
Car parking costs	-0,877	6	-2,631	-7,893	-5,262

** = insignificant at a 90% level*

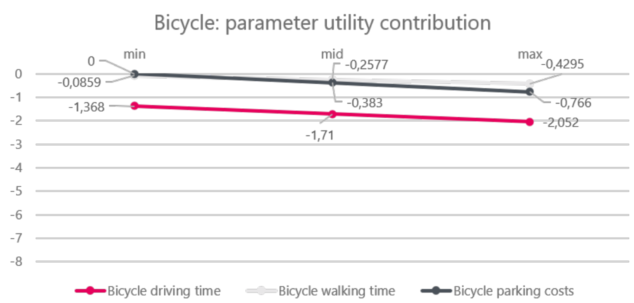


Figure 6.1: Utility contribution significant bicycle parameters (driving time, walking time, and parking costs)

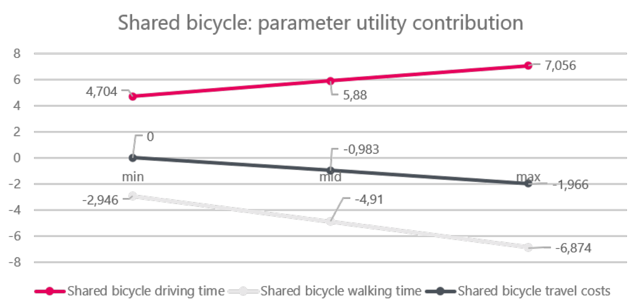


Figure 6.2: Utility contribution significant shared bicycle parameters (driving time, walking time, and travel costs)

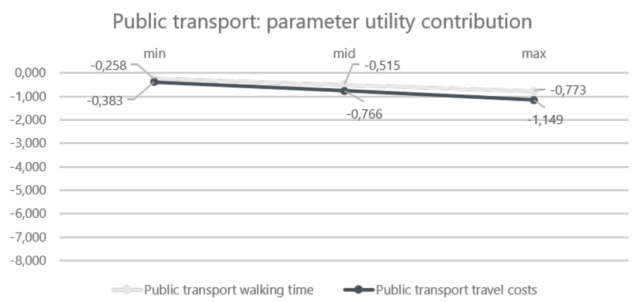


Figure 6.3: Utility contribution significant public transport parameters (walking time and travel costs)

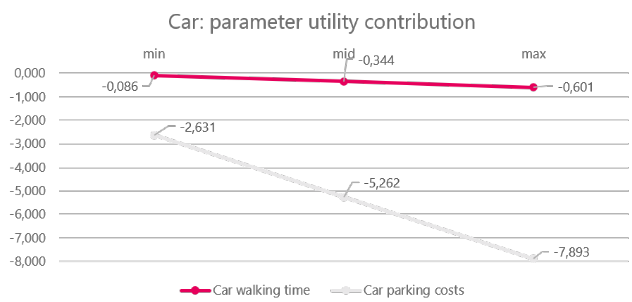


Figure 6.4: Utility contribution significant car parameters (walking time and parking costs)

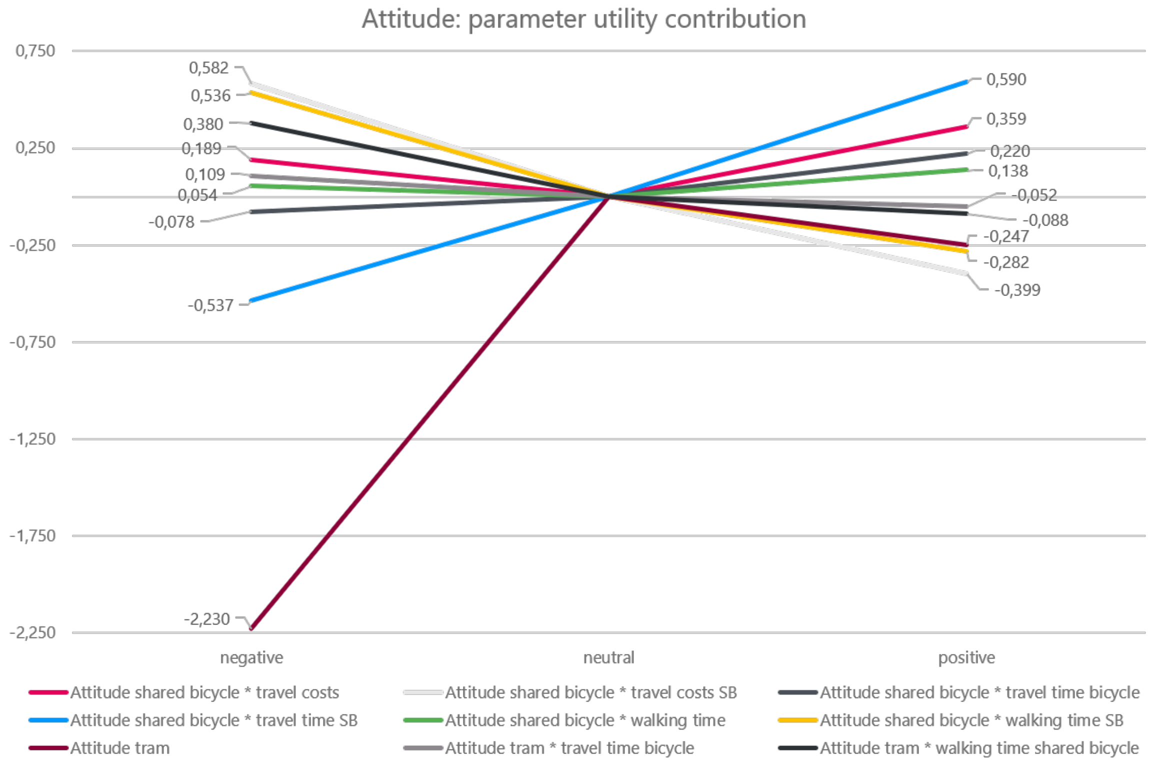


Figure 6.5: Utility contribution significant attitude interactions

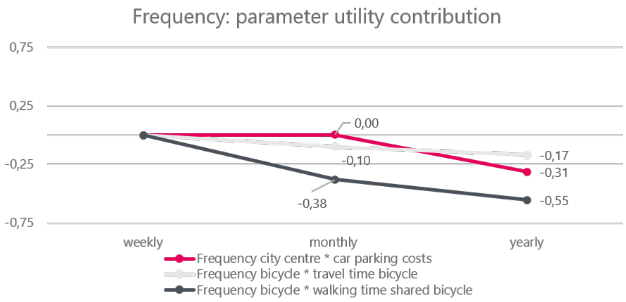


Figure 6.6: Utility contribution significant frequency interaction parameters

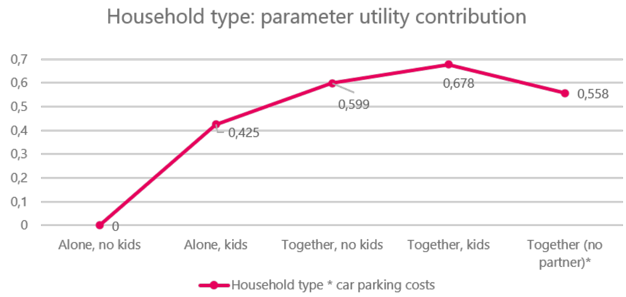


Figure 6.7: Utility contribution significant household type interactions (* = N<30)

Scenario 2: 5 kilometer

In Table 6.7, the utility contributions of scenario 5 kilometer are shown. From this table can be seen that the attributes with the highest relative utility importance are bicycle driving time, bicycle parking costs, public transport travel costs, and shared bicycle driving time. This is confirmed by the figures Figure 6.8, Figure 6.9, and Figure 6.10. For the bicycle alternative, the minimum driving time in the model starts at a higher disutility than the utility of maximum bicycle parking costs. For public transport, the travel costs weigh heavier than the public transport frequency.

In line with scenario 2.5 kilometer, a negative attitude towards tram gives disutility to the three sustainable modes (Figure 6.11), while positive utility is added to the three sustainable modes when one has a positive utility for tram. Besides the tram attitude, three frequency interaction variables have a significant utility contribution. First, frequency of car driving in the city: less frequent car drivers in the city add positive utility to the three sustainable modes. Second, the frequency of going to the city centre is as in scenario 2.5 kilometer interacted with car parking costs. The same relation is visible here: less frequent city centre visitors are more sensitive for car parking costs. Lastly, the cycling frequency influences the sustainable modes: the less frequent one cycles, the less attractive become the three sustainable modes for car users.

The last two significant utility parameter contributors are the number of cars in household and age. Starting with the number of cars in household. There is an interaction between number of cars in household and walking time: the more cars one has in its household, the less is one minute of walking time evaluated (Figure 6.13). The last interaction is between age and travel costs: compared to the youngest group (18 to 40 years old), the elder groups (41 to 64 years old and 65+ years old) are less sensitive for travel costs (Figure 6.14).

Table 6.7: Utility contribution scenario 5 kilometer

Beta	**Value**	**Attribute range**	**Utility range**		**Relative importance**
			min	max	
Bicycle driving time	-0,214	6	-3,638	-4,922	-1,284
Bicycle walking time	0,080*	4	0,080	0,402	0,322
Bicycle parking search time	0,009*	4	0,009	0,0462	0,037
Bicycle parking costs	-0,624	2	0,000	-1,248	-1,248
Shared bicycle driving time	-0,179	6	-3,043	-4,117	-1,074
Shared bicycle walking time	-0,163*	4	-0,489	-1,141	-0,652
Shared bicycle mode type (electric SB)	0,041*	1	0,000	0,0406	0,041
1-2 shared bicycles available	0,363*	1	0,000	0,363	0,363
3+ shared bicycles available	0,625	1	0,000	0,625	0,625
Public transport driving time	-0,031*	6	-0,368	-0,5526	-0,184
Public transport walking time	0,080*	6	0,241	0,7236	0,482
Public transport not quiet/not busy	-0,650	1	0,000	-0,65	-0,650
Public transport busy	-0,507	1	0,000	-0,507	-0,507
Public transport mode type (tram)	0,174*	1	0,000	0,174	0,174
Public transport travel costs	-0,624	2	-0,624	-1,872	-1,248
Public transport frequency	-0,035	10	-0,176	-0,528	-0,352
Car driving time	-0,031*	6	-0,368	-0,5526	-0,184
Car walking time	0,080*	4	0,080	0,5628	0,482
Car parking search time	0,009*	4	0,009	0,0462	0,037
Car parking costs	0,028*	6	0,084	0,2511	0,167

* = *insignificant at a 90% level*

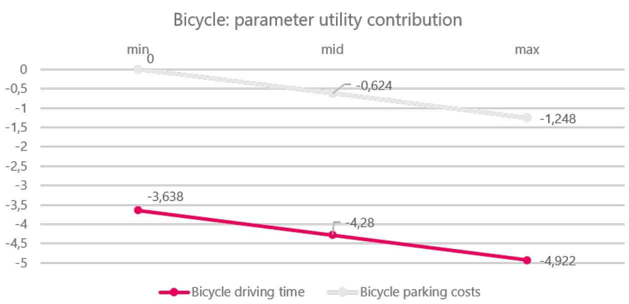


Figure 6.8: Utility contribution significant bicycle parameters

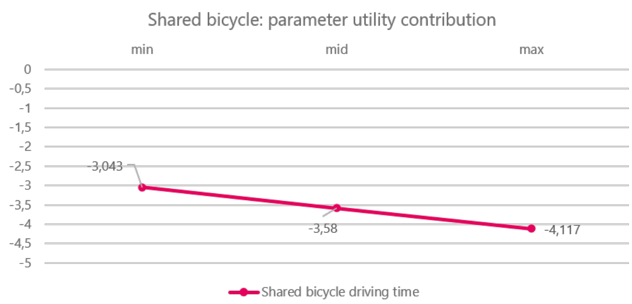


Figure 6.9: Utility contribution significant shared bicycle parameters

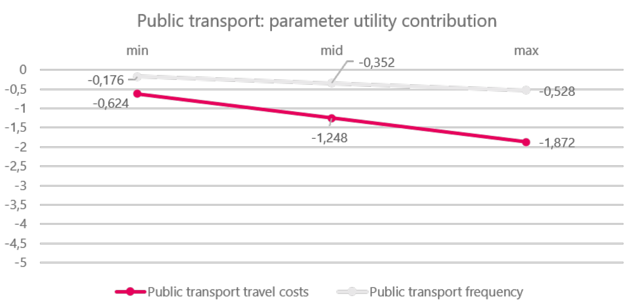


Figure 6.10: Utility contribution significant public transport parameters

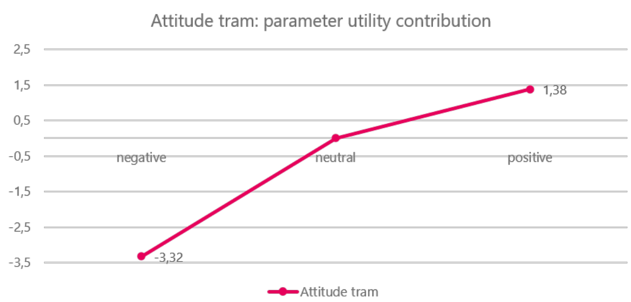


Figure 6.11: Utility contribution significant attitude towards tram

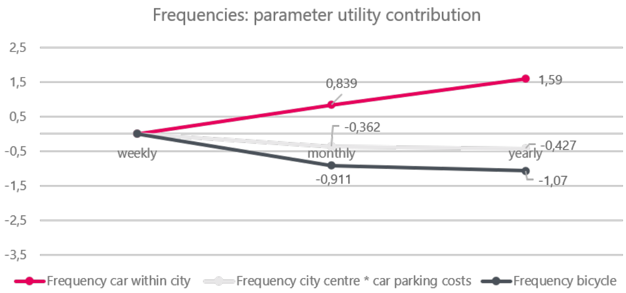


Figure 6.12: Utility contribution significant frequency interaction parameters

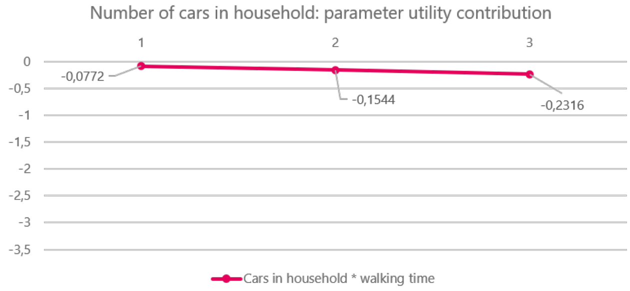


Figure 6.13: Utility contribution significant number of cars in household interaction parameter

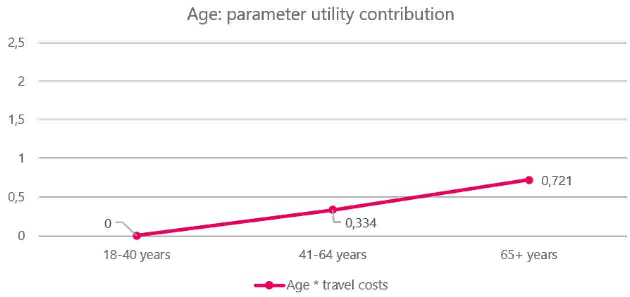


Figure 6.14: Utility contribution significant age interaction parameter

6.4 Conclusion

The final model is a hybrid model, with both specific and generic mode parameters, and without linear parameters. This hybrid model is best explained by a panel mixed logit model with error component *bicycle* on the bicycle and shared bicycle alternative, and interaction variables. In scenario 2.5 kilometer are the parameters with most impact on the utility functions: car parking costs, and shared bicycle driving time, walking time, and travel costs. The interaction variable with most impact is tram attitude. In scenario 5 kilometer have bicycle driving time, bicycle parking costs, public transport travel costs, and shared bicycle driving time most impact on the utility functions. The interaction variables with impact are attitude towards tram, and frequency of car within the city.

There are a couple of similarities between scenario 2.5 kilometer and scenario 5 kilometer. First, bicycle and shared bicycle are in general preferred over car. Second, an electric shared bicycle is not preferred over a regular shared bicycle. Thirdly, there is no difference found between bus and tram as public transport mode type. Furthermore, tram attitude is in both scenarios very influential on the mode choice. Likewise, frequency of going to the city centre is related to car parking costs: people who go to the city centre on a less than five days per year basis are more sensitive to car parking costs than weekly city centre visitors.

Besides the similarities, a couple of differences between scenario 2.5 kilometer and scenario 5 kilometer are identified. First, in scenario 5 kilometer is the public transport alternative specific constant significant and positive. Second, the walking time parameters are insignificant in scenario 5 kilometer. Thirdly, the scenarios differ in availability of shared bicycles. In scenario 2.5 kilometer, the booked version is preferred over the non-booked version. The opposite is found in scenario 5 kilometer, where 3+ available shared bicycles are preferred over a booked shared bicycle. The fourth and second-to last difference is public transport frequency, which is significant in scenario 5 kilometer only. Lastly, in terms of interaction variables is age and frequency of car driving with in the city part of scenario 5 kilometer. In scenario 2.5 kilometer is shared bicycle attitude part of the model.

Chapter 7

Case study: The Hague, the Netherlands

As briefly introduced in Section 2.4, the results will be applied on a specific context: The Hague, the Netherlands. For The Hague, the challenges regarding the increase of sustainable modalities will be covered which within the scope of this research. First, the problem statement and case study context will be introduced in Section 7.1. The results will be applied on The Hague's mobility transition program to identify the impact in mode characteristic changes on the modal split (Section 7.2). The potential usage for the sustainable modes is calculated in Section 7.3. The case study is ended with conclusions and recommendations for The Hague and HTM.

7.1 Case study context

As mentioned in the introduction, it is expected that the number of inhabitants increase in the upcoming years. Within the current modal split has car the biggest share: on average in Europe 56%, and in the Netherlands 53% (Fiorello et al., 2016). When the modal split stays the same, while the number of inhabitants grows, the livability and accessibility of cities will be worsened. Therefore, the search for sustainable, less space-occupying alternatives is searched for. The Hague, a Dutch mid-sized city, copes with this same issue.

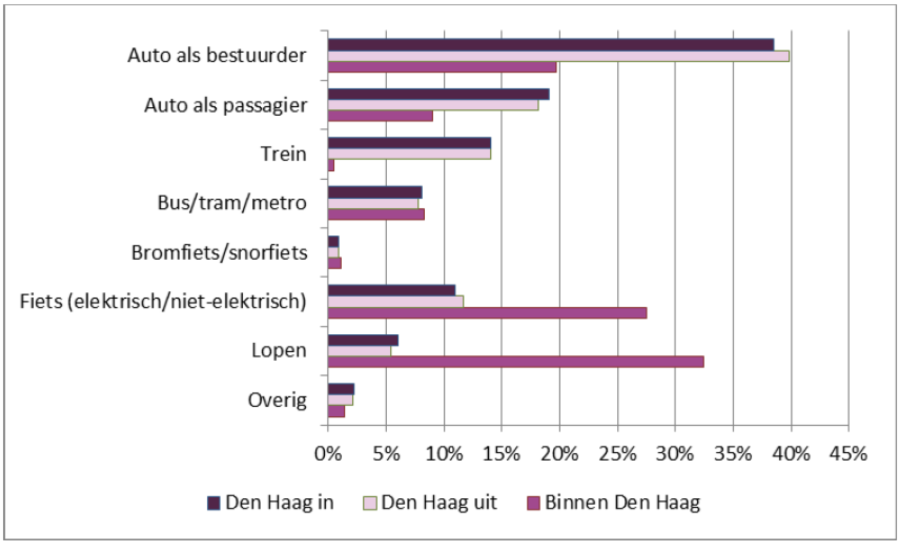


Figure 7.1: Main used mode of trips in, to, and starting in The Hague, image from: Gemeente Den Haag (2016)

The choice for The Hague has a couple of reasons. The first reason is the number of inhabitants. The Netherlands has five big cities: Amsterdam, Rotterdam, The Hague, Utrecht, and Eindhoven (Randolph, 2020). Of these five big cities, The Hague is mid-sized with about 545.000 inhabitants, and is with a 41% car share in the middle of the five big cities as well (KiM, 2019). This big car share is the second reason for choosing The Hague. For trips within The Hague, 28% of the trips are made by car (Figure 7.1). If nothing changes, congestion will grow exponentially: a car increase of 15% within The Hague will lead to 25% to 30% more congestion (van Asten, 2019). Public transport has a share of 8% within the city. Both cycling and walking add up to almost 60%. This relatively big active mode share is seen in short trips of 1 to 5 kilometer (Figure 7.2, Figure 7.3). In trips between 1 and 3 kilometer, the car share is 20%, which increases to 35% in 3 to 5 kilometer trips. This indicates that car usage is high in The Hague, and increases quickly on short trips. Especially these short trips can be made by other modalities, such as bicycle. The third and last reason for choosing The Hague is because of HTM, the public transport operator in The Hague. This research is conducted for HTM, so it is valuable for

HTM to conduct this case study in the context of The Hague. In addition, HTM will get insights in the factors that are valued by car users in order to let them switch.

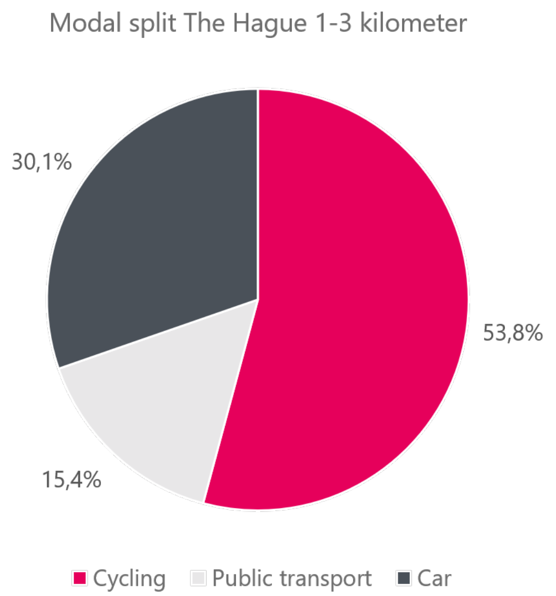


Figure 7.2: Modal split in The Hague 1 to 3 km (Gemeente Den Haag, 2016)

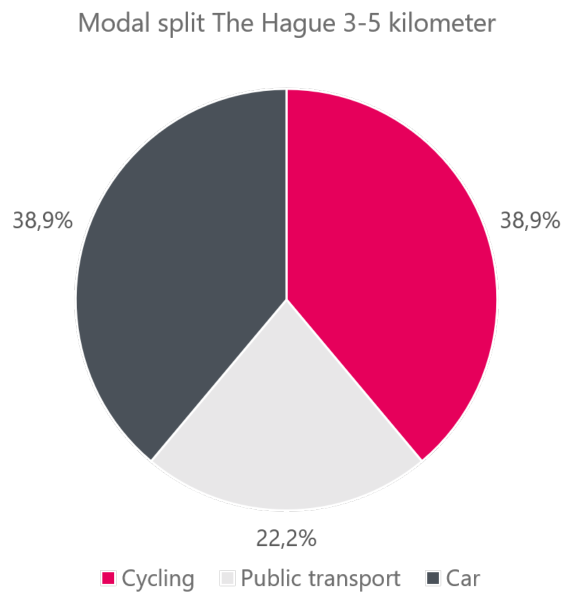


Figure 7.3: Modal split in The Hague 3 to 5 km (Gemeente Den Haag, 2016)

The Hague has developed a 'mobility transition program' in order to act on the upcoming mobility issues (van Asten, 2019). In this program is the aim to remain a livable, safe, and accessible city. The plan consists of six goals that should be reached by 2040. This case study will focus on three of the six goals, as those three goals contain means which fit within the scope of this research. The three goals that will be focused on here are *efficient mobility*, *affordable mobility*, and *sustainable mobility without emissions*. For each of the goals are means developed within the program (van Asten, 2019). Below, an overview of the three goals and its corresponding means which will be covered in this research.

- Goal 1: Efficient mobility
  - Lower the car parking demand
  - Quick public transport
  - Good bicycle parking facilities
- Goal 2: Affordable mobility
  - Implementation of shared modalities
- Goal 3: Sustainable mobility without emissions
  - Attractive sustainable mobility alternatives

The main questions that will be answered in this case study are the following. First, what factors help reaching the goals, through the means? And second, what are the factors that make car users switch towards (one of) the sustainable modes? The remainder of the case study chapter will be structured as follows. In Section 7.2, the final model results from Chapter 6 will be applied on the goals in the mobility transition program. This section will be followed by the total effect on change in car modal split due to the changes in attribute values in line with the mobility transition plan in Section 7.3.

7.2 Mobility transition program application

This section will step wise describe three of the The Hague mobility transition program goals: efficient mobility, sustainable mobility without emissions, and affordable mobility.

7.2.1 Efficient mobility

In 2040, mobility should become more space efficient, mobility flows should be smoother, as well as public transport should become quicker (van Asten, 2019). To reach this goal, three means are described in the mobility transition program: lower the car parking demand, quicker public transport, and good bicycle parking facilities. Each of these means can be reached by (a part of the) factors in this research.

Lower the car parking demand

The car parking demand should be lowered within the city, as the city continuously grows. When the expected increase in inhabitants and thus in car trips continues, there will not be enough space for car. Therefore, a lower car parking demand can help in preventing over-occupied space within the city.

The factor in this research that has directly impact on the car parking demand is *car parking costs*. Currently, the car parking costs the city centre are on average €4.00/hour. Increasing the car parking costs from €4.00 to €6.00 per hour has the following effect (Figure 7.4). The minimum change in car share is a decrease of 15.6%, while the maximum change is a decrease of 30.3%. Mainly on the longer distance trips the car share decreases more, where the public transport share increases with a maximum of 15.8%. The effect on (shared) bicycle share is relatively low compared to the public transport share increase band width. So, it is expected that car users are attracted to public transport as alternative.

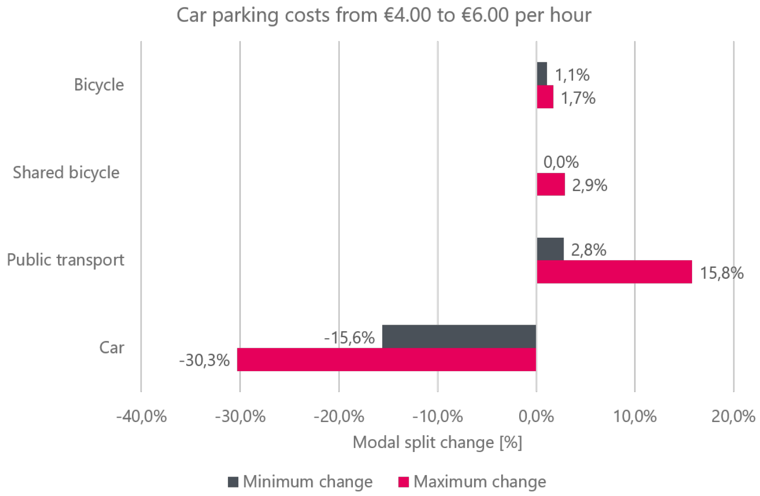


Figure 7.4: Effect of change in car parking costs from €4.00 to €6.00 per hour

Household types 'together, no kids' and 'together, kids' have compared to the household types 'alone' with or without kids a higher car share when going to the city centre for shopping. Of the two household types 'together' is the household type 'together, no kids' more sensitive to the change in car parking costs than the household type 'together, kids'. In addition, weekly city centre visitors are least influenced by the change in car parking costs. Monthly or yearly city centre visitors are both influenced mostly by the change in car parking costs.

Quick public transport

Quick public transport is a mean by which efficient mobility can be achieved. Quick public transport could be a competitor to car, especially when car travel times go up. Quick public transport can be reached through the two significant factors in this model: public transport walking time and frequency. In one minute walking, the distance covered is about 100 meters. So, a decrease of 100 meters walking time leads to an increase in public transport share between 1.3% and 3.7% (Figure 7.5). Although lower walking time decreases the travel time for the passenger, more stops in the network has an opposite effect on the transport time as it increases the in-vehicle time. Households with two cars are more sensitive to changes in walking time than households who own one car.

Figure 7.6 shows the changes in frequency from both 4 to 6 times per hour as 6 to 8 times per hour. The change from 4 to 6 times per hour leads to a higher public transport share increase than the change from 6 to 8 times per hour. Nevertheless, both have most impact on the car share. Furthermore, this effect was found on the longer distance only, so the change in frequency does not influence the mode choice in shorter trips. For the best effect of car users switching towards public transport, it is better to improve public transport frequency from 4 to 6 times per hour first, as that leads to the highest win.

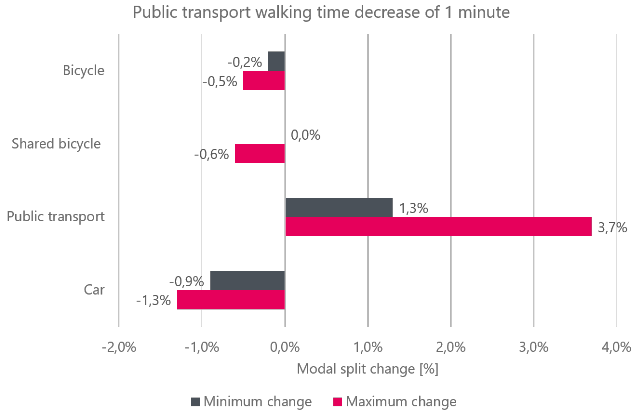


Figure 7.5: Effect of change in one minute (+/- 100 meter) walking time towards public transport

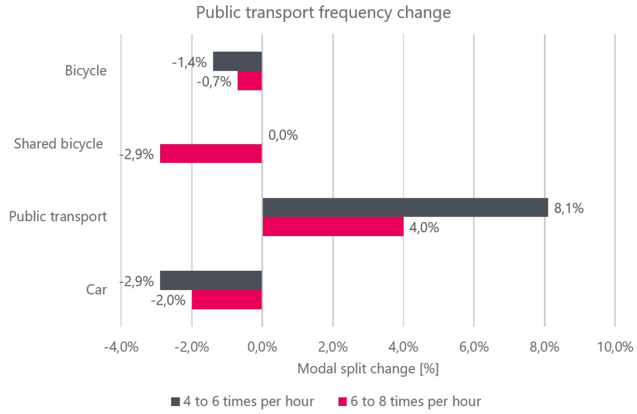


Figure 7.6: Effect of change in public transport frequency

Good bicycle parking facilities

Bicycle is the mode which has least CO_2 emissions of all modalities in this research. One of the ways to make bicycle more attractive is by making bicycle facilities more attractive. Two factors in this study that influence the bicycle parking facilities are walking time to the bicycle parking, and the bicycle parking costs. By means of a lower walking time becomes the bicycle trip shorter. The effect of walking time is bigger on shorter trips, and households with two cars are - again - more sensitive to walking time than households who own one car.

Currently bicycle parking is free. Therefore shows Figure 7.8 the effect of implementing bicycle parking costs of €0.50. As a result of bicycle parking costs will increase all three other modalities, of which the increase in shared bicycle is highest. In percentage points, the change shared bicycle is the same as for car (0.4 percentage points), but as shared bicycle has a lower share this change leads to a bigger relative change for shared bicycle than for car.

The conclusion remains that to make bicycle usage more attractive, this can be reached through lowering the bicycle walking time. Implementing bicycle parking costs has the opposite effect on the attractiveness of bicycle usage. Over all weigh bicycle parking costs heavier than bicycle walking time.

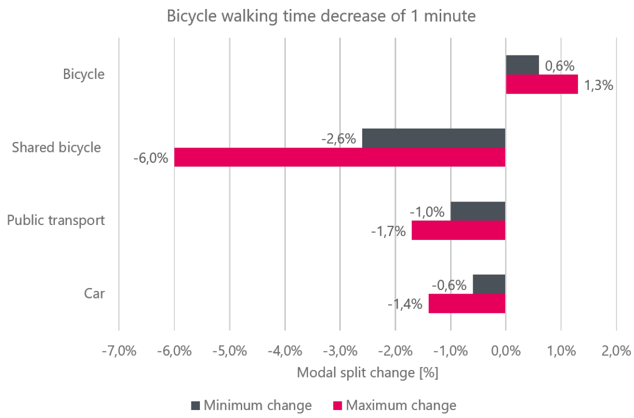


Figure 7.7: Effect of change in one minute (+/- 100 meter) walking time towards parked bicycle

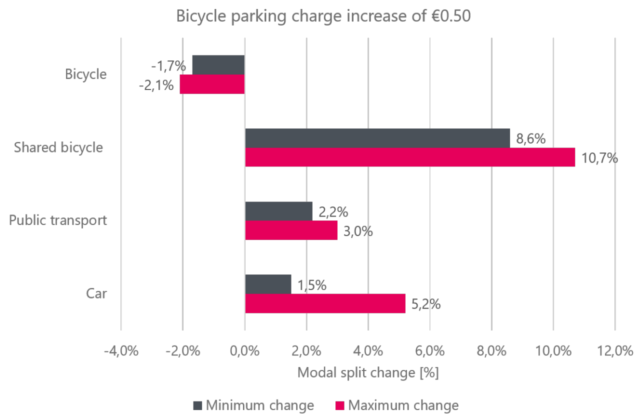


Figure 7.8: Effect of increasing bicycle parking fee

7.2.2 Affordable mobility

Affordable mobility in The Hague is the second goal in this research to be covered. One of the means is to implement shared modalities. Through the implementation of shared modalities pay users the usage costs only. The users do not have to own the modality themselves anymore, neither do they have to pay for the maintenance of the modality. As this research contained as shared modality the shared bicycle, the focus will be on shared bicycle and its attribute changes in the remainder of this chapter.

Implementation of shared modalities

In this study, shared bicycles have a couple of characteristics. The first one is walking time to and from the drop zone. The second characteristic is shared bicycle costs. The third and last characteristic is the availability of the shared bicycle, which is the reliability of having an available shared bicycle.

Change in walking time for shared bicycle has more impact on shorter distance than on longer distance (Figure 7.9). So, the effect of changing the shared bicycle walking time differs between 14.7% and 78.3%. The shared bicycle changes have hardly any impact on the car usage, as it influences the bicycle share more.

For the shared bicycle costs, the effect of lowering the costs from the current €1.00 to €0.50 has the following effect (Figure 7.10). People who like to use the shared bicycle are influenced mostly by the change in costs. Of all age groups is in the youngest age group of 18 to 40 years old the biggest change in shared bicycle modal split visible (+32.0%). The change in the shared bicycle attribute seems to attract bicycle users mostly, and has hardly any impact on public transport and car modal split.

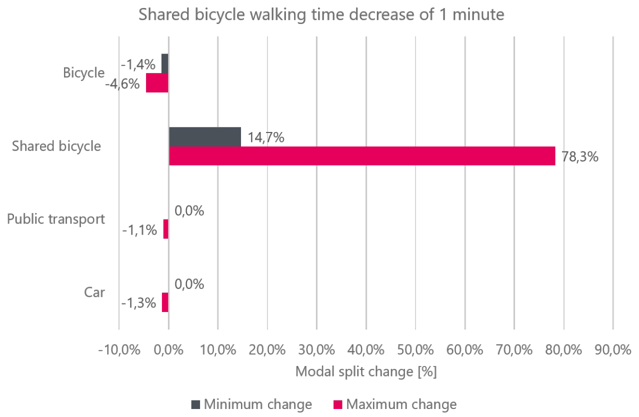


Figure 7.9: Effect of change in one minute (+/- 100 meter) walking time towards the shared bicycle drop zone

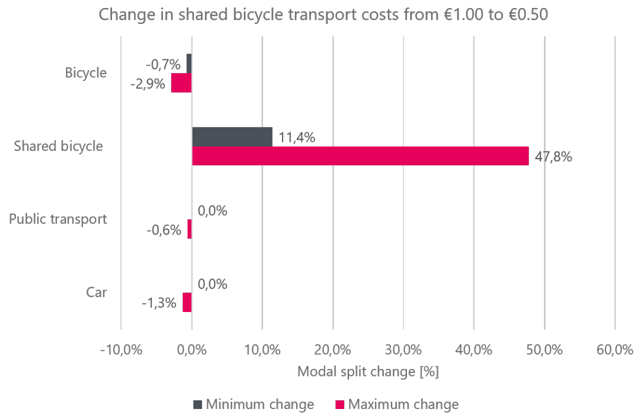


Figure 7.10: Effect of lower shared bicycle costs

The availability of the shared bicycle is related to the reliability of the shared bicycle service. For different trip distances are contrasting effects found when the availability from 1-2 bicycles at a drop zone is changed to either 3+ available bicycles (Figure 7.11) or to 'booked for you' at the drop zone (Figure 7.12). On the shorter distance is a booked version preferred while on a longer distance 3+ available bicycles is preferred over a booked shared bicycle. Both 3+ and 'booked for you' give however the same type of result: people like having more certainty over the availability of the shared bicycle.

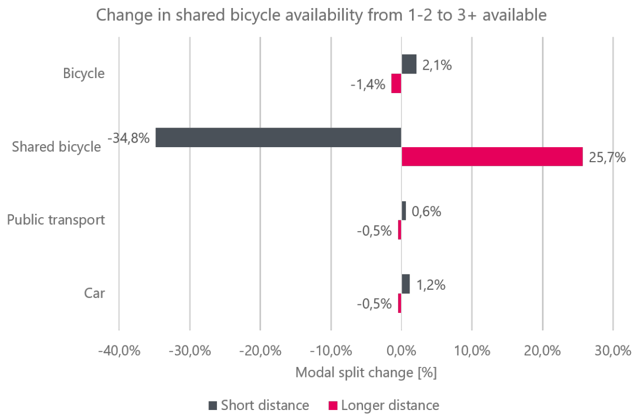


Figure 7.11: Effect of change in shared bicycle availability: from 1-2 to 3+ available shared bicycles at the drop zone

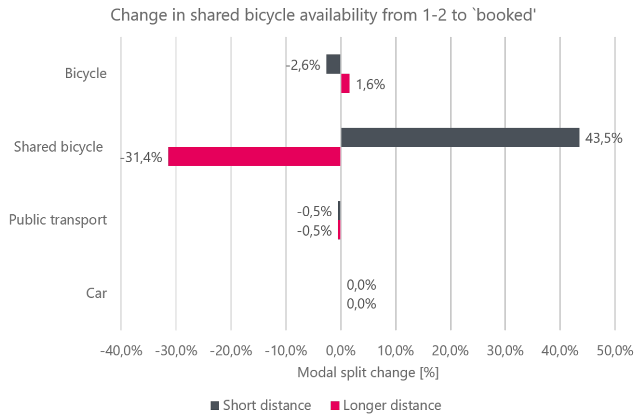


Figure 7.12: Effect of change in shared bicycle availability: from 1-2 to 'booked for you' shared bicycle at the drop zone

7.2.3 Sustainable mobility without emissions

In the third goal of the mobility transition program should modalities be more sustainable, and without emissions. To reach that goal, the mean is to have attractive sustainable mobility alternatives. In this section, one of the sustainable alternatives will not be discussed: shared bicycle. The shared bicycle alternative has been discussed in the previous section, but is a sustainable alternative which is applicable in this mobility goal as well.

Attractive sustainable mobility alternatives

Besides shared bicycle are in this study bicycle and public transport two sustainable alternatives to car. Sustainable modalities should be attractive at least in order to make car users switch to those modes. For the bicycle is bicycle driving time a not yet discussed factor which could influence the me modal split.For public transport have in-vehicle crowdedness and travel costs possibly impact on modal split. So those three factors will be discussed here.

In this research, the average cycling speed is 15 km/h (Fietsersbond, 2019). A decrease of cycling time of one minute leads to a new average speed of 15.8 km/h. The effect of a quicker bicycle trip compared to the current situation is visualized in Figure 7.13. Here, the bicycle share increases by 2.7% to 3.5%. For car share can a possible decrease of 2.0% to 7.8% be achieved when the cycling time becomes 1 minute less. In addition, due to an improvement in cycling time while the shared bicycle time is unchanged, a lower shared bicycle share is the result. So, changing bicycle travel time impacts all modalities, including car share.

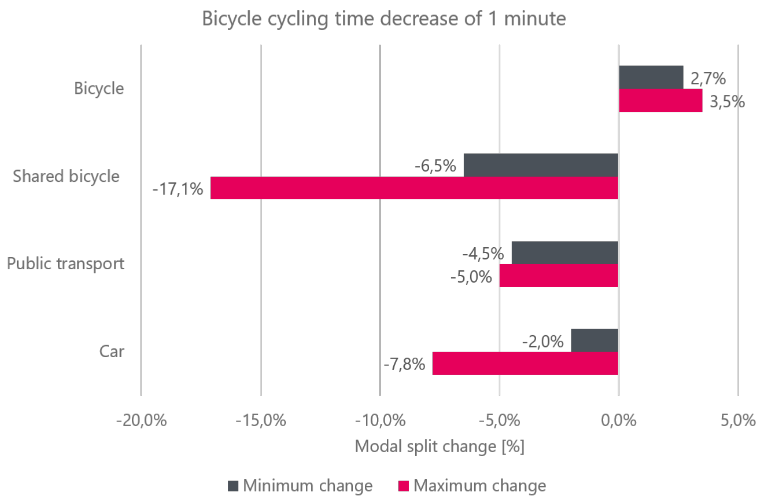


Figure 7.13: Effect of decrease in bicycle travel time of 1 minute

For public transport, the change in-vehicle crowdedness is visible in Figure 7.14. Changing the in-vehicle crowdedness from ‘not quiet/not busy’ (meaning: seating not guaranteed) to ‘quiet’ (meaning: guaranteed seat) has most effect on the car share. The car share decreases between 10.4% and 13.1%. Besides the car share is both bicycle and shared bicycle influenced by this change in in-vehicle crowdedness.

The effect of a change in public transport costs has less impact on the car share. A decrease of public transport costs from €2.00 to €1.50 is a cost decrease of 25.0%. The public transport share increases due to this change, but the effect lies between 3.9% and 6.0%. Car user share is affected mostly by the change in public transport costs. The effect is however not as big as the change in in-vehicle crowdedness. So, a change in in-vehicle crowdedness first has more impact than changing the public transport fee.

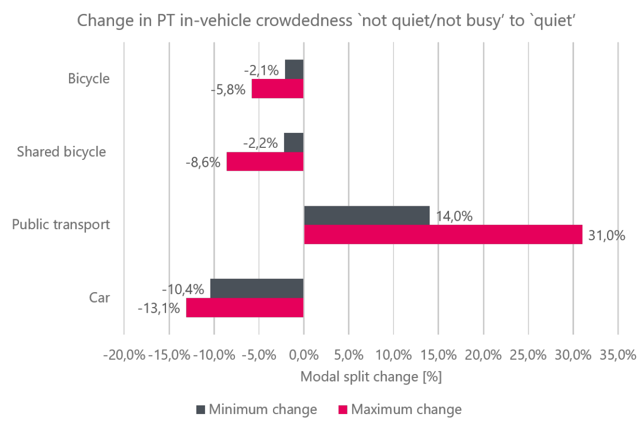


Figure 7.14: Effect of change in public transport in-vehicle crowdedness from ‘not quiet/not busy’ to ‘quiet’

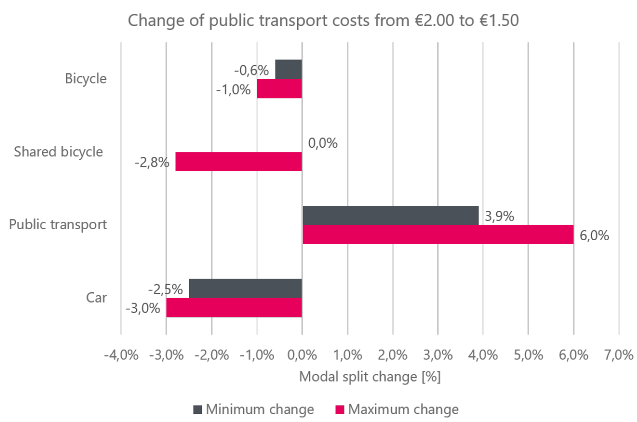


Figure 7.15: Effect of €0.50 decrease in public transport costs

7.2.4 Conclusion mobility transition program

Looking back at the means for reaching the mobility transition goals, the factors with most impact on car share are the following. Starting with car parking costs, followed by an improvement in public transport in-vehicle crowdedness, public transport costs, public transport frequency. The last factor that influences the car share mostly is bicycle travel time. So, besides the changes in the car parking costs, car users are attracted to public transport when the in-vehicle crowdedness is ‘quiet’. Most share can be won when changing car parking costs and public transport in-vehicle crowdedness, so it is advised to focus on those two factors first.

Car share is hardly influenced by changes in the shared bicycle characteristics. Therefore can be concluded that shared bicycle is not a good alternative for trips to the city centre with trip purpose shopping. Nevertheless, a couple of conclusions can be drawn for the factors that influence shared bicycle usage mostly - according to car users. Shared bicycle walking time and usage costs have most impact on the shared bicycle share. Especially on short trips is both lower walking time and lower travel costs valued by users. Lower usage costs have in addition most impact on age group 18 to 40 years old. So, for stimulating shared bicycle usage is for short trips especially recommended to keep the walking time low, as well as lowering the usage costs.

7.3 Maximum potential

The factors with most impact on the car share are car parking costs, public transport in-vehicle crowdedness, public transport costs, and public transport frequency. With those factors, the maximum potential will be calculated by combining the improved value from the previous section. A couple of cases will be calculated to see the differences in impact. First of all, the current situation modal split will be calculated. This is followed by the modal split when changing public transport values only, and the combined impact of public transport values and car parking costs. In addition, the impact of changes in shared bicycle is evaluated, as well as the change in bicycle travel time. Lastly, all impacts will be calculated.

Table 7.1 gives an overview of the values used for the calculation of the current situation. Table 7.2 gives an overview of the changed values in *green*, which are the same changes as in the previous section. For changes in public transport only, walking time, in-vehicle crowdedness, costs, and frequency is changed. For car is the car parking costs from 6 euros per 1.5 hour to 9 euros per 1.5 hour. Shared bicycle changes are made in the walking time, costs, and the availability. For bicycle, the only change is in cycling time.

Table 7.1: Used values for modal split of current situation

		Bicycle	Shared bicycle	Public transport	Car
Driving time	2.5 km	10 minutes	10 minutes	8 minutes	8 minutes
	5 km	20 minutes	20 minutes	15 minutes	15 minutes
Walking time		3 minutes	5 minutes	6 minutes	4 minutes
Crowdedness		3 minutes parking search time	-	Not quiet/not busy	3 minutes parking search time
Mode type		Own bicycle	Shared bicycle	Bus	Own car
Costs		0 euro	1 euro	2 euro	6 euro
Availability		-	1-2 available	-	-
Frequency		-	-	Every 10 minutes	-

Table 7.2: Used values for modal split of changes in changed situation

		Bicycle	Shared bicycle	Public transport	Car
Driving time	2.5 km	9 minutes	10 minutes	8 minutes	8 minutes
	5 km	19 minutes	20 minutes	15 minutes	15 minutes
Walking time		3 minutes	4 minutes	5 minutes	4 minutes
Crowdedness		3 minutes parking search time	-	Quiet	3 minutes parking search time
Mode type		Own bicycle	Shared bicycle	Bus	Own car
Costs		0 euro	0.50 euro	1.50 euro	9 euro
Availability		-	Booked	-	-
Frequency		-	-	Every 7.5 minutes	-

Figure 7.16 and Figure 7.17 show the changed modal split for each of the changes in modes. Figure 7.18 and Figure 7.19 give a clear overview of the relative change in modal split. It shows that for all changes the car share decreases. However, the changes are biggest when changes are made in public transport and car. It is clear that car users switch towards

public transport when changes for public transport are made. Within public transport, the advised sequence for changes in attribute level values is in-vehicle crowdedness to a guaranteed seating for the passengers. This is followed by public transport costs, public transport frequency, and lastly public transport walking time. The impact of increased car parking costs on the modal split is bigger than the in-vehicle crowdedness. However, the combination of higher parking costs and higher comfort in terms of guaranteed seating within public transport for car users is valuable. In addition, the change in modal split on the longer trip distance (5 kilometer) is bigger than on the short distance, so the focus should be at first on the longer distance.

Changes in shared bicycle modal split have a big impact on the relative change in modal split, as the current shared bicycle modal share is relatively low compared to the other modalities. For shared bicycle, the changes with most impact are walking time at the shorter trip distance. When comparing the two trip distances, the shared bicycle has a higher share in the short trip distance. So, the shared bicycle is more attractive at shorter distance than at the longer distance, especially when the walking time to the shared bicycle is shorter. The second highest impact is the availability of shared bicycles: on shorter distance is a booking option preferred over a non-booked version. On the contrary, on the longer distance is a higher availability at the drop zone enough, and 'booking' is less preferred. Lastly, the change in usage costs has most impact on shorter trips. Currently, the fee is per 30 minutes, so especially for shorter trips this value is relatively high compared to longer trips within 30 minutes. This is confirmed by the lower impact of travel cost changes on the longer distance.

Lastly, a lower bicycle travel time has impact on the car usage mostly on the shorter distance than on the longer distance, but in both cases car share decreases. The bicycle share however increases more in the longer distance than in the shorter distance, meaning that improved travel time for bicycle has a positive impact on the bicycle usage.

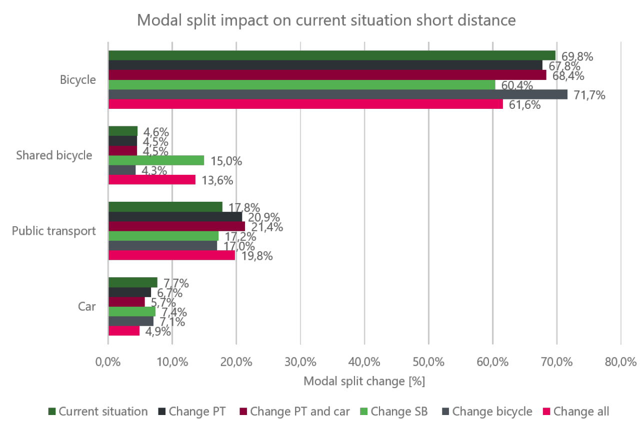


Figure 7.16: Effect of (combined) changes on modal split on shorter distance

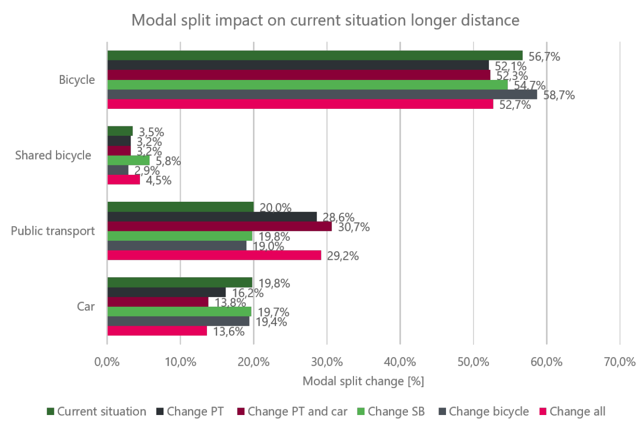


Figure 7.17: Effect of (combined) changes on modal split on longer distance

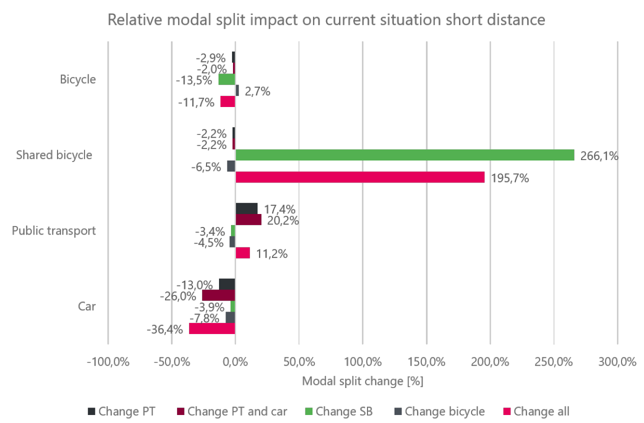


Figure 7.18: Percentual change of (combined) changes on modal split on shorter distance

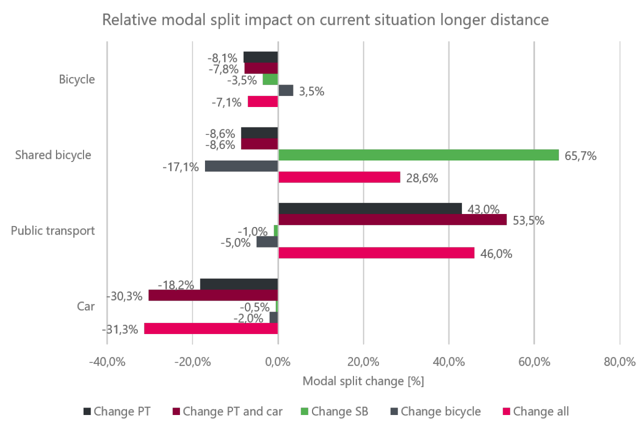


Figure 7.19: Percentual change of (combined) changes on modal split on longer distance

7.4 Conclusion

For trip purpose shopping, insights are gained for the mobility transition program in The Hague. Car users are mainly influenced by changes in car parking costs. As a result of an increase in car parking costs, car users switch towards public transport mostly. Public transport can be made more attractive for car users by changing the in-vehicle crowdedness from 'seat uncertain' to 'guaranteed seat'. The second to best implementation that has impact on an increased public transport share and a decreased car share is public transport costs, followed by public transport frequency. Therefore is the advice to The Hague to increase the car parking costs. The advice for HTM is to change the public transport in-vehicle crowdedness first. Those two factors have most impact on car modal split change. Changes in the car and public transport characteristics are in line with two goals in the mobility transition program: efficient mobility and sustainable mobility without emissions.

The shared bicycle is an alternative which is part of the mobility transition progam's goal 'affordable mobility'. The shared bicycle seems to be not a good mode substitution for car trips to The Hague's city centre for trip purpose shopping, as changes in shared bicycle characteristics hardly influence car modal share. This could be due to the fact that car users in this study own a bicycle themselves as well. Another explanation could be that currently shared bicycle is hardly used for trips to the city centre, and therefore is not part of the mode choice. Yet, a couple of conclusions and recommendations can be given for the impact of changes in two of the shared bicycle characteristics - according to car users. The shared bicycle factors shared bicycle walking time and usage costs have most impact on the shared bicycle. Especially on shorter trips is the impact of more positive values for those two factors is big. Therefore is for an increase in short distance shared bicycle usage to have a look at the number of drop zones as well as a more attractive usage fee.

Bicycle is the last of the three sustainable alternatives for car in this research. Change in bicycle travel time is part of the third discussed goal of The Hague's mobility transition program: *sustainable mobility without emissions*. Bicycle becomes more attractive to car users when the cycling time becomes lower. As the actual cycling speed on a regular bicycle cannot be influenced, changes should be made in the cycling infrastructure where cyclists get prioritized such that their waiting time in the trip becomes lower.

An important thing to keep in mind during these conclusions, the current modal split in The Hague (Figure 7.2 & Figure 7.3) does not fully match the modal split from the model. Bicycle is higher in the model outcome than in reality, while car share is lower than in reality. The Hague's modal split however is not specifically for trips to the city centre. Therefore is expected that the percentual changes due to the changes in mode characteristics not fully match the sketched profile. Nevertheless, the relative importance of the mode characteristics is not expected to change. Therefore, it does not influence the advice on changes to be made, but the impact in real life can differ.

Chapter 8

Conclusion

This research aimed for finding factors which car users evaluate as important and could lead to a switch towards sustainable modes. Sustainable modes are the bicycle, shared bicycle, and urban public transport being bus and tram. The main research question that is answered by this research is: "*Which factors influence the usage of private bicycle, shared bicycle, and urban public transport (bus and tram) for stand-alone trips of car users in a mid-sized city with trip purpose shopping, and what measures could increase the potential usage of these sustainable modes?*". In addition, the research gap on shared bicycle reliability will be filled as well. All components have been gathered to answer this main research question. Step by step, the answer to the main research question will be given.

Theoretical impact of factors

First, factors that theoretically influence the mode choice of bicycle, shared bicycle, urban public transport, and car, have been identified. In general, factors can be classified in three categories: characteristics of the trip maker (socio-demographics), characteristics of the journey (e.g. trip purpose), and mode characteristics. At first, the factors that influence the mode choice of the four modes will be concluded, followed by the factors which influence the switch towards the three sustainable modes.

Bicycle use is influenced by a couple of factors. First, the availability of a car influences bicycle use negatively. Bicycle availability influences the bicycle usage positively. Public transport availability nearby (<500 meters) influences bicycle usage positively, however stimulating public transport usage and bicycle usage at the same time turns out to have a negative influence on bicycle usage. Furthermore, positive intention and attitude influence bicycle usage positively as well. Benefits of cycling are comfort, flexibility and time-saving. The last factor which influences bicycle usage positively is the certainty of bicycle parking at the destination side.

Shared bicycles can be seen as a form of public transport, so the pyramid of traveler desires applies, which consists of minimum requirements (dissatisfiers) and factors that make the service more attractive (satisfiers). Therefore, at least the shared bicycle should be reliable and safe, the speed should be good, and ease of use should be arranged. Literature confirms these minimum requirements: shared bicycles are valued positively as one can get around easier, faster and shorter, while the distance between home and docking station should be short, and drop zones should be available around facilities. Reliability of shared bicycles is mentioned once in literature as factor for to use the shared bicycle more often. As reliability was not quantified yet, this gap in literature will be filled.

For public transport, the factors which make the service attractive can be categorized based on the pyramid of travel desires as well. Factors related to reliability are the service being on time, meeting the expected service quality and being able to rely on the service. Speed is directly related to all time components: access, egress, waiting, in-vehicle, and transfer time. Ease of use, also known as convenience, is amongst others mainly related to accessibility (short access time), and in-vehicle crowdedness. Comfort and experience can make public transport more attractive if the vehicles are comfortable and clean, have a good seating probability, and lastly if the service is punctual.

Car usage is attractive due to a couple of factors: convenience, speed, comfort, and individual freedom. Comfort is defined in literature as no waiting time, a trip can made whenever, and the car can bring one close to its destination. Car use is highly influenced by the number of cars in households, where more cars lead to a higher car frequency. Car parking at the activity end influences car usage strongly, especially in highly dense areas.

Switching towards (shared) bicycles is influenced by the travel cost and travel time. Lower (shared) bicycle costs than car attract car users. Shared bicycle travel cost and time are valued more negatively than car travel time and costs. Therefore, on longer trips car is more attractive than shared bicycles. Furthermore, the car parking availability at the activity end influences the switch away from car. Switching towards public transport is influenced by travel time and travel costs, and car parking availability as well. Furthermore, for public transport the frequency is important as that relates directly to flexibility, freedom, and independence. Moreover, the service should be reliable and convenient. Lastly, frequent car users have a preference for bus over tram.

The theoretical factors from above were combined with literature about switching away from car towards the sustainable modes, and factors that influence the switch to bicycle, shared bicycle, and urban public transport. The factors which are most influential are mentioned at least a couple of times and had a significant influence previously. The factors which are measurable and therefore included in the stated preference survey are visualized in Table 8.1.

Table 8.1: Measurable and influential factors in the stated preference survey.

	Bicycle	Shared bicycle	Public transport	Car
Driving time	X	X	X	X
Walking time	X	X	X	X
Crowdedness	X *parking search time*	-	X *in-vehicle crowdedness*	X *parking search time*
Mode type	-	X *(electric) shared bicycle*	X *bus or tram*	-
Costs	X *parking costs*	X	X	X *parking costs*
Availability	-	X	-	-
Frequency	-	-	X	-

Actual impact of factors

The actual influence of the selected factors was measured in two scenarios: distance of 2.5 kilometer and 5 kilometer to the city centre of The Hague, with trip purpose shopping. Within the factors of both scenarios are a couple of similarities and differences. The similarities between the two scenarios are the driving time of bicycle and shared bicycle, in-vehicle crowdedness, costs for all alternatives, and the availability (reliability) of shared bicycles. In terms of interaction variables, similarities are the effect of number of cars in household, the frequency of cycling and going to the city centre, and attitude towards tram. The differences are in 2.5 kilometer, walking time is significant while in the 5 kilometer scenario walking time is insignificant. The other difference is that the public transport frequency is significant in 5 kilometer scenario, while the public transport frequency is insignificant in the 2.5 kilometer scenario. In the interaction variables, in 2.5 kilometer scenario, household type and the attitude towards shared bicycle is significant. While in the 5 kilometer scenario age and frequency of car driving within the city have an effect on the mode choice as well.

Table 8.2: Significant ($p<0.05$) factors (in green) scenario 2.5 kilometer

	Bicycle	Shared bicycle	Public transport	Car
Driving time	**X**	**X**	X	X
Walking time	**X**	**X**	**X**	**X**
Crowdedness	X *parking search time*	-	**X** ***in-vehicle crowdedness***	X parking search time
Mode type	-	X *(electric) shared bicycle*	X *bus or tram*	-
Costs	**X** ***parking costs***	**X**	**X**	**X** ***parking costs***
Availability	-	**X**	-	-
Frequency	-	-	X	-

Table 8.3: Significant (p<0.10) factors (in green) scenario 5 kilometer

	Bicycle	Shared bicycle	Public transport	Car
Driving time	X	X	X	X
Walking time	X	X	X	X
Crowdedness	X *parking search time*	-	X *in-vehicle crowdedness*	X *parking search time*
Mode type	-	X *(electric) shared bicycle*	X *bus or tram*	-
Costs	X *parking costs*	X	X	X *parking costs*
Availability	-	X	-	-
Frequency	-	-	X	-

Potential usage of sustainable modes

The potential usage is expressed in modal split. In the case study, the impact of significant parameters on the *current situation* modal split is identified, which is combined the potential usage. Figure 8.1 and Figure 8.2 show the potential modal split, including between brackets the percentual change compared to the current situation.

Changes in the *car parking costs*, the *public transport in-vehicle crowdedness*, *public transport walking time*, and the *public transport frequency* have mainly impact on the car share. Of these factors have an increase in car parking costs from 4 to 6 euros per hour the most impact on the modal shift, followed by the three public transport factors in that order. The change in public transport in-vehicle crowdedness is valued highly by car users, which is in line with the comfort factor that was found in literature. So, car users are likely to switch away from the car when the car parking costs increase, in combination of a guaranteed seat in public transport, as well as short walking time (on the shorter trip distance), and higher frequency (on the longer trip distance).

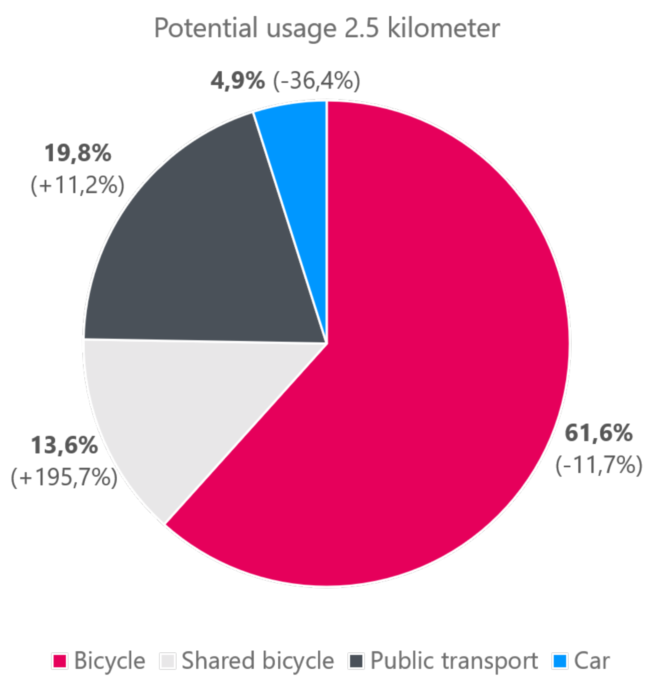


Figure 8.1: Potential modal split scenario 1: 2.5 km

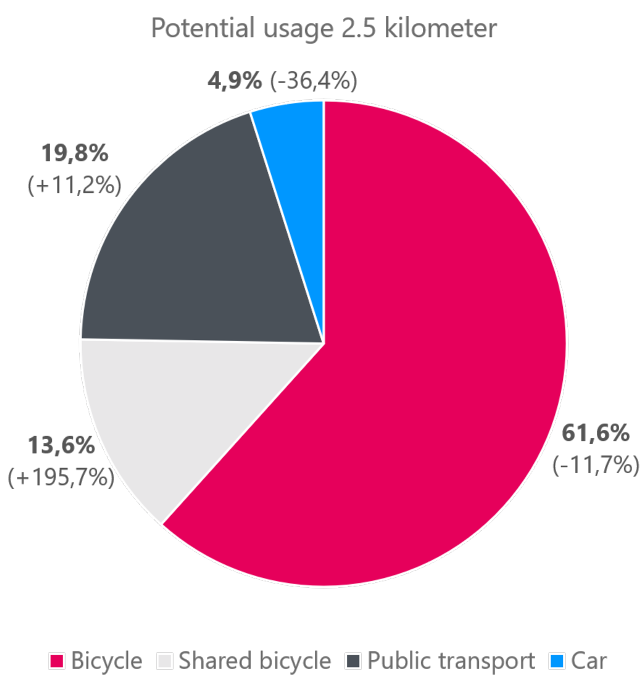


Figure 8.2: Potential modal split scenario 2: 5 km

Changes in the shared bicycle alternative hardly influence the car modal share. So, car users will not switch away from car towards shared bicycle when shared bicycle characteristics change. However, a couple of shared bicycle characteristics have impact on the shared bicycle modal share. The two factors with most impact on the bicycle modal share is *walking time to the drop zone*, and *usage costs*. Both factors have more impact on the shorter trip distance of 2.5 kilometer. So, for attracting users to use the shared bicycle for shorter trips, more drop zones could offer a solution. Other pricing policy, by making shorter trips cheaper, for short trip distances could attract users to the shared bicycle.

In addition to shared bicycle walking time and travel costs, the *reliability of the shared bicycle* is valued importantly. On the short distance leads being able to book the shared bicycle to a higher shared bicycle share, while on the longer distance 3+ available bicycles are preferred. So, for reaching both user groups, a booking system is advised in combination with a 3+ availability of shared bicycles at the drop zones.

The last sustainable mode in this research is bicycle. Two factors influence the bicycle share and have impact on the modal split: travel time and bicycle parking costs. Lower cycling travel time leads to an increase in bicycle usage, and decrease in the other three modalities. Cycling travel time could be lowered by changes in cycling routes. For instance, traffic lights can be adapted to prioritize cyclists. Another possibility could be improvements in dedicated infrastructure such that cyclists have more space while safely travelling. Bicycle parking costs should not be introduced, as those lower the bicycle share, and increase the car share. So, the introduction of bicycle parking costs results in an opposite effect compared to the goals in mobility transition programs.

All pieces to for answering the main research question are gathered. These conclusions apply on the specific context of this research: short trips (<5 kilometer) with trip purpose shopping including grocery shopping. The two factors with most impact are car parking costs, and public transport in-vehicle crowdedness. Changes in those two factors lead to a switch from car towards public transport mainly. The potential can be achieved by increasing car parking costs, and by less crowded public transport vehicles where a seating place can be guaranteed.

Bicycle parking costs and travel time both influence the car share in a positive way as well, of which bicycle parking costs weigh heavier. Bicycle parking costs should be avoided in order to keep the bicycle most attractive. Implementation of bicycle parking costs leads to an increase in car share, which is the opposite of what cities want to achieve nowadays. Bicycle travel time is valued heavier than the car travel time, so lower bicycle travel times attract car users. Lower bicycle travel times could be reached by improving cycling infrastructure facilities such as prioritizing the bicycle at traffic lights.

Of the three sustainable alternatives is the shared bicycle the least popular one. Car users hardly react on changes in the shared bicycle alternative. Nevertheless, an answer to the gap in literature on shared bicycle reliability can be given. On the shortest distance trips is a booking option preferred over non-booked availability options, while at the longer trip distances 3+ available shared bicycles are preferred over the booked version. So, both 3+ available shared bicycles and 'booked' increase the reliability of the service.

Besides mode-specific factors is another factor important for the mode choice as well. This is the attitude from car users towards tram and bus. The group with a negative attitude towards the usage of those public transport modalities has the highest car share. An improvement in attitude to neutral is important in order to actually let car users switch towards public transport.

Changes in (a combination of) the above factors have potential impact on the car share, with as result the switch towards the two sustainable modes public transport and bicycle mainly.

Chapter 9

Discussion and recommendations

This last chapter consists of a discussion in Section 9.1, and is ended with recommendations for both practice and further research in Section 9.2.

9.1 Discussion

The first part of this section consists of the research limitations. The second part of this section will compare the results in this research to previously found literature.

9.1.1 Research limitations

This section reflects on the decisions made in this research which had impact on the outcomes. First, the respondent representation is gone into. This is followed by the discussion of survey design, the used methodology, and the analysis of the stated preference survey. The second-last discussion point is about the geographical context of this research. Lastly, the influence of the covid-19 pandemic on the research is discussed.

Respondent representation

The respondents who filled in the survey were gathered via a payed platform called PanelClix (PanelClix, 2021), where the respondents are rewarded with money for filling in surveys. Therefore, it could be that respondents filled in the survey less precise than one would do when filling in the survey on a voluntary basis. Compared to the Dutch population, there are some groups under represented and over represented. The age group 18 to 27 years old was under represented, while the age groups 41 to 64 and 65+ were over represented. Furthermore, the age group 18 to 27 years old was smaller than 30 respondents (N=13). For that reason, it was added to the age group 28 to 40 years old. This restricts the conclusions that can be drawn with regard to the youngest age group. In terms of education level, more high educated people than both the Dutch and The Hague population were part of the survey, while lower level educated people were under represented. In terms of household type, the most underrepresented household type is 'alone, no kids', while that household type has the highest share in both the Netherlands and The Hague.

In terms of mode frequencies, on average the total car frequency was highest of all modes, followed by bicycle frequency and car frequency within the city. These numbers show that the target group of car users within the city was correctly targeted by PanelClix.

Survey design and methodology

The methodology for this research was a survey, containing a stated preference choice experiment, socio-demographics and a couple of statements about their attitude towards the mode alternatives of the stated choice experiment. The choice experiment part of the survey contained 7 attributes, of which two attributes belonged to only one alternative. It could be that due to this big number of attributes the respondents made their decision on only a couple of characteristics instead of all. One of the insignificant factors which is opposed to literature is 'mode type'. Mode type was located directly under the headers, which could be a reason for the respondents to overlook the shared bicycle and public transport mode type. The other insignificant value was 'parking search time', which was the crowdedness factor for bicycle and car. That factor can thus have no influence on mode choice, or was a factor valued as least important, or was overlooked by the respondents.

The cost attribute was added to all four alternatives. For shared bicycle and public transport these were costs for using the service. For bicycle and car, the costs were parking costs at the destination side. For car was chosen not to add fuel costs to these short trips. Therefore, the actual costs for the trips are not exactly equal to reality, as car costs are in reality a bit higher.

The scenario that has been presented in the stated preference part of the survey to the respondents had a very optimistic scenario. In this scenario, (shared) bicycle could be more attractive than the other two alternatives. In the scenario the respondent did not carry heavy goods with them, and the weather was good for cycling: no rain, no hard wind, and 17 degrees Celsius. Therefore, it could be that a change in these circumstances, either in carrying goods or bad weather, change the outcomes of the model.

Stated preference analysis

A stated preference analysis has been done in this research, which provides hypothetical choices. This means that respondents should imagine themselves undertaking the trip, given the sketched scenario. As was found in literature by H. Aarts (1996), a lot of trips are habitual for which not every time all alternatives are weighed. In addition, it is not sure if respondents normally take all the attributes in cooperation for their mode choice. Therefore, it cannot be stated with certainty that respondents would make these choices in reality as well. A solution to this problem could have been revealed preference, where the actual choices of the respondents are gathered and analysed. However, the main drawback of revealed preference is that their choice set remains unknown, as well as the researcher cannot add other alternatives to the respondents' mode choice set.

Another important factor of stated preference is that the results can only be interpreted based on the attribute ranges from the survey, so conclusions cannot be extrapolated. Lastly, in the stated choice experiment, the respondents were asked for both their first and second choices. It could be that this extra choice increased the survey duration, which may have lead to less reliable choice data from the last choice sets.

The analysis of the choice experiment has been done by estimating a multinominal logit model, panel mixed logit model, extended panel mixed logit model with error component. In the last version were interaction effects added as well. In a (panel) mixed logit model with error components, the modeller should test best fitting error components instead of letting the model determine the fitting error component. Although a couple of combinations were tried, it could be that different error components fit the model better than the bicycle error component. Besides a panel mixed logit model, a latent class model could have been estimated as well or instead. The advantage of a latent class model is that several classes are made in which the preferences are similar, while different classes have different preferences. Due to that approach, insights are gained in the diversity of groups and its specific mode choice preferences. This could be an added value for the research, as currently the significant interaction effects determine the differences of users.

The Hague

City The Hague, the Netherlands, was chosen because of four reasons. Firstly because of the cooperation with HTM, The Hague public transport operator. Secondly, because more than half of all visits to the city centre are undertaken by inhabitants of The Hague (Gemeente Den Haag, 2018). Thirdly, The Hague is a dense city where with a radius of 5 kilometer nearly the whole city is covered.

The fourth reason is that The Hague has a high car share on short distances. The Hague is average compared to the other four big Dutch cities Amsterdam, Rotterdam, Utrecht and Eindhoven. Although the car share is in the middle of the cities, there are a couple of differences between The Hague and the other four cities. Starting with the number of inhabitants. Amsterdam has 873.000 inhabitants, Rotterdam 651.000 inhabitants, Eindhoven 235.000, Utrecht 359.000, and The Hague 548.000. In terms of mobility, Amsterdam and Rotterdam both have a metro network, of which from Rotterdam to The Hague via a light rail network The Hague is connected to the Rotterdam metro network as well.

Despite the differences with other Dutch cities, it is expected that the results of this study can be generalized to other Dutch cities as other Dutch cities have in general the same characteristics. All have public transport, and since there is no difference found between bus and tram it does not matter whether a city has a tram or not. In addition, in the whole Netherlands the cycling frequency is high as well as the bicycle occupancy and the infrastructure characteristics.

Generalization to Dutch villages becomes more difficult, which has a couple of reasons. First of all, public transport is there not a good alternative as the public transport network in most villages is not as dense as in cities. In addition, besides last-mile shared bicycle docking stations, villages do not have shared bicycle facilities, so the shared bicycle is not a good alternative in villages. Furthermore, most car parking spots in villages are free, or limited to 2 hours due to the 'blauwe schijf'. Therefore is car usage attractive for shopping. Lastly is expected that bicycle and walking are good alternative for shopping trips within villages.

Generalization to European cities can be done under a couple of conditions. The Netherlands has a higher cycling frequency than the average in the European Union: 28% of the Dutch population cycles a couple of days per week, which is 11 percentage points higher than in the European Union (European Commission, 2013). Furthermore has the Netherlands a high quality cycling infrastructure, flat terrain, mild climate, lots of bicycle parking facilities, and short travel distances within cities (Heinen et al., 2010; Schepers et al., 2017). The Dutch public transport share is relatively low compared to other European countries (Fiorello et al., 2016). Therefore, these differences should be kept in mind when applying the results on other European countries.

Covid-19 pandemic

This research was conducted during the Covid-19 pandemic, due to which travel patterns have changed for a lot of people. Especially public transport share decreased due to government regulations. Regardless of the disclaimer in the survey to fill in the choice sets, mode frequencies and mode attitudes as without the corona virus, it could be that respondents were not able to visualize the situation as without Covid-19. This could be due to the fact that The Netherlands was in lockdown from mid December 2020 to mid April 2021, while the survey was conducted in the beginning of March. Therefore, it could be that judgements towards public transport are biased in a negative manner, due to regulation where mouth masks in public transport vehicles are mandatory. In addition, the virus in combination with the government regulations not to use public transport could be an explanation that quiet public transport vehicles are preferred.

Trip purpose: shopping

This research focused on one trip purpose, this is shopping including grocery shopping. This is due to the high car share within the trip purpose and little research that has been conducted to this trip purpose previously. In the survey was no distinction between ‘grocery shopping’ and ‘fun shopping’ in the city centre, as the scenario stated that respondents would go there for both shopping purposes. So, no conclusion can be drawn on the differences in mode choice for those two. Therefore could it be that the car share in the model was found to be lower than in the found modal split.

The focus in this research was on shopping trips in the city centre. Other locations in the city contain shopping malls and grocery stores as well. It is expected that with similar characteristics as payed parking, good accessible by public transport, available shared bicycle drop zones, and bicycle parking facilities, the results can be generalized. However if (one of) the characteristics differ, the results will differ for these malls.

It is expected that the results differ from other trip purposes as follows. The difference with trip purpose shopping is expected as follows. Travellers with trippurpose work are often familiar with more crowded vehicles, especially in peak hours. It is expected that for car users in peak hours the in-vehicle crowdedness is valued heavily as well. In addition is expected that those travellers are less cost sensitive due to travel allowances. At the same time, travellers are expected to be more time sensitive as trips take place in their free time. As working trips are on average 23 kilometer (CBS, 2018), so the conventional bicycle and shared bicycle are unattractive alternatives. However, for inhabitants who work and live in the same city, the results could apply.

Other trip purposes on short trips within the city are mainly going out or visiting family and friends (Gemeente Den Haag, 2016). This research was conducted with scenario of an individual travelling to the destination. Usually for those two trip purposes are undertaken with more than one. Therefore is expected that car and bicycle are alternatives that will be used mostly in those trips. Public transport and shared bicycle could be a good alternative if the destination is accessible with public transport, and the trip time is comparable to car or bicycle.

9.1.2 Comparison with previous research

This section will compare the findings of the literature research to the findings in this research. This enables identifying the similarities and differences compared to previous researches.

Bicycle usage

In the Netherlands, 43% of the Dutch population cycles on a daily basis, and 28% cycle a couple of days per week, which is respectively 31 and 11 percent points higher than average in the European Union (European Commission, 2013). In this study’s sample, 37,8% of the respondents cycle on a daily basis, and 26,9% cycle a couple of times per week. Thus, we can speak of an average Dutch cycling sample. However, when generalizing to the European Union, the daily cycling share in this study is 25 percent points higher, 10 percent points higher for the cycling share of a couple of days a week. Thus, for an application of this research on European context, these differences should be taken into consideration as this research has a higher cycling share than average European Union countries.

The meta study about cycling by Muñoz et al. (2016) gave insights in the socio-demograhpics of the cyclists. In the literature review in Chapter 3, the focus was on Dutch cycling studies given the Dutch situation. Here will be checked if findings in this research comparable to Muñoz et al. (2016)'s study in Table 9.1. Female cycle more often than male, on average frequent cyclists are younger. Income was not asked for in the socio-demographics, instead level of studies was asked for. Higher educated respondents did have more bicycles available in their household. Furthermore, household type 'together, with kids' has a higher number of bicycles in their household than the other household types in this study. Besides the socio-economic characteristics, mode availability was found significant in Muñoz et al. (2016). Car availability and bicycle availability did not have a significant effect on the cycling frequency. The availability of public transport was not asked in the survey, so cannot be compared to the findings by Heinen et al. (2013).

Table 9.1: Validation of socio-economic and household characteristic variables of Dutch studies in Muñoz et al. (2016); adapted table, * reference = university, ** reference = living with both parents; x = not significant, + = significant positive effect, - = significant negative effect

	Gender (male)	Age (young)	Income	Level of studies *	Family type **	Car availability	Bicycle availability	Transit availability
Rietveld and Daniel (2004)		+	x			-		
Bruijn et al. (2005)	-	-		+	+			
Engbers and Hendriksen (2010)	x	x	x	x				
Heinen et al. (2011)								
Heinen et al. (2013)	x	+				-	+	+
M. J. Aarts et al. (2013)	x	+				-		
This research	-	+	N/A	+	+	x	x	N/A

In literature, both attitude and intention to cycle had a positive effect on bicycle usage (Bruijn et al., 2005; Heinen et al., 2013). This study asked for bicycle attitude, and in line with Bruijn et al. (2005) and Heinen et al. (2013), a positive attitude towards bicycle has a significant higher cycling frequency than both neutral and negative attitudes towards cycling.

The last literature finding about bicycle usage was about trip distance: trip distance influences the bicycle usage negatively (H. Aarts, 1996; Engbers & Hendriksen, 2010; Heinen et al., 2013). In this study, the 2.5 kilometer scenario had a bicycle modal share of 69.8%, and in the 5 kilometer scenario this share decreased to 56.7%, which shows the same pattern.

Shared bicycle usage

In literature was found that shared bicycles were mostly used for short distances (Bachand-Marleau et al., 2012), and the trip distances varied between 2.4 and 4.4 kilometer (Fishman et al., 2014; Jensen et al., 2010; Zhang & Mi, 2018). In this study was found that in 2.5 kilometer scenario the shared bicycle usage is more attractive than in the 5 kilometer scenario, given the modal splits of shared bicycle in both the current situation (2.5 kilometer: 4.6%; 5 kilometer: 3.5%) and the maximum potential situation (2.5 kilometer: 13.6%; 5 kilometer: 4.5%). This is in line with the finding of Ma et al. (2019) as well, where switching towards shared bicycle was found more likely at short trips (<2 kilometer) than longer trips. Furthermore, Arendsen (2019) and Halldórsdóttir et al. (2011) both found travel time and travel cost had a stronger negative effect for shared bicycle compared to bicycle and car. That finding can partly be confirmed by this study, as travel time is not valued more negatively than bicycle and car. However, the travel costs and the walking time are valued more negatively in the 2.5 kilometer scenario, and in the 5 kilometer scenario walking time was valued more negatively than bicycle, public transport and car walking time.

Previous research on the HTM Fiets specifically by van Marsbergen (2019) gave insights in the modes which would have been used if HTM Fiets was unavailable. van Marsbergen (2019) found 37.3% would shift towards tram, and 8.5% to bus. In this research, a significant correlation between bus frequency and shared bicycle frequency was found ($r(358)=0.142$, $p=0.007$), and a significant ($p<0.10$) correlation between tram frequency and shared bicycle frequency ($r(358)=0.093$, $p=0.079$). Here, the correlation between bus frequency and shared bicycle frequency was thus found stronger than the correlation between tram frequency and shared bicycle frequency.

Fishman (2016) found that the substitute fo cars by shared bicycle differed ranging from 2% to 21%. van Marsbergen (2019) found HTM Fiets was a substitute for car in 4.2% of the cases. This study did not focus on identifying the substitute of car due to the introduction of shared bicycle. However, improvements of the shared bicycle alternative only did give insights in the modal shift due to the improvements. By increasing the shared bicycle to its maximum potential, in scenario 2.5 kilometer and 5 kilometer decreased the car share by respectively 7.8% and 0.5%. The average of these trips is the same as van Marsbergen (2019) found. Fishman et al. (2013) and Murphy and Usher (2015) found that most shared bicycle users come from public transport. The modal shift due to improving shared bicycle in its maximum potential resulted in -3.4% (2.5 kilometer) and -1.0% (5 kilometer). In both cases, improvements in the shared bicycle alternative only resulted in a modal shift mainly from bicycle users: -13.5% (scenario 2.5 kilometer) and -3.5% (scenario 5 kilometer).

Public transport

In literature was found that public transport usage was mostly influenced by speed, travel time and comfort (Beirão & Cabral, 2007; Peek & van Hagen, 2002; van Hagen & van Oort, 2019). Of those three factors is speed a 'dissatisfier' in in the pyramid of travelers' desires, and comfort is a 'satisfier' (van Hagen & van Oort, 2019). In this research, in-vehicle time is insignficant. However, on the shorter trip distance of 2.5 kilometer, the walking time is significant, and on the longer trip distance of 5 kilometer is public transport frequency significant. So, in those terms is speed valued as important in this study. The comfort factor has in this research a big impact on the utility of the public transport alternative. In-vehicle public transport crowdedness is valued most positively when the vehicle is 'quiet'. This is in line with the earlier found factor *comfort* in literature (Corpuz, 2007). So, for car users in this research, in-vehicle time is seen as less important, while walking time and frequency are more important. In line with the comfort factor, the in-vehicle crowdedness is seen as important.

In literature, Bunschoten et al. (2013) found the tram bonus. In addition was found that frequent car drivers are more likely to use bus than tram. In this research is no difference found between the two public transport mode types bus and tram. This confirms the finding of Bunschoten et al. (2013) that frequent car users are likely to switch towards bus, as no additional value for tram was found.

9.2 Recommendations

The recommendations will be made in two parts. First, the recommendations for practice are made. The recommendations will be mainly for HTM and the municipality of The Hague. This is followed by recommendations for further research.

9.2.1 Recommendations for practice

Given the results in the case study, a couple of recommendations for practice can be made. First of all, the biggest change in modal split can be made through an increase in car parking costs of 2 euros per hour. Then, mainly visitors who go to the city centre 1-3 times per month are stimulated to search for other alternatives. Therefore is advised to The Hague municipality to revise the car parking costs in the city centre, as well as the direct surrounding neighborhoods to prevent car users to park their cars just outside the city centre.

As a result of the increasing car parking costs, car users switch mainly towards public transport. The second piece of recommendations are therefore for improvements in public transport which attract more car users. First of all, car users are indifferent for the public transport mode type, so there is no preference for either bus or tram. Therefore is advised not to focus on changing bus lines by tram. The focus can be better on other factors. Starting with in-vehicle crowdedness. Car users prefer a guaranteed seating in public transport, as by non-crowded vehicles attract most car users. Therefore is the advise for HTM to make car users aware of non-crowded vehicles, by using the 'HTM drukteindicator' (HTM, 2020) for broader purposes. By experiencing the non-crowded trips could car users create a new habit for their trips to the city centre.

The third recommendation is for public transport as well. A couple of correlations were found between car frequency and attitudes towards bicycle, shared bicycle, bus, tram and car. Frequent car users have a positive attitude towards cars, and a negative attitude towards bicycle, shared bicycle, bus and tram. At the same time, frequent bus and tram users have a positive attitude towards bus, tram, and shared bicycle. In the modal split became visible that car users with a negative attitude towards bus and tram have highest car share, and a low public transport share. Therefore, a change in attitude can lead to an increase in public transport frequency. So, the recommendation is to do marketing on these high frequent car users. High frequent car users are in particular weekly city centre visitors, on average younger (average age: 51 years old) than infrequent car drivers (average age: 56 years old) and have on average 1.34 cars in their household.

The fourth recommendation is with respect to the shared bicycles. Changes in shared bicycle characteristics has mainly impact on the bicycle modal share. The factors which are found valuable for shared bicycle are walking time and usage costs, as well as the availability of shared bicycles. Especially on shorter trip distances (2.5 kilometer), users are more attracted to shared bicycle when walking time is lowered by 1 minute. In addition, a decrease in usage costs to €0.50 attract shared bicycle users. Certainty of a shared bicycle is valued by users as well, for which on short trips a 'booked' service is preferred. Therefore is recommended in order to attract users on short trips to increase the number of drop zones such that every drop zone can be reached within 2 minutes. This can be best combined with a booking system, where the users can make a reservation for using the shared bicycle. Furthermore, a change in fare system is recommended, where it becomes more attractive to use shared bicycle for shorter trips.

The fifth and last recommendation are for The Hague municipality. Lower bicycle travel time is valued by car users, and attract car users towards bicycle. Lower bicycle travel time can be reached by increasing cycling speed. The cyclist's speed cannot be changed, so changes in bicycle infrastructure are recommended by which the cycling speed increases. One of the components where time can be won is waiting time. Therefore is recommended to make changes in infrastructure where cyclists are prioritized over other modalities. This can increase the cycling speed, and thus make cycling more attractive. The last recommendation is with respect bicycle parking fee. It is recommended not to implement bicycle parking costs, as the bicycle share is highest when the parking is free. Implementing bicycle parking costs would have an opposite effect on efficient mobility in the city, as car share increases when bicycle parking costs are implemented.

9.2.2 Recommendations for further research

For science, a couple of recommendations can be made. The first one is on a found gap in literature, which could not be filled by this research. In the literature review was found that trips by car are attractive as those trips are comfortable. Comfortable is defined by literature as 'having no waiting time', and 'flexibility' (Corpuz, 2007). Therefore is expected that the public transport reliability attracts car users. However, public transport reliability was not part of the stated preference survey. Therefore is recommended to do further research on the effect of public transport reliability on public transport mode choice of car users.

This research focused on stand-alone trips, and the trip *towards* the city centre is researched. Although the scenario contained a side note saying that for the trip homewards the characteristics would be the same, it could be that the mode choice differs when including the trip homewards. Therefore is recommended to further research the mode choices for the return trip as well because it could be that car users evaluate trips differently. In addition, tour-trips are recommended to research as well. It could be that due to the car benefits for specific tours, car is valued over other modalities. It is however unclear what the effect of tour-trips would be.

This research collected the zipcode-4 postal codes of respondents from three different areas: The Hague, Rijswijk, and Leidschendam-Voorburg, the Netherlands. This research did not contain analysis of the differences in mode choice for different areas. Therefore is recommended to do further research on the differences of residential areas on mode choice. In addition, research on other city sizes or rural areas can be done, in both Dutch context as international context in order to reduce car share worldwide.

For further research on short trips within a city is recommended to include walking as alternative as well because walking is on short trips (<2 kilometer) a big part of the modal share. Besides walking is recommended to do further research on other shared modalities as substitution for car trips. Think of shared cars, scooters, and mopeds. Especially the view of car users on shared modalities is of added value, as based on that view mode sharing can be made more attractive and help in the mobility transition towards more sustainable modes. This further research is recommended for trip purpose shopping, as well as for other trip purposes.

The last recommendation for further research is as follows. The difference between 'fun shopping' and 'grocery shopping' has not been part of this research. So, the differences between those shopping trips in terms of mode choice is valuable to research further, as is expected that mode choice could differ for those purposes.

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Appendix A

Pilot survey

The pilot survey was done to test the setup of the survey, and to gain new priors for the final survey. This appendix will show the complete setup and the results of the pilot survey.

A.1 Experimental design pilot survey: MNL efficient design in Ngene

The used priors are generated based on literature.

EFFICIENT DESIGN PILOT SURVEY - SCENARIO 1: 2.5 kilometer to the city centre

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Design
;alts = fiets,deelfiets,ov,auto
;rows = 12
;eff = (mnl,d)
;model:
U(fiets) = traveltimef[-0.076] * fietstime[11,12,13] /
U(deelfiets) = traveltimedf[-0.377] * dftime[12,13,14] + modetypedf.dummy[0.01] * dfmode[0,1] + costsdf[-0.479] * dfcost[0,1,2] + reliabilitydf.dummy[-0.02|-0.01] * dfrel[2,1,0] /
U(ov) = traveltimeov[-0.058] * ovtime[11,13,15] + modetypeov.dummy[0.057] * ovmode[0,1] + costsov[-0.207] * ovcost[1,2,3] + frequency[-0.014] * freq[5,10,15] + comfortov.dummy[-0.674|-0.337] * comf[2,1,0] /
U(auto) = traveltimeauto[-0.043] * autotime[9,11,13] + costsauto[-0.17] * autocost[5,10,15] + reliabilityauto.dummy[-0.02|-0.01] * autorel[2,1,0]
$

EFFICIENT DESIGN PILOT SURVEY - SCENARIO 2: 5 kilometer to the city centre

---

Design
;alts = fiets,deelfiets,ov,auto
;rows = 12
;eff = (mnl,d)
;model:
U(fiets) = traveltimef[-0.076] * fietstime[21,22,23] /
U(deelfiets) = traveltimedf[-0.377] * dftime[22,23,24] + modetypedf.dummy[0.01] * dfmode[0,1] + costsdf[-0.479] * dfcost[0,1,2] + reliabilitydf.dummy[-0.02|-0.01] * dfrel[2,1,0] /
U(ov) = traveltimeov[-0.074] * ovtime[19,21,23] + modetypeov.dummy[0.057] * ovmode[0,1] + costsov[-0.207] * ovcost[1,2,3] + frequency[-0.014] * freq[5,10,15] + comfortov.dummy[-0.674|-0.337] * comf[2,1,0] /
U(auto) = traveltimeauto[-0.074] * autotime[18,20,22] + costsauto[-0.17] * autocost[5,10,15] + reliabilityauto.dummy[-0.02|-0.01] * autorel[2,1,0]
$

Table A.1: Generated choice sets of pilot survey in Ngene - Scenario 1: 2.5 kilometer
D error = 0.71 ; A error = 12.77 ; B estimate = 3.71 ; S estimate = 2,445,925.95

Alternatives	**Bicycle**	**Shared bicycle**				**Public transport**					**Car**		
Attributes	**Time**	**Time**	**Mode**	**Cost**	**Availability**	**Time**	**Mode**	**Cost**	**Frequency**	**Crowdedness**	**Time**	**Cost**	**Crowdedness**
1	11	12	1	0	1	15	1	2	10	2	11	15	1
2	13	13	1	0	0	11	0	3	5	0	9	10	2
3	12	14	0	1	1	15	1	3	15	0	9	5	1
4	13	14	1	1	2	11	1	1	15	0	11	10	2
5	13	12	0	0	2	11	1	3	5	2	9	15	0
6	12	13	1	2	0	13	1	2	10	1	13	5	0
7	11	14	1	1	2	13	0	2	10	2	13	5	2
8	11	14	0	1	1	15	0	1	5	0	13	10	0
9	13	13	1	2	2	15	1	1	5	1	9	10	2
10	12	12	0	0	0	13	0	1	15	2	11	15	1
11	11	13	0	2	0	13	0	2	10	1	13	5	1
12	12	12	0	2	1	11	0	3	15	1	11	15	0

Table A.2: Generated choice sets of pilot survey in Ngene - Scenario 2: 5 kilometer
D error = 1.53 ; A error = 233.76 ; B estimate = 0.19 ; S estimate = 51,747,244.22

Alternatives	**Bicycle**	**Shared bicycle**				**Public transport**					**Car**		
Attributes	**Time**	**Time**	**Mode**	**Cost**	**Availability**	**Time**	**Mode**	**Cost**	**Frequency**	**Crowdedness**	**Time**	**Cost**	**Crowdedness**
1	22	24	1	1	1	21	1	1	15	0	22	5	0
2	23	23	0	2	0	19	1	2	15	1	18	15	0
3	23	22	0	0	2	19	1	1	5	2	20	15	2
4	22	22	1	0	0	21	0	3	10	2	22	10	0
5	22	24	1	1	1	23	0	1	10	0	18	10	1
6	21	23	0	2	2	21	1	3	5	1	22	5	1
7	21	22	0	0	1	23	1	2	10	2	20	15	2
8	21	23	1	2	2	23	0	1	5	1	20	15	1
9	21	22	1	0	2	23	1	3	10	0	22	5	2
10	23	24	0	1	0	19	0	2	15	1	18	5	2
11	22	23	1	2	1	21	0	2	15	2	18	10	1
12	23	24	0	1	0	19	0	3	5	0	20	10	0

A.2 Biogeme syntax

A.2.1 Multinomial Logit (MNL)

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# [Choice]
CHOICE

#[Beta]
#Parameters to be estimated
# Arguments:
# 1  Name for report. Typically, the same as the variable
# 2  Starting value
# 3  Lower bound
# 4  Upper bound
# 5  0: estimate the parameter, 1: keep it fixed

# --- ASCs ---
ASC_FIETS = Beta('ASC_FIETS',0,-1000,1000,0)
ASC_DEELFIETS = Beta('ASC_DEELFIETS',0,-1000,1000,0)
ASC_OV = Beta('ASC_OV',0,-1000,1000,0)
ASC_AUTO = Beta('ASC_AUTO',0,-1000,1000,1)

# --- Shared bicycle ---
BETA_MODEDF = Beta('BETA_MODEDF',0,-1000,1000,0)
BETA_RELDF1 = Beta('BETA_RELDF1',0,-1000,1000,0)
BETA_RELDF2 = Beta('BETA_RELDF2',0,-1000,1000,0)

# --- Public transport ---
BETA_MODEOV = Beta('BETA_MODEOV',0,-1000,1000,0)
BETA_FREQOV = Beta('BETA_FREQOV',0,-1000,1000,0)
BETA_COMFOV1 = Beta('BETA_COMFOV1',0,-1000,1000,0)
BETA_COMFOV2 = Beta('BETA_COMFOV2',0,-1000,1000,0)

# --- Car ---
BETA_RELAUTO = Beta('BETA_RELAUTO',0,-1000,1000,0)

# --- General betas ---
BETA_TIME = Beta('BETA_TIME',0,-1000,1000,0)
BETA_COST = Beta('BETA_COST',0,-1000,1000,0)

#[Utilities]
Alt1 = ASC_FIETS * one + BETA_TIME * TTA
Alt2 = ASC_DEELFIETS * one + BETA_TIME * TTB + BETA_MODEDF * MOB + BETA_COST * TCB + BETA_RELDF1 *
    REB1 + BETA_RELDF2 * REB2
Alt3 = ASC_OV * one + BETA_TIME * TTC + BETA_MODEOV * MOC + BETA_COST * TCC + BETA_FREQOV * FRC +
    BETA_COMFOV1 * CMC1 + BETA_COMFOV2 * CMC2
Alt4 = ASC_AUTO * one + BETA_TIME * TTD + BETA_COST * TCD + BETA_RELAUTO * RED

#[one]
one = 1

#[Choice set and availability]
choiceset = {1: Alt1,2: Alt2,3: Alt3,4: Alt4}

#availability = {1: AV1,2: AV2,3: AV3,4: AV4}
availability = {1: availability1,2: availability2,3: availability3,4: availability4}

#Exclude [if you want to exclude observations]

#[Model]
# MNL  // Logit Model
# The choice model is a logit, with availability conditions
prob = bioLogit(choiceset,availability,CHOICE)
l = log(prob)

# Defines an itertor on the data [in this case each row is a separate individual]
rowIterator('obsIter')

# Define the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(l,'obsIter')
```

```
# you can define which optimization algorithm to use, BIO is standard and is ok for MNL or PSL
BIOGEME_OBJECT.PARAMETERS['optimizationAlgorithm'] = "BIO"
BIOGEME_OBJECT.PARAMETERS['shareOfProcessors'] = "50"

#Print some statistics
BIOGEME_OBJECT.FORMULAS['Alt 1 utility'] = Alt1
BIOGEME_OBJECT.FORMULAS['Alt 2 utility'] = Alt2
BIOGEME_OBJECT.FORMULAS['Alt 3 utility'] = Alt3
BIOGEME_OBJECT.FORMULAS['Alt 4 utility'] = Alt4

nullLoglikelihood(availability,'obsIter')
choiceSet = [1,2,3,4]
cteLoglikelihood(choiceSet,CHOICE,'obsIter')
availabilityStatistics(availability,'obsIter')
```

A.2.2 Mixed Logit (ML) panel

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# [Choice]
CHOICE

#[Beta]
#Parameters to be estimated
# Arguments:
#   1  Name for report. Typically, the same as the variable
#   2  Starting value
#   3  Lower bound
#   4  Upper bound
#   5  0: estimate the parameter, 1: keep it fixed

# --- ASC ---
ASC_FIETS = Beta('ASC_FIETS',0,-1000,1000,0)
ASC_DEELFIETS = Beta('ASC_DEELFIETS',0,-1000,1000,0)
ASC_OV = Beta('ASC_OV',0,-1000,1000,0)
ASC_AUTO = Beta('ASC_AUTO',0,-1000,1000,1)

# --- SHARED BICYCLE ---
BETA_MODEDF = Beta('BETA_MODEDF',0,-1000,1000,0)
BETA_RELDF1 = Beta('BETA_RELDF1',0,-1000,1000,0)
BETA_RELDF2 = Beta('BETA_RELDF2',0,-1000,1000,0)

# --- PUBLIC TRANSPORT ---
BETA_MODEOV = Beta('BETA_MODEOV',0,-1000,1000,0)
BETA_FREQOV = Beta('BETA_FREQOV',0,-1000,1000,0)
BETA_COMFOV1 = Beta('BETA_COMFOV1',0,-1000,1000,0)
BETA_COMFOV2 = Beta('BETA_COMFOV2',0,-1000,1000,0)

# --- CAR ---
BETA_RELAUTO = Beta('BETA_RELAUTO',0,-1000,1000,0)

# --- GENERAL BETAS ---
BETA_TIME = Beta('BETA_TIME',0,-1000,1000,0)
BETA_COST = Beta('BETA_COST',0,-1000,1000,0)

# --- SIGMA ---
Sigma_panel = Beta('Sigma_panel',0,-100,100,0)
Zero = Beta('Zero',0,-100,100,1)

#random parameter for sigma data
Zero_sigma_panel = Zero + Sigma_panel * bioDraws('Zero_sigma_panel')

#[one]
one = DefineVariable('one',1)

#[Utilities]
Alt1 = ASC_FIETS * one + BETA_TIME * TTA + Zero_sigma_panel * one
Alt2 = ASC_DEELFIETS * one + BETA_TIME * TTB + BETA_MODEDF * MOB + BETA_COST * TCB + BETA_RELDF1 *
    REB1 + BETA_RELDF2 * REB2 + Zero_sigma_panel * one
Alt3 = ASC_OV * one + BETA_TIME * TTC + BETA_MODEOV * MOC + BETA_COST * TCC + BETA_FREQOV * FRC +
    BETA_COMFOV1 * CMC1 + BETA_COMFOV2 * CMC2 + Zero_sigma_panel * one
```

```
Alt4 = ASC_AUTO * one + BETA_TIME * TTD + BETA_COST * TCD + BETA_RELAUTO * RED

#[Choice set and availability]
choiceset = {1: Alt1,2: Alt2,3: Alt3,4: Alt4}

availability = {1: availability1,2: availability2,3: availability3,4: availability4}

#Exclude [if you want to exclude observations]

#[Model]
# MNL // Logit Model
# The choice model is a logit, with availability conditions
prob = bioLogit(choiceset,availability,CHOICE)
#l = log(prob)

#Iterator on individuals, that is on groups of rows.
metaIterator('personIter','__dataFile__','panelObsIter','ID')

# Defines an itertor on the data [in this case each row is a separate individual]
rowIterator('panelObsIter','personIter')

#Conditional probability for the sequence of choices of an individual
condProbIndiv = Prod(prob,'panelObsIter')

#Integration by simulation
probIndiv = MonteCarlo(condProbIndiv)

# Define the likelihood function for the estimation
loglikelihood = Sum(log(probIndiv),'personIter')
BIOGEME_OBJECT.ESTIMATE = loglikelihood

#the model is estimated with 10 draws so that it is estimated fast for demonstration purposes; more
    draws are needed though; set this parameter to 1000 draws
#Halton draws (from Chorus, lecture 2: 250 draws)
BIOGEME_OBJECT.PARAMETERS['NbrOfDraws'] = "250"


# you can define which optimization algorithm to use, BIO is standard and is ok for MNL or PSL
BIOGEME_OBJECT.PARAMETERS['optimizationAlgorithm'] = "BIO"
#BIOGEME_OBJECT.PARAMETERS['shareOfProcessors'] = "50"

# laten zien dat de draws van een random distribution komen van Halton
BIOGEME_OBJECT.PARAMETERS['RandomDistribution'] = "HALTON"

#nog even uitzoeken waar deze vandaan komen
BIOGEME_OBJECT.PARAMETERS['numberOfThreads'] = "4"

#draws from a normal distribution; ID is multiple observations per ID and draws will be the same for
     the same individual
BIOGEME_OBJECT.DRAWS = {'Zero_sigma_panel': ('NORMAL','ID')}

BIOGEME_OBJECT.STATISTICS['Number of individuals'] = Sum(1,'personIter')

#Print some statistics
BIOGEME_OBJECT.FORMULAS['Alt 1 utility'] = Alt1
BIOGEME_OBJECT.FORMULAS['Alt 2 utility'] = Alt2
BIOGEME_OBJECT.FORMULAS['Alt 3 utility'] = Alt3
BIOGEME_OBJECT.FORMULAS['Alt 4 utility'] = Alt4

nullLoglikelihood(availability,'panelObsIter')
choiceSet = [1,2,3,4]
cteLoglikelihood(choiceSet,CHOICE,'panelObsIter')
availabilityStatistics(availability,'panelObsIter')
```

A.3 Biogeme results

A.3.1 Multinomial Logit (MNL)

Scenario 1: 2.5 kilometer

Table A.3: Statistics MNL of scenario 1

Final log likelihood	-339.847
Null log likelihood	-765.234
Rho-square	0.556
AIC	705.694
BIC	761.770

Table A.4: Statistics of chosen alternatives in scenario 1

Total choices: 552	**# chosen**	**% chosen**
Alternative 1: Bicycle	451	81.7%
Alternative 2: Shared bicycle	10	1.8%
Alternative 3: Public transport	61	11.1%
Alternative 4: Car	30	5.4%

Table A.5: Pilot survey MNL 2.5 kilometer resuls Biogeme; * = insignificant at p=0.05 level

Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**	**Robust t-test**	**p-value**	
ASC									
Bicycle	1.04	0.514	2.03	0.04		0.503	2.08	0.04	
Shared bicycle	-2.39	0.799	-2.99	0.00		0.727	-3.29	0.00	
Public transport	-0.465	0.608	-0.77	0.44	*	0.607	-0.77	0.44	*
General betas									
Beta travel time	-0.161	0.0520	-3.10	0.00		0.0521	-3.09	0.00	
Beta travel costs	-0.174	0.0493	-3.52	0.00		0.0534	-3.25	0.00	
Shared bicycle									
Beta type	-0.545	0.673	-0.81	0.42	*	0.821	-0.66	0.51	*
Beta availability 1	-0.377	0.926	-0.41	0.68	*	0.963	-0.39	0.70	*
Beta availability 2	0.641	0.747	0.86	0.39	*	0.808	0.79	0.43	*
Public transport									
Beta type	0.395	0.279	1.41	0.16	*	0.278	1.42	0.16	*
Beta frequency	-0.00284	0.0323	-0.09	0.93	*	0.0323	-0.09	0.93	*
Beta crowdedness 1	-0.303	0.336	-0.90	0.37	*	0.334	-0.91	0.36	*
Beta crowdedness 2	-0.370	0.341	-1.09	0.28	*	0.341	-1.09	0.28	*
Car									
Beta crowdedness	-0.0871	0.0819	-1.06	0.29	*	0.0826	-1.05	0.29	*

Scenario 2: 5 kilometer

Table A.6: Statistics MNL of scenario 2

Final log likelihood	-256.994
Null log likelihood	-632.15
Rho-square	0.593
AIC	539.988
BIC	593.581

Table A.7: Statistics of chosen alternatives in scenario 2

Total choices: 456	**# chosen**	**% chosen**
Alternative 1: Bicycle	380	83.3%
Alternative 2: Shared bicycle	6	1.3%
Alternative 3: Public transport	43	9.2%
Alternative 4: Car	27	5.9%

Table A.8: Pilot survey MNL 5 kilometer resuls Biogeme; * = insignificant at p=0.05 level

Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**	**Robust t-test**	**p-value**	
ASC									
Bicycle	1.73	0.635	2.73	0.01		0.650	2.66	0.01	
Shared bicycle	-2.93	1.21	-2.42	0.02		1.05	-2.80	0.01	
Public transport	-0.153	0.721	-0.21	0.83	*	0.758	-0.20	0.84	*
General betas									
Beta travel time	-0.159	0.0557	-2.85	0.00		0.0567	-2.80	0.01	
Beta travel costs	-0.173	0.0557	-3.11	0.00		0.0555	-3.12	0.00	
Shared bicycle									
Beta type	2.06	1.11	1.86	0.06	*	1.18	1.75	0.08	*
Beta availability 1	-11.0	114.	-0.10	0.92	*	0.690	-15.95	0.00	
Beta availability 2	-0.226	0.841	-0.27	0.79	*	0.888	-0.25	0.80	*
Public transport									
Beta type	0.220	0.329	0.67	0.50	*	0.325	0.68	0.50	*
Beta frequency	-0.0134	0.0384	-0.35	0.73	*	0.0382	-0.35	0.73	*
Beta crowdedness 1	-0.294	0.407	-0.72	0.47	*	0.396	-0.74	0.46	*
Beta crowdedness 2	-0.158	0.397	-0.40	0.69	*	0.405	-0.39	0.70	*
Car									
Beta crowdedness	0.0880	0.0891	0.99	0.32	*	0.0861	1.02	0.31	*

A.3.2 Mixed Logit (ML) panel

Scenario 1: 2.5 kilometer

Table A.9: Statistics ML panel of scenario 1

Final log likelihood	-276.210
Null log likelihood	-765.234
Rho-square	0.639
AIC	580.419
BIC	640.809

Table A.10: Statistics of chosen alternatives in scenario 1

Total choices: 552	**# chosen**	**% chosen**
Alternative 1: Bicycle	451	81.7%
Alternative 2: Shared bicycle	10	1.8%
Alternative 3: Public transport	61	11.1%
Alternative 4: Car	30	5.4%

Table A.11: Pilot survey ML panel 2.5 kilometer resuls Biogeme; * = insignificant at p=0.05 level

Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**	**Robust t-test**	**p-value**	
ASC									
Bicycle	6.20	3.04	2.04	0.04		3.18	1.95	0.05	*
Shared bicycle	2.87	3.10	0.93	0.35	*	3.25	0.89	0.38	*
Public transport	5.32	3.08	1.73	0.08	*	3.10	1.72	0.09	*
General betas									
Beta travel time	-0.225	0.0642	-3.51	0.00		0.0501	-4.50	0.00	
Beta travel costs	-0.428	0.0979	-4.37	0.00		0.116	-3.69	0.00	
Shared bicycle									
Beta type	-0.343	0.662	-0.52	0.60	*	0.503	-0.68	0.50	*
Beta availability 1	-0.222	0.925	-0.24	0.81	*	0.645	-0.34	0.73	*
Beta availability 2	0.614	0.743	0.83	0.41	*	0.817	0.75	0.45	*
Public transport									
Beta type	0.299	0.286	1.04	0.30	*	0.299	1.00	0.32	*
Beta frequency	-0.0158	0.0329	-0.48	0.63	*	0.0174	-0.91	0.36	*
Beta crowdedness 1	-0.206	0.349	-0.59	0.55	*	0.212	-0.97	0.33	*
Beta crowdedness 2	-0.242	0.348	-0.69	0.49	*	0.180	-1.35	0.18	*
Car									
Beta crowdedness	-0.168	0.145	-1.16	0.24	*	0.144	-1.17	0.24	*
Sigmas									
Sigma panel	-6.76	2.34	-2.89	0.00		2.42	-2.79	0.01	

Scenario 2: 5 kilometer

Table A.12: Statistics ML panel of scenario 2

Final log likelihood	-223.146
Null log likelihood	-632.15
Rho-square	0.647
AIC	474.292
BIC	532.007

Table A.13: Statistics of chosen alternatives in scenario 2

Total choices: 456	**# chosen**	**% chosen**
Alternative 1: Bicycle	380	83.3%
Alternative 2: Shared bicycle	6	1.3%
Alternative 3: Public transport	43	9.2%
Alternative 4: Car	27	5.9%

Table A.14: Pilot survey ML panel 5 kilometer resuls Biogeme; * = insignificant at p=0.05 level

Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**	**Robust t-test**	**p-value**	
ASC									
Bicycle	5.01	1.70	2.94	0.00		1.44	3.49	0.00	
Shared bicycle	0.444	2.00	0.22	0.82	*	1.73	0.26	0.80	*
Public transport	3.36	1.75	1.92	0.05	*	1.25	2.68	0.01	
General betas									
Beta travel time	-0.197	0.0629	-3.13	0.00		0.0748	-2.63	0.01	
Beta travel costs	-0.287	0.0753	-3.81	0.00		0.121	-2.37	0.02	
Shared bicycle									
Beta type	1.98	1.11	1.79	0.07	*	1.26	1.58	0.12	*
Beta availability 1	-10.8	111.	-0.10	0.92	*	0.716	-15.04	0.00	
Beta availability 2	-0.113	0.840	-0.13	0.89	*	0.735	-0.15	0.88	*
Public transport									
Beta type	0.191	0.334	0.57	0.57	*	0.356	0.54	0.59	*
Beta frequency	-0.0173	0.0386	-0.45	0.65	*	0.0211	-0.82	0.41	*
Beta crowdedness 1	-0.334	0.412	-0.81	0.42	*	0.202	-1.65	0.10	*
Beta crowdedness 2	-0.210	0.405	-0.52	0.61	*	0.284	-0.74	0.46	*
Car									
Beta crowdedness	0.217	0.123	1.77	0.08	*	0.0778	2.79	0.01	
Sigmas									
Sigma panel	-3.78	1.16	-3.26	0.00		0.952	-3.98	0.00	

A.4 Descriptive statistics pilot survey

Table A.15: Number of completes per scenario in pilot survey

	N
Scenario 1: 2.5 kilometer	45
Scenario 2: 5 kilometer	38

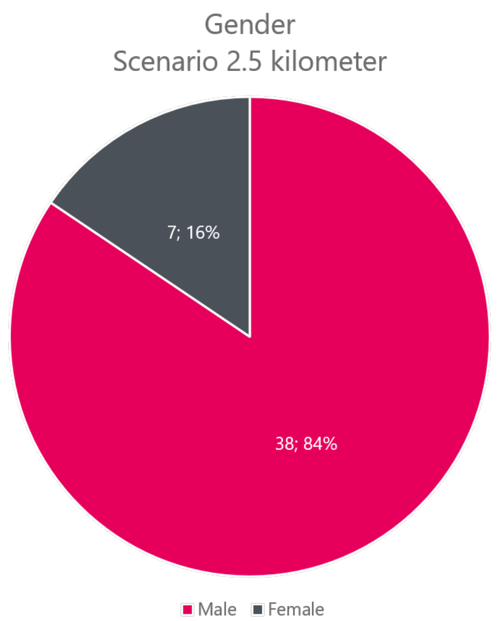

Figure A.1: Gender in 2.5 km scenario

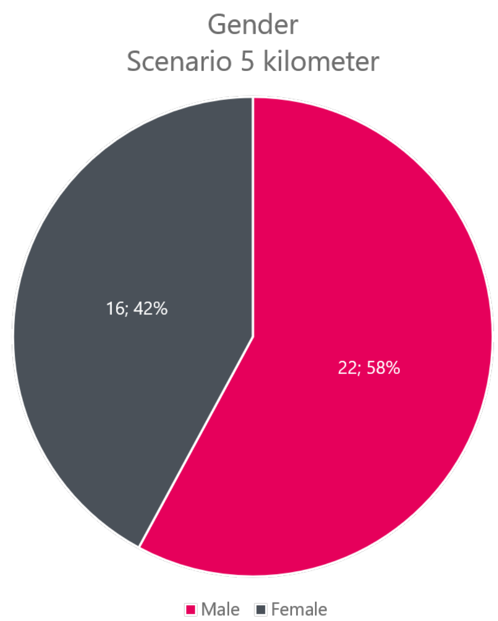

Figure A.2: Gender in 5 km scenario

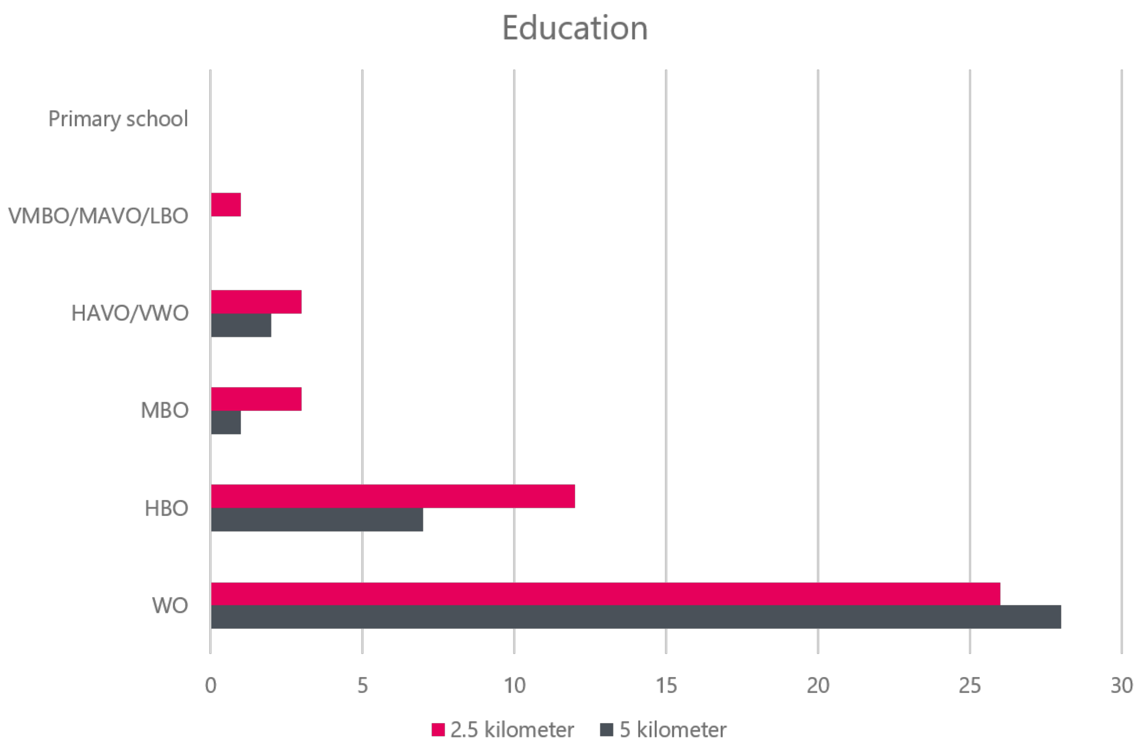

Figure A.4: Pilot survey respondents' highest finished education

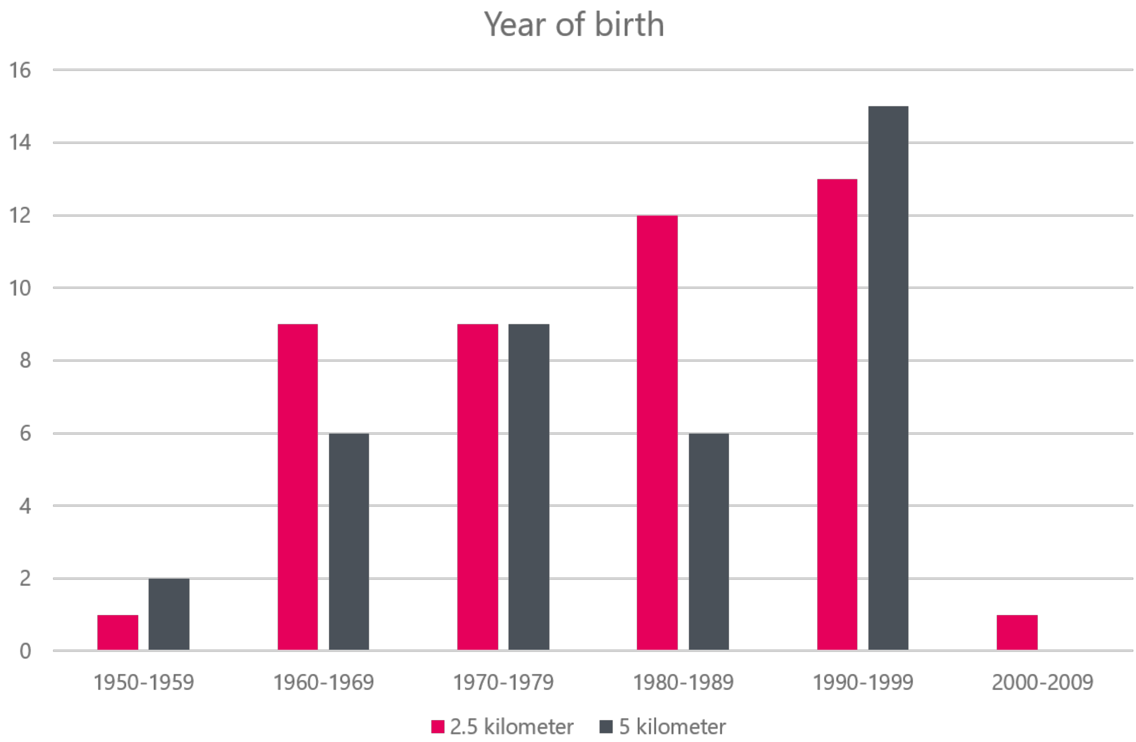

Figure A.3: Year of birth division in pilot survey; Scenario 2.5 km: N = 45, mean = 1981, median = 1983, std. dev = 11.8; Scenario 5 km: N = 38, mean = 1982, median = 1987, std. dev = 13.7

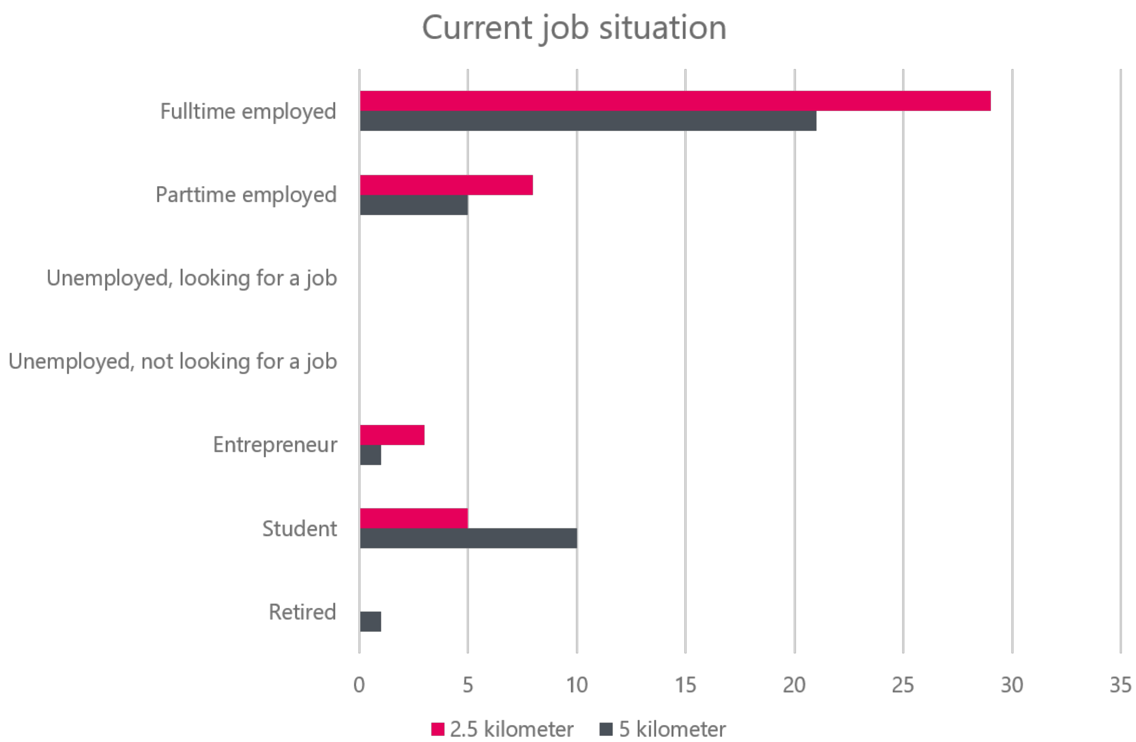

Figure A.5: Current job situation of respondents

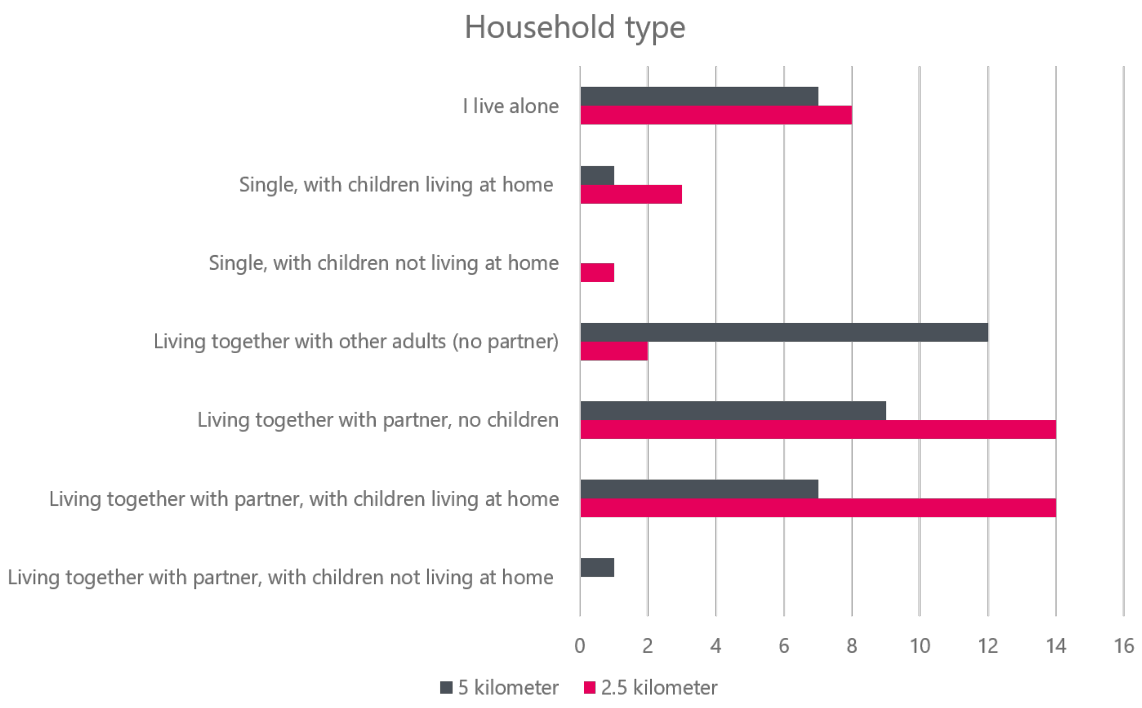

Figure A.6: Household type division of respondents

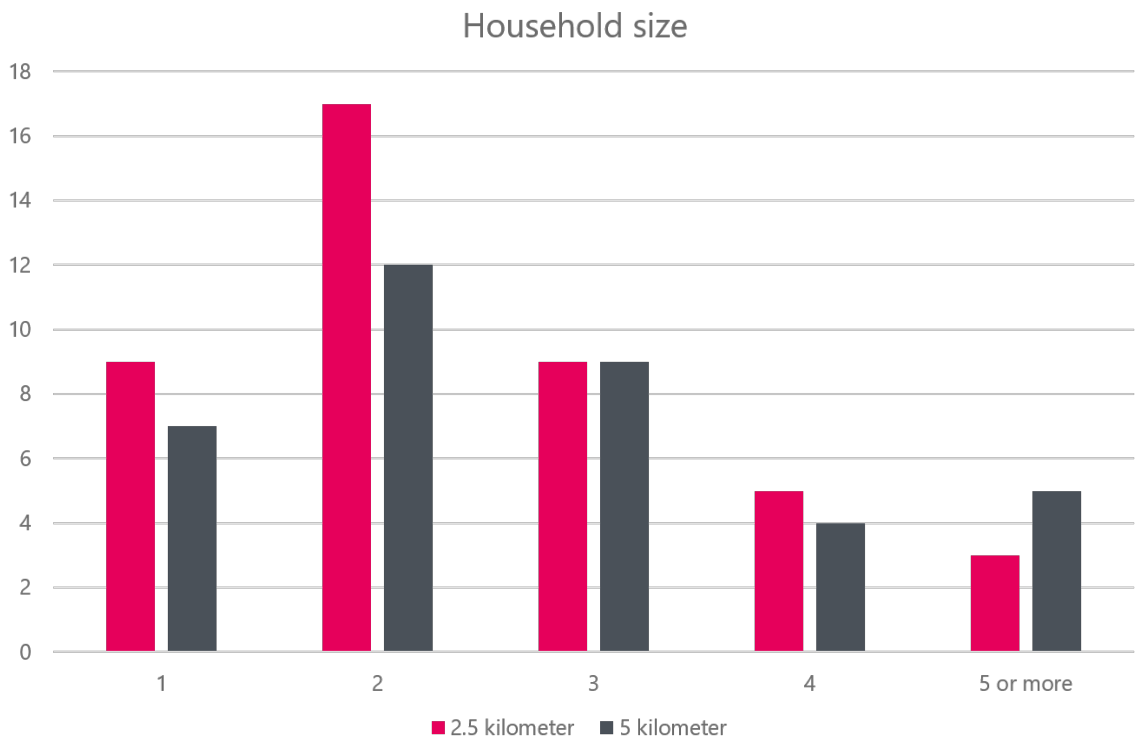

Figure A.7: Household size division of respondents

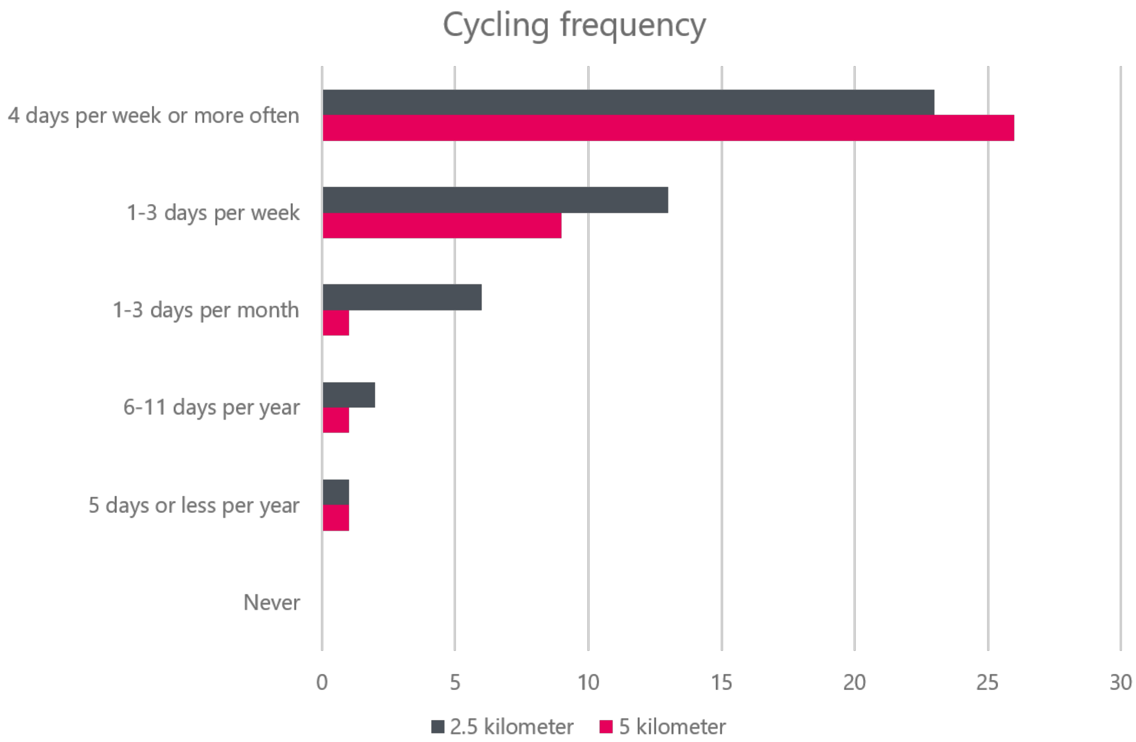

Figure A.8: Cycling frequency

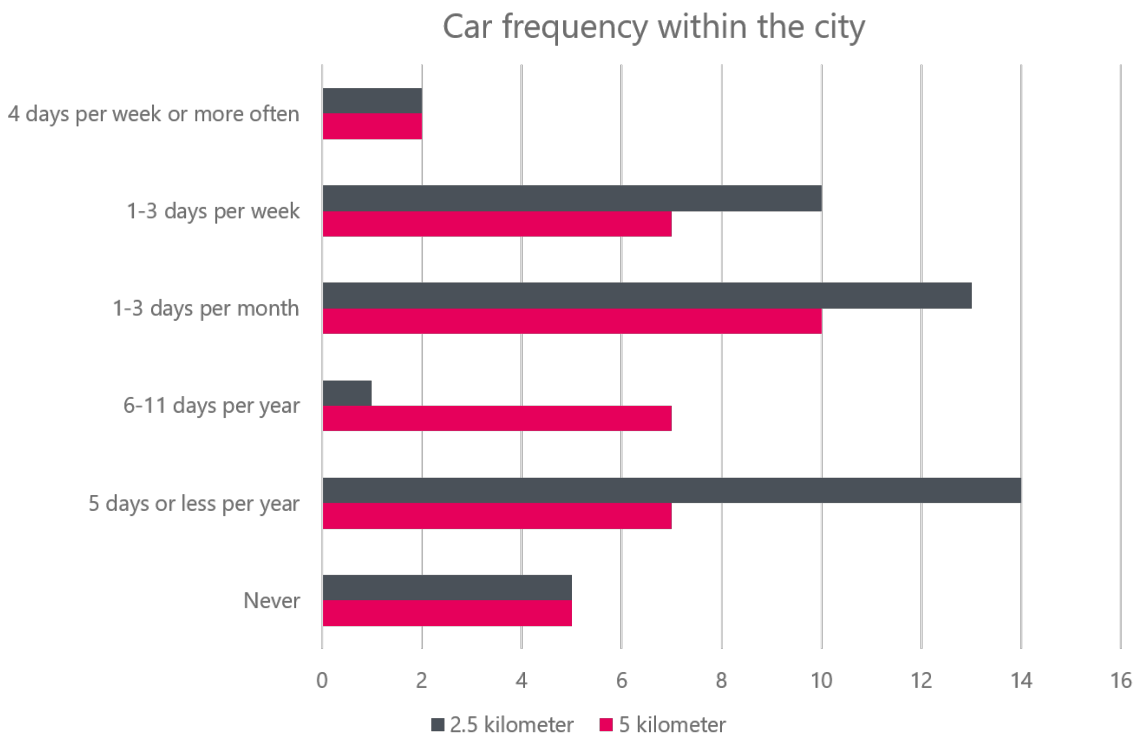

Figure A.9: Car frequency within the city

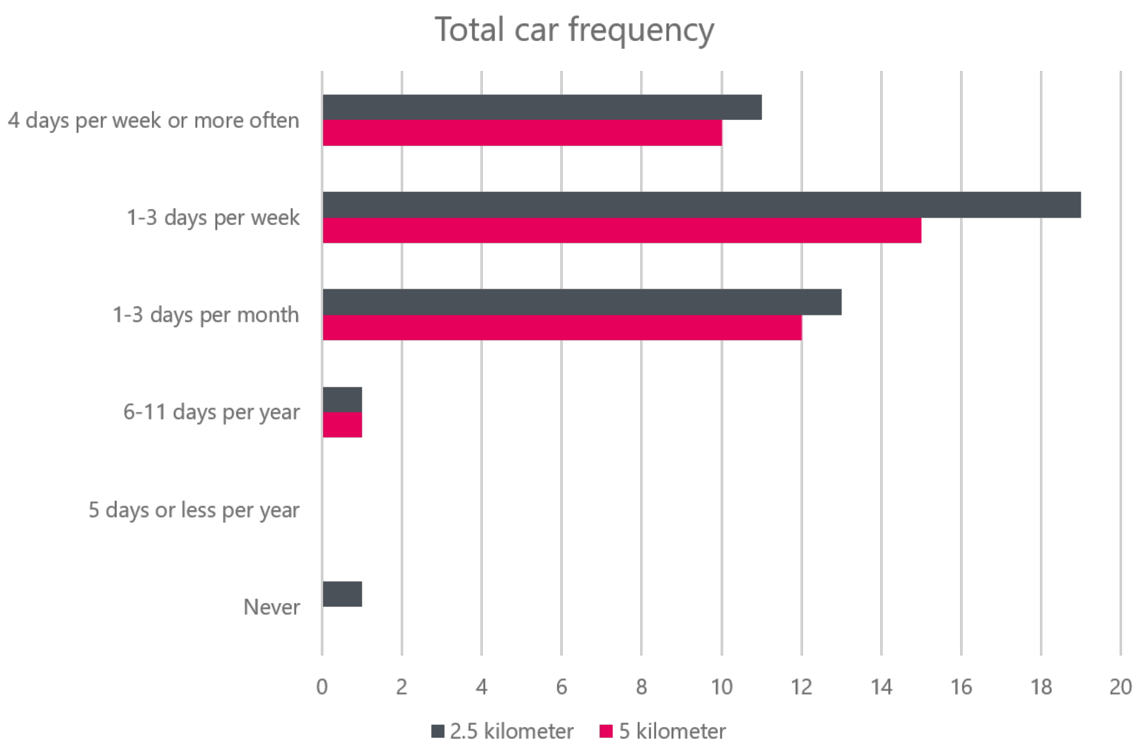

Figure A.10: Car frequency within the city

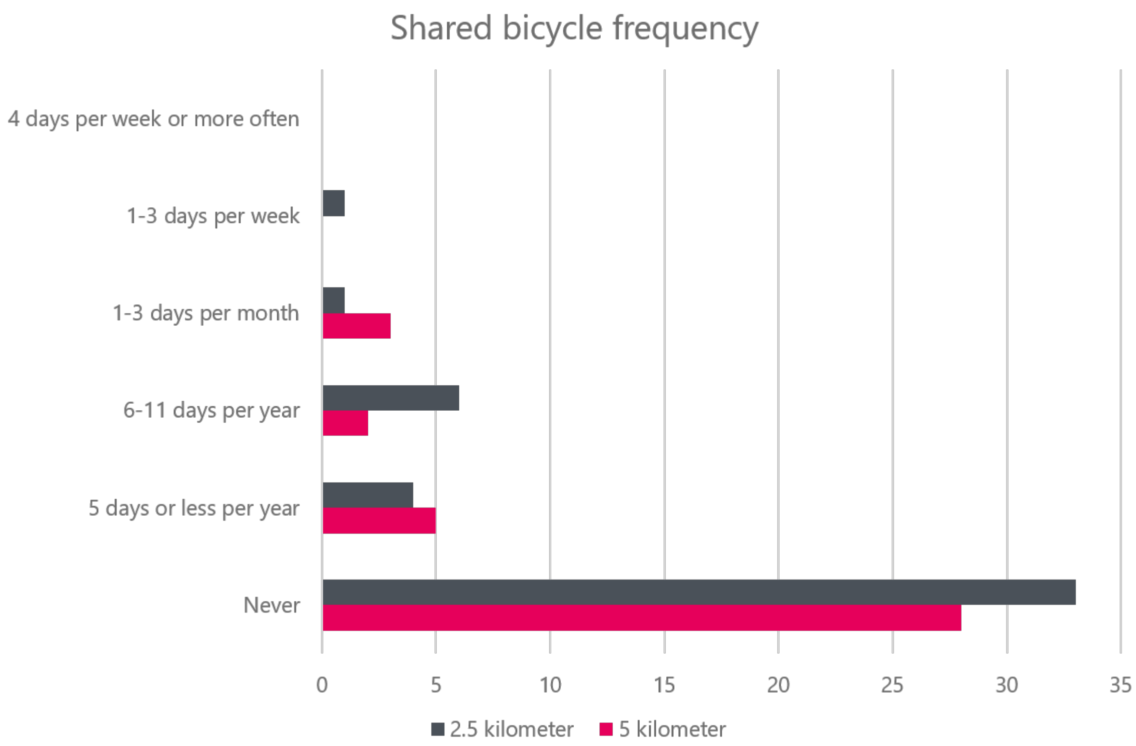

Figure A.11: Shared bicycle frequency

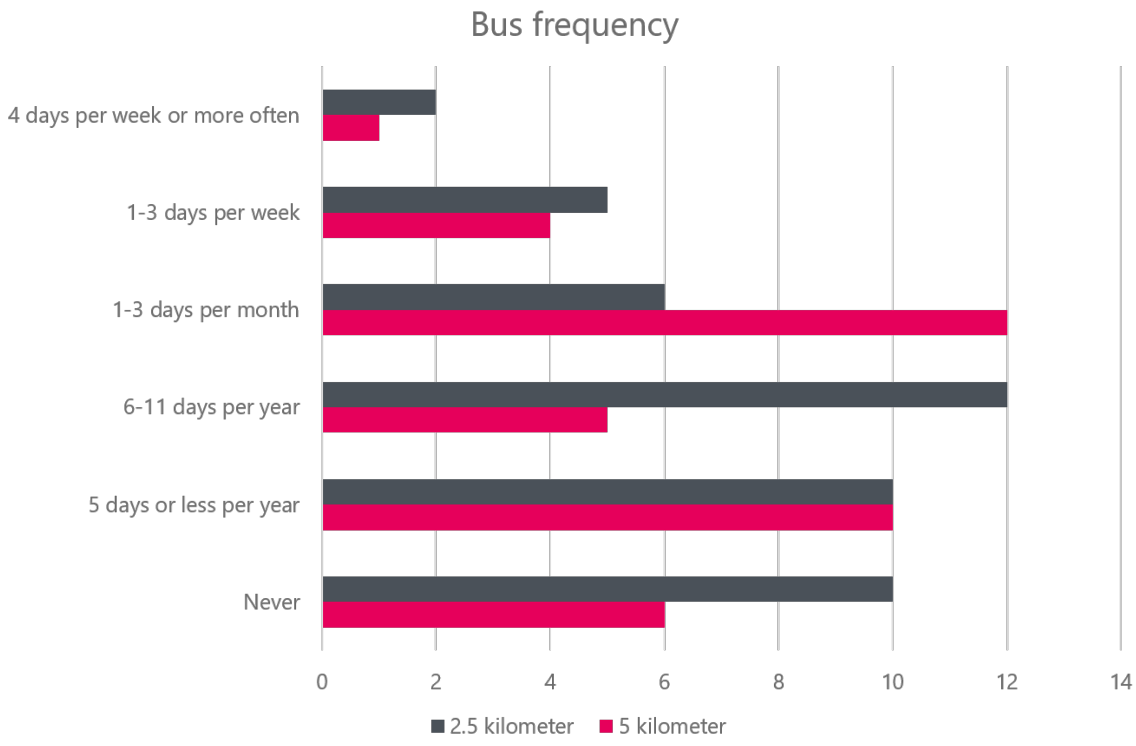

Figure A.12: Bus frequency

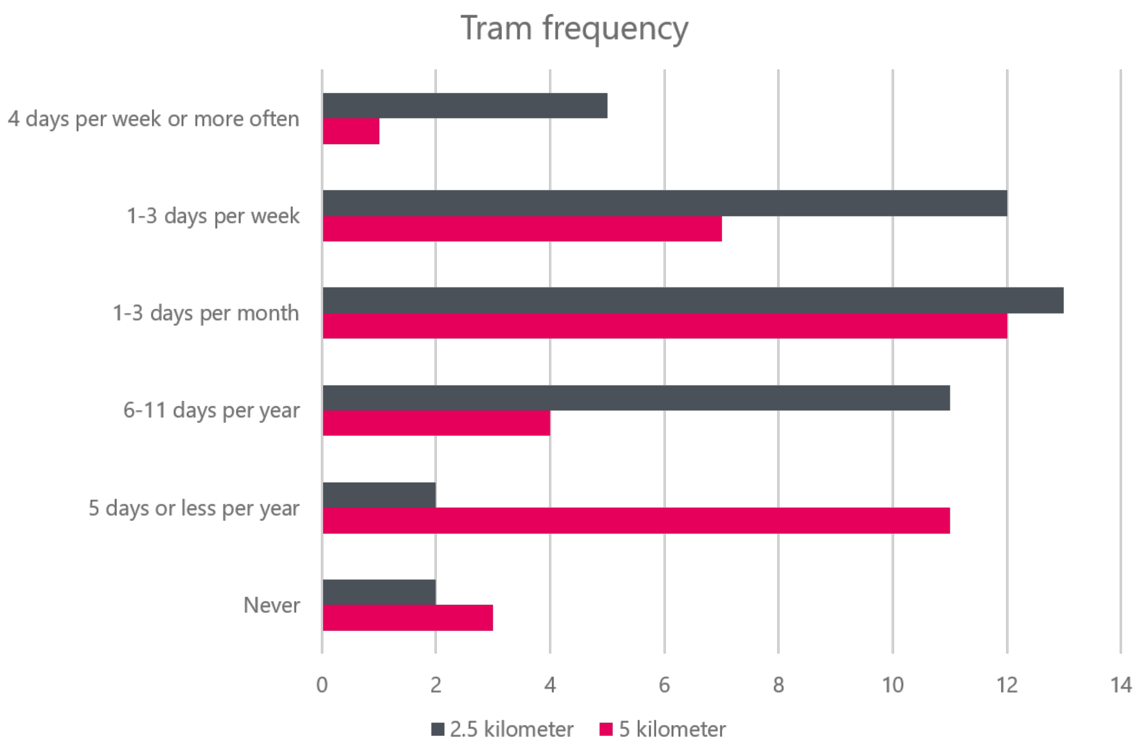

Figure A.13: Tram frequency

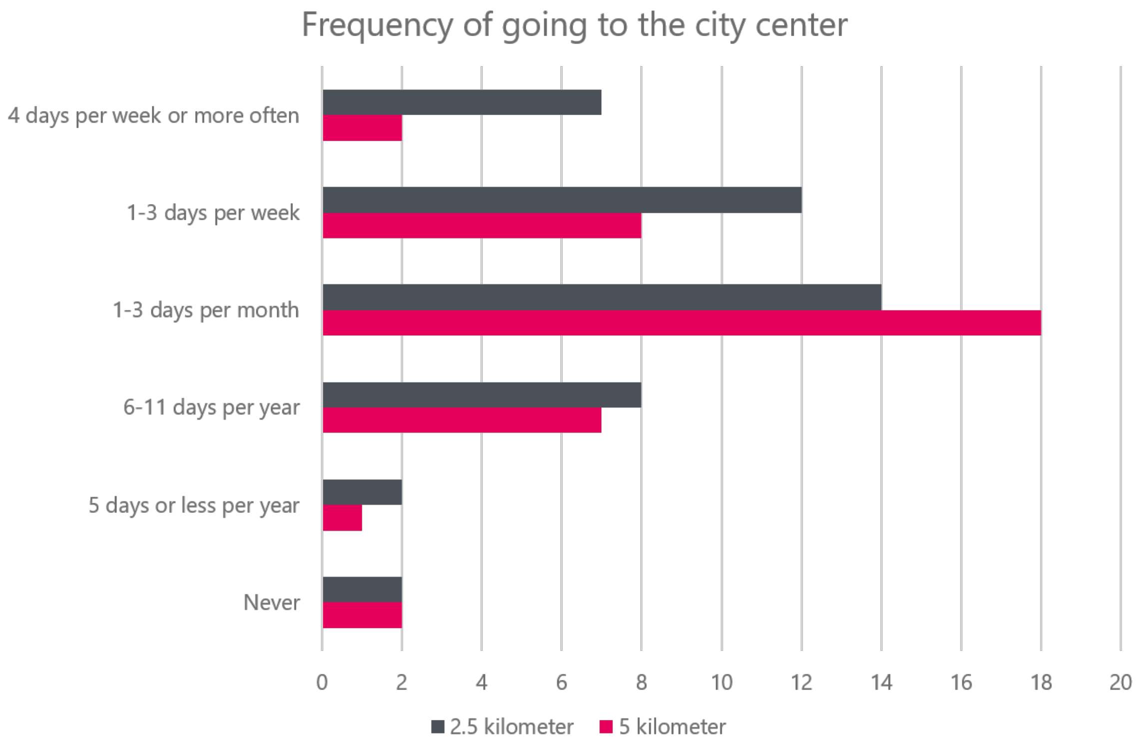

Figure A.14: Frequency respondents go to the city centre

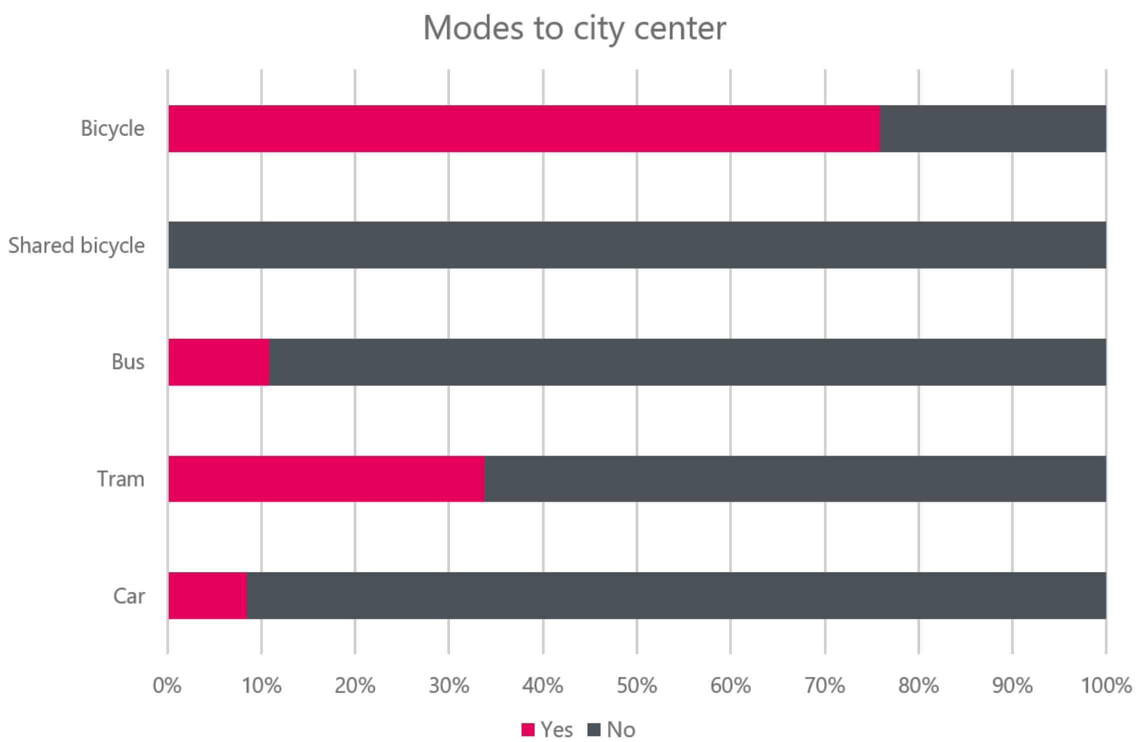

Figure A.15: Modes taken to the city centre total of both scenarios

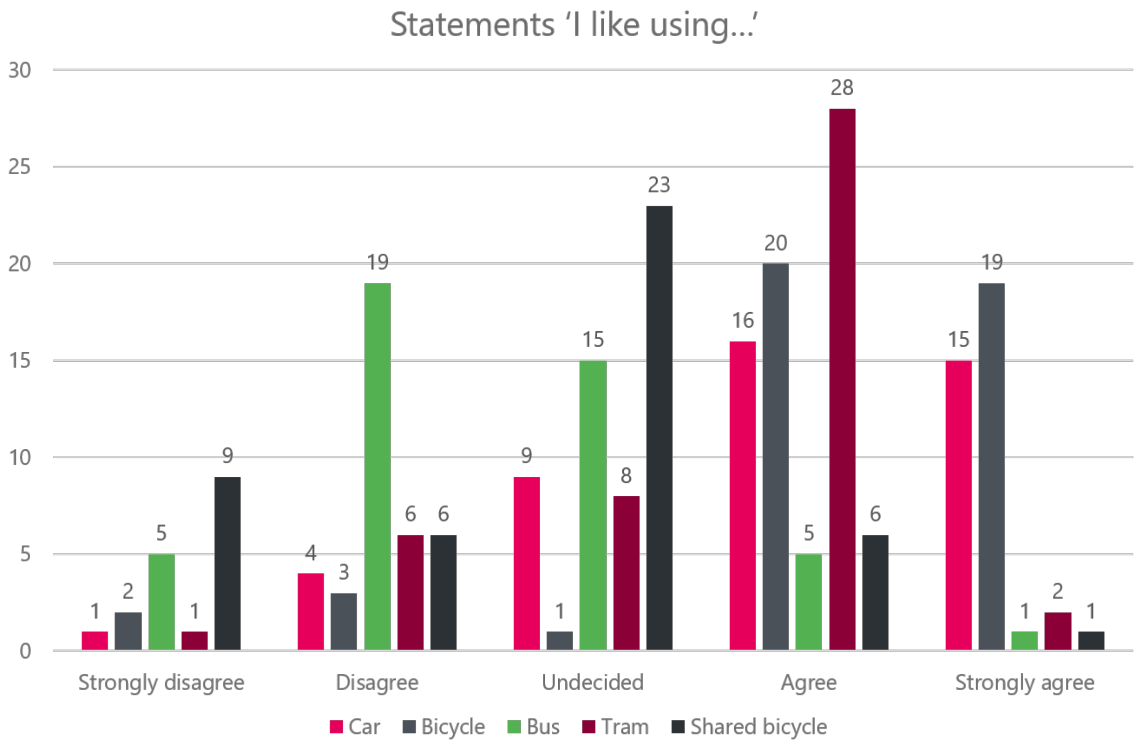

Figure A.16: Statements on mode use, responses of 2.5 kilometer scenario

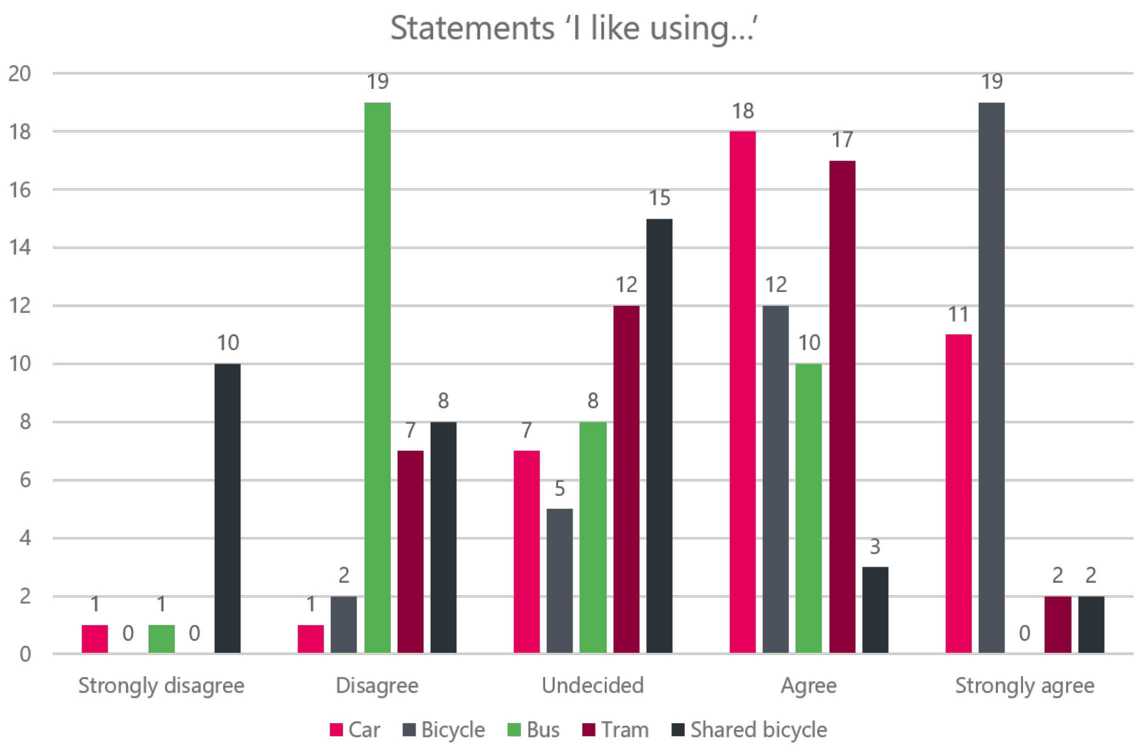

Figure A.17: Statements on mode use, responses of 5 kilometer scenario

Appendix B

Final survey design

B.1 Experimental design final survey: MNL bayesian efficient design in Ngene

EFFICIENT DESIGN FINAL SURVEY - SCENARIO 1: 2.5 kilometer to the city centre

Design
;alts = fiets,deelfiets,ov,auto
;rows = 12
;eff = (mnl,d,mean)
;model:
U(fiets) = ASCf[(n,1.04,0.503)] + traveltime[(n,-0.161,0.0521)] * fietstime[8,10,12] + walktime[(n,-0.161,0.0521)] * fietswalk[1,3,5] + crowdedf[(n,-0.0871,0.0826)] * fietscrowded[1,3,5] + costs[(n,-0.174,0.0534)] * fcost[0,1,2] /
U(deelfiets) = ASCdf[(n,-2.39,0.727)] + traveltime * dftime[8,10,12] + walktime * dfwalk[3,5,7] + modetypedf.dummy[(n,-0.545,0.821)] * dfmode[0,1] + costs * dfcost[0,1,2] + availabilitydf.dummy[(n,0.641,0.808)|(n,-0.377,0.963)] * dfavail[2,1,0] /
U(ov) = ASCov[(n,-0.465,0.607)] + traveltime * ovtime[6,8,10] + walktime * ovwalk[3,6,9] + modetypeov.dummy[(n,0.395,0.395)] * ovmode[0,1] + costs * ovcost[1,2,3] + frequency[(n,-0.00284,0.0323)] * freq[5,10,15] + crowdedov.dummy[(n,-0.370,0.341)|(n,-0.303,0.334)] * ovcrowded[2,1,0] /
U(auto) = traveltime * autotime[6,8,10] + walktime * autowalk[1,4,7] + costs * autocost[3,6,9] + crowdedauto[(n,-0.0871,0.0826)] * autocrowded[1,3,5]
$

EFFICIENT DESIGN FINAL SURVEY - SCENARIO 2: 5 kilometer to the city centre

Design
;alts = fiets,deelfiets,ov,auto
;rows = 12
;eff = (mnl,d,mean)
;model:
U(fiets) = ASCf[(n,1.73,0.650)] + traveltime[(n,-0.159,0.0567)] * fietstime[17,20,23] + walktime[(n,-0.159,0.0567)] * fietswalk[1,3,5] + crowdedf[(n,-0.0880,0.0861)] * fietscrowded[1,3,5] + costs[(n,-0.173,0.0555)] * fcost[0,1,2] /
U(deelfiets) = ASCdf[(n,-2.93,1.05)] + traveltime * dftime[17,20,23] + walktime * dfwalk[3,5,7] + modetypedf.dummy[(n,2.06,1.18)] * dfmode[0,1] + costs * dfcost[0,1,2] + availabilitydf.dummy[-0.02|-0.01] * dfavail[2,1,0] /
U(ov) = ASCov[(n,-0.153,0.758)] + traveltime * ovtime[12,15,18] + walktime * ovwalk[3,6,9] + modetypeov.dummy[(n,0.220,0.325)] * ovmode[0,1] + costs * ovcost[1,2,3] + frequency[(n,-0.0134,0.0382)] * freq[5,10,15] + crowdedov.dummy[(n,-0.158,0.405)|(n,-0.294,0.396)] * ovcrowded[2,1,0] /
U(auto) = traveltime * autotime[12,15,18] + walktime * autowalk[1,4,7] + costs * autocost[3,6,9] + crowdedauto[(n,-0.0880,0.0861)] * autocrowded[1,3,5]
$

Table B.1: Generated choice sets by MNL bayesian efficient design, scenario 1: 2.5 kilometer

Alternatives	Bicycle				Shared bicycle				
Attributes	**Driving time**	**Walking time**	**Crowdedness**	**Costs**	**Driving time**	**Walking time**	**Mode**	**Costs**	**Availability**
1	8	1	3	0	12	7	0	2	1
2	8	5	1	2	10	5	0	1	0
3	12	1	1	2	10	5	1	1	0
4	8	1	3	0	12	7	0	2	1
5	12	3	5	2	8	3	0	0	2
6	12	5	5	0	8	3	1	0	1
7	8	3	5	1	12	7	1	2	2
8	10	5	1	1	10	5	0	1	1
9	10	3	1	0	12	7	1	2	2
10	10	3	3	1	8	3	1	0	2
11	10	5	5	1	8	3	1	0	0
12	12	1	3	2	10	5	0	1	0

Alternatives	Public transport						Car			
Attributes	**Driving time**	**Walking time**	**Mode**	**Costs**	**Freqency**	**Crowdedness**	**Driving time**	**Walking time**	**Costs**	**Crowdedness**
1	10	9	1	3	10	0	10	4	6	1
2	8	6	0	2	15	0	10	1	3	1
3	6	9	0	1	5	2	6	1	3	5
4	8	6	0	3	15	0	8	7	6	3
5	8	6	0	1	15	1	6	7	6	5
6	10	9	1	3	10	2	6	1	9	1
7	10	6	1	2	10	1	10	1	3	5
8	6	3	1	2	15	2	8	4	9	3
9	6	3	0	3	5	1	8	4	9	3
10	6	3	1	1	5	0	10	7	6	3
11	10	3	0	1	5	2	8	4	9	5
12	8	9	1	2	10	1	6	7	3	1

Table B.2: Generated choice sets by MNL bayesian efficient design, scenario 2: 5 kilometer

Alternatives	**Bicycle**				**Shared bicycle**				
Attributes	**Driving time**	**Walking time**	**Crowdedness**	**Costs**	**Driving time**	**Walking time**	**Mode**	**Costs**	**Availability**
1	20	5	5	0	20	7	1	1	0
2	17	1	3	0	23	7	1	2	2
3	20	3	3	1	23	5	0	1	0
4	20	3	5	2	17	3	0	0	1
5	20	5	1	2	17	3	0	0	2
6	23	5	5	1	17	3	1	0	2
7	17	3	3	0	23	5	0	2	2
8	23	3	1	2	20	5	1	1	1
9	17	1	1	1	20	7	0	2	1
10	23	1	5	2	17	3	0	0	0
11	23	5	1	0	20	5	1	1	0
12	17	1	3	1	23	7	1	2	1

Alternatives	**Public transport**						**Car**			
Attributes	**Driving time**	**Walking time**	**Mode**	**Costs**	**Freqency**	**Crowdedness**	**Driving time**	**Walking time**	**Costs**	**Crowdedness**
1	15	3	1	1	5	0	12	1	9	1
2	18	6	0	3	10	2	18	7	6	3
3	12	3	0	1	15	2	15	4	9	1
4	15	9	1	1	15	0	18	1	3	5
5	12	9	0	3	15	0	18	1	3	1
6	15	6	0	2	5	1	12	4	9	5
7	18	6	1	3	10	2	18	4	6	3
8	12	9	1	1	5	2	15	4	3	5
9	15	3	0	2	5	0	15	7	6	3
10	18	9	1	3	10	1	12	7	3	1
11	12	3	1	2	15	1	12	1	9	5
12	18	6	0	2	10	1	15	7	6	3

B.2 Human Research Ethics Committee application

Date 03-03-2021
Contact person Ir. J.B.J. Groot Kormelink, secretary HREC
Telephone +31 152783260
E-mail j.b.j.grootkormelink@tudelft.nl

Human Research Ethics Committee
TU Delft
(http://hrec.tudelft.nl/)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Identifying factors for switching from car towards sustainable modes in short-trips in a mid-sized city.
Applicant: Limburg, Babette

Dear Babette Limburg,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your HREC submission which has been approved. We would suggest that you include a note in your Opening Statement to the Informed Consent about the provision of a postcode being optional. We would also suggest that in future HREC applications you provide information on any compensation to be given to participants.
Best wishes,

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

B.3 Complete survey

Welkom

Beste deelnemer,

Deze vragenlijst is onderdeel van mijn afstudeeronderzoek aan de TU Delft. Het onderzoek wordt uitgevoerd in samenwerking met mobiliteitsadviesbureau Goudappel. In mijn project onderzoek ik reisgedrag in Den Haag en omgeving.

De vragenlijst bestaat uit 3 delen. In deel 1 kijk ik of u tot de juiste doelgroep behoort. In deel 2 wordt 12 keer een denkbeeldige situatie voorgelegd, waar u wordt gevraagd om te kiezen tussen 4 vervoermiddelen. In het laatste deel vraag ik u naar enkele persoonlijke kenmerken. Uw deelname is anoniem, uw antwoorden worden vertrouwelijk behandeld en alleen gebruikt voor dit onderzoek.

Uw deelname is vrijwillig en u kunt op elk moment stoppen. Door mee te doen aan deze vragenlijst gaat u akkoord met de hiervoor genoemde voorwaarden en geeft u toestemming dat de door u ingevulde gegevens voor dit onderzoek gebruikt mogen worden.

Het invullen van de vragenlijst duurt ongeveer 10 minuten. Het invullen werkt het beste op een computer of tablet.

Hartelijk dank voor uw deelname!

Babette Limburg

Bij vragen kunt u contact opnemen via: b.m.limburg@student.tudelft.nl

Onderdeel 1: Introductie

In dit eerste deel worden controlevragen gesteld om te kijken of u binnen de doelgroep van deze vragenlijst valt. Als u binnen de doelgroep valt, dan gaat u hierna door naar deel 2 en deel 3 van de vragenlijst. Als u niet binnen de doelgroep valt, dan eindigt de vragenlijst na dit deel.

[Onzichtbare vraag voor de respondent]

0) De respondent krijgt met een 50/50% kans nummer 1 of nummer 2 toegewezen.

1) Woont u Den Haag, Rijswijk of Leidschendam-Voorburg?
   - Ja
   - Nee

2) Bent u in het bezit van een autorijbewijs?
   - Ja
   - Nee

3) Heeft u binnen uw huishouden beschikking over een auto?
   - Ja, wanneer ik maar wil
   - Ja, alleen ik moet dit wel afstemmen met huishouden
   - Nee

4) Heeft u binnen uw huishouden beschikking over een fiets?
   - Ja, wanneer ik maar wil
   - Ja, alleen ik moet dit wel afstemmen met huishouden
   - Nee

[De respondenten gaan door naar de rest van de enquête als op alle vragen 'ja' is beantwoord.]

[Als de respondent bij vraag 0 nummer 1 heeft toegewezen gekregen.]
Onderdeel 2, scenario 1: Korte rit naar centrum van Den Haag
In dit deel krijgt u 12 keer een denkbeeldige situatie voorgelegd waarin u wordt gevraagd te kiezen uit 4 vervoersopties: fiets, deelfiets, openbaar vervoer en auto. De opties verschillen in type vervoermiddel, rijtijd, looptijd, drukte, kosten, beschikbaarheid en frequentie. In deze situaties reist u naar het centrum van de stad Den Haag (let op: dit is dus een denkbeeldige reis). U wordt gevraagd welke vervoersoptie uw eerste en tweede voorkeur heeft, als u die reis zou gaan maken.

1) Weet u wat een deelfiets is en hoe deze gebruikt kan worden?
   Voorbeelden deelfiets: OV-fiets, HTM Fiets, Mobike
   [als nee -> extra uitleg over de deelfiets en controlevraag of ze het snappen]

Extra uitleg over de deelfiets: Een deelfiets is een fiets die gemakkelijk door iedereen (tegen betaling) gebruikt kan worden. De deelfiets in dit onderzoek kan worden opgehaald op bepaalde locaties en kan worden achtergelaten op andere bepaalde locaties. Deze locaties zijn overzichtelijk te vinden in de Deelfiets-app. Na het parkeren van de fiets kan de fiets weer door anderen worden gebruikt. De locaties en beschikbaarheid van de deelfiets zijn te vinden in de Deelfiets-app op uw eigen mobiele telefoon. De Deelfiets-app gebruikt u ook om de fiets mee te openen en de rit mee te betalen.

OV-fiets *HTM Fiets* *Mobike*

Hieronder krijgt u uitleg van de vervoermiddelen waartussen u moet kiezen voor uw denkbeeldige reis en krijgt u een voorbeeldvraag te zien. Daarna wordt gevraagd uw voorkeuren te geven.

Uitleg	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Type deelfiets	Type openbaar vervoer	Eigen auto
Rijtijd	Het aantal minuten rijtijd op de (deel)fiets, met het openbaar vervoer of in de auto.			
Looptijd	De totale looptijd in uw reis in minuten.			
Drukte	Totale **zoektijd** in uw reis naar een fietsenstalling en parkeerplek.	-	Drukte in het vervoermiddel, uitgedrukt in wel of geen zitplekken.	Totale **zoektijd** in uw reis naar een parkeergarage en parkeerplek.
Kosten	**Parkeerkosten** voor 1,5 uur parkeren in een bewaakte fietsenstalling in het stadscentrum.	Kosten voor gebruik van de deelfiets op de heenreis.	Kosten voor het kaartje van de heenreis van het openbaar vervoer.	**Parkeerkosten** voor 1,5 uur parkeren in een parkeergarage in het stadscentrum.
Beschikbaarheid	-	Aantal deelfietsen bij de dichtstbijzijnde oppiklocatie, of de fiets kan worden gereserveerd. De kans is 90% dat u de fiets kunt gebruiken.	-	-
Frequentie	-	-	Hoe vaak de bus of tram rijdt, uitgedrukt in minuten.	-

Fiets: Uw eigen fiets.

Deelfiets: De deelfiets is te vinden in 'dropzones' in de stad. In sommige keuzes kunt u een reservering maken voor de deelfiets. Deze reservering maakt u 10 minuten voordat u vertrekt en uw fiets blijft 30 minuten gereserveerd. Wanneer u geen reservering kunt maken ziet u 10 minuten voor uw vertrek hoeveel fietsen er beschikbaar zijn op locatie. Het aantal fietsen kan meer of minder worden in de tijd tot uw vertrek. Op de terugweg zijn de beschikbaarheid en kosten hetzelfde als op de heenreis.

Openbaar vervoer: De tram of bus zijn de twee types openbaar vervoer in deze enquête. De bus/tram heeft een directe verbinding met het centrum van de stad. Op de terugweg zijn de frequentie en kosten hetzelfde als op de heenreis.

Auto: Uw eigen auto.

Voorbeeld keuze set korte afstand

Voorbeeld	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	10 minuten	8 minuten	10 minuten	8 minuten
Looptijd	3 minuten	5 minuten	3 minuten	4 minuten
Drukte	1 minuut zoektijd		Wat drukker, weinig zitplekken	3 minuten zoektijd
Kosten	1 euro	2 euro	1 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 10 minuten	

Voorbeeld vraag: Welke optie heeft uw voorkeur?

2) Welk type fiets omschrijft uw eigen (meest gebruikte) fiets het beste?
   - Fiets zonder versnellingen
   - Fiets met versnellingen
   - Elektrische fiets
   - Anders:

3) Welk type auto omschrijft uw eigen (meest gebruikte) auto het beste?
   - Lease auto, diesel of benzine
   - Lease auto, hybride of elektrisch
   - Privé auto, diesel of benzine
   - Privé auto, hybride of elektrische
   - Anders:

Bij de optie fiets en auto zal het vervoermiddel altijd uw eigen fiets of eigen auto zijn. Houd dit tijdens het invullen van de vragenlijst in gedachten.

Nu beginnen de keuzesets. Er zullen 12 keuzesets zijn. De omstandigheden zullen voor elke vraag hetzelfde zijn, namelijk:
Stel u gaat alleen naar het centrum van de stad Den Haag. Hier zult u 1,5 uur zijn voor boodschappen en winkelen. De afstand van uw huis tot en met het centrum van de stad is kort. Het is 17 graden, droog en er is weinig wind. U heeft geen (grote) bagage bij u. De corona crisis is voorbij. Alles is weer zoals voor corona. 10 minuten voordat u vertrekt kiest u hoe u naar het centrum van Den Haag reist.

*Keuzeset 1

Herhaling omstandigheden: Stel u gaat alleen naar het centrum van de stad Den Haag. Hier zult u 1,5 uur zijn voor boodschappen en winkelen. De afstand van uw huis tot en met het centrum van de stad is kort. Het is 17 graden, droog en er is weinig wind. U heeft geen (grote) bagage bij u. De corona crisis is voorbij. Alles is weer zoals voor corona. 10 minuten voordat u vertrekt kiest u hoe u naar het centrum van Den Haag reist.

Keuze 1	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	8 minuten	12 minuten	10 minuten	10 minuten
Looptijd	1 minuut	7 minuten	9 minuten	4 minuten
Drukte	3 minuten zoektijd		Rustig, veel zitplekken	1 minuut zoektijd
Kosten	0 euro	2 euro	3 euro	6 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 10 minuten	

Welke optie heeft uw voorkeur?

Kies minstens 2 antwoorden

	Fiets	Deelfiets	Openbaar vervoer	Auto
Eerste keuze	○	○	○	○
Tweede keuze	○	○	○	○

Let op: Eerste keuze en tweede keuze mogen niet hetzelfde zijn.

Keuze 2	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	8 minuten	10 minuten	8 minuten	10 minuten
Looptijd	5 minuten	5 minuten	6 minuten	1 minuut
Drukte	1 minuut zoektijd		Rustig, veel zitplekken	1 minuut zoektijd
Kosten	2 euro	1 euro	2 euro	3 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 15 minuten	

Keuze 3	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	12 minuten	10 minuten	6 minuten	6 minuten
Looptijd	1 minuut	5 minuten	9 minuten	1 minuut
Drukte	1 minuut zoektijd		Druk, waarschijnlijk alleen staplekken	5 minuten zoektijd
Kosten	2 euro	1 euro	1 euro	3 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 5 minuten	

Keuze 4	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	8 minuten	12 minuten	8 minuten	8 minuten
Looptijd	1 minuut	7 minuten	6 minuten	7 minuten
Drukte	3 minuten zoektijd		Rustig, veel zitplekken	3 minuten zoektijd
Kosten	0 euro	2 euro	3 euro	6 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 15 minuten	

Keuze 5	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	12 minuten	8 minuten	8 minuten	6 minuten
Looptijd	3 minuten	3 minuten	6 minuten	7 minuten
Drukte	5 minuten looptijd		Wat drukker, weinig zitplekken	5 minuten zoektijd
Kosten	2 euro	0 euro	1 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 15 minuten	

Keuze 6	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	12 minuten	8 minuten	10 minuten	6 minuten
Looptijd	5 minuten	3 minuten	9 minuten	1 minuut
Drukte	5 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	1 minuut zoektijd
Kosten	0 euro	0 euro	3 euro	9 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 10 minuten	

Keuze 7	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	8 minuten	12 minuten	10 minuten	10 minuten
Looptijd	3 minuten	7 minuten	6 minuten	1 minuut
Drukte	5 minuten zoektijd		Wat drukker, weinig zitplekken	5 minuten zoektijd
Kosten	1 euro	2 euro	2 euro	3 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 10 minuten	

Keuze 8	Fiets	Deelfiets	Openbaar vervoer	Auto
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	10 minuten	10 minuten	6 minuten	8 minuten
Looptijd	5 minuten	5 minuten	3 minuten	4 minuten
Drukte	1 minuut zoektijd		Druk, waarschijnlijk alleen staplekken	3 minuten zoektijd
Kosten	1 euro	1 euro	2 euro	9 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 15 minuten	

Keuze 9	Fiets	Deelfiets	Openbaar vervoer	Auto
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	10 minuten	12 minuten	6 minuten	8 minuten
Looptijd	3 minuten	7 minuten	3 minuten	4 minuten
Drukte	1 minuut zoektijd		Wat drukker, weinig zitplekken	3 minuten zoektijd
Kosten	0 euro	2 euro	3 euro	9 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 5 minuten	

Keuze 10	Fiets	Deelfiets	Openbaar vervoer	Auto
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	10 minuten	8 minuten	6 minuten	10 minuten
Looptijd	3 minuten	3 minuten	3 minuten	7 minuten
Drukte	3 minuten zoektijd		Rustig, veel zitplekken	3 minuten zoektijd
Kosten	1 euro	0 euro	1 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 5 minuten	

Keuze 11	Fiets	Deelfiets	Openbaar vervoer	Auto
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	10 minuten	8 minuten	10 minuten	8 minuten
Looptijd	5 minuten	3 minuten	3 minuten	4 minuten
Drukte	5 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	5 minuten zoektijd
Kosten	1 euro	0 euro	1 euro	9 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 5 minuten	

Keuze 12	Fiets	Deelfiets	Openbaar vervoer	Auto
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	12 minuten	10 minuten	8 minuten	6 minuten
Looptijd	1 minuut	5 minuten	9 minuten	7 minuten
Drukte	3 minuten zoektijd		Wat drukker, weinig zitplekken	1 minuut zoektijd
Kosten	2 euro	1 euro	2 euro	3 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 10 minuten	

[Als in de 12 keuzesets nul keer voor deelfiets is gekozen in keuze 1 en 2]

1) U heeft niet gekozen voor de deelfiets. Kunt u aangeven waarom u niet heeft gekozen voor de deelfiets? [open vraag]

[Als in de keuzesets nul keer voor het openbaar vervoer is gekozen in keuze 1 en 2]

2) U heeft niet gekozen voor het openbaar vervoer. Kunt u aangeven waarom u niet heeft gekozen voor het openbaar vervoer? [open vraag]

[Als in de 12 keuzesets meer dan nul keer voor deelfiets is gekozen in keuze 1 en 2]

3) U heeft een of meerdere keren gekozen voor de deelfiets. Overweegt u normaal gesproken de deelfiets ook als vervoersoptie voor een rit binnen de stad Den Haag?
   - o Ja, altijd
   - o Ja, soms
   - o Nee, nooit

[Als in vraag 4 'Nee, nooit' is gekozen]

4) Kunt u aangeven waarom u de deelfiets nooit als vervoersoptie overweegt voor een rit binnen Den Haag? [open vraag]

[Als de respondent bij vraag 0 nummer 2 heeft toegewezen gekregen.]

Onderdeel 2, scenario 2: Lange rit naar centrum van Den Haag

In dit deel krijgt u 12 keer een denkbeeldige situatie voorgelegd waarin u wordt gevraagd te kiezen uit 4 vervoersopties: fiets, deelfiets, openbaar vervoer en auto. De opties verschillen in type vervoermiddel, rijtijd, looptijd, drukte, kosten, beschikbaarheid en frequentie. In deze situaties reist u naar het centrum van de stad Den Haag (let op: dit is dus een denkbeeldige reis). U wordt gevraagd welke vervoersoptie uw eerste en tweede voorkeur heeft, als u die reis zou gaan maken.

1) Weet u wat een deelfiets is en hoe deze gebruikt kan worden?
   Voorbeelden deelfiets: OV-fiets, HTM Fiets, Mobike
   [als nee -> extra uitleg over de deelfiets en controlevraag of ze het snappen]

Extra uitleg over de deelfiets: Een deelfiets is een fiets die gemakkelijk door iedereen (tegen betaling) gebruikt kan worden. De deelfiets in dit onderzoek kan worden opgehaald op bepaalde locaties en kan worden achtergelaten op andere bepaalde locaties. Deze locaties zijn overzichtelijk te vinden in de Deelfiets-app. Na het parkeren van de fiets kan de fiets weer door anderen worden gebruikt. De locaties en beschikbaarheid van de deelfiets zijn te vinden in de Deelfiets-app op uw eigen mobiele telefoon. De Deelfiets-app gebruikt u ook om de fiets mee te openen en de rit mee te betalen.

OV-fiets *HTM Fiets* *Mobike*

Hieronder krijgt u uitleg van de vervoermiddelen waartussen u moet kiezen voor uw denkbeeldige reis en krijgt u een voorbeeldvraag te zien. Daarna wordt gevraagd uw voorkeuren te geven.

Uitleg	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Type deelfiets	Type openbaar vervoer	Eigen auto
Rijtijd	Het aantal minuten rijtijd op de (deel)fiets, met het openbaar vervoer of in de auto.			
Looptijd	De totale looptijd in uw reis in minuten.			
Drukte	Totale **zoektijd** in uw reis naar een fietsenstalling en parkeerplek.	-	Drukte in het vervoermiddel, uitgedrukt in wel of geen zitplekken.	Totale **zoektijd** in uw reis naar een parkeergarage en parkeerplek.
Kosten	**Parkeerkosten** voor 1,5 uur parkeren in een bewaakte fietsenstalling in het stadscentrum.	Kosten voor gebruik van de deelfiets op de heenreis.	Kosten voor het kaartje van de heenreis van het openbaar vervoer.	**Parkeerkosten** voor 1,5 uur parkeren in een parkeergarage in het stadscentrum.
Beschikbaarheid	-	Aantal deelfietsen bij de dichtstbijzijnde oppiklocatie, of de fiets kan worden gereserveerd. De kans is 90% dat u de fiets kunt gebruiken.	-	-
Frequentie	-	-	Hoe vaak de bus of tram rijdt, uitgedrukt in minuten.	-

Fiets: Uw eigen fiets.

Deelfiets: De deelfiets is te vinden in 'dropzones' in de stad. In sommige keuzes kunt u een reservering maken voor de deelfiets. Deze reservering maakt u 10 minuten voordat u vertrekt en uw fiets blijft 30 minuten gereserveerd. Wanneer u geen reservering kunt maken ziet u 10 minuten voor uw vertrek hoeveel fietsen er beschikbaar zijn op locatie. Het aantal fietsen kan meer of minder worden in de tijd tot uw vertrek. Op de terugweg zijn de beschikbaarheid en kosten hetzelfde als op de heenreis.

Openbaar vervoer: De tram of bus zijn de twee types openbaar vervoer in deze enquête. De bus/tram heeft een directe verbinding met het centrum van de stad. Op de terugweg zijn de frequentie en kosten hetzelfde als op de heenreis.

Auto: Uw eigen auto.

Voorbeeld keuzeset lange afstand

Voorbeeld	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	20 minuten	17 minuten	15 minuten	18 minuten
Looptijd	3 minuten	5 minuten	3 minuten	4 minuten
Drukte	1 minuut zoektijd		Wat drukker, weinig zitplekken	3 minuten zoektijd
Kosten	1 euro	2 euro	1 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 10 minuten	

Voorbeeld vraag: Welke optie heeft uw voorkeur?

2) Welk type fiets omschrijft uw eigen (meest gebruikte) fiets het beste?
   - Fiets zonder versnellingen
   - Fiets met versnellingen
   - Elektrische fiets
   - Anders:

3) Welk type auto omschrijft uw eigen (meest gebruikte) auto het beste?
   - Lease auto, diesel of benzine
   - Lease auto, hybride of elektrisch
   - Privé auto, diesel of benzine
   - Privé auto, hybride of elektrische
   - Anders:

Bij de optie fiets en auto zal het vervoermiddel altijd uw eigen fiets of eigen auto zijn. Houd dit tijdens het invullen van de vragenlijst in gedachten.

Nu beginnen de keuzesets. Er zullen 12 keuzesets zijn. De omstandigheden zullen voor elke vraag hetzelfde zijn, namelijk:

Stel u gaat alleen naar het centrum van de stad Den Haag. Hier zult u 1,5 uur zijn voor boodschappen en winkelen. De afstand van uw huis tot en met het centrum van de stad is kort. Het is 17 graden, droog en er is weinig wind. U heeft geen (grote) bagage bij u. De corona crisis is voorbij. Alles is weer zoals voor corona. 10 minuten voordat u vertrekt kiest u hoe u naar het centrum van Den Haag reist.

*Keuzeset 1

Herhaling omstandigheden: Stel u gaat alleen naar het centrum van de stad Den Haag. Hier zult u 1,5 uur zijn voor boodschappen en winkelen. De afstand van uw huis tot en met het centrum van de stad is lang. Het is 17 graden, droog en er is weinig wind. U heeft geen (grote) bagage bij u. De corona crisis is voorbij. Alles is weer zoals voor corona. 10 minuten voordat u vertrekt kiest u hoe u naar het centrum van Den Haag reist.

Keuze 1	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	20 minuten	20 minuten	15 minuten	12 minuten
Looptijd	5 minuten	7 minuten	3 minuten	1 minuut
Drukte	5 minuten zoektijd		Rustig, veel zitplekken	1 minuut zoektijd
Kosten	0 euro	1 euro	1 euro	9 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 5 minuten	

Welke optie heeft uw voorkeur?

Kies minstens 2 antwoorden

	Fiets	Deelfiets	Openbaar vervoer	Auto
Eerste keuze	○	○	○	○
Tweede keuze	○	○	○	○

Let op: Eerste keuze en tweede keuze mogen niet hetzelfde zijn.

Keuze 2	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	17 minuten	23 minuten	18 minuten	18 minuten
Looptijd	1 minuut	7 minuten	6 minuten	7 minuten
Drukte	3 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	3 minuten zoektijd
Kosten	0 euro	2 euro	3 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 10 minuten	

Keuze 3	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	20 minuten	23 minuten	12 minuten	15 minuten
Looptijd	3 minuten	5 minuten	3 minuten	4 minuten
Drukte	3 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	1 minuut zoektijd
Kosten	1 euro	1 euro	1 euro	9 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 15 minuten	

Keuze 3	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	20 minuten	23 minuten	12 minuten	15 minuten
Looptijd	3 minuten	5 minuten	3 minuten	4 minuten
Drukte	3 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	1 minuut zoektijd
Kosten	1 euro	1 euro	1 euro	9 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 15 minuten	

Keuze 4	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	20 minuten	17 minuten	15 minuten	18 minuten
Looptijd	3 minuten	3 minuten	9 minuten	1 minuut
Drukte	5 minuten zoektijd		Rustig, veel zitplekken	5 minuten zoektijd
Kosten	2 euro	0 euro	1 euro	3 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 15 minuten	

Keuze 5	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	20 minuten	17 minuten	12 minuten	18 minuten
Looptijd	5 minuten	3 minuten	9 minuten	1 minuut
Drukte	1 minuut zoektijd		Rustig, veel zitplekken	1 minuut zoektijd
Kosten	2 euro	0 euro	3 euro	3 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 15 minuten	

Keuze 6	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	23 minuten	17 minuten	15 minuten	12 minuten
Looptijd	5 minuten	3 minuten	6 minuten	4 minuten
Drukte	5 minuten zoektijd		Wat drukker, weinig zitplekken	5 minuten zoektijd
Kosten	1 euro	0 euro	2 euro	9 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 5 minuten	

Keuze 7	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	17 minuten	23 minuten	18 minuten	18 minuten
Looptijd	3 minuten	5 minuten	6 minuten	4 minuten
Drukte	3 minuten zoektijd		Druk, waarschijnlijk alleen staplekken	3 minuten zoektijd
Kosten	0 euro	2 euro	3 euro	6 euro
Beschikbaarheid		1-2 beschikbaar		
Frequentie			Elke 10 minuten	

Keuze 8	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	23 minuten	20 minuten	12 minuten	15 minuten
Looptijd	3 minuten	5 minuten	9 minuten	4 minuten
Drukte	1 minuut zoektijd		Druk, waarschijnlijk alleen staplekken	5 minuten zoektijd
Kosten	2 euro	1 euro	1 euro	3 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 5 minuten	

Keuze 9	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Bus	Eigen auto
Rijtijd	17 minuten	20 minuten	15 minuten	15 minuten
Looptijd	1 minuut	7 minuten	3 minuten	7 minuten
Drukte	1 minuut zoektijd		Rustig, veel zitplekken	3 minuten zoektijd
Kosten	1 euro	2 euro	2 euro	6 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			5 minuten	

Keuze 10	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Deelfiets	Tram	Eigen auto
Rijtijd	23 minuten	17 minuten	18 minuten	12 minuten
Looptijd	1 minuut	3 minuten	9 minuten	7 minuten
Drukte	5 minuten zoektijd		Wat drukker, weinig zitplekken	1 minuut zoektijd
Kosten	2 euro	0 euro	3 euro	3 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 10 minuten	

Keuze 11	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Tram	Eigen auto
Rijtijd	23 minuten	20 minuten	12 minuten	12 minuten
Looptijd	5 minuten	5 minuten	3 minuten	1 minuut
Drukte	1 minuut zoektijd		Wat drukker, weinig zitplekken	5 minuten zoektijd
Kosten	0 euro	1 euro	2 euro	9 euro
Beschikbaarheid		Gereserveerd		
Frequentie			Elke 15 minuten	

Keuze 12	**Fiets**	**Deelfiets**	**Openbaar vervoer**	**Auto**
Type	Eigen fiets	Elektrische deelfiets	Bus	Eigen auto
Rijtijd	17 minuten	23 minuten	18 minuten	15 minuten
Looptijd	1 minuut	7 minuten	6 minuten	7 minuten
Drukte	3 minuten zoektijd		Wat drukker, weinig zitplekken	3 minuten zoektijd
Kosten	1 euro	2 euro	2 euro	6 euro
Beschikbaarheid		3+ beschikbaar		
Frequentie			Elke 10 minuten	

[Als in de 12 keuzesets nul keer voor deelfiets is gekozen in keuze 1 en 2]
1) U heeft niet gekozen voor de deelfiets. Kunt u aangeven waarom u niet heeft gekozen voor de deelfiets? [open vraag]

[Als in de keuzesets nul keer voor het openbaar vervoer is gekozen in keuze 1 en 2]
2) U heeft niet gekozen voor het openbaar vervoer. Kunt u aangeven waarom u niet heeft gekozen voor het openbaar vervoer? [open vraag]

[Als in de 12 keuzesets meer dan nul keer voor deelfiets is gekozen in keuze 1 en 2]
3) U heeft een of meerdere keren gekozen voor de deelfiets. Overweegt u normaal gesproken de deelfiets ook als vervoersoptie voor een rit binnen de stad Den Haag?
   - Ja, altijd
   - Ja, soms
   - Nee, nooit

[Als in vraag 4 'Nee, nooit' is gekozen]
4) Kunt u aangeven waarom u de deelfiets nooit als vervoersoptie overweegt voor een rit binnen Den Haag? [open vraag]

Onderdeel 3: Persoonlijke kenmerken
In dit laatste deel wordt gevraagd om antwoord te geven op vragen over persoonlijke informatie.

1) Wat is uw geslacht?
   - o Man
   - o Vrouw
   - o Anders

2) In welk jaar bent u geboren? (Voorbeeld: 1980)

3) Wat zijn de eerste vier cijfers van uw postcode? (Voorbeeld: 1234)

4) Wat is uw hoogst afgeronde opleiding?
   - o Geen of lagere school
   - o VMBO/MAVO/LBO
   - o HAVO/VWO
   - o MBO
   - o HBO
   - o WO
   - o Wil ik niet zeggen

5) Wat is uw huidige werksituatie?
   - o Full time dienstverband
   - o Parttime dienstverband
   - o Werkloos, op zoek naar werk
   - o Werkloos, niet op zoek naar werk
   - o Zelfstandig
   - o Student
   - o Gepensioneerd

6) Welk van de volgende opties omschrijft uw huishouden het beste?
   [als antwoord 'alleenstaand zonder kinderen', en 'alleenstaand met kinderen die niet thuis wonen' dan door naar vraag 7]
   - o Alleenstaand zonder kinderen
   - o Alleenstaand met kinderen die thuis wonen
   - o Alleenstaand met kinderen die niet thuis wonen
   - o Ik woon samen met één of meerdere volwassen huisgenoten (geen partner)
   - o Ik woon samen met een partner zonder kinderen
   - o Ik woon samen met een partner en kinderen die thuis wonen
   - o Ik woon samen met een partner en kinderen die niet thuis wonen
   - o Anders:

7) Uit hoeveel personen bestaat uw huishouden?
   - o 1
   - o 2
   - o 3
   - o 4
   - o 5 of meer

8) Hoeveel auto's heeft u beschikbaar in uw huishouden?
   - o 0
   - o 1
   - o 2
   - o 3 of meer

9) Hoeveel fietsen heeft u beschikbaar in uw huishouden?
   - o 0
   - o 1
   - o 2
   - o 3
   - o 4
   - o 5 of meer

10) Hoe vaak reisde u voor corona gemiddeld met elk van de volgende vervoersmiddelen?

	4 dagen per week of vaker	1-3 dagen per week	1-3 dagen per maand	6-11 dagen per jaar	5 of minder dagen per jaar	Nooit
Fiets	○	○	○	○	○	○
Auto binnen de stad	○	○	○	○	○	○
Auto totaal	○	○	○	○	○	○
Deelfiets	○	○	○	○	○	○
Bus	○	○	○	○	○	○
Tram	○	○	○	○	○	○

11) Hoe vaak reisde u voor corona gemiddeld naar het centrum van de stad Den Haag voor boodschappen of om te winkelen?
   - o 4 dagen per week of vaker
   - o 1-3 dagen per week
   - o 1-3 dagen per maand
   - o 6-11 dagen per jaar
   - o 5 of minder dagen per jaar
   - o Nooit

12) Welke vervoersmiddelen gebruikte u voor corona het meest als u naar het centrum van de stad Den Haag reisde? [meerdere opties mogelijk]
- o Lopend
- o Fiets
- o Deelfiets
- o Bus
- o Tram
- o Auto
- o Anders:

13) Geef hier aan in hoeverre u het eens bent met de volgende stellingen
Let op: bedenk dit voor de situatie voor corona

	Helemaal mee oneens	Mee oneens	Niet eens/niet oneens	Mee eens	Helemaal mee eens
Ik vind het fijn om met de auto te rijden	○	○	○	○	○
Ik vind het fijn om te fietsen	○	○	○	○	○
Ik vind het fijn om met de bus te reizen	○	○	○	○	○
Ik vind het fijn om met de tram te reizen	○	○	○	○	○
Ik vind het fijn om een deelfiets te gebruiken	○	○	○	○	○

14) Heeft u nog vragen of opmerkingen over deze vragenlijst? Dan kunt u ze hier invullen.

Afsluittekst
Dit is het einde van de enquête.

Mocht u nog vragen of opmerkingen hebben naar aanleiding van deze enquête, dan kunt u mij bereiken via b.m.limburg@student.tudelft.nl

Bedankt voor uw deelname aan dit onderzoek!

B.4 Descriptive statistics final survey

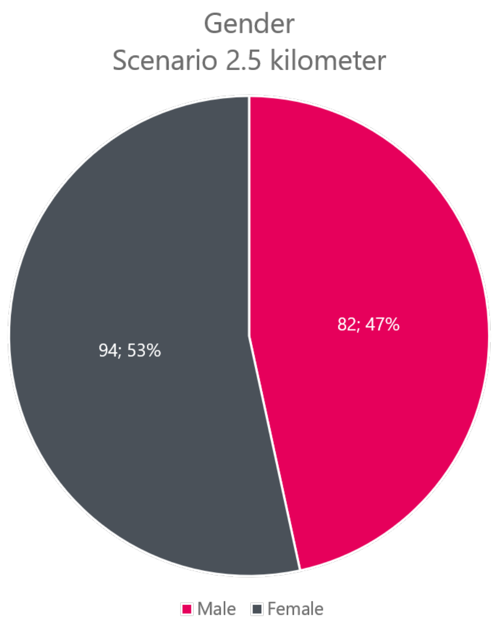

Figure B.1: Gender in 2.5 km scenario

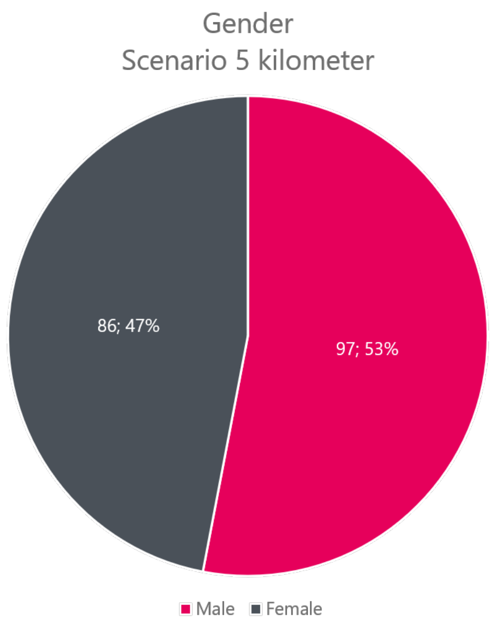

Figure B.2: Gender in 5 km scenario

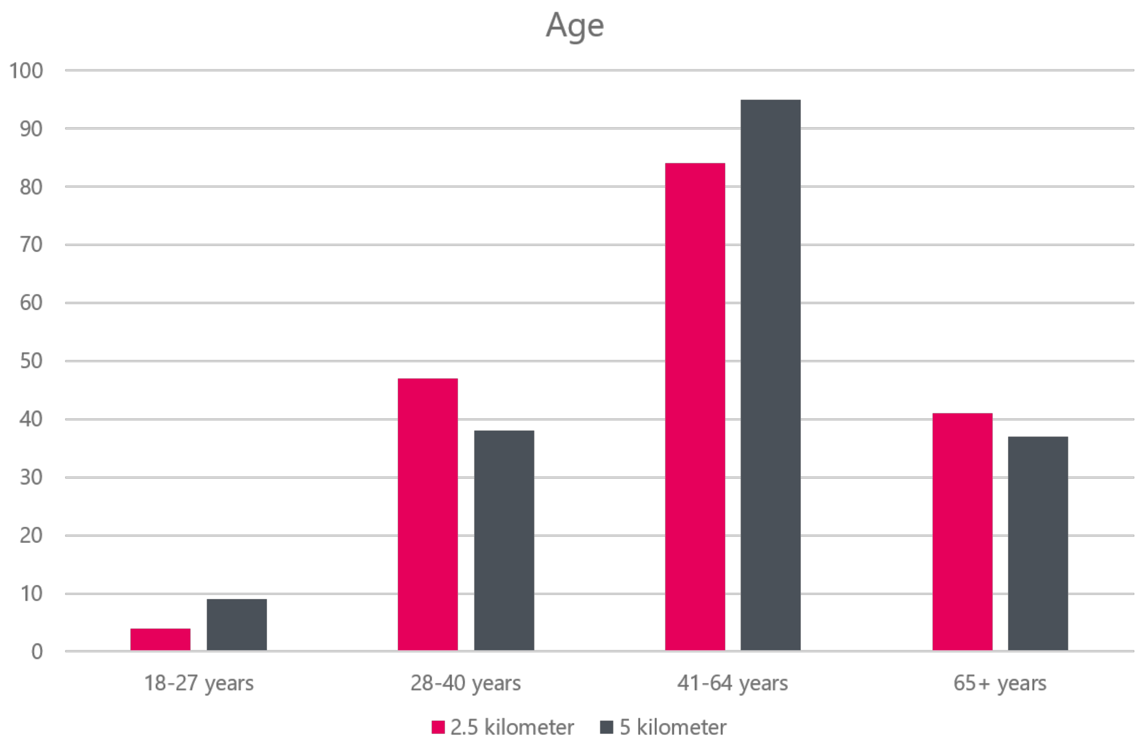

Figure B.3: Respondents' age in scenario 1 and 2

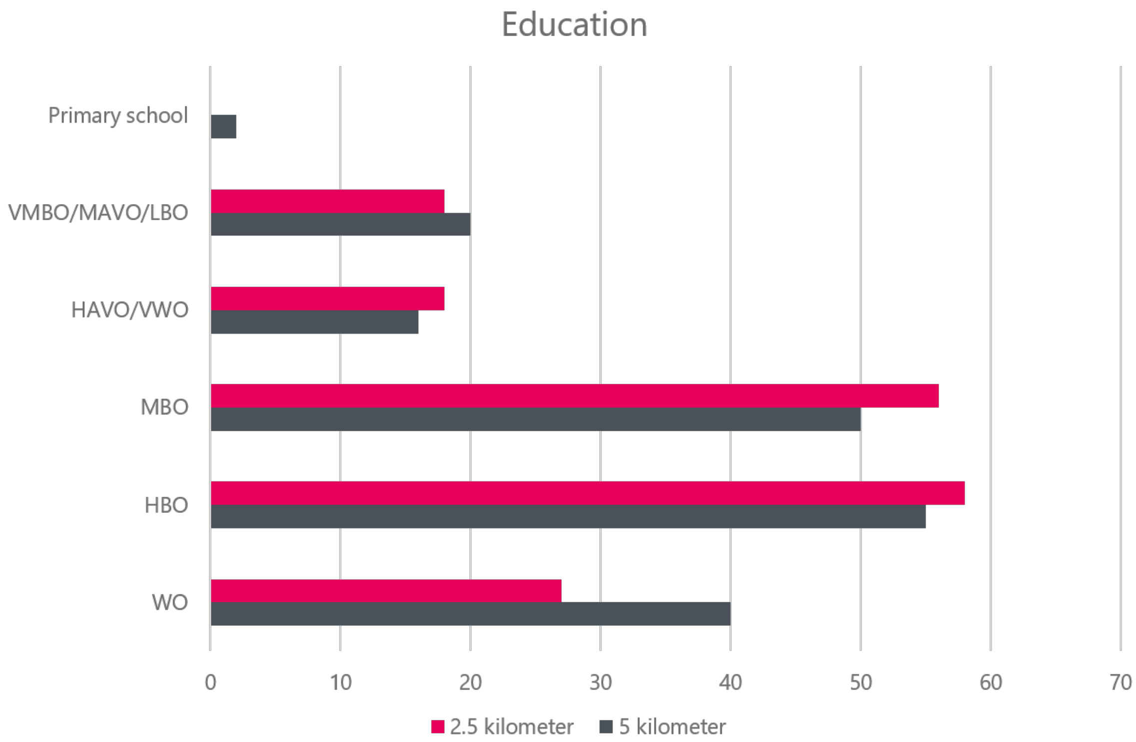

Figure B.4: Pilot survey respondents' highest finished education

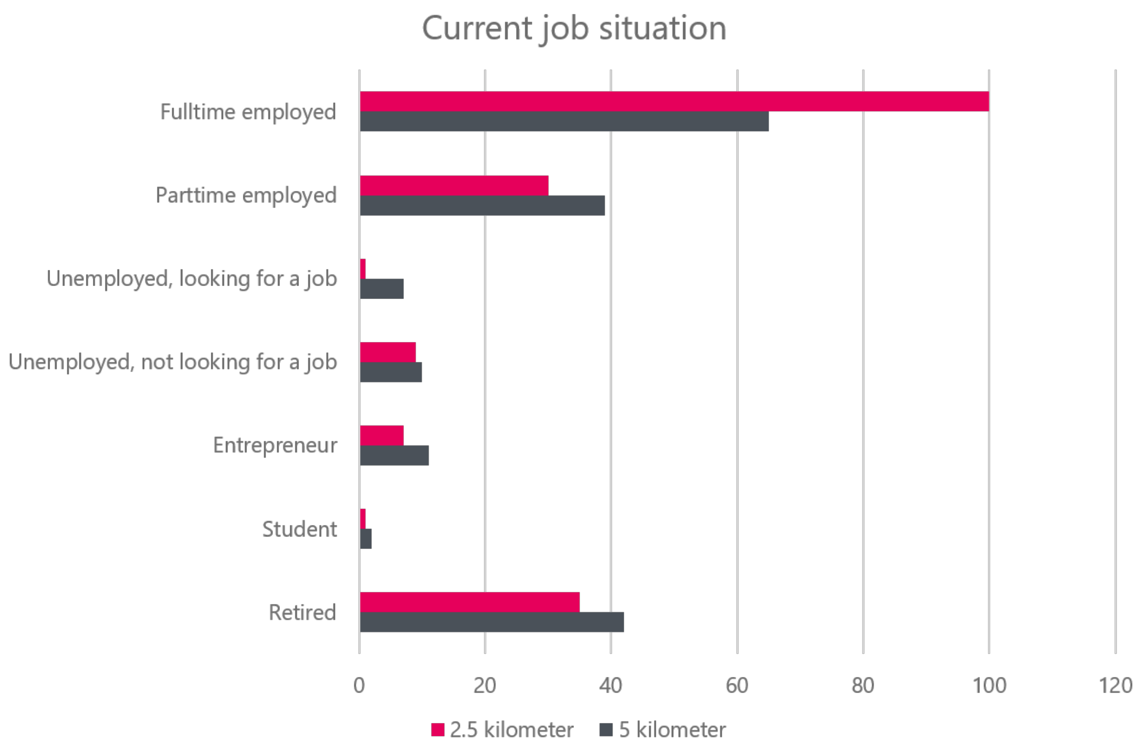

Figure B.5: Current job situation of respondents

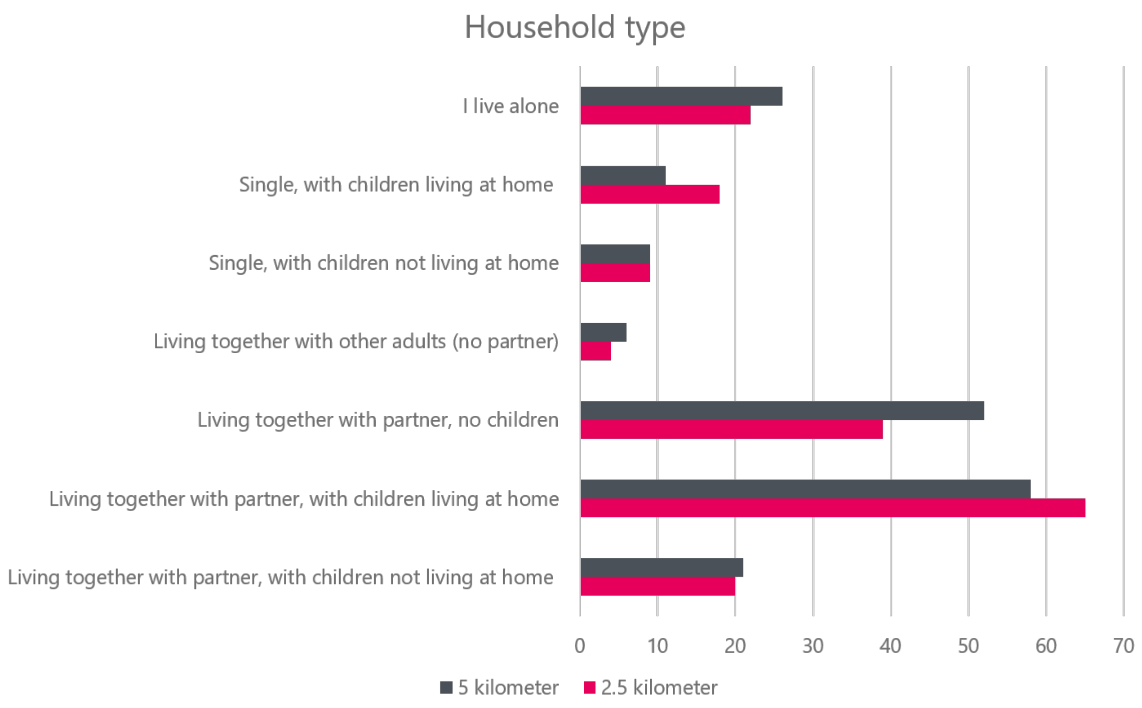

Figure B.6: Household type division of respondents

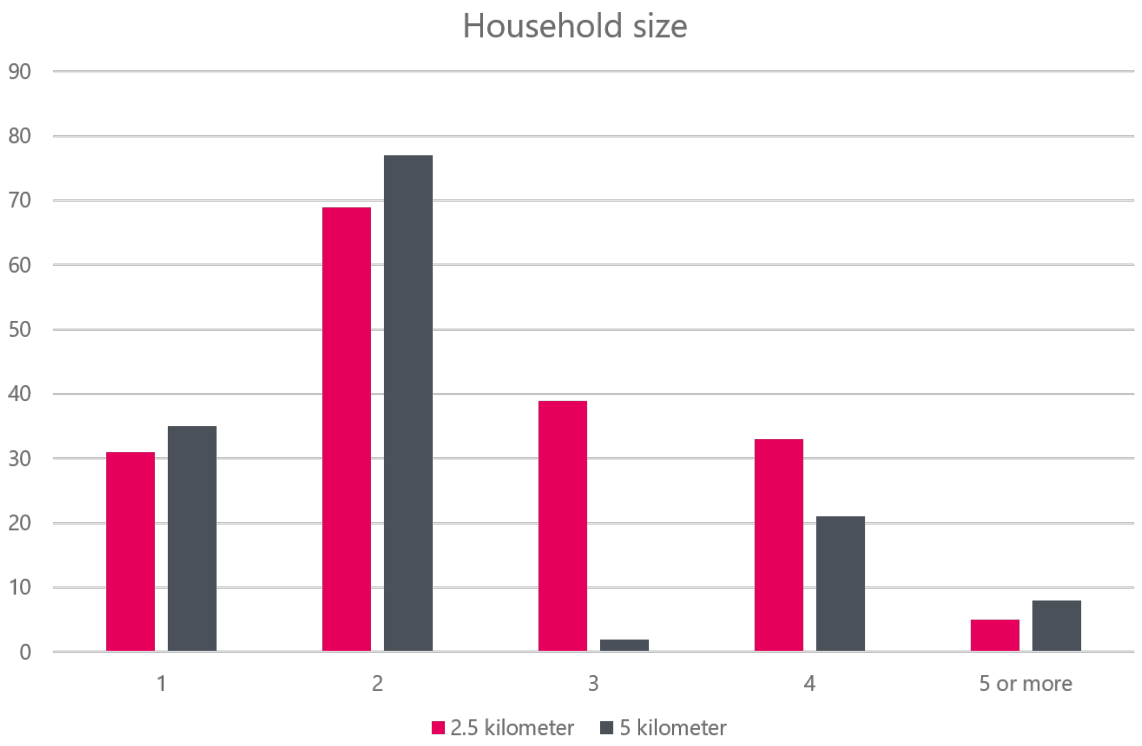

Figure B.7: Household size division of respondents

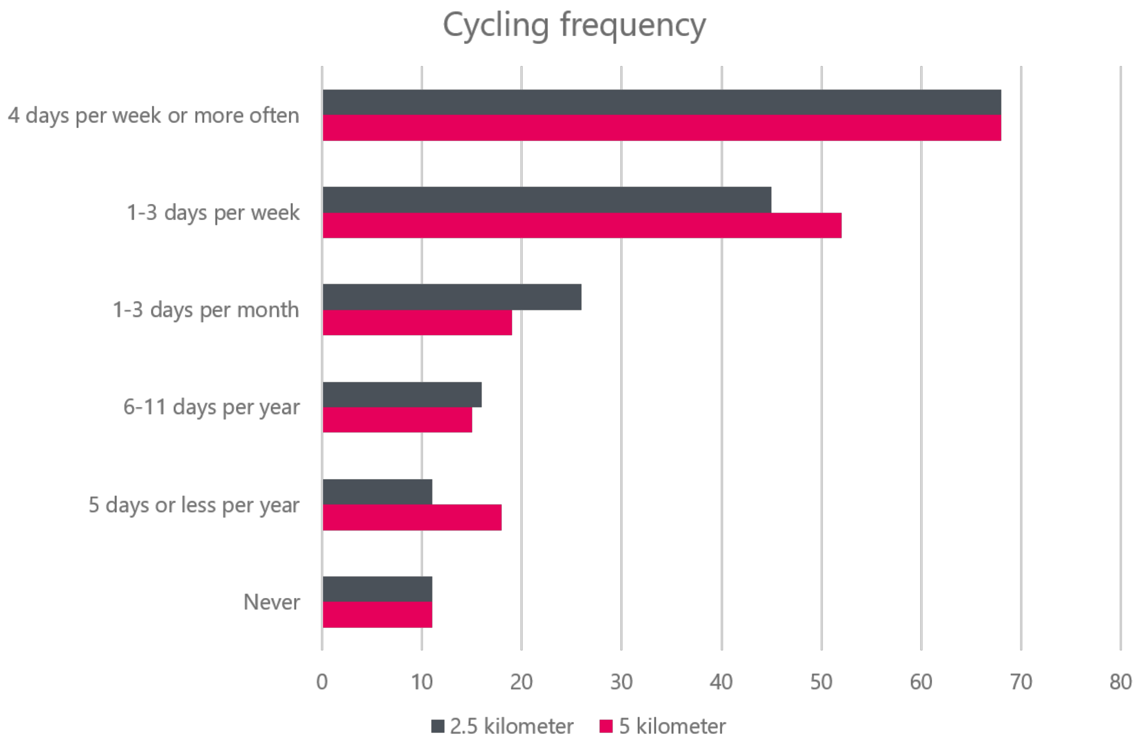

Figure B.8: Cycling frequency

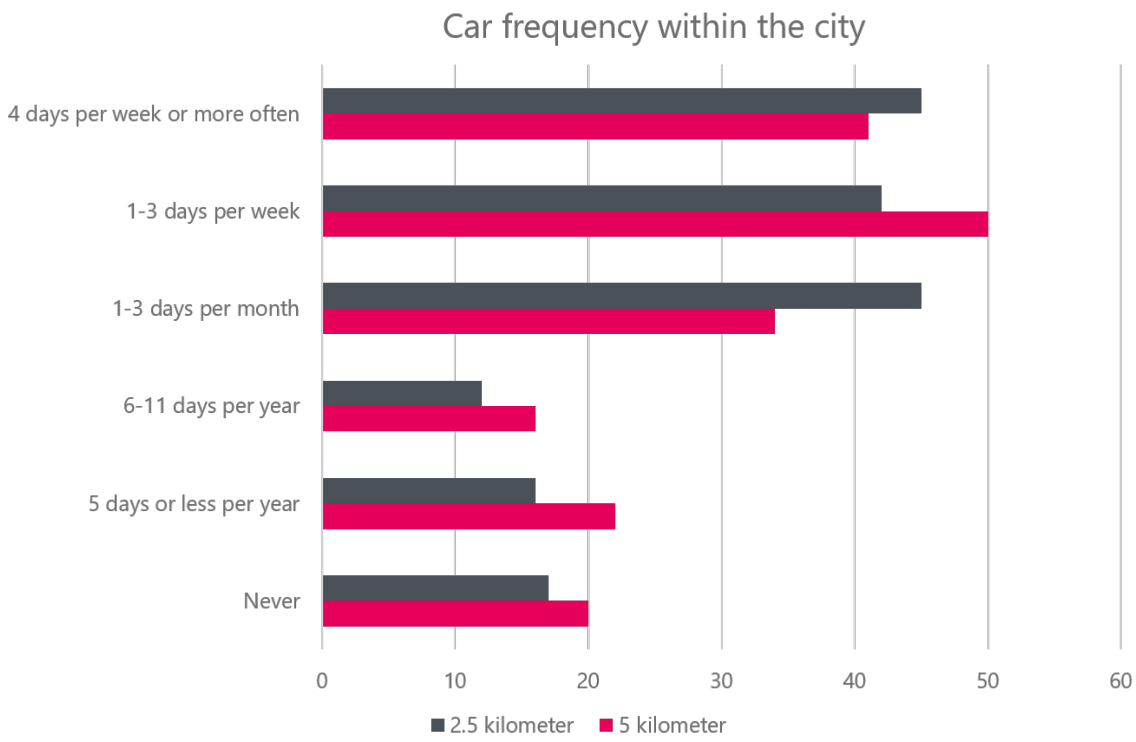

Figure B.9: Car frequency within the city

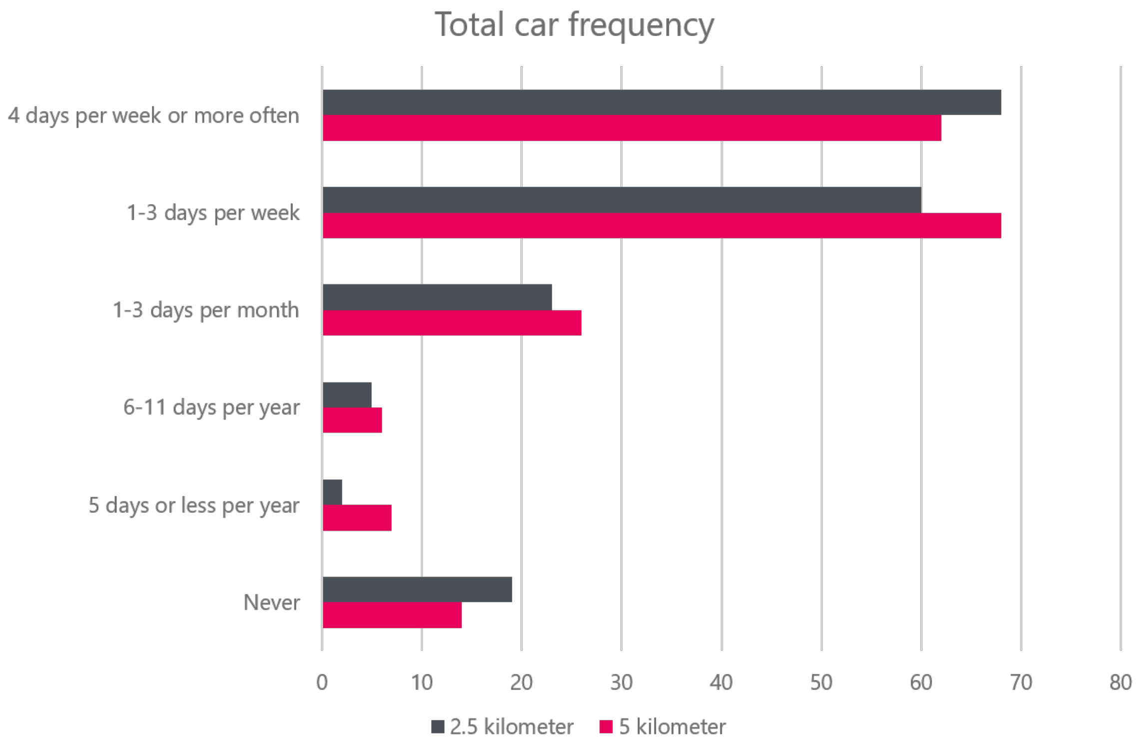

Figure B.10: Car frequency within the city

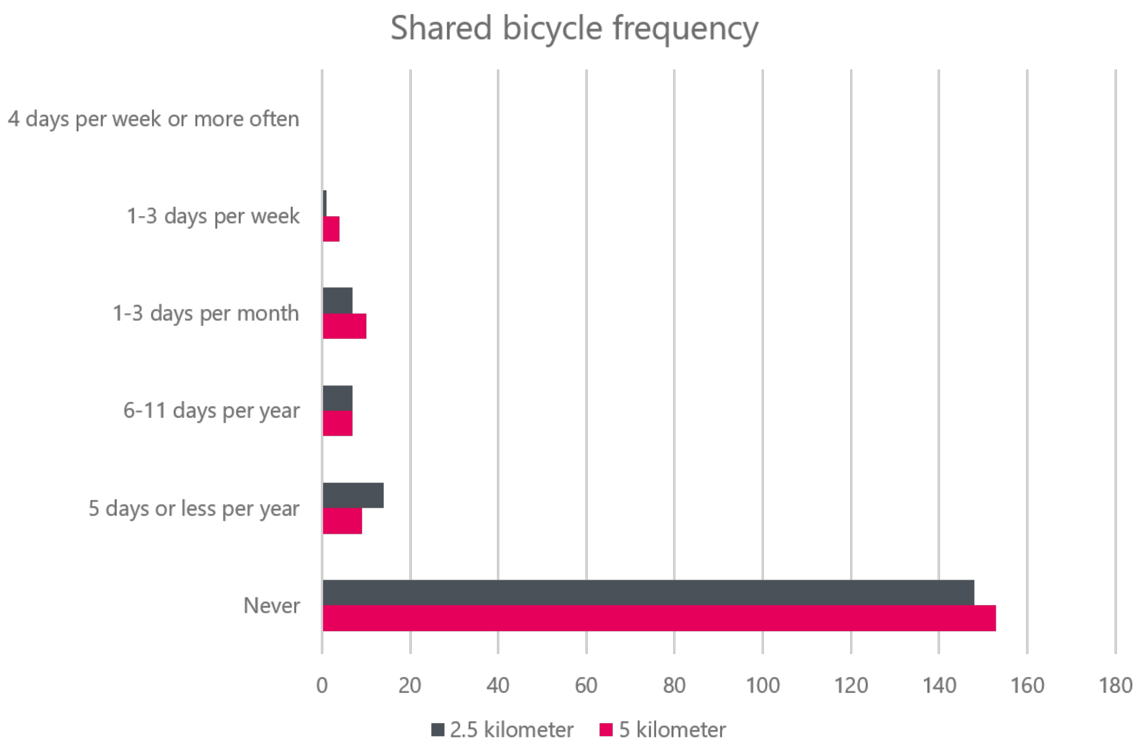

Figure B.11: Shared bicycle frequency

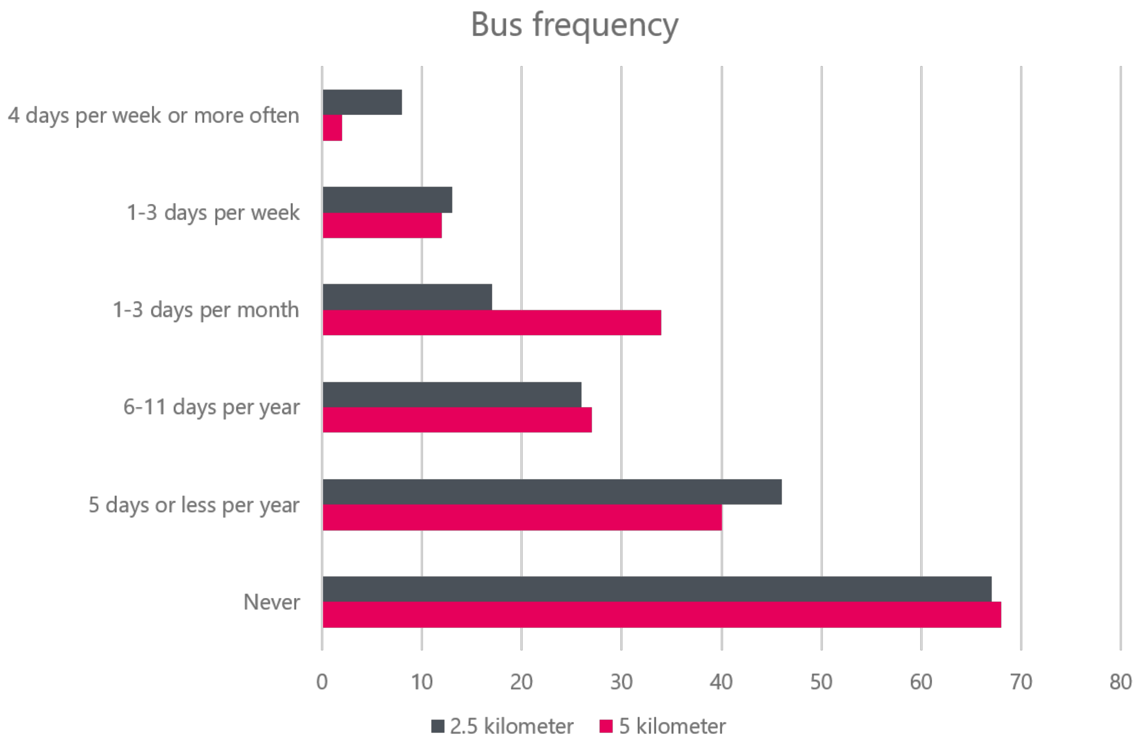

Figure B.12: Bus frequency

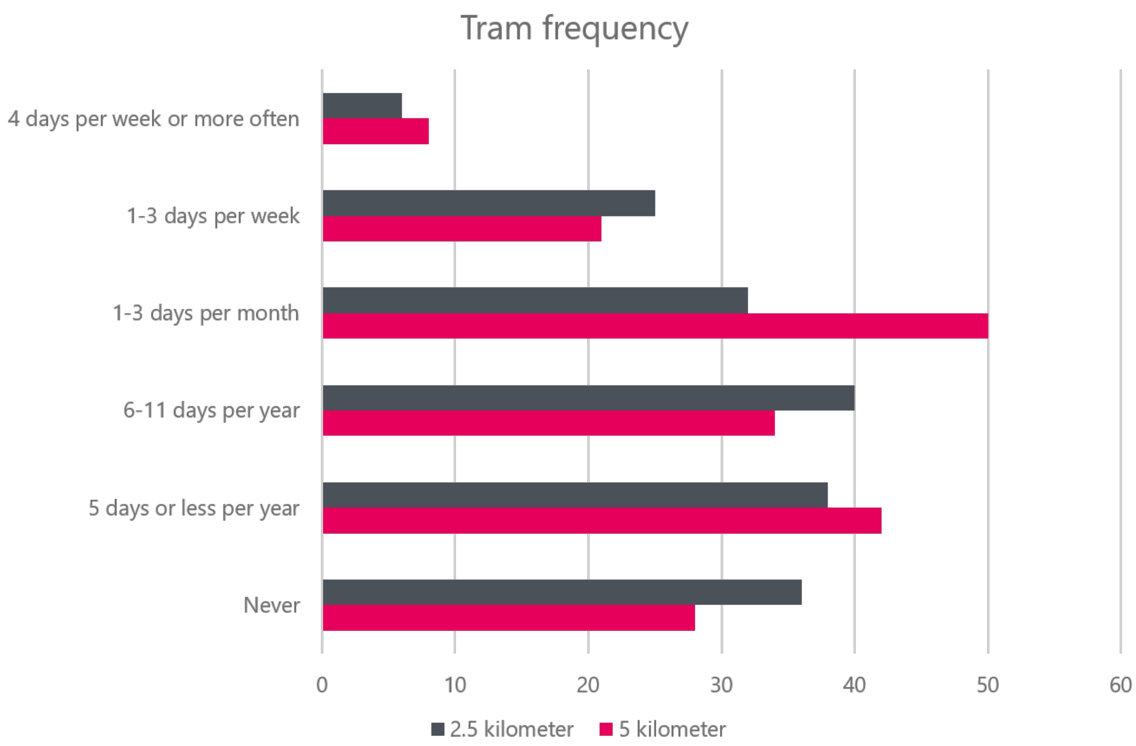

Figure B.13: Tram frequency

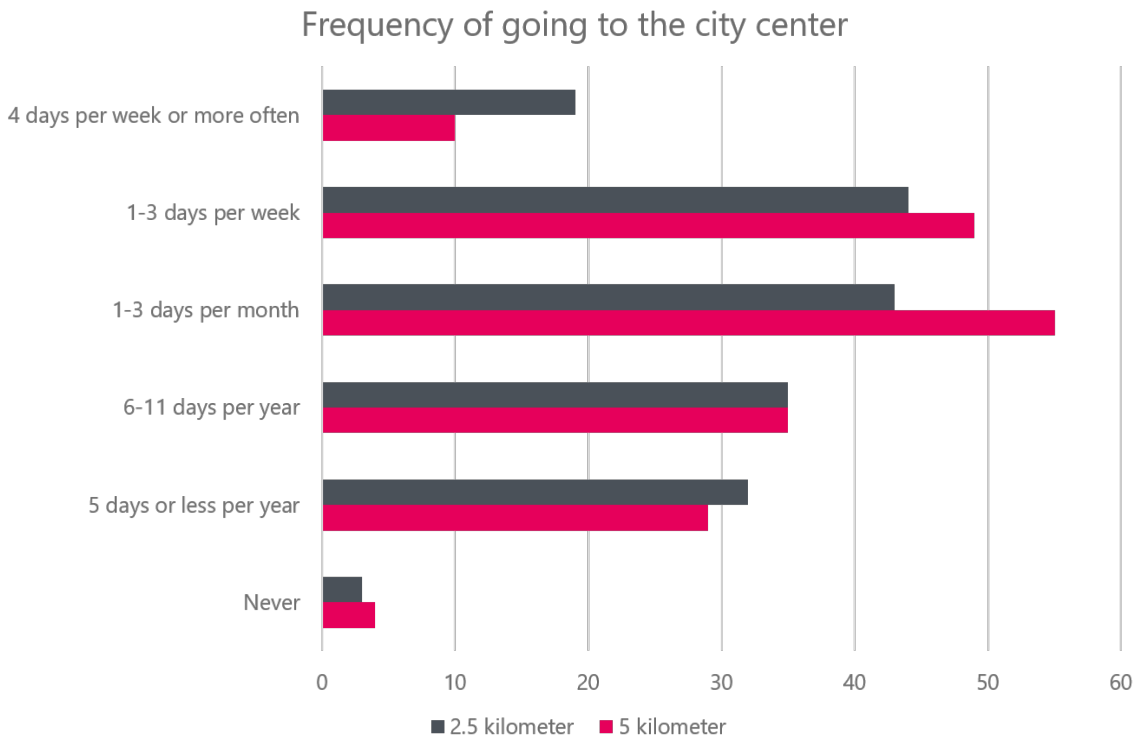

Figure B.14: Frequency respondents go to the city centre

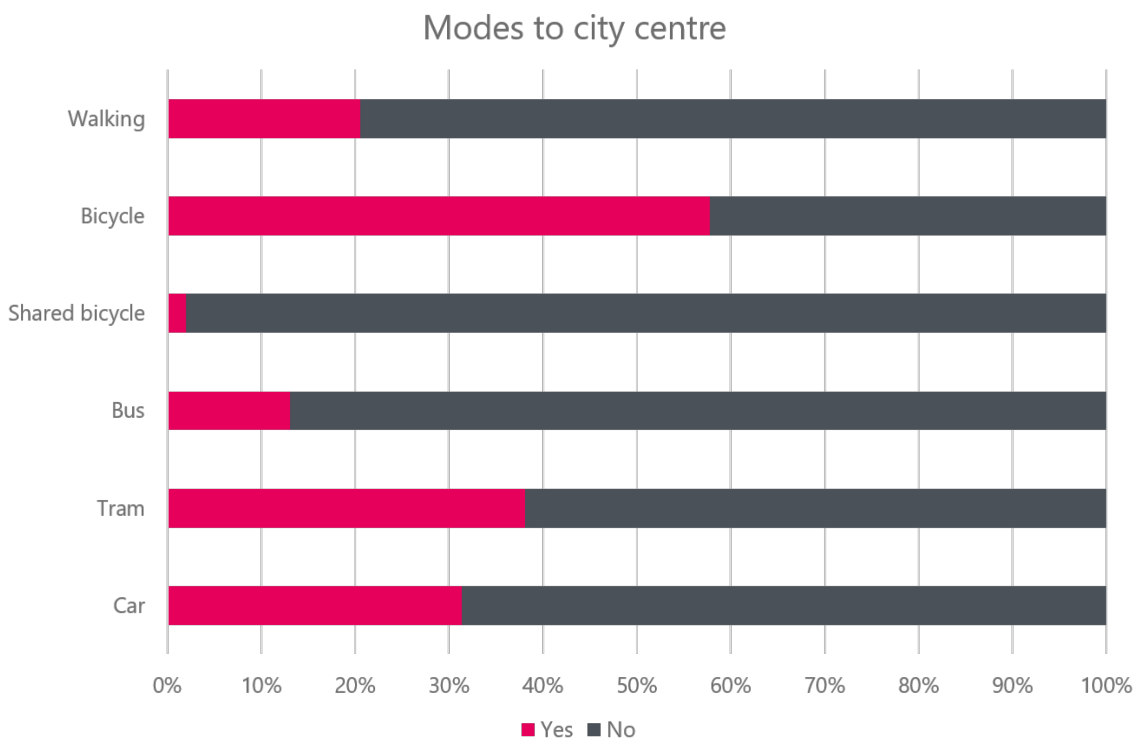

Figure B.15: Modes taken to the city centre, cumulative value of both scenarios

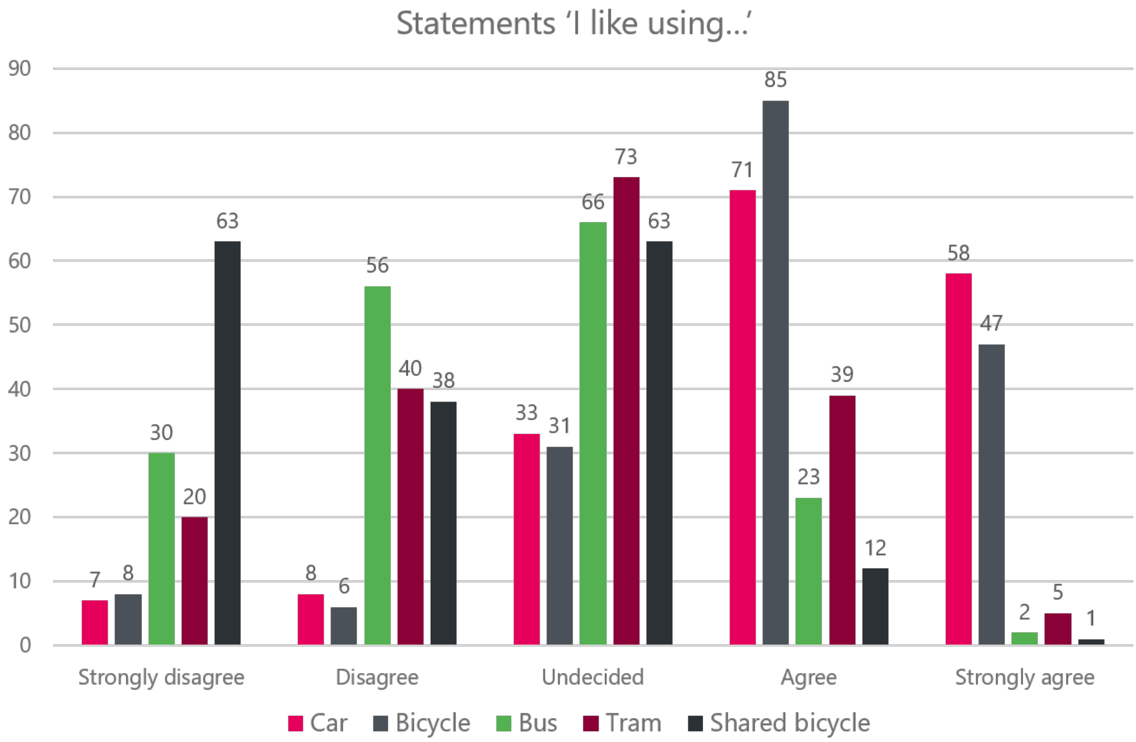

Figure B.16: Statements on mode use, responses of 2.5 kilometer scenario

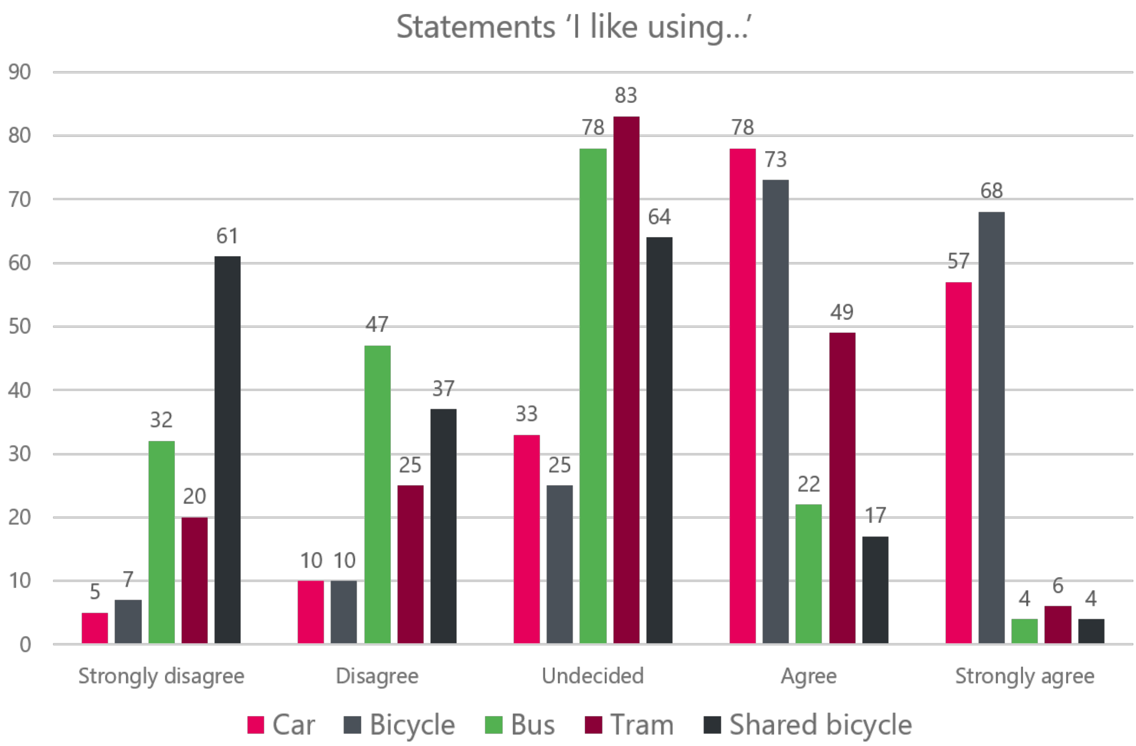

Figure B.17: Statements on mode use, responses of 5 kilometer scenario

Appendix C

Statistical tests

This appendix focuses on statistical tests between the socio-demographics from the survey, being gender, age, education level, household type, bicycle types, number of cars in household, frequencies: cycling, car driving within the city, total car driving, bus, tram, shared bicycle and going to the city centre. The last variables are attitudes towards car, bicycle, bus, tram, and shared bicycle. The ONEWAY ANOVA test is used, as this test enables comparing the means of groups. In this appendix, tables are shown with significant relations only.

C.1 Gender

Gender is the only exception where the chi-square test is used instead of ONEWAY ANOVA, as gender consists of two groups: male and female. In the survey, women are younger than men. Furthermore, women cycle more often on a weekly basis, while men cycle more on a yearly basis. There is no difference between men and women on a monthly cycling frequency level.

Table C.1: Chi-square test gender and age ($\chi^2(2, N = 359) = 18.483, p < 0.001$)

			Age			
			18-40 years	**41-64 years**	**65+ years**	Total
Gender	**Male**	Count	33	89	52	174
		Expected Count	47.7	88.0	38.3	174.0
	Female	Count	64	90	26	180
		Expected Count	49.3	91.0	39.7	180.0
	Total	Count	97	179	78	354
		Expected Count	97.0	179.0	78.0	354.0

Table C.2: Chi-square test gender and cycling frequency ($\chi^2(2, N = 359) = 5.092, p = 0.078$)

			Cycling frequency			
			Weekly	**Monthly**	**<5 days per year**	Total
Gender	**Male**	Count	106	43	30	179
		Expected Count	116.2	37.4	25.4	179.0
	Female	Count	127	32	21	180
		Expected Count	116.8	37.6	25.6	180.0
	Total	Count	233	75	51	359
		Expected Count	233.0	75.0	51.0	359.0

C.2 Age

- The category 18 to 40 years is higher educated than both 41 to 64 years old and 65+ years old group.
- Age category 41 to 64 years old own more bicycles (average of 2.55) than 65+ years old.
- The age category 18 to 40 years old have more often a regular bicycle compared to 65+ years old, who own on average an electric bicycle.
- Both 18 to 40 years old and 41 to 64 years old go more often to the city centre than 65+ years old.
- The age group 18 to 40 years old use shared bicycle more often than both 41 to 64 years old and 65+ years old.

Table C.3: Average education level, for age (ONEWAY ANOVA)

	Education level			p (post hoc test Bonferroni)	
Age	**Mean**	**Std. dev**	**N**	**41-64 years**	**65+ years**
18-40 years	1.91	0.801	98	**0.009**	**0.006**
41-64 years	1.63	0.742	179	-	1.000
65+ years	1.55	0.732	78	-	-

Table C.4: Average number of bicycles in household, for age (ONEWAY ANOVA)

	Bicycles in household			p (post hoc test Bonferroni)	
Age	**Mean**	**Std. dev**	**N**	**41-64 years**	**65+ years**
18-40 years	2.32	1.151	97	0.310	0.096
41-64 years	2.55	1.204	179	-	**<0.001**
65+ years	1.95	.924	78	-	-

Table C.5: Average bicycle type, for age (ONEWAY ANOVA)

	Bicycle type			p (post hoc test Bonferroni)	
Age	**Mean**	**Std. dev**	**N**	**41-64 years**	**65+ years**
18-40 years	1.80	.579	94	0.113	**0.011**
41-64 years	1.93	.493	167	-	0.569
65+ years	2.03	.434	75	-	-

Table C.6: Average frequency car within city, for age (ONEWAY ANOVA)

	Frequency: car in city			p (post hoc test Bonferroni)	
Age	**Mean**	**Std. dev**	**N**	**41-64 years**	**65+ years**
18-40 years	1.63	.751	98	1.000	**0.044**
41-64 years	1.65	.766	179	-	**0.034**
65+ years	1.92	.849	78	-	-

Table C.7: Average frequency shared bicycle, for age (ONEWAY ANOVA)

	Frequency: shared bicycle			p (post hoc test Bonferroni)	
Age	**Mean**	**Std. dev**	**N**	**41-64 years**	**65+ years**
18-40 years	2.78	.508	98	**0.002**	**0.001**
41-64 years	2.92	.269	179	-	1.000
65+ years	2.96	.194	78	-	-

C.3 Education level

- Lower level educated people are on average older than higher educated respondents.
- Higher level educated respondents have on average more bicycles in their household than lower level educated respondents.
- Medium level educated respondents have a more negative attitude towards bus than lower level educated respondents.

Table C.8: Average age, for education level (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Education level	**Mean**	**Std. dev**	**N**	**Medium level education**	**Higher level education**
Lower level education	54,39	14,438	177	0.065	**0.002**
Medium level education	50,38	13,824	112	-	0.505
Higher level education	47,30	15,148	66	-	-

Table C.9: Average bicycles in household, for education level (ONEWAY ANOVA)

	Bicycles in household			p (post hoc test Bonferroni)	
Education level	**Mean**	**Std. dev**	**N**	**Medium level education**	**Higher level education**
Lower level education	2.18	1.075	180	0.334	**0.002**
Medium level education	2.40	1.086	112	-	0.152
Higher level education	2.75	1.363	67	-	-

Table C.10: Average attitude towards bus, for education level (ONEWAY ANOVA)

	Attitude towards bus			p (post hoc test Bonferroni)	
Education level	**Mean**	**Std. dev**	**N**	**Medium level education**	**Higher level education**
Lower level education	1.78	.729	180	**0.015**	0.875
Medium level education	1.54	.669	112	-	0.672
Higher level education	1.67	.683	67	-	-

C.4 Household type

- Households who live alone and have no kids are on average younger (average: 46 years old) than households who live alone, and have kids (average: 54 years old) and than households who live together with a partner and have kids (average: 54 years old).
- Households who live together and have kids, have on average more bicycles in their households than the other household types: 'alone, no kids', 'alone, kids', and 'together, no kids'.

Table C.11: Average age, for household type (ONEWAY ANOVA) (note: 'together (no partner) has N = 9, so no conclusions can be drawn from that group)

	Age			p (post hoc test Bonferroni)			
Household type	**Mean**	**Std. dev**	**N**	**Alone, kids**	**Together, no kids**	**Together, kids**	**Together (no partner)**
Alone, no kids	45,53	14,627	47	0.062	**0.006**	**0.048**	1.000
Alone, kids	53,66	13,712	47	-	1.000	1.000	0.091
Together, no kids	54,49	16,901	90	-	-	1.000	**0.040**
Together, kids	52,26	12,512	162	-	-	-	0.128
Together (no partner)	40,00	17,671	9	-	-	-	-

Table C.12: Average number of bicycles in household, for household type (ONEWAY ANOVA) (note: 'together (no partner) has N = 10, so no conclusions can be drawn from that group)

	Bicycles in household			p (post hoc test Bonferroni)			
Household type	**Mean**	**Std. dev**	**N**	**Alone, kids**	**Together, no kids**	**Together, kids**	**Together (no partner)**
Alone, no kids	1,53	,830	47	0.088	0.086	**<0.001**	**0.002**
Alone, kids	2,11	1,068	47	-	1.000	**0.001**	0.317
Together, no kids	2,03	,912	91	-	-	**0.000**	0.142
Together, kids	2,81	1,159	164	-	-	-	1.000
Together (no partner)	2,90	1,370	10	-	-	-	-

Table C.13: Average shared bicycle frequency, for household type (ONEWAY ANOVA) (note: 'together (no partner) has N = 10, so no conclusions can be drawn from that group)

	Frequency: shared bicycle			p (post hoc test Bonferroni)			
Household type	**Mean**	**Std. dev**	**N**	**Alone, kids**	**Together, no kids**	**Together, kids**	**Together (no partner)**
Alone, no kids	2,88	,334	48	1.000	1.000	1.000	**0.001**
Alone, kids	2,83	,481	47	-	0.675	1.000	**0.005**
Together, no kids	2,95	,273	91	-	-	**0.046**	**0.000**
Together, kids	2,90	,318	164	-	-	-	**0.000**
Together (no partner)	2,40	,699	10	-	-	-	-

C.5 Bicycle types

- Respondents who own a regular bicycle are on average younger (average: 46 years old) than respondents who own an electric bicycle (average age: 53 years).
- Respondents who own a regular bicycle drive car more often than respondents who own an 'other' bicycle type.
- Respondents who own a regular bicycle use the shared bicycle more often than the two other groups, electric bicycle and other bicycle type.
- Respondents who own a regular bicycle go to the city centre more often than respondents who own an electric bicycle or an other bicycle type.

Table C.14: Average age, for bicycle types (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Bicycle type	**Average**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	45.81	13.644	59	0.002	0.055
Electric bicycle	53.11	14.790	246	-	1.000
Other bicycle	53.42	13.488	31	-	-

Table C.15: Average total car frequency, for bicycle types (ONEWAY ANOVA)

	Frequency: car total			p (post hoc test Bonferroni)	
Bicycle type	**Mean**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	1.30	.667	61	.896	.020
Electric bicycle	1.40	.671	249	-	.054
Other bicycle	1.71	.864	31	-	-

Table C.16: Average shared bicycle frequency, for bicycle type (ONEWAY ANOVA)

	Frequency: shared bicycle			p (post hoc test Bonferroni)	
Bicycle type	**Average**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	2.70	0.587	61	<0.001	0.036
Electric bicycle	2.92	0.281	249	-	1.000
Other bicycle	2.90	0.301	31	-	-

Table C.17: Average frequency going to the city centre, for bicycle type (ONEWAY ANOVA)

	Frequency: city centre			p (post hoc test Bonferroni)	
Bicycle type	**Average**	**Std. dev**	**N**	**Electric bicycle**	**Other bicycle**
Regular bicycle	1.61	0.690	61	0.009	0.045
Electric bicycle	1.91	0.724	249	-	1.000
Other bicycle	2.00	0.655	31	-	-

C.6 Number of cars in household

- The average household type who has 1 car in its household is 'together, no kids', while the average household type for a 2-car household is 'together, kids'.
- Households who own two cars drive more often by car in the city centre than households who own one car.
- Households who own one car travel more often by bus than households who own two cars.
- Households who own one car have a less positive attitude towards car than households who own two cars.
- Households who own one car have a less negative attitude towards bus than households who own two cars.
- Households who own one car have on average a neutral attitude towards tram, while households who own two cars have a more negative attitude towards trams.

Table C.18: Average household type, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Household type			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	2,96	1,140	269	**0.000**	1.000
2	3,61	,733	82	-	0.525
3	2,83	1,722	6	-	-

Table C.19: Average frequency of car within city, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Frequency: car within city			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	1,80	,790	269	**0.002**	1.000
2	1,44	,722	82	-	1.000
3	1,83	,983	6	-	-

Table C.20: Average bus frequency, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Frequency: bus			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	2,45	,693	269	**0.006**	1.000
2	2,73	,498	82	-	1.000
3	2,50	,837	6	-	-

Table C.21: Average attitude towards car, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Attitude car			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	2,59	,661	269	**0.015**	0.669
2	2,83	,466	82	-	1.000
3	3,00	,000	6	-	-

Table C.22: Average attitude towards bus, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Attitude bus			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	1,76	,726	269	**0.002**	1.000
2	1,44	,590	82	-	1.000
3	1,67	,516	6	-	-

Table C.23: Average attitude towards tram, for number of cars in household (ONEWAY ANOVA) (note: no conclusions can be drawn from 3 cars in household, given N<30)

	Attitude tram			p (post hoc test Bonferroni)	
Number of cars in household	**Mean**	**Std. dev**	**N**	**2**	**3**
1	2,05	,754	269	**0.019**	1.000
2	1,77	,725	82	-	1.000
3	2,00	,632	6	-	-

C.7 Frequency: cycling

- Cyclist who cycle on a monthly basis have a higher frequency of car driving within the city than cyclists who cycle on a weekly basis.
- The more often a respondent cycles, the more positive is their average attitude towards shared bicycle.

Table C.24: Average frequency of car within city, for cycling frequency (ONEWAY ANOVA)

	Frequency: car within city			**p (post hoc test Bonferroni)**	
Cycling frequency	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,79	,818	233	**0.005**	1.000
Monthly	1,46	,642	76	-	0.096
<5 days per year	1,76	,790	51	-	-

Table C.25: Average attitude towards bicycle, for cycling frequency (ONEWAY ANOVA)

	Attitude bicycle			**p (post hoc test Bonferroni)**	
Cycling frequency	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,86	,447	233	**<0.001**	**<0.001**
Monthly	2,51	,643	76	-	**<0.001**
<5 days per year	2,06	,835	51	-	-

C.8 Frequency: car within city

- Car drivers who drive less than five days per year have on average a higher age (on average: 56 years old) than car drivers who drive on a weekly basis (average age: 51 years old).
- Car drivers who drive in the city on a weekly basis have on average more cars (average: 1.34 cars) in their household than who drive in the city on a monthly basis (average: 1.14 cars).
- Car drivers who drive in the city on a weekly or monthly basis have a higher total car frequency than car drivers who drive less than 5 days per year.
- Car drivers with a weekly car frequency within the city go more often to the city centre than car drivers who drive less than five days per year by car in the city.
- Car drivers who drive on a monthly basis in the city, have a less negative attitude towards bus than car drivers who drive in the city on a weekly basis.
- Car drivers who drive by car in the city on a weekly basis have on average a negative to neutral attitude towards tram, while car drivers who drive by car in the city on a monthly basis have a neutral to positive attitude towards tram.

Table C.26: Average age, for frequency car within city (ONEWAY ANOVA)

	Age			**p (post hoc test Bonferroni)**	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	50,67	14,039	177	1.000	**0.036**
Monthly	50,97	15,075	105	-	0.092
<5 days per year	55,77	14,810	73	-	-

Table C.27: Average number of cars in household, for frequency car within city (ONEWAY ANOVA)

	Number of cars in household			**p (post hoc test Bonferroni)**	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,34	,532	178	**0.002**	0.097
Monthly	1,14	,399	107	-	1.000
<5 days per year	1,20	,465	75	-	-

Table C.28: Average total car driving frequency, for frequency car within city (ONEWAY ANOVA)

	Total car frequency			p (post hoc test Bonferroni)	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,27	,634	178	0.402	<0.001
Monthly	1,39	,641	107	-	0.004
<5 days per year	1,72	,781	75	-	-

Table C.29: Average frequency of going to the city centre, for frequency car within city (ONEWAY ANOVA)

	Frequency going to the city centre			p (post hoc test Bonferroni)	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,73	,709	178	0.203	0.001
Monthly	1,89	,705	107	-	0.208
<5 days per year	2,08	,682	73	-	-

Table C.30: Average attitude towards bus, for frequency car within city (ONEWAY ANOVA)

	Attitude towards bus			p (post hoc test Bonferroni)	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,58	,670	178	0.020	0.249
Monthly	1,81	,766	107	-	1.000
<5 days per year	1,75	,680	75	-	-

Table C.31: Average attitude towards tram, for frequency car within city (ONEWAY ANOVA)

	Attitude towards tram			p (post hoc test Bonferroni)	
Frequency car within city	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,85	,760	178	0.008	0.084
Monthly	2,13	,753	107	-	1.000
<5 days per year	2,08	,693	75	-	-

C.9 Frequency: car total

- Weekly car drivers drive more often by car within the city than monthly and yearly car drivers.
- Weekly car drivers have a more positive attitude towards cars than monthly car drivers.
- Weekly car drivers have a more negative attitude towards shared bicycles than monthly car drivers.

Table C.32: Average car frequency within city, for frequency car total (ONEWAY ANOVA)

	Frequency car within city			p (post hoc test Bonferroni)	
Frequency car total	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,57	,726	258	0.000	0.012
Monthly	2,20	,755	60	-	0.221
<5 days per year	1,93	,894	42	-	-

Table C.33: Average attitude towards car, for frequency car total (ONEWAY ANOVA)

	Attitude car			p (post hoc test Bonferroni)	
Frequency car total	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,72	,563	258	<0.001	0.408
Monthly	2,38	,761	60	-	0.392
<5 days per year	2,57	,703	42	-	-

Table C.34: Average attitude towards shared bicycle, for frequency car total (ONEWAY ANOVA)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Frequency car total	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,47	,631	258	**0.002**	0.782
Monthly	1,80	,708	60	-	0.359
<5 days per year	1,60	,701	42	-	-

C.10 Frequency: shared bicycle

- Monthly shared bicycle users have a higher cycling frequency than shared bicycle users who use a shared bicycle less than 5 days per year.
- Monthly shared bicycle users have a positive attitude towards shared bicycles, while users who use a shared bicycle less than 5 days per year have an average negative attitude towards shared bicycles.

Table C.35: Average age, for frequency shared bicycle (ONEWAY ANOVA) (note: no conclusions can be drawn from weekly shared bicycle users, because N < 30)

	Age			p (post hoc test Bonferroni)	
Frequency shared bicycle	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	32,00	4,163	4	0.194	**0.014**
Monthly	46,16	14,942	31	-	0.053
<5 days per year	52,60	14,389	320	-	-

Table C.36: Average car type, for frequency shared bicycle (ONEWAY ANOVA) (note: no conclusions can be drawn from weekly shared bicycle users, because N < 30)

	Car type			p (post hoc test Bonferroni)	
Frequency shared bicycle	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,60	,548	5	**0.027**	0.072
Monthly	1,10	,305	30	-	0.587
<5 days per year	1,20	,399	319	-	-

Table C.37: Average cycling frequency, for frequency shared bicycle (ONEWAY ANOVA) (note: no conclusions can be drawn from weekly shared bicycle users, because N < 30)

	Frequency: cycling			p (post hoc test Bonferroni)	
Frequency shared bicycle	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,40	,548	5	**0.014**	**0.019**
Monthly	1,16	,374	31	-	**0.029**
<5 days per year	1,51	,744	324	-	-

Table C.38: Average attitude towards shared bicycle, for frequency shared bicycle (ONEWAY ANOVA) (note: no conclusions can be drawn from weekly shared bicycle users, because N < 30)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Frequency shared bicycle	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,60	,894	5	1.000	**<0.001**
Monthly	2,39	,803	31	-	**<0.001**
<5 days per year	1,44	,567	324	-	-

C.11 Frequency: bus

- Weekly bus users are older (average: 55 years old) than monthly bus users (average: 48 years old). Monthly bus users are younger than bus users who use the bus less than 5 days per year (average age: 53 years old).

- Weekly bus users have on average less cars (average: 1.09 cars) in their household compared to bus users who use the bus less than 5 days per year (average cars: 1.31).
- Weekly bus users use the shared bicycle more often than bus users who use the bus less than 5 days per year.
- Weekly bus users use the tram more frequently than monthly and '<5 days per year'-users. Monthly bus users use in itself the tram also more often than '<5 days per year'-users.
- Weekly bus users have the most positive attitude towards bus, while monthly bus users are neutral and '<5 days per year'-users have a mainly negative attitude towards bus.
- Weekly and monthly bus users have a positive attitude towards tram, while '<5 days per year'-users have a negative attitude towards tram.
- Weekly bus users have the least negative attitude towards shared bicycle, while '<5 days per year'-users differ from this attitude: they have a more negative attitude towards shared bicycle.

Table C.39: Average age, for bus frequency (ONEWAY ANOVA)

	Age			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	54,83	16,871	35	**0.049**	1.000
Monthly	48,01	16,058	103	-	**0.010**
<5 days per year	53,12	13,159	217	-	-

Table C.40: Average number of cars in household, for bus frequency (ONEWAY ANOVA)

	Number of cars in household			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,09	,445	35	0.784	**0.037**
Monthly	1,19	,420	104	-	0.139
<5 days per year	1,31	,518	221	-	-

Table C.41: Average frequency shared bicycle, for bus frequency (ONEWAY ANOVA)

	Frequency shared bicycle			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,83	,453	35	1.000	0.331
Monthly	2,81	,464	104	-	**0.010**
<5 days per year	2,93	,270	221	-	-

Table C.42: Average tram frequency, for bus frequency (ONEWAY ANOVA)

	Frequency tram			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,26	,657	35	**<0.001**	**<0.001**
Monthly	1,88	,425	104	-	**<0.001**
<5 days per year	2,55	,613	221	-	-

Table C.43: Average attitude towards bus, for bus frequency (ONEWAY ANOVA)

	Attitude bus			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,34	,684	35	**0.035**	**<0.001**
Monthly	2,04	,709	104	-	**<0.001**
<5 days per year	1,41	,554	221	-	-

Table C.44: Average tram attitude, for bus frequency (ONEWAY ANOVA)

	Attitude tram			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,37	,690	35	0.777	**<0.001**
Monthly	2,21	,720	104	-	**<0.001**
<5 days per year	1,81	,730	221	-	-

Table C.45: Average attitude towards shared bicycle, for bus frequency (ONEWAY ANOVA)

	Attitude shared bicycle			**p (post hoc test Bonferroni)**	
Frequency bus	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,80	,719	35	0.338	**0.020**
Monthly	1,60	,718	104	-	0.365
<5 days per year	1,48	,615	221	-	-

C.12 Frequency: tram

- Weekly tram users have a lower cycling frequency than monthly tram users.
- Weekly tram users have a higher bus frequency than both monthly and '<5 days per year' tram users. Monthly tram users have also a higher tram bus frequency than '<5 days per year'-users.
- Monthly tram users go more often to the city centre than '<5 days per year'-users.
- Weekly tram users have a less positive attitude towards the bicycle than '<5 days per year'-users.
- Weekly tram users have a positive attitude towards bus, while '<5 days per year'-users have a negative attitude towards bus. Monthly tram users have a negative to neutral attitude towards bus usage, which is a less negative attitude than '<5 days per year'-users.
- Weekly and monthly tram users have a positive attitude towards tram, while '<5 days per year'-tram users have a negative attitude towards tram.
- Weekly tram users have the least negative attitude towards shared bicycles, while '<5 days per year'-tram users have the most negative attitude towards shared bicycles.

Table C.46: Average cycling frequency, for tram frequency (ONEWAY ANOVA)

	Frequency cycling			**p (post hoc test Bonferroni)**	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,70	,809	60	**0.038**	0.169
Monthly	1,42	,672	156	-	1.000
<5 days per year	1,49	,748	144	-	-

Table C.47: Average bus frequency, for tram frequency (ONEWAY ANOVA)

	Frequency bus			**p (post hoc test Bonferroni)**	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,73	,821	60	**<0.001**	**<0.001**
Monthly	2,45	,512	156	-	**<0.001**
<5 days per year	2,92	,365	144	-	-

Table C.48: Average frequency of going to the city centre, for tram frequency (ONEWAY ANOVA)

	Frequency going to the city centre			**p (post hoc test Bonferroni)**	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,73	,665	60	1.000	0.069
Monthly	1,78	,628	156	-	**0.041**
<5 days per year	1,98	,800	144	-	-

Table C.49: Average attitude towards bicycle, for tram frequency (ONEWAY ANOVA)

	Attitude bicycle			p (post hoc test Bonferroni)	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,47	,747	60	0.063	**0.012**
Monthly	2,69	,620	156	-	1.000
<5 days per year	2,74	,564	144	-	-

Table C.50: Average attitude towards bus, for tram frequency (ONEWAY ANOVA)

	Attitude bus			p (post hoc test Bonferroni)	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,15	,755	60	0.001	**<0.001**
Monthly	1,78	,694	156	-	**<0.001**
<5 days per year	1,38	,555	144	-	-

Table C.51: Average attitude towards tram, for tram frequency (ONEWAY ANOVA)

	Attitude tram			p (post hoc test Bonferroni)	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,52	,651	60	0.003	**<0.001**
Monthly	2,19	,683	156	-	**<0.001**
<5 days per year	1,53	,614	144	-	-

Table C.52: Average attitude towards shared bicycle, for tram frequency (ONEWAY ANOVA)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Frequency tram	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,70	,720	60	0.525	**0.043**
Monthly	1,56	,674	156	-	0.418
<5 days per year	1,45	,613	144	-	-

C.13 Frequency: city centre

- Respondents who go to the city centre on a weekly basis have a lower age (average: 50 years old) than respondents who go less than 5 days per year to the city centre (average age: 56 years old).
- Respondents who go to the city centre on a weekly basis have a higher car frequency than respondents who go monthly and < 5 days per year to the city centre.
- Respondents who go the city centre have a higher tram frequency than respondents who go the city centre less than 5 days per year. For respondents who go the city centre on a monthly basis, this same pattern is found: they use the tram more often than respondents who go to the city centre less than 5 days per year.

Table C.53: Average age, for frequency of going to the city centre (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Frequency city centre	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	49,63	15,593	121	0.814	**0.008**
Monthly	51,53	14,306	167	-	0.073
<5 days per year	56,32	12,646	65	-	-

Table C.54: Average car frequency within the city, for frequency of going to the city centre (ONEWAY ANOVA)

	Frequency car within city			p (post hoc test Bonferroni)	
Frequency city centre	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	1,50	,695	122	**0.007**	**0.002**
Monthly	1,78	,800	168	-	0.874
<5 days per year	1,90	,831	68	-	-

Table C.55: Average tram frequency, for frequency of going to the city centre (ONEWAY ANOVA)

	Frequency tram			p (post hoc test Bonferroni)	
Frequency city centre	**Mean**	**Std. dev**	**N**	**Monthly**	**<5 days per year**
Weekly	2,20	,735	122	1.000	**0.003**
Monthly	2,14	,683	168	-	**<0.001**
<5 days per year	2,54	,679	68	-	-

C.14 Attitude: car

- People with a negative attitude towards car have more often a lease car than respondents with a neutral attitude towards car.
- Respondents with a positive attitude towards car have on average more cars within their household (1.31 cars) than respondents with a neutral attitude (average number of cars: 1.12) and respondents with a negative attitude towards cars (average number of cars: 1.07).
- Respondents with a positive attitude towards car drive more often car than respondents with a negative attitude towards car.
- Respondents with a positive attitude towards car have a more positive attitude towards bicycle than respondents with a negative attitude towards car.

Table C.56: Average car type, for attitude towards car (ONEWAY ANOVA)

	Car type			p (post hoc test Bonferroni)	
Attitude car	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,07	,254	30	**0.043**	0.330
Neutral	1,28	,453	64	-	0.278
Positive	1,19	,392	260	-	-

Table C.57: Average number of cars in household, for attitude towards car (ONEWAY ANOVA)

	Number of cars in household			p (post hoc test Bonferroni)	
Attitude car	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,07	,365	30	1.000	**0.030**
Neutral	1,12	,329	66	-	**0.016**
Positive	1,31	,524	264	-	-

Table C.58: Average total car frequency, for attitude towards car (ONEWAY ANOVA)

	Frequency car total			p (post hoc test Bonferroni)	
Attitude car	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,67	,758	30	0.807	**0.045**
Neutral	1,50	,707	66	-	0.299
Positive	1,34	,669	264	-	-

Table C.59: Average attitude towards bicycle, for attitude towards car (ONEWAY ANOVA)

	Attitude bicycle			p (post hoc test Bonferroni)	
Attitude car	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,33	,884	30	0.107	**0.004**
Neutral	2,62	,651	66	-	0.693
Positive	2,72	,575	264	-	-

C.15 Attitude: bicycle

- Respondents with a neutral attitude towards bicycle have more often a lease car than respondents with a positive attitude towards bicycle.
- Respondents with a positive attitude towards bicycle cycle more often than both respondents with a neutral and negative attitude towards bicycle.
- Respondents who have a positive attitude towards bicycle have a less negative attitude towards shared bicycle than respondents who have a negative attitude towards bicycle.

Table C.60: Average car type, for attitude towards bicycle (ONEWAY ANOVA)

	Car type			p (post hoc test Bonferroni)	
Attitude bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,23	,425	31	0.160	1.000
Neutral	1,05	,229	55	-	**0.014**
Positive	1,22	,415	268	-	-

Table C.61: Average cycling frequency, for attitude towards bicycle (ONEWAY ANOVA)

	Frequency bicycle			p (post hoc test Bonferroni)	
Attitude bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,23	,884	31	0.459	**$<$ 0.001**
Neutral	2,02	,751	56	-	**$<$ 0.001**
Positive	1,30	,593	273	-	-

Table C.62: Average attitude towards car, for attitude towards bicycle (ONEWAY ANOVA)

	Attitude car			p (post hoc test Bonferroni)	
Attitude bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,29	,864	31	**0.049**	**0.002**
Neutral	2,63	,620	56	-	1.000
Positive	2,70	,587	273	-	-

Table C.63: Average attitude towards shared bicycle, for attitude towards bicycle (ONEWAY ANOVA)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Attitude bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,26	,514	31	1.000	**0.016**
Neutral	1,39	,562	56	-	0.084
Positive	1,60	,684	273	-	-

C.16 Attitude: bus

- Respondents with a negative attitude towards bus are on average younger (50 years old) than respondents with a neutral attitude towards bus (average age: 54 years old).
- Respondents wih a positive attitude towards bus have on average less cars in their household (average: 1.06) than both respondents with a neutral attitude towards bus (on average 1.25 cars) and a negative attitude towards bus (average: 1.32 cars).

- Respondents with a positive attitude towards bus cycle less often than both respondents with a neutral and negative attitude towards bus.
- Respondents with a positive attitude towards bus have a lower car frequency than both respondents with a neutral and negative attitude towards bus.
- Respondents with a positive attitude towards bus have a higher shared bicycle frequency than respondents with a neutral and negative attitude towards bus.
- Respondents with a positive attitude towards bus have a higher bus frequency than respondents with a neutral and negative attitude towards bus. Also, respondents with a neutral attitude towards bus have a higher travel frequency by bus than respondents with a negative attitude towards bus.
- Respondents with a positive attitude towards bus have a higher tram frequency than both respondents with a neutral and negative attitude towards bus. Also, respondents with a neutral attitude towards bus have a higher tram frequency than respondents who have a negative attitude towards bus.
- Respondents who have a positive attitude towards bus have on average a positive attitude towards tram, which is more positive than respondents who have a neutral and negative attitude towards bus. Furthermore, respondents with a negative attitude towards bus have a negative attitude towards tram as well, which is negative compared to respondents with a neutral attitude towards bus.
- Respondents with a positive attitude towards bus have the least negative to neutral attitude towards shared bicycle, while respondents with both neutral and negative attitude towards bus have a negative attitude towards shared bicycle.

Table C.64: Average age, for attitude towards bus (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	50,14	13,657	163	**0.045**	1.000
Neutral	54,23	14,225	141	-	0.337
Positive	50,45	17,690	51	-	-

Table C.65: Average number of cars in household, for attitude towards bus (ONEWAY ANOVA)

	Number of cars in household			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,32	,516	165	0.714	**0.003**
Neutral	1,25	,495	144	-	**0.047**
Positive	1,06	,311	51	-	-

Table C.66: Average cycling frequency, for attitude towards bus (ONEWAY ANOVA)

	Frequency bicycle			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,46	,703	165	1.000	**0.045**
Neutral	1,44	,727	144	-	**0.034**
Positive	1,75	,796	51	-	-

Table C.67: Average total car frequency, for attitude towards bus (ONEWAY ANOVA)

	Frequency car total			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,39	,686	165	1.000	**0.033**
Neutral	1,32	,611	144	-	**0.006**
Positive	1,67	,841	51	-	-

Table C.68: Average frequency shared bicycle, for attitude towards bus (ONEWAY ANOVA)

	Frequency shared bicycle			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,90	,335	165	1.000	**0.018**
Neutral	2,92	,277	144	-	**0.010**
Positive	2,75	,560	51	-	-

Table C.69: Average bus frequency, for attitude towards bus (ONEWAY ANOVA)

	Frequency bus			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,81	,454	165	**< 0.001**	**< 0.001**
Neutral	2,43	,676	144	-	**< 0.001**
Positive	1,82	,654	51	-	-

Table C.70: Average tram frequency, for attitude towards bus (ONEWAY ANOVA)

	Frequency tram			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,49	,640	165	**< 0.001**	**< 0.001**
Neutral	2,14	,686	144	-	**< 0.001**
Positive	1,67	,653	51	-	-

Table C.71: Average attitude towards tram, for attitude towards bus (ONEWAY ANOVA)

	Attitude tram			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,53	,729	165	**< 0.001**	**< 0.001**
Neutral	2,21	,441	144	-	**< 0.001**
Positive	2,80	,530	51	-	-

Table C.72: Average attitude towards shared bicycle, for attitude towards bus (ONEWAY ANOVA)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Attitude bus	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,41	,595	165	0.124	**< 0.001**
Neutral	1,56	,634	144	-	**0.004**
Positive	1,90	,806	51	-	-

C.17 Attitude: tram

- Respondents with a negative attitude towards tram are on average younger (average: 50 years old) than respondents with a neutral attitude towards tram (average age: 54 years old).
- Respondents with a negative attitude towards tram have on average more cars in their household (average: 1.32 cars) than respondents with a positive attitude towards tram (average: 1.15 cars).
- Respondents with a negative and neutral attitude towards tram drive more often by car in the city than respondents with a positive attitude towards tram.
- Respondents with a neutral attitude towards tram have a lower shared bicycle frequency than respondents with a positive attitude towards tram.
- Respondents with a positive attitude towards tram have a higher bus frequency than both respondents with a neutral and negative attitude towards tram. Also, respondents with a neutral attitude towards tram have a higher bus frequency than respondents with a negative attitude towards tram.
- Respondents with a positive attitude towards tram have a higher tram frequency than both respondents with a negative and neutral attitude towards tram. Also, respondents with a neutral attitude towards tram have a higher tram frequency than respondents with a negative attitude towards tram.

- Respondents with a positive attitude towards tram have on average a positive attitude towards bus as well, which is more positive than the bus attitude from respondents with a neutral or negative attitude towards tram. Respondents with a negative attitude towards tram have on average a more negative attitude towards bus than respondents with a neutral attitude towards tram.

Table C.73: Average age, for attitude towards tram (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	49,60	15,113	104	**0.046**	1.000
Neutral	54,08	13,541	154	-	0.187
Positive	50,57	15,318	97	-	-

Table C.74: Average number of cars in household, for attitude towards tram (ONEWAY ANOVA)

	Number of cars in household			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,32	,509	105	1.000	**0.036**
Neutral	1,27	,512	156	-	0.181
Positive	1,15	,413	99	-	-

Table C.75: Average car within city frequency, for attitude towards tram (ONEWAY ANOVA)

	Frequency car in city			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,51	,735	105	**0.017**	**0.023**
Neutral	1,79	,819	156	-	1.000
Positive	1,81	,765	99	-	-

Table C.76: Average frequency shared bicycle, for attitude towards tram (ONEWAY ANOVA)

	Frequency shared bicycle			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,87	,369	105	0.281	0.996
Neutral	2,94	,234	156	-	**0.021**
Positive	2,82	,482	99	-	-

Table C.77: Average bus frequency, for attitude towards tram (ONEWAY ANOVA)

	Frequency bus			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,75	,515	105	**0.016**	**< 0.001**
Neutral	2,53	,657	156	-	**0.003**
Positive	2,25	,733	99	-	-

Table C.78: Average tram frequency, for attitude towards tram (ONEWAY ANOVA)

	Frequency tram			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,68	,563	105	**< 0.001**	**< 0.001**
Neutral	2,26	,661	156	-	**< 0.001**
Positive	1,73	,620	99	-	-

Table C.79: Average attitude towards bus, for attitude towards tram (ONEWAY ANOVA)

	Attitude bus			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,08	,359	105	**< 0.001**	**< 0.001**
Neutral	1,76	,487	156	-	**< 0.001**
Positive	2,21	,799	99	-	-

Table C.80: Average attitude towards shared bicycle, for attitude towards tram (ONEWAY ANOVA)

	Attitude shared bicycle			p (post hoc test Bonferroni)	
Attitude tram	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,42	,617	105	1.000	**< 0.001**
Neutral	1,48	,595	156	-	**0.002**
Positive	1,77	,754	99	-	-

C.18 Attitude: shared bicycle

- Respondents with a positive attitude towards shared bicycle are on average younger (average age: 43 years old) than respondents with a neutral and negative attitude towards shared bicycle (respectively 52 and 53 years old).
- Respondents with a neutral attitude towards shared bicycle have a higher cycling frequency than respondents with a negative attitude towards shared bicycle.
- Respondents with a neutral attitude towards shared bicycle have a lower frequency of car driving within the city than respondents with both a positive and negative attitude towards shared bicycle.
- Respondents with a positive attitude towards shared bicycle have a higher shared bicycle frequency than respondents with both a neutral and negative attitude towards shared bicycle.
- Respondents with a positive attitude towards shared bicycle have a higher bus frequency than respondents with a negative attitude towards shared bicycle.
- Respondents with a positive attitude towards shared bicycle go to the city centre more often than respondents with both a neutral and negative attitude towards shared bicycle.
- Respondents with a negative attitude towards shared bicycle have a less positive attitude towards bicycle than respondents with both a neutral and positive attitude towards shared bicycle.
- Respondents with a positive attitude towards shared bicycle have on average a more positive attitude towards bus than respondents with both a neutral and negative attitude towards shared bicycle.
- Respondents with a negative attitude towards shared bicycle have a negative attitude towards tram, while respondents with a positive attitude towards shared bicycle have a positive attitude towards tram.

Table C.81: Average age, for attitude towards shared bicycle (ONEWAY ANOVA)

	Age			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	53,08	14,910	195	1.000	**0.001**
Neutral	52,13	14,006	127	-	**0.004**
Positive	43,06	12,324	33	-	-

Table C.82: Average cycling frequency, for attitude towards shared bicycle (ONEWAY ANOVA)

	Frequency bicycle			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,59	,779	199	**0.019**	0.829
Neutral	1,36	,638	127	-	1.000
Positive	1,44	,705	34	-	-

Table C.83: Average car within city frequency, for attitude towards shared bicycle (ONEWAY ANOVA)

	Frequency car in city			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,63	,786	199	**0.009**	1.000
Neutral	1,90	,805	127	-	**0.026**
Positive	1,50	,615	34	-	-

Table C.84: Average shared bicycle frequency, for attitude towards shared bicycle (ONEWAY ANOVA)

	Frequency shared bicycle			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,96	,221	199	1.000	**< 0.001**
Neutral	2,94	,229	127	-	**< 0.001**
Positive	2,24	,654	34	-	-

Table C.85: Average bus frequency, for attitude towards shared bicycle (ONEWAY ANOVA)

	Frequency bus			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,59	,612	199	0.458	**0.013**
Neutral	2,48	,711	127	-	0.167
Positive	2,24	,741	34	-	-

Table C.86: Average frequency of going to the city centre, for attitude towards shared bicycle (ONEWAY ANOVA)

	Frequency going to the city centre			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,87	,742	198	1.000	**0.016**
Neutral	1,91	,670	126	-	**0.008**
Positive	1,50	,615	34	-	-

Table C.87: Average attitude towards bicycle, for attitude towards shared bicycle (ONEWAY ANOVA)

	Attitude bicycle			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	2,58	,698	199	**0.026**	**0.025**
Neutral	2,76	,526	127	-	0.967
Positive	2,88	,409	34	-	-

Table C.88: Average attitude towards bus, for attitude towards shared bicycle (ONEWAY ANOVA)

	Attitude bus			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,56	,663	199	0.055	**< 0.001**
Neutral	1,75	,690	127	-	**0.009**
Positive	2,15	,821	34	-	-

Table C.89: Average attitude towards tram, for attitude towards shared bicycle (ONEWAY ANOVA)

	Attitude tram			p (post hoc test Bonferroni)	
Attitude shared bicycle	**Mean**	**Std. dev**	**N**	**Neutral**	**Positive**
Negative	1,87	,734	199	0.066	**0.001**
Neutral	2,06	,732	127	-	0.130
Positive	2,35	,812	34	-	-

C.19 Correlations mode frequency and mode attitude

Correlations

		Bicycle frequency	Car in city frequency	Car total frequency	Shared bicycle frequency	Bus frequency	Tram frequency	Bicycle attitude	Car attitude	Bus attitude	Tram attitude	Shared bicycle attitude
Bicycle frequency	**Pearson Correlation**	1	-.068	-.040	.013	-.091	-.072	**-.453**	.087	.099	.086	**-.117**
	Sig. (2-tailed)	-	.198	.451	.799	.084	.173	**.000**	.101	.061	.104	**.026**
	N	360	360	360	360	360	360	360	360	360	360	360
Car in city frequency	**Pearson Correlation**	-.068	1	**.242**	.081	-.052	-.074	.097	-.101	**.117**	**.142**	.047
	Sig. (2-tailed)	.198	-	**.000**	.124	.328	.163	.066	.055	**.027**	**.007**	.375
	N	360	360	360	360	360	360	360	360	360	360	360
Car total frequency	**Pearson Correlation**	-.040	.242	1	-.063	-.008	.064	.001	**-.145**	.089	.024	**.122**
	Sig. (2-tailed)	.451	.000	-	.233	.873	.224	.981	**.006**	.091	.655	**.020**
	N	360	360	360	360	360	360	360	360	360	360	360
Shared bicycle frequency	**Pearson Correlation**	.013	.081	-.063	1	**.142**	.093	-.030	.033	**-.109**	-.048	**-.431**
	Sig. (2-tailed)	.799	.124	.233	-	**.007**	.079	.569	.536	**.038**	.362	**.000**
	N	360	360	360	360	360	360	360	360	360	360	360
Bus frequency	**Pearson Correlation**	-.091	-.052	-.008	.142	1	**.609**	.093	.014	**-.490**	**-.282**	**-.150**
	Sig. (2-tailed)	.084	.328	.873	.007	-	**.000**	.078	.792	**.000**	**.000**	**.004**
	N	360	360	360	360	360	360	360	360	360	360	360
Tram frequency	**Pearson Correlation**	-.072	-.074	.064	.093	.609	1	**.140**	.021	**-.392**	**-.498**	**-.132**
	Sig. (2-tailed)	.173	.163	.224	.079	.000	-	**.008**	.691	**.000**	**.000**	**.012**
	N	360	360	360	360	360	360	360	360	360	360	360
Bicycle attitude	**Pearson Correlation**	-.453	.097	.001	-.030	.093	.140	1	**.167**	-.096	-.082	**.174**
	Sig. (2-tailed)	.000	.066	.981	.569	.078	.008	-	**.001**	.068	.119	**.001**
	N	360	360	360	360	360	360	360	360	360	360	360
Car attitude	**Pearson Correlation**	.087	-.101	-.145	.033	.014	.021	.167	1	-.031	.035	-.079
	Sig. (2-tailed)	.101	.055	.006	.536	.792	.691	.001	-	.562	.512	.136
	N	360	360	360	360	360	360	360	360	360	360	360
Bus attitude	**Pearson Correlation**	.099	.117	.089	-.109	-.490	-.392	-.096	-.031	1	**.606**	**.236**
	Sig. (2-tailed)	.061	.027	.091	.038	.000	.000	.068	.562	-	**.000**	**.000**
	N	360	360	360	360	360	360	360	360	360	360	360
Tram attitude	**Pearson Correlation**	.086	.142	.024	-.048	-.282	-.498	-.082	.035	.606	1	**.197**
	Sig. (2-tailed)	.104	.007	.655	.362	.000	.000	.119	.512	.000	-	**.000**
	N	360	360	360	360	360	360	360	360	360	360	360
Shared bicycle attitude	**Pearson Correlation**	-.117	.047	.122	-.431	-.150	-.132	.174	-.079	.236	.197	1
	Sig. (2-tailed)	.026	.375	.020	.000	.004	.012	.001	.136	.000	.000	-
	N	360	360	360	360	360	360	360	360	360	360	360

Appendix D

Data set coding

Table D.1: Dummy coding socio-demographics

Gender	**GENDER**			
Male	0			
Female	1			
Age	**AGE1**	**AGE2**	**AGE3**	
18-27	0	0	0	
28-40	1	0	0	
41-64	0	1	0	
65+	0	0	1	
Education	**EDU1**	**EDU2**		
Lower level education	0	0		
Medium level education	1	0		
Higher level education	0	1		
Household type	**HH1**	**HH2**	**HH3**	**HH4**
Alone, no kids	0	0	0	0
Alone, kids	1	0	0	0
Together, no kids	0	1	0	0
Together, kids	0	0	1	0
Together (no partner)	0	0	0	1
Mode frequency	**FREQ1**	**FREQ2**		
4 days per week or more often	0	0		
1-3 days per week	0	0		
1-3 days per month	1	0		
6-11 days per year	1	0		
<5 days per year	0	1		
Never	0	1		
Mode attitude	**POS**	**NEG**		
Strongly agree	1	0		
Agree	1	0		
Undecided	0	0		
Disagree	0	-1		
Strongly disagree	0	-1		

Appendix E

Model estimation

E.1 Linearity testing

This section starts with two types of linearity testing. First, a generic quadratic component is added to the generic MNL model which has one beta estimated on crowdedness, travel cost, travel time, and walking time. This is done both for scenario 1 and 2. The results are that in scenario 1 travel time has a significant quadratic component. However, what is remarkable is that the linear component has a positive sign, and the quadratic component value a negative sign. In scenario 2, both travel costs and travel time have a significant quadratic component. However, when adding both travel cost and its quadratic component and travel time and its quadratic component into one model, the quadratic component of travel cost becomes insignificant.

Besides, given the three-level attributes of crowdedness, travel cost, travel time, and walking time, one could also estimate dummies which gives insight in the differences between the three levels. When this difference is equal, there is linearity. If it is not equal and significant, then there is a non-linear relation within one of the attributes. In both scenario 1 and 2, there is only one alternative which is significant in both the first and second attribute: travel time 1 and travel time 2. This is in line with the findings in Table E.1 and Table E.2 of travel time being non-linear.

Where:
[1] = MNL model with all generic parameters, no quadratic parameter components, nor dummy parameter components
[2] = MNL model with all generic parameters, quadratic parameter component crowdedness
[3] = MNL model with all generic parameters, quadratic parameter component travel cost
[4] = MNL model with all generic parameters, quadratic parameter component travel time
[5] = MNL model with all generic parameters, quadratic parameter component walking time
[6] = MNL model with all generic parameters, quadratic parameter component travel cost and travel time
[7] = MNL model with all generic parameters, dummy parameter component crowdedness
[8] = MNL model with all generic parameters, dummy parameter component travel cost
[9] = MNL model with all generic parameters, dummy parameter component travel time
[10] = MNL model with all generic parameters, dummy parameter component walking time

Followed by the different MNL models and the parameter values for each of the tested parameters, a LRS test is ran for both the models with the quadratic components and the dummy variables. The LRS test shows whether the model with - in this case - one more parameter explains the model significantly better than the model with - in this case - one less parameter. The findings of the LRS tests are made visible in Table E.6. It can be concluded that for scenario 2.5 kilometer the travel time is non-linear, while in scenario 5 kilometer both travel cost and travel time are non-linear. However, with both travel cost and travel time in a model, the quadratic travel cost parameter becomes insignificant. Therefore is chosen to take the quadratic travel time component into consideration in finding the best fitting model in Section E.2.

Table E.1: Quadratic component tests scenario 1: 2.5 kilometer

MNL SC1		Crowdedness	Crowdedness^2	Travel cost	Travel cost^2	Travel time	Travel time^2	Walking time	Walking time^2
[1]	**Parameter estimate**	**-0.0903**		**-0.125**		**-0.117**		**-0.0436**	
	rob. t-value	-3.69		-5.82		-7.27		-3.46	
	rob. p-value	<0.001		<0.001		<0.001		<0.001	
[2]	**Parameter estimate**	-0.0915	0.000211	**-0.125**		**-0.117**		**-0.0436**	
	rob. t-value	-0.489	0.00654	-5.63		-7.21		-3.16	
	rob. p-value	0.625	0.995	<0.001		<0.001		0.002	
[3]	**Parameter estimate**	**-0.0888**		**-0.146**	0.0026	**-0.114**		**-0.0424**	
	rob. t-value	-3.56		-2.50	0.384	-6.23		-3.27	
	rob. p-value	<0.001		0.012	0.701	<0.001		0.001	
[4]	**Parameter estimate**	**-0.0594**		**-1.112**		**0.516**	**-0.035**	**-0.0593**	
	rob. t-value	-2.24		-5.14		2.79	-3.44	-4.32	
	rob. p-value	0.025		<0.001		0.005	<0.001	<0.001	
[5]	**Parameter estimate**	**-0.0911**		**-0.125**		**-0.116**		-0.0158	-0.00315
	rob. t-value	-3.72		-5.79		-7.22		-0.242	-0.428
	rob. p-value	<0.001		<0.001		<0.001		0.809	0.669

Table E.2: Quadratic component tests scenario 2: 5 kilometer

MNL SC2		Crowdedness	Crowdedness^2	Travel cost	Travel cost^2	Travel time	Travel time^2	Walking time	Walking time^2
[1]	**Parameter estimate**	-0.033		**-0.124**		**-0.0713**		**-0.0322**	
	rob. t-value	-1.55		-6.97		-7.21		-2.70	
	rob. p-value	0.121		<0.001		<0.001		<0.001	
[2]	**Parameter estimate**	0.300	-0.0573	**-0.117**		**-0.0619**		**-0.0369**	
	rob. t-value	1.54	-1.72	-6.37		-5.40		-3.04	
	rob. p-value	0.124	0.0856	<0.001		<0.001		0.002	
[3]	**Parameter estimate**	-0.0226		**-0.317**	**0.0212**	**-0.0471**		**-0.0331**	
	rob. t-value	-41.06		-5.27	3.35	-3.83		-2.76	
	rob. p-value	0.291		<0.001	<0.001	<0.001		0.006	
[4]	**Parameter estimate**	**-0.0474**		**-0.0827**		**0.677**	**-0.0214**	**-0.0248**	
	rob. t-value	-2.20		-4.33		5.74	-6.37	-1.98	
	rob. p-value	0.0281		<0.001		<0.001	<0.001	0.0474	
[5]	**Parameter estimate**	-0.0322		**-0.123**		**-0.0748**		0.0191	-0.00569
	rob. t-value	-1.51		-6.50		-7.29		0.398	-1.11
	rob. p-value	0.131		<0.001		<0.001		0.691	0.269
[6]	**Parameter estimate**	-0.0395		**-0.202**	0.0127	**0.64**	**-0.0199**	**-0.0263**	
	rob. t-value	-1.8		-3.09	1.91	5.3	-5.72	-2.1	
	rob. p-value	0.0726		0.002	0.056	<0.001	<0.001	0.036	

Table E.3: Dummy linearity test scenario 1: 2.5 kilometer

MNL SC1		Crowdedness 1	Crowdedness 2	Travel cost 1	Travel cost 2	Travel time 1	Travel time 2	Walking time 1	Walking time 2
[7]	Parameter estimate	-0.181	**-0.361**	**-0.125**		**-0.117**		**-0.0436**	
	rob. t-value	-1.47	-3.51	-5.63		-7.21		-3.16	
	rob. p-value	0.142	<0.001	<0.001		<0.001		0.002	
[8]	Parameter estimate	**-0.083**		-0.175	**-0.369**	**-1.04**		**-0.0421**	
	rob. t-value	-3.22		-1.96	-5.38	-6.09		-2.93	
	rob. p-value	0.001		0.050	<0.001	<0.001		0.003	
[9]	Parameter estimate	**-0.0996**		**-0.132**		**-0.353**	**-0.484**	**-0.0275**	
	rob. t-value	-3.87		-6.04		-3.53	-4.36	-2.09	
	rob. p-value	<0.001		<0.001		<0.001	<0.001	0.037	
[10]	Parameter estimate	**-0.0875**		**-0.136**		**-0.121**		0.038	**-0.26**
	rob. t-value	-3.57		-6.07		-7.32		0.38	-3.98
	rob. p-value	<0.001		<0.001		<0.001		0.704	<0.001

Table E.4: Dummy linearity test scenario 2: 5 kilometer

MNL SC2		Crowdedness 1	Crowdedness 2	Travel cost 1	Travel cost 2	Travel time 1	Travel time 2	Walking time 1	Walking time 2
[7]	Parameter estimate	0.142	**-0.174**	**-0.117**		**-0.0619**		**-0.0369**	
	rob. t-value	1.10	-1.97	-6.37		-5.40		-3.04	
	rob. p-value	0.270	0.049	<0.001		<0.001		0.002	
[8]	Parameter estimate	-0.036		-0.0419	**-0.492**	**-0.057**		**-0.0376**	
	rob. t-value	-1.65		-0.443	-7.69	-5.44		-3.17	
	rob. p-value	0.099		0.657	<0.001	<0.001		0.002	
[9]	Parameter estimate	-0.0238		**-0.129**		**-0.233**	**-0.533**	**-0.0298**	
	rob. t-value	-1.09		-7.14		-3.16	-6.20	-2.33	
	rob. p-value	0.275		<0.001		0.002	<0.001	0.020	
[10]	Parameter estimate	-0.0327		**-0.136**		**-0.0703**		0.0305	**-0.19**
	rob. t-value	-1.54		-6.87		-6.96		0.299	-3.10
	rob. p-value	0.124		<0.001		<0.001		0.765	0.02

Table E.5: LRS test quadratic and dummy components both scenarios, in green significant LRS value at p=0.01 level

			Quadratic component	
	#parameters	LRS test	2.5 kilometer	5 kilometer
[1] - [2]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [2]	-2089.868	-2393.893
		LRS	0.000	2.940
[1] - [3]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [3]	-2089.789	-2389.930
		LRS	0.158	**10.866**
[1] - [4]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [4]	-2084.158	-2375.950
		LRS	**11.420**	**38.826**
[1] - [5]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [5]	-2089.773	-2394.777
		LRS	0.190	1.172
[3] - [6]	15	Final log-likelihood [3]	N/A	-2389.930
	16	Final log-likelihood [6]	N/A	-2374.134
		LRS	N/A	**31.592**
[4] - [6]	15	Final log-likelihood [4]	N/A	-2375.950
	16	Final log-likelihood [6]	N/A	-2374.134
		LRS	N/A	3.632

			Dummy variable	
	#parameters	LRS test	2.5 kilometer	5 kilometer
[1] - [7]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [7]	-2089.868	-2393.893
		LRS	0.000	2.940
[1] - [8]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [8]	-2091.731	-2386.558
		LRS	-3.726	**17.610**
[1] - [9]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [9]	-2091.535	-2398.052
		LRS	-3.334	-5.378
[1] - [10]	14	Final log-likelihood [1]	-2089.868	-2395.363
	15	Final log-likelihood [10]	-2087.393	-2393.555
		LRS	4.950	3.616

E.2 Final model determination

From the linearity test, the quadratic travel time component will be considered in the final model determination. The final model is determined by a couple of steps, while keeping in mind the maximum likelihood criterion, and while testing with the Likelihood Ratio Statistic (LRS) if models with more parameters have a significantly better final log-likelihood.

1. All parameters generic
2. All parameters generic, with a generic quadratic travel time component included
3. All parameters generic, specific crowdedness parameter on bicycle and car,
   with a generic quadratic travel time component included
4. All parameters generic, specific travel cost parameter on all alternatives,
   with a generic quadratic travel time component included
5. All parameters generic, specific travel time parameter on all alternatives,
   with a generic quadratic travel time component included
6. All parameters generic, specific travel time and specific quadratic travel time parameter on all alternatives
7. All parameters generic, specific walking time parameter on all alternatives,
   with a generic quadratic travel time component included
8. Without generic quadratic travel time component
   (a) All parameters generic, specific crowdedness parameter on bicycle and car
   (b) All parameters generic, specific travel cost parameter on all alternatives
   (c) All parameters generic, specific travel time parameter on all alternatives
   (d) All parameters generic, specific walking time parameter on all alternatives
9. Combined model of significant values from models without quadratic travel time component (8a to 8d)
10. Testing for combined model
    (a) Significant parameters on all alternatives (with previously found significant parameters)
    (b) Keeping significant parameters from step 10a, while turning the insignificant parameters
    into generic parameters again

For scenario 2.5 kilometer, the significant values were travel cost for shared bicycle and car, and walking time for alternative shared bicycle. It is remarkable that with specific travel time, both the linear and quadratic component, are insignificant in all cases. In case of specific travel costs [4] and specific walking time [7[, respectively both the linear and quadratic travel time are insignificant, and the quadratic travel time parameter is not significant.

In scenario 5 kilometer, other significant values were found. Starting with the crowdedness parameter for bicycle and car, which is significant for car. In the specific travel cost case, travel costs are significant for all but public transport. Like in scenario 2.5 kilometer, the linear and quadratic component for travel time are insignificant in the specific cases. And, like scenario 2.5 as well, the walking time for shared bicycle is significant.

Given the results from model [2] to [7], model [8] to [11] will be the same model as [3], [4], [5], and [7] without the quadratic travel time component. The Likelihood Ratio Statistic is used to compare the same models with and without the quadratic travel time component in Table E.6. From the LRS analysis, appears that for the specific travel time and walking time the model without the quadratic travel time parameter fits better than the model with the quadratic travel time component. In scenario 2.5 kilometer, the model without the quadratic travel time component is also better than the model with the quadratic component.

Where:
[1] = MNL model with all generic parameters
[2] = MNL model with all generic parameters,
quadratic parameter component travel time
[3] = MNL model with all generic parameters, specific parameter crowdedness,
with quadratic parameter component travel time
[4] = MNL model with all generic parameters, specific parameter travel cost,
with quadratic parameter component travel time
[5] = MNL model with all generic parameters, specific parameter travel time,
with quadratic parameter component travel time
[6] = MNL model with all generic parameters, specific parameter travel time and specific parameter quadratic travel time
[7] = MNL model with all generic parameters, specific parameter walking time,
with quadratic parameter component travel time
[8] = MNL model with all generic parameters, specific parameter crowdedness,
without quadratic parameter component travel time
[9] = MNL model with all generic parameters, specific parameter travel cost,
without quadratic parameter component travel time

[10] = MNL model with all generic parameters, specific parameter travel time,
without quadratic parameter component travel time
[11] = MNL model with all generic parameters, specific parameter walking time,
without quadratic parameter component travel time
[12] = MNL model with all significant specific parameters from [8] to [11] (scenario 1: 2.5 kilometer)
[13] = MNL model with all significant specific parameters from [12] (scenario 1: 2.5 kilometer)
[14] = MNL model with all significant specific parameters from [8] to [11] (scenario 2: 5 kilometer)
[15] = MNL model with all significant specific parameters from [14] (scenario 2: 5 kilometer)
[16] = MNL model with all significant specific parameters from [15] (scenario 2: 5 kilometer)

Table E.6: LRS test specific models [1] to [16], in green significant LRS value, * at p=0.01 level, and ** at p=0.05 level

LRS test	#par	LRS test	2.5 kilometer	5 kilometer
[1] - [2]	14	**Final log-likelihood [1]**	-2089.868	-2395.363
	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	df = 1	**LRS**	**11.420***	**38.826***
[2] - [3]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	16	**Final log-likelihood [3]**	-2084.133	-2372.806
	df = 1	**LRS**	0.050	**6.288***
[2] - [4]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	18	**Final log-likelihood [4]**	-2076.075	-2362.303
	df = 3	**LRS**	**16.166***	**27.294***
[2] - [5]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	18	**Final log-likelihood [5]**	-2074.646	-2364.614
	df = 3	**LRS**	**19.024***	**22.672***
[2] - [6]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	21	**Final log-likelihood [6]**	-2073.489	-2362.204
	df = 6	**LRS**	**21.338***	**27.492***
[2] - [7]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	18	**Final log-likelihood [7]**	-2075.636	-2361.148
	df = 3	**LRS**	**17.044***	**29.604***
[3]- [8]	15	**Final log-likelihood [8]**	-2089.669	-2395.217
	16	**Final log-likelihood [3]**	-2084.133	-2372.806
	df = 1	**LRS**	**11.072***	**44.822***
[4]- [9]	17	**Final log-likelihood [9]**	-2077.089	-2364.747
	18	**Final log-likelihood [4]**	-2076.075	-2362.303
	df = 1	**LRS**	2.028	**4.888****
[5]- [10]	17	**Final log-likelihood [10]**	-2075.032	-2364.971
	18	**Final log-likelihood [5]**	-2074.646	-2364.614
	df = 1	**LRS**	0.772	0.714
[7]- [11]	17	**Final log-likelihood [11]**	-2076.685	-2362.601
	18	**Final log-likelihood [7]**	-2075.636	-2361.148
	df = 1	**LRS**	2.098	2.906
[2] - [8]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	15	**Final log-likelihood [8]**	-2089.669	-2395.217
	df = 0	**LRS**	N/A	N/A
[2] - [9]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	17	**Final log-likelihood [9]**	-2077.089	-2364.747
	df = 2	**LRS**	**14.138***	**22.406***
[2] - [10]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	17	**Final log-likelihood [10]**	-2075.032	-2364.971
	df = 2	**LRS**	**18.252***	**21.958***
[2] - [11]	15	**Final log-likelihood [2]**	-2084.158	-2375.950
	17	**Final log-likelihood [11]**	-2076.685	-2362.601
	df = 2	**LRS**	**14.946***	**26.698***

LRS test	#par	LRS test	2.5 kilometer	5 kilometer
[1] - [13]	14	**Final log-likelihood [1]**	-2089.868	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 5	**LRS**	**29.046***	
[2] - [13]	15	**Final log-likelihood [2]**	-2084.158	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 4	**LRS**	**17.986***	
[1] - [16]	14	**Final log-likelihood [1]**	N/A	-2395.363
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 4	**LRS**		**68.72***
[2] - [16]	15	**Final log-likelihood [2]**	N/A	-2375.950
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 3	**LRS**		**29.894***
[8] - [13]	15	**Final log-likelihood [8]**	-2089.669	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 4	**LRS**	**29.008***	
[9] - [13]	17	**Final log-likelihood [9]**	-2077.089	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 2	**LRS**	3.848	
[10] - [13]	17	**Final log-likelihood [10]**	-2075.032	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 2	**LRS**	-0.266	
[11] - [13]	17	**Final log-likelihood [11]**	-2076.685	N/A
	19	**Final log-likelihood [13]**	-2075.165	N/A
	df = 2	**LRS**	3.04	
[8] - [16]	15	**Final log-likelihood [8]**	N/A	-2395.217
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 3	**LRS**		**68.428***
[9] - [16]	17	**Final log-likelihood [9]**	N/A	-2364.747
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 1	**LRS**		**7.488***
[10] - [16]	17	**Final log-likelihood [10]**	N/A	-2364.971
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 1	**LRS**		**7.936***
[11] - [16]	17	**Final log-likelihood [11]**	N/A	-2362.601
	18	**Final log-likelihood [16]**	N/A	-2361.003
	df = 1	**LRS**		3.196

Table E.7: AIC and BIC comparison for scenario 2.5 kilometer and 5 kilometer

Scenario 1: 2.5 kilometer	**AIC**	**BIC**	**Scenario 2: 5 kilometer**	**AIC**	**BIC**
[1]	4207.737	4286.177	**[1]**	4818.725	4897.741
[2]	4198.317	4282.360	**[2]**	4781.900	4866.559
[3]	4200.266	4289.912	**[3]**	4777.611	4867.914
[4]	4188.149	4289.001	**[4]**	4760.606	4862.197
[5]	4185.292	4286.144	**[5]**	4765.227	4866.819
[6]	4188.979	4306.640	**[6]**	4766.407	4884.930
[7]	4187.272	4288.124	**[7]**	4758.295	4859.886
[8]	4209.338	4293.382	**[8]**	4820.434	4905.093
[9]	4188.178	4283.428	**[9]**	4763.494	4859.441
[10]	4184.065	4279.314	**[10]**	4763.943	4859.890
[11]	4187.369	4282.619	**[11]**	4759.202	4855.150
[12]	4190.013	4302.071	**[12]**	N/A	N/A
[13]	4188.330	4294.785	**[13]**	N/A	N/A
[14]	N/A	N/A	**[14]**	4761.635	4874.514
[15]	N/A	N/A	**[15]**	4759.922	4867.158
[16]	N/A	N/A	**[16]**	4758.007	4859.598

Table E.8: Percentage significant parameters in the models, scenario 2.5 kilometer and scenario 5 kilometer

Scenario 1: 2.5 kilometer	# sign. values	**# par**	**% sign.**	**Scenario 2: 5 kilometer**	# sign. values	**# par**	**% sign.**
[1]	6	14	42.9%	**[1]**	6	14	42.9%
[2]	9	15	60.0%	**[2]**	11	15	73.3%
[3]	8	16	50.0%	**[3]**	11	16	68.8%
[4]	5	18	27.8%	**[4]**	8	18	44.4%
[5]	7	18	38.9%	**[5]**	4	18	22.2%
[6]	4	21	19.0%	**[6]**	2	21	9.5%
[7]	6	18	33.3%	**[7]**	5	18	27.8%
[8]	6	15	40.0%	**[8]**	6	15	40.0%
[9]	6	17	35.3%	**[9]**	7	17	41.2%
[10]	7	17	41.2%	**[10]**	8	17	47.1%
[11]	8	17	47.1%	**[11]**	6	17	35.3%
[12]	11	20	55.0%	**[12]**	N/A	N/A	N/A
[13]	11	19	57.9%	**[13]**	N/A	N/A	N/A
[14]	N/A	N/A	N/A	**[14]**	2	20	10.0%
[15]	N/A	N/A	N/A	**[15]**	5	19	26.3%
[16]	N/A	N/A	N/A	**[16]**	7	18	38.9%

Table E.9: Explanation attribute abbreviations from Table E.10 and Table E.11

ASC_A	Alternative specific constant bicycle	**TCD**	Travel costs car
ASC_B	Alternative specific constant shared bicycle	**TT**	Generic travel time parameter
ASC_C	Alternative specific constant public transport	**TTA**	Travel time bicycle
AVB_1	3+ shared bicycles available (dummy)	**TTB**	Travel time shared bicycle
AVB_2	1-2 shared bicycles available (dummy)	**TTC**	Travel time public transport
CR	Generic crowdedness (parking search time) variable	**TTD**	Travel time car
CRA	Crowdedness (parking search time) bicycle	**TTq**	Generic quadratic travel time component
CRD	Crowdedness (parking search time) car	**TTqA**	Quadratic travel time component bicycle
CRC1	In-vehicle crowdedness public transport - not quit/not busy (dummy)	**TTqB**	Quadratic travel time component shared bicycle
CRC2	In-vehicle crowdedness public transport - busy (dummy)	**TTqC**	Quadratic travel time component public transport
FRC	Frequency public transport vehicles	**TTqD**	Quadratic travel time component car
MTB	Mode type shared bicycle - electric shared bicycle (dummy)	**WT**	Generic walking time parameter
MTC	Mode type public transport - tram (dummy)	**WTA**	Walking time bicycle
TC	Generic travel cost parameter	**WTB**	Walking time shared bicycle
TCA	Travel costs bicycle	**WTC**	Walking time public transport
TCB	Travel costs shared bicycle	**WTD**	Walking time car
TCC	Travel costs public transport		

Table E.10: Scenario 1: 2.5 kilometer parameter values

SC1: 2.5 kilometer		ASC_A	ASC_B	ASC_C	AVB_1	AVB_2	CR	CRA	CRD	CRC1	CRC2	FRC	MTB	MTC	TC
[1]	value	1.470	-0.331	0.127	-0.842	-0.224	-0.090			-0.274	-0.235	0.011	0.104	-0.028	-0.125
	rob. std err	0.136	0.204	0.227	0.203	0.167	0.025			0.146	0.144	0.014	0.153	0.116	0.022
	rob. p-value	0.000	0.105	0.577	0.000	0.179	0.000			0.060	0.103	0.407	0.499	0.813	0.000
[2]	value	1.490	-0.362	0.494	-0.813	-0.127	-0.059			-0.401	-0.305	-0.005	0.197	0.009	-0.112
	rob. std err	0.135	0.208	0.262	0.204	0.171	0.027			0.153	0.147	0.015	0.155	0.116	0.022
	rob. p-value	0.000	0.081	0.060	0.000	0.458	0.025			0.009	0.037	0.755	0.205	0.937	0.000
[3]	value	1.450	-0.389	0.473	-0.809	-0.124		-0.055	-0.067	-0.402	-0.307	-0.005	0.199	0.013	-0.112
	rob. std err	0.214	0.244	0.280	0.205	0.172		0.032	0.044	0.153	0.147	0.015	0.155	0.117	0.022
	rob. p-value	0.000	0.111	0.091	0.000	0.471		0.081	0.125	0.009	0.036	0.745	0.201	0.911	0.000
[4]	value	1.390	0.190	0.340	-0.875	-0.296	-0.045			-0.273	-0.184	0.001	0.010	-0.039	
	rob. std err	0.293	0.293	0.322	0.249	0.177	0.031			0.154	0.153	0.016	0.179	0.117	
	rob. p-value	0.000	0.517	0.291	0.000	0.094	0.152			0.076	0.228	0.953	0.954	0.739	
[5]	value	3.500	4.230	0.108	-0.864	-0.381	-0.033			-0.321	-0.337	0.015	-0.073	-0.117	-0.100
	rob. std err	1.350	1.250	0.541	0.208	0.184	0.029			0.160	0.186	0.018	0.177	0.124	0.023
	rob. p-value	0.009	0.001	0.842	0.000	0.038	0.260			0.045	0.070	0.393	0.681	0.344	0.000
[6]	value	3.730	8.300	8.110	-0.899	-0.393	-0.030			-0.348	-0.519	0.037	-0.034	-0.237	-0.107
	rob. std err	4.450	8.160	5.930	0.233	0.245	0.032			0.161	0.224	0.024	0.195	0.150	0.028
	rob. p-value	0.402	0.309	0.171	0.000	0.109	0.358			0.031	0.021	0.121	0.862	0.115	0.000
[7]	value	1.390	1.220	0.487	-0.814	-0.308	-0.049			-0.273	-0.120	0.003	0.049	-0.017	-0.094
	rob. std err	0.207	0.454	0.357	0.211	0.183	0.028			0.153	0.163	0.015	0.167	0.117	0.023
	rob. p-value	0.000	0.007	0.173	0.000	0.093	0.085			0.075	0.464	0.852	0.770	0.888	0.000
[8]	value	1.570	-0.262	0.200	-0.851	-0.227		-0.100	-0.068	-0.278	-0.233	0.011	0.103	-0.036	-0.125
	rob. std err	0.215	0.240	0.259	0.203	0.167		0.029	0.043	0.146	0.144	0.014	0.153	0.117	0.022
	rob. p-value	0.000	0.276	0.440	0.000	0.174		0.001	0.115	0.057	0.106	0.412	0.503	0.758	0.000
[9]	value	1.540	0.314	0.221	-0.793	-0.331	-0.062			-0.221	-0.130	0.006	-0.016	-0.056	
	rob. std err	0.277	0.280	0.310	0.238	0.175	0.029			0.148	0.148	0.016	0.179	0.116	
	rob. p-value	0.000	0.261	0.475	0.001	0.058	0.033			0.136	0.381	0.730	0.930	0.631	
[10]	value	2.420	3.320	0.161	-0.853	-0.334	-0.035			-0.309	-0.265	0.006	-0.010	-0.075	-0.100
	rob. std err	0.751	0.814	0.538	0.209	0.176	0.029			0.159	0.170	0.015	0.161	0.116	0.023
	rob. p-value	0.001	0.000	0.764	0.000	0.058	0.224			0.052	0.117	0.700	0.952	0.518	0.000
[11]	value	1.350	1.350	0.173	-0.802	-0.358	-0.062			-0.211	-0.082	0.010	-0.020	-0.049	-0.098
	rob. std err	0.205	0.434	0.285	0.207	0.178	0.026			0.145	0.161	0.014	0.162	0.116	0.023
	rob. p-value	0.000	0.002	0.543	0.000	0.044	0.018			0.147	0.611	0.499	0.902	0.674	0.000
[12]	value	2.660	-0.160	0.329	-0.860	-0.327		-0.028	-0.058	-0.330	-0.298	0.007	-0.015	-0.069	-0.088
	rob. std err	0.624	0.030	0.332	0.213	0.177		0.034	0.045	0.158	0.168	0.014	0.163	0.118	0.042
	rob. p-value	0.000	0.000	0.321	0.000	0.064		0.417	0.195	0.037	0.077	0.636	0.927	0.556	0.039
[13]	value	2.660	-0.167	0.385	-0.866	-0.328	-0.039			-0.324	-0.284	0.007	-0.014	-0.076	-0.088
	rob. std err	0.626	0.030	0.316	0.213	0.176	0.028			0.158	0.167	0.014	0.163	0.118	0.043
	rob. p-value	0.000	0.000	0.223	0.000	0.063	0.171			0.040	0.089	0.643	0.929	0.517	0.038

SC1: 2.5 kilometer		TCA	TCB	TCC	TCD	TT	TTA	TTB	TTC	TTD	TTq	TTqA	TTqB	TTqC	TTqD	WT	WTA	WTB	WTC	WTD
[1]	value					-0.117										-0.044				
	rob. std err					0.016										0.013				
	rob. p-value					0.000										0.001				
[2]	value					0.516					-0.035					-0.059				
	rob. std err					0.185					0.010					0.014				
	rob. p-value					0.005					0.001					0.000				
[3]	value					0.527					-0.036					-0.060				
	rob. std err					0.191					0.011					0.014				
	rob. p-value					0.006					0.001					0.000				
[4]	value	-0.067	-0.692	-0.103	-0.114	0.240					-0.018					-0.034				
	rob. std err	0.114	0.161	0.117	0.038	0.229					0.013					0.016				
	rob. p-value	0.555	0.000	0.379	0.003	0.295					0.161					0.030				
[5]	value						-0.627	-0.873	-0.370	-0.408	0.024					-0.026				
	rob. std err						0.520	0.501	0.394	0.399	0.025					0.016				
	rob. p-value						0.228	0.081	0.347	0.307	0.353					0.095				
[6]	value						-0.156	-1.250	-1.860	0.194		-0.001	0.044	0.116	-0.013	-0.030				
	rob. std err						0.712	1.510	1.090	0.904		0.036	0.077	0.068	0.056	0.017				
	rob. p-value						0.826	0.407	0.088	0.830		0.969	0.573	0.088	0.824	0.069				
[7]	value					0.267					-0.019						0.000	-0.357	-0.058	-0.042
	rob. std err					0.240					0.013						0.038	0.077	0.032	0.031
	rob. p-value					0.266					0.148						0.998	0.000	0.071	0.169
[8]	value					-0.117										-0.043				
	rob. std err					0.016										0.013				
	rob. p-value					0.000										0.001				
[9]	value	-0.130	-0.781	-0.070	-0.099	-0.080										-0.025				
	rob. std err	0.105	0.146	0.115	0.037	0.019										0.014				
	rob. p-value	0.215	0.000	0.542	0.007	0.000										0.078				
[10]	value						-0.144	-0.413	-0.007	-0.044						-0.033				
	rob. std err						0.042	0.070	0.042	0.053						0.014				
	rob. p-value						0.001	0.000	0.865	0.402						0.021				
[11]	value					-0.080											0.005	-0.381	-0.031	-0.046
	rob. std err					0.018											0.037	0.072	0.027	0.030
	rob. p-value					0.000											0.889	0.000	0.241	0.129
[12]	value		-0.519		-0.106	-0.016	-0.160	0.177								-0.033		-0.409		
	rob. std err		0.086		0.032	0.037	0.043	0.074								0.014		0.082		
	rob. p-value		0.000		0.001	0.666	0.000	0.016								0.020		0.000		
[13]	value		-0.556		-0.106	-0.022	-0.154	0.168								-0.033		-0.378		
	rob. std err		0.086		0.032	0.035	0.042	0.074								0.014		0.082		
	rob. p-value		0.000		0.001	0.543	0.000	0.023								0.022		0.000		

Table E.11: Scenario 2: 5 kilometer parameter values

SC2: 5 kilometer		ASC_A	ASC_B	ASC_C	AVB_1	AVB_2	CR	CRA	CRD	CRC1	CRC2	FRC	MTB	MTC	TC	TCA	TCB	TCC	TCD	TT	TTA	TTB	TTC	TTD	TTq	TTqA	TTqB	TTqC	TTqD	WT	WTA	WTB	WTC	WTD
[1]	value	0.867	-1.220	0.221	0.320	0.335	-0.033			-0.209	-0.191	-0.025	-0.233	0.074	-0.124					-0.071										-0.032				
	rob. std err	0.120	0.210	0.191	0.206	0.197	0.021			0.127	0.127	0.012	0.164	0.105	0.018					0.010										0.012				
	rob. p-value	0.000	0.000	0.246	0.121	0.090	0.121			0.098	0.133	0.043	0.155	0.483	0.000					0.000										0.007				
[2]	value	1.080	-1.290	0.251	0.600	0.610	-0.047			-0.633	-0.152	0.007	-0.484	-0.111	-0.083					0.677					-0.021					-0.025				
	rob. std err	0.128	0.209	0.197	0.210	0.206	0.022			0.146	0.126	0.014	0.176	0.111	0.019					0.118					0.003					0.013				
	rob. p-value	0.000	0.000	0.202	0.004	0.003	0.028			0.000	0.226	0.610	0.006	0.317	0.000					0.000					0.000					0.047				
[3]	value	0.756	-1.460	0.053	0.577	0.616		-0.002	-0.126	-0.705	-0.185	0.012	-0.564	-0.130	-0.075					0.779					-0.024					-0.026				
	rob. std err	0.177	0.216	0.206	0.212	0.206		0.028	0.038	0.149	0.126	0.014	0.181	0.110	0.019					0.127					0.004					0.012				
	rob. p-value	0.000	0.000	0.796	0.006	0.003		0.957	0.001	0.000	0.143	0.399	0.002	0.237	0.000					0.000					0.000					0.033				
[4]	value	1.140	-0.742	0.523	0.601	0.231	-0.017			-0.342	-0.187	-0.007	0.087	0.020		-0.167	-0.991	-0.136	-0.062	0.308					-0.010					-0.018				
	rob. std err	0.202	0.244	0.287	0.222	0.225	0.023			0.156	0.129	0.015	0.213	0.122		0.078	0.186	0.078	0.029	0.157					0.005					0.015				
	rob. p-value	0.000	0.002	0.068	0.007	0.304	0.445			0.028	0.148	0.652	0.685	0.869		0.033	0.000	0.080	0.033	0.050					0.025					0.231				
[5]	value	1.790	4.860	0.915	0.483	0.228	-0.025			-0.398	-0.240	-0.012	0.017	-0.002	-0.081						0.219	-0.068	0.229	0.266	-0.008					-0.010				
	rob. std err	1.860	1.910	0.683	0.227	0.235	0.025			0.165	0.136	0.015	0.210	0.122	0.024						0.385	0.390	0.291	0.304	0.010					0.014				
	rob. p-value	0.335	0.011	0.180	0.034	0.332	0.310			0.016	0.079	0.434	0.935	0.987	0.001						0.571	0.861	0.430	0.381	0.396					0.478				
[6]	value	-2.090	24.400	-10.900	0.495	-0.010	0.004			-0.204	-0.044	0.000	0.298	0.035	-0.077						0.141	-2.520	1.180	-0.357		-0.006	0.053	-0.040	0.012	0.001				
	rob. std err	6.700	13.200	7.540	0.229	0.266	0.033			0.237	0.209	0.016	0.256	0.125	0.024						0.681	1.390	0.713	0.531		0.017	0.035	0.024	0.017	0.018				
	rob. p-value	0.755	0.064	0.150	0.031	0.969	0.911			0.390	0.833	0.987	0.244	0.781	0.002						0.837	0.071	0.098	0.501		0.719	0.132	0.093	0.480	0.937				
[7]	value	0.810	0.764	0.113	0.527	0.010	-0.015			-0.321	-0.227	-0.011	0.260	0.052	-0.096					0.216					-0.008						0.000	-0.538	0.003	-0.031
	rob. std err	0.230	0.481	0.260	0.223	0.255	0.023			0.159	0.131	0.014	0.241	0.121	0.020					0.157					0.005						0.041	0.102	0.022	0.030
	rob. p-value	0.000	0.113	0.665	0.018	0.969	0.503			0.043	0.083	0.431	0.281	0.666	0.000					0.169					0.087						0.999	0.000	0.890	0.307
[8]	value	0.793	-1.250	0.181	0.307	0.328		-0.023	-0.049	-0.213	-0.199	-0.025	-0.238	0.074	-0.124					-0.071										-0.033				
	rob. std err	0.179	0.220	0.203	0.207	0.198		0.028	0.036	0.127	0.128	0.012	0.164	0.105	0.018					0.010										0.012				
	rob. p-value	0.000	0.000	0.372	0.138	0.097		0.395	0.171	0.093	0.121	0.042	0.146	0.480	0.000					0.000										0.006				
[9]	value	1.080	-0.606	0.450	0.465	0.066	-0.009			-0.159	-0.216	-0.023	0.324	0.139		-0.211	-1.210	-0.102	-0.075	-0.041										-0.020				
	rob. std err	0.201	0.243	0.282	0.218	0.225	0.022			0.132	0.128	0.013	0.198	0.108		0.076	0.172	0.076	0.029	0.012										0.014				
	rob. p-value	0.000	0.013	0.110	0.033	0.768	0.671			0.227	0.091	0.081	0.101	0.199		0.005	0.000	0.177	0.009	0.001										0.154				
[10]	value	3.020	6.270	0.831	0.441	0.164	-0.016			-0.377	-0.286	-0.018	0.084	0.010	-0.083						-0.108	-0.402	-0.016	0.010						-0.005				
	rob. std err	1.160	1.160	0.673	0.224	0.230	0.023			0.162	0.126	0.013	0.205	0.122	0.023						0.032	0.056	0.028	0.037						0.013				
	rob. p-value	0.009	0.000	0.217	0.049	0.475	0.469			0.020	0.023	0.177	0.683	0.937	0.000						0.001	0.000	0.555	0.778						0.679				
[11]	value	0.689	1.160	0.049	0.426	-0.159	-0.007			-0.165	-0.255	-0.023	0.484	0.127	-0.108					-0.051											0.004	-0.637	0.009	-0.037
	rob. std err	0.214	0.438	0.256	0.218	0.239	0.022			0.129	0.131	0.013	0.201	0.112	0.019					0.012											0.040	0.087	0.022	0.029
	rob. p-value	0.001	0.008	0.849	0.051	0.507	0.763			0.201	0.052	0.079	0.016	0.256	0.000					0.000											0.929	0.000	0.663	0.204
[14]	value	2.130	4.540	0.530	0.360	-0.134	-0.006			-0.232	-0.226	-0.018	0.409	0.073		-0.168	0.215	-0.125	-0.071	-0.015	-0.074	-0.225								-0.011		-0.503		
	rob. std err	1.140	2.440	0.304	0.262	0.288	0.022			0.175	0.130	0.014	0.256	0.137		0.088	0.469	0.081	0.029	0.030	0.039	0.132								0.017		0.139		
	rob. p-value	0.062	0.063	0.081	0.169	0.642	0.775			0.184	0.082	0.200	0.109	0.594		0.058	0.647	0.121	0.015	0.625	0.053	0.089								0.494		0.000		
[15]	value	2.200	3.360	0.529	0.407	-0.077	-0.006			-0.246	-0.230	-0.018	0.370	0.068	-0.124	-0.162			-0.071	-0.013	-0.077	-0.173								-0.011		-0.404		
	rob. std err	1.130	1.110	0.303	0.240	0.258	0.022			0.172	0.130	0.014	0.243	0.136	0.081	0.088			0.029	0.030	0.038	0.074								0.017		0.132		
	rob. p-value	0.052	0.002	0.081	0.090	0.766	0.775			0.154	0.076	0.212	0.128	0.621	0.124	0.064			0.015	0.656	0.043	0.019								0.517		0.002		
[16]	value	2.360	3.370	0.559	0.435	-0.058	-0.005			-0.259	-0.237	-0.016	0.349	0.049	-0.142				-0.072	-0.009	-0.083	-0.171								-0.008		-0.398		
	rob. std err	0.979	1.110	0.287	0.222	0.250	0.022			0.167	0.128	0.013	0.231	0.120	0.054				0.029	0.026	0.031	0.074								0.013		0.130		
	rob. p-value	0.016	0.002	0.051	0.050	0.815	0.810			0.121	0.064	0.221	0.132	0.685	0.008				0.013	0.724	0.008	0.021								0.549		0.002		

Table E.12: Descriptives final models MNL, ML panel, ML panel + EC bicycle, and ML panel + EC bicycle + interaction

	MNL model		**ML panel**		**ML panel + EC bicycle**		**ML panel + EC bicycle + interaction**	
	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer	2.5 kilometer	5 kilometer
Init. log likelihood	-2778.134	-2894.538	-2778.134	-2894.538	-2778.134	-2894.538	-2778.134	-2894.538
Final log likelihood	-2075.165	-2361.003	-1850.664	-1912.084	-1491.257	-1544.417	-1252.980	-1365.152
Rho square	0.253	0.184	0.334	0.339	0.463	0.466	0.549	0.520
Rho square bar	0.246	0.178	0.327	0.333	0.456	0.460	0.527	0.509
AIC	4188.330	4758.007	3741.328	3862.168	3024.513	3128.834	2625.960	2794.303
BIC	4294.785	4859.598	3803.688	3922.190	3089.991	3192.015	2813.039	2894.836
Number of draws	N/A	N/A	200	200	200	200	100	100

Table E.13: Statistical tests ML panel to ML panel error component models, scenario 2.5 kilometer

Model 1	**Model 2**	**LL**		**AIC**		**BIC**		**LRS**	**Ben-Akiva and Swait**
		Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**		
ML panel	*ML panel + EC own mode*	-1850.664	-1620.768	3741.328	3283.536	3803.688	3349.014	**459.792**	N/A
ML panel	*ML panel + EC public transport*	-1850.664	-1620.768	3741.328	3283.536	3803.688	3349.014	**459.792**	N/A
ML panel	*ML panel + EC bicycle*	-1850.664	-1491.257	3741.328	3024.513	3803.688	3089.991	**718.814**	N/A
ML panel + EC own mode	*ML panel + EC public transport*	-1620.768	-1620.768	3283.536	3283.536	3349.014	3349.014	N/A	N/A
ML panel + EC own mode	*ML panel + EC bicycle*	-1620.768	-1491.257	3283.536	3024.513	3349.014	3089.991	N/A	**<0.001**
ML panel + EC public transport	*ML panel + EC bicycle*	-1620.768	-1491.257	3283.536	3024.513	3349.014	3089.991	N/A	**<0.001**

Table E.14: Statistical tests ML panel to ML panel error component models, scenario 5 kilometer

Model 1	**Model 2**	**LL**		**AIC**		**BIC**		**LRS**	**Ben-Akiva and Swait**
		Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**		
ML panel	*ML panel + EC own mode*	-1912.084	-1855.760	3862.168	3751.520	3922.190	3814.701	**112.648**	N/A
ML panel	*ML panel + EC public transport*	-1912.084	-1855.760	3862.168	3751.520	3922.190	3814.701	**112.648**	N/A
ML panel	*ML panel + EC bicycle*	-1912.084	-1544.417	3862.168	3128.834	3922.190	3192.015	**735.334**	N/A
ML panel + EC own mode	*ML panel + EC public transport*	-1855.760	-1855.76	3751.520	3751.520	3814.701	3814.701	N/A	N/A
ML panel + EC own mode	*ML panel + EC bicycle*	-1855.760	-1544.417	3751.520	3128.834	3814.701	3192.015	N/A	**<0.001**
ML panel + EC public transport	*ML panel + EC bicycle*	-1855.760	-1544.417	3751.52	3128.834	3814.701	3192.015	N/A	**<0.001**

E.3 Final models

E.3.1 Final MNL model scenario 1: 2.5 kilometer

Utility functions of final MNL model scenario 1: 2.5 kilometer are shown in Equation E.1 to Equation E.4. The estimated model parameters are presented in Table E.15.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A \quad \text{(E.1)}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC_B} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B \quad \text{(E.2)}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C \quad \text{(E.3)}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \quad \text{(E.4)}$$

Table E.15: Scenario 1: MNL results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	2.660	0.627	4.240	0.000	0.626	4.240	**0.000***
Shared bicycle	-0.167	0.031	-5.470	0.000	0.030	-5.530	**0.000***
Public transport	0.385	0.315	1.220	0.221	0.316	1.220	0.223
Generic							
Crowdedness	-0.039	0.028	-1.370	0.170	0.028	-1.370	0.171
Travel costs	-0.088	0.042	-2.080	0.038	0.043	-2.080	**0.038****
Travel time	-0.022	0.036	-0.601	0.548	0.035	-0.608	0.543
Walking time	-0.033	0.014	-2.270	0.023	0.014	-2.290	**0.022****
Bicycle							
Travel time bicycle	-0.154	0.042	-3.700	0.000	0.042	-3.670	**0.000***
Shared bicycle							
1-2 bicycles available	-0.328	0.177	-1.850	0.064	0.176	-1.860	**0.063*****
3+ bicycles available	-0.866	0.212	-4.090	0.000	0.213	-4.070	**0.000***
Mode type (electric SB)	-0.014	0.165	-0.087	0.930	0.163	-0.089	0.929
Travel costs shared bicycle	-0.556	0.087	-6.420	0.000	0.086	-6.500	**0.000***
Travel time shared bicycle	0.168	0.074	2.260	0.024	0.074	2.280	**0.023****
Walking time shared bicycle	-0.378	0.083	-4.560	0.000	0.082	-4.630	**0.000***
Public transport							
Not quiet/not busy	-0.324	0.157	-2.070	0.039	0.158	-2.050	**0.040****
Busy	-0.284	0.167	-1.710	0.088	0.167	-1.700	**0.089*****
Frequency PT	0.007	0.014	0.466	0.641	0.014	0.464	0.643
Mode type (tram)	-0.076	0.118	-0.647	0.518	0.118	-0.647	0.517
Car							
Parking costs car	-0.106	0.032	-3.340	0.001	0.032	-3.320	**0.001***

E.3.2 Final MNL model scenario 2: 5 kilometer

Utility functions of final MNL model scenario 2: 5 kilometer are shown in Equation E.5 to Equation E.8. The estimated model parameters are presented in Table E.16.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A \quad \text{(E.5)}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B \quad \text{(E.6)}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C \quad \text{(E.7)}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \quad \text{(E.8)}$$

Table E.16: Scenario 2: MNL results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	2.360	0.989	2.380	0.017	0.979	2.410	**0.016****
Shared bicycle	3.370	1.380	2.430	0.015	1.110	3.030	**0.002***
Public transport	0.559	0.282	1.980	0.048	0.287	1.950	**0.051*****
Generic							
Crowdedness	-0.005	0.022	-0.241	0.809	0.022	-0.240	0.810
Travel costs	-0.142	0.053	-2.660	0.008	0.054	-2.640	**0.008***
Travel time	-0.009	0.026	-0.354	0.723	0.026	-0.353	0.724
Walking time	-0.008	0.013	-0.598	0.550	0.013	-0.600	0.549
Bicycle							
Travel time bicycle	-0.083	0.032	-2.610	0.009	0.031	-2.650	**0.008***
Shared bicycle							
1-2 bicycles available	-0.058	0.250	-0.233	0.815	0.250	-0.233	0.815
3+ bicycles available	0.435	0.227	1.910	0.056	0.222	1.960	**0.050****
Mode type (electric SB)	0.349	0.236	1.480	0.140	0.231	1.510	0.132
Travel time shared bicycle	-0.171	0.098	-1.730	0.083	0.074	-2.320	**0.021****
Walking time shared bicycle	-0.398	0.161	-2.480	0.013	0.130	-3.070	**0.002***
Public transport							
Not quiet/not busy	-0.259	0.167	-1.550	0.122	0.167	-1.550	0.121
Busy	-0.237	0.128	-1.840	0.065	0.128	-1.850	**0.064*****
Frequency PT	-0.016	0.013	-1.240	0.217	0.013	-1.220	0.221
Mode type (tram)	0.049	0.119	0.411	0.681	0.120	0.406	0.685
Car							
Parking costs car	-0.072	0.029	-2.510	0.012	0.029	-2.490	**0.013****

E.3.3 Final panel model scenario 1: 2.5 kilometer

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{panel} \tag{E.9}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC_B} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{panel} \tag{E.10}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} \tag{E.11}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \tag{E.12}$$

Table E.17: Scenario 1: ML panel results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	4,810	0,862	5,580	0,000	0,796	6,040	**0,000***
Shared bicycle	0,219	0,042	5,200	0,000	0,049	4,440	**0,000***
Public transport	2,490	0,623	4,000	0,000	0,657	3,800	**0,000***
Generic							
Crowdedness	-0,059	0,034	-1,720	0,085	0,029	-2,020	**0,044****
Travel costs	-0,076	0,043	-1,770	0,076	0,029	-2,620	**0,009***
Travel time	-0,051	0,041	-1,240	0,215	0,037	-1,400	0,161
Walking time	-0,039	0,016	-2,430	0,015	0,014	-2,910	**0,004***
Bicycle							
Travel time bicycle	-0,179	0,045	-3,980	0,000	0,034	-5,190	**0,000***
Shared bicycle							
1-2 bicycles available	-0,301	0,178	-1,690	0,092	0,140	-2,150	**0,032****
3+ bicycles available	-0,912	0,214	-4,260	0,000	0,170	-5,350	**0,000***
Mode type (electric SB)	-0,020	0,166	-0,118	0,906	0,113	-0,174	0,862
Travel costs shared bicycle	-0,667	0,113	-5,920	0,000	0,132	-5,070	**0,000***
Travel time shared bicycle	0,401	0,116	3,460	0,001	0,136	2,950	**0,003***
Walking time shared bicycle	-0,530	0,100	-5,280	0,000	0,117	-4,540	**0,000***
Public transport							
Not quiet/not busy	-0,379	0,160	-2,370	0,018	0,093	-4,070	**0,000***
Busy	-0,356	0,172	-2,070	0,039	0,116	-3,080	**0,002***
Frequency PT	0,009	0,014	0,657	0,511	0,010	0,971	0,331
Mode type (tram)	-0,087	0,119	-0,727	0,468	0,067	-1,290	0,198
Car							
Parking costs car	-0,221	0,046	-4,820	0,000	0,057	-3,870	**0,000***
Sigmas							
Bicycle	3,650	0,476	7,670	0,000	0,562	6,490	**0,000***

E.3.4 Final panel model scenario 2: 5 kilometer

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{panel} \tag{E.13}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{panel} \tag{E.14}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} \tag{E.15}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \tag{E.16}$$

Table E.18: Scenario 2: ML panel results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	5,460	1,360	4,030	0,000	1,280	4,280	**0,000***
Shared bicycle	5,580	1,550	3,610	0,000	1,490	3,740	**0,000***
Public transport	2,880	0,651	4,430	0,000	0,587	4,900	**0,000***
Generic							
Crowdedness	-0,011	0,028	-0,375	0,708	0,020	-0,535	0,593
Travel costs	-0,118	0,058	-2,020	0,043	0,044	-2,720	**0,007***
Travel time	-0,005	0,034	-0,145	0,885	0,029	-0,169	0,866
Walking time	-0,008	0,016	-0,469	0,639	0,013	-0,615	0,538
Bicycle							
Travel time bicycle	-0,121	0,039	-3,160	0,002	0,036	-3,420	**0,001***
Shared bicycle							
1-2 bicycles available	0,093	0,261	0,358	0,721	0,188	0,496	0,620
3+ bicycles available	0,549	0,233	2,350	0,019	0,186	2,950	**0,003***
Mode type (electric SB)	0,205	0,249	0,825	0,409	0,158	1,300	0,192
Travel time shared bicycle	-0,176	0,099	-1,780	0,075	0,074	-2,400	**0,017****
Walking time shared bicycle	-0,358	0,162	-2,210	0,027	0,112	-3,190	**0,001***
Public transport							
Not quiet/not busy	-0,403	0,187	-2,160	0,031	0,167	-2,410	**0,016****
Busy	-0,277	0,135	-2,050	0,041	0,104	-2,670	**0,008***
Frequency PT	-0,016	0,014	-1,180	0,240	0,010	-1,570	0,117
Mode type (tram)	-0,031	0,127	-0,243	0,808	0,093	-0,333	0,739
Car							
Parking costs car	-0,216	0,047	-4,590	0,000	0,060	-3,590	**0,000***
Sigmas							
Bicycle	4,640	0,561	8,270	0,000	0,596	7,790	**0,000***

E.3.5 Final panel model with error component bicycle scenario 1: 2.5 kilometer

Utility functions of final panel model scenario 1: 2.5 kilometer are shown in Equation E.17 to Equation E.20. The estimated model parameters are presented in Table E.19.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{bicycle} + \sigma_{panel} \tag{E.17}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC_B} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{bicycle} + \sigma_{panel} \tag{E.18}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} \tag{E.19}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \tag{E.20}$$

Table E.19: Scenario 1: ML panel with error component bicycle results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	3.510	0.851	4.130	0.000	0.712	4.930	**0.000***
Shared bicycle	0.047	0.039	1.220	0.223	0.044	1.070	0.283
Public transport	-1.490	0.526	-2.840	0.005	0.544	-2.740	**0.006***
Generic							
Crowdedness	-0.029	0.034	-0.848	0.397	0.028	-1.030	0.303
Travel costs	-0.244	0.069	-3.510	0.000	0.075	-3.240	**0.001***
Travel time	-0.069	0.045	-1.520	0.128	0.042	-1.630	0.102
Walking time	-0.035	0.019	-1.790	0.074	0.020	-1.740	**0.083*****
Bicycle							
Travel time bicycle	-0.177	0.050	-3.530	0.000	0.040	-4.460	**0.000***
Shared bicycle							
1-2 bicycles available	-0.293	0.184	-1.600	0.111	0.150	-1.950	**0.051*****
3+ bicycles available	-0.677	0.229	-2.950	0.003	0.192	-3.530	**0.000***
Mode type (electric SB)	0.123	0.171	0.720	0.472	0.125	0.984	0.325
Travel costs shared bicycle	-0.570	0.106	-5.390	0.000	0.122	-4.660	**0.000***
Travel time shared bicycle	0.175	0.101	1.730	0.084	0.111	1.580	0.115
Walking time shared bicycle	-0.370	0.098	-3.790	0.000	0.115	-3.210	**0.001***
Public transport							
Not quiet/not busy	-0.268	0.236	-1.140	0.256	0.205	-1.310	0.192
Busy	-0.162	0.244	-0.664	0.507	0.228	-0.712	0.477
Frequency PT	0.021	0.022	0.938	0.348	0.023	0.912	0.362
Mode type (tram)	-0.071	0.180	-0.393	0.694	0.151	-0.470	0.639
Car							
Parking costs car	-0.112	0.035	-3.250	0.001	0.035	-3.220	**0.001***
Sigmas							
Bicycle	6.330	0.688	9.200	0.000	0.950	6.660	**0.000***
Panel	-2.270	0.367	-6.180	0.000	0.558	-4.070	**0.000***

E.3.6 Final panel model with error component bicycle scenario 2: 5 kilometer

Utility functions of final panel model scenario 2: 5 kilometer are shown in Equation E.21 to Equation E.24. The estimated model parameters are presented in Table E.20.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{bicycle} + \sigma_{panel} \tag{E.21}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{bicycle} + \sigma_{panel} \tag{E.22}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} \tag{E.23}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D \tag{E.24}$$

Table E.20: Scenario 2: ML panel with error component bicycle results

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	4.260	1.610	2.650	0.008	1.510	2.820	**0.005***
Shared bicycle	7.380	1.520	4.850	0.000	1.560	4.740	**0.000***
Public transport	2.840	0.485	5.860	0.000	0.515	5.520	**0.000***
Generic							
Crowdedness	0.003	0.034	0.085	0.932	0.029	0.101	0.920
Travel costs	-0.209	0.071	-2.930	0.003	0.059	-3.570	**0.000***
Travel time	-0.006	0.035	-0.182	0.856	0.030	-0.210	0.833
Walking time	-0.010	0.021	-0.490	0.624	0.018	-0.575	0.566
Bicycle							
Travel time bicycle	-0.223	0.049	-4.530	0.000	0.059	-3.800	**0.000***
Shared bicycle							
1-2 bicycles available	0.382	0.287	1.330	0.183	0.247	1.540	0.123
3+ bicycles available	0.647	0.249	2.600	0.009	0.219	2.950	**0.003***
Mode type (electric SB)	-0.061	0.275	-0.222	0.825	0.224	-0.272	0.786
Travel time shared bicycle	-0.151	0.102	-1.480	0.138	0.078	-1.950	**0.051*****
Walking time shared bicycle	-0.219	0.172	-1.270	0.204	0.127	-1.720	**0.086*****
Public transport							
Not quiet/not busy	-0.599	0.221	-2.710	0.007	0.229	-2.610	**0.009***
Busy	-0.368	0.159	-2.310	0.021	0.140	-2.640	**0.008***
Frequency PT	-0.025	0.018	-1.390	0.164	0.016	-1.520	0.128
Mode type (tram)	0.055	0.150	0.369	0.712	0.120	0.460	0.646
Car							
Parking costs car	-0.167	0.043	-3.880	0.000	0.051	-3.260	**0.001***
Sigmas							
Bicycle	-4.530	0.466	-9.720	0.000	0.666	-6.800	**0.000***
Panel	-2.890	0.366	-7.880	0.000	0.664	-4.350	**0.000***

E.4 Interaction variables

Table E.21: Scenario 1: 2.5 kilometer correlations between interaction variables

	Gender			Age			Education			Household type			Cars in HH			Bicycles in HH			Car type (2cat)			FR bicycle			FR car city			FR car total		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	x	x	x	15.639	2	0.000	0.528	2	0.768	1.87	4	0.760	1.751	3	0.626	2.846	5	0.724	0.277	1	0.599	5.813	2	0.055	1.327	2	0.515	0.327	2	0.849
Age	15.639	2	0.000	x	x	x	9.606	4	0.048	19.217	8	0.014	8.164	6	0.226	19.126	10	0.039	5.468	2	0.065	4.969	4	0.290	9.322	4	0.054	2.351	4	0.671
Education							x	x	x	8.949	8	0.347	15.870	6	0.014	17.949	10	0.056	4.590	2	0.101	3.336	4	0.503	1.417	4	0.841	6.382	4	0.172
Household type										x	x	x	20.476	12	0.059	48.224	20	0.000	5.847	4	0.211	9.383	8	0.311	11.067	8	0.198	10.993	8	0.202
Cars in household													x	x	x	30.410	15	0.011	5.232	3	0.156	3.678	6	0.720	10.364	6	0.110	20.269	6	0.002
Bicycles in household																x	x	x	0.510	5	0.992	16.567	10	0.085	13.216	10	0.212	6.818	10	0.742
Car type (2cat)																			x	x	x	1.019	2	0.601	0.587	2	0.746	0.540	2	0.763
Frequency bicycle																						x	x	x	8.065	4	0.089	2.323	4	0.677
Frequency car city																									x	x	x	21.306	4	0.000
Frequency car total																												x	x	x
Frequency shared bicycle																														
Frequency bus																														
Frequency tram																														
Frequency city centre																														
Attitude car (3cat)																														
Attitude bicycle (3cat)																														
Attitude bus (3cat)																														
Attitude tram (3cat)																														
Attitude shared bicycle (3cat)																														

	FR shared bicycle			FR bus			FR tram			FR city centre			Att car			Att bicycle			Att bus			Att tram			Att shared bicycle		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	0.880	2	0.644	3.445	2	0.179	6.597	2	0.037	1.106	2	0.575	1.304	2	0.521	0.086	2	0.958	0.01	2	0.995	0.097	2	0.953	8.696	2	0.013
Age	8.501	4	0.075	6.308	4	0.177	12.913	4	0.012	11.933	4	0.018	4.286	4	0.369	0.882	4	0.927	5.504	4	0.239	5.905	4	0.206	3.372	4	0.498
Education	3.750	4	0.441	3.169	4	0.530	2.735	4	0.603	4.342	4	0.362	1.779	4	0.776	7.890	4	0.096	9.520	4	0.049	2.940	4	0.568	2.965	4	0.564
Household type	19.179	8	0.014	15.713	8	0.047	11.007	8	0.201	3.842	8	0.871	4.825	8	0.776	9.825	8	0.278	28.888	8	0.000	14.877	8	0.062	14.080	8	0.080
Cars in household	3.638	6	0.726	5.840	6	0.441	9.192	6	0.163	3.989	6	0.678	10.875	6	0.092	4.728	6	0.579	9.101	6	0.168	7.376	6	0.287	7.048	6	0.316
Bicycles in household	11.016	10	0.356	7.750	10	0.653	15.303	10	0.121	11.101	10	0.350	9.790	10	0.459	9.066	10	0.526	21.313	10	0.019	7.930	10	0.636	12.489	10	0.254
Car type (2cat)	5.478	2	0.065	2.098	2	0.350	2.855	2	0.240	2.214	2	0.331	4.275	2	0.118	7.467	2	0.024	1.197	2	0.550	0.745	2	0.689	1.477	2	0.478
Frequency bicycle	10.518	4	0.033	6.225	4	0.183	2.223	4	0.695	5.465	4	0.243	1.847	4	0.764	38.156	4	0.000	6.199	4	0.185	5.363	4	0.252	6.750	4	0.150
Frequency car city	2.404	4	0.662	7.801	4	0.099	3.986	4	0.408	6.025	4	0.197	2.928	4	0.570	0.978	4	0.913	11.761	4	0.019	9.244	4	0.055	11.528	4	0.021
Frequency car total	0.973	4	0.914	3.349	4	0.501	6.109	4	0.191	10.308	4	0.036	9.852	4	0.043	3.570	4	0.467	11.082	4	0.026	9.827	4	0.043	11.361	4	0.023
Frequency shared bicycle	x	x	x	12.878	4	0.012	7.435	4	0.115	7.962	4	0.093	3.675	4	0.452	13.603	4	0.009	1.732	4	0.785	4.740	4	0.315	56.130	4	0.000
Frequency bus				x	x	x	139.636	4	0.000	4.967	4	0.291	1.622	4	0.805	4.087	4	0.394	48.057	4	0.000	19.464	4	0.001	2.022	4	0.732
Frequency tram							x	x	x	14.935	4	0.005	2.654	4	0.617	5.413	4	0.248	38.089	4	0.000	44.397	4	0.000	2.645	4	0.619
Frequency city centre										x	x	x	7.362	4	0.118	4.413	4	0.353	1.561	4	0.816	7.212	4	0.125	6.606	4	0.158
Attitude car (3cat)													x	x	x	14.676	4	0.005	10.170	4	0.038	8.612	4	0.072	3.274	4	0.513
Attitude bicycle (3cat)																x	x	x	3.871	4	0.424	0.597	4	0.963	3.819	4	0.431
Attitude bus (3cat)																			x	x	x	129.629	4	0.000	7.888	4	0.096
Attitude tram (3cat)																						x	x	x	8.386	4	0.078
Attitude shared bicycle (3cat)																									x	x	x

Table E.22: Scenario 2: 5 kilometer correlations between interaction variables

	Gender			Age			Education			Household type			Cars in HH			Bicycles in HH			Car type (2cat)			FR bicycle			FR car city			FR car total		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	x	x	x	6.444	2	0.040	0.391	2	0.822	12.49	4	0.014	1.498	3	0.683	4.065	4	0.397	0	1	0.983	0.707	2	0.702	2.744	2	0.254	3.015	2	0.222
Age				x	x	x	18.839	4	0.001	23.793	8	0.002	3.861	6	0.695	5.778	8	0.672	9.240	2	0.010	2.526	4	0.640	4.158	4	0.385	1.847	4	0.764
Education							x	x	x	8.373	8	0.398	11.226	6	0.082	5.646	8	0.687	0.315	2	0.854	3.412	4	0.491	2.724	4	0.605	6.270	4	0.180
Household type										x	x	x	35.310	12	0.000	51.977	16	0.000	7.158	4	0.128	3.335	8	0.912	4.250	8	0.834	5.145	8	0.742
Cars in household													x	x	x	8.677	12	0.730	3.737	3	0.291	3.623	6	0.728	10.777	6	0.096	6.596	6	0.360
Bicycles in household																x	x	x	6.516	4	0.164	19.626	8	0.012	3.901	8	0.866	5.639	8	0.688
Car type (2cat)																			x	x	x	4.962	2	0.084	0.228	2	0.892	3.008	2	0.222
Frequency bicycle																						x	x	x	5.970	4	0.201	5.428	4	0.246
Frequency car city																									x	x	x	19.030	4	0.001
Frequency car total																												x	x	x
Frequency shared bicycle																														
Frequency bus																														
Frequency tram																														
Frequency city centre																														
Attitude car (3cat)																														
Attitude bicycle (3cat)																														
Attitude bus (3cat)																														
Attitude tram (3cat)																														
Attitude shared bicycle (3cat)																														

	FR shared bicycle			FR bus			FR tram			FR city centre			Att car			Att bicycle			Att bus			Att tram			Att shared bicycle		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	1.094	2	0.579	0.106	2	0.948	2.946	2	0.229	1.575	2	0.455	2.669	2	0.263	3.297	2	0.192	1.664	2	0.435	1.317	2	0.518	0.993	2	0.609
Age	11.499	4	0.021	21.558	4	0.000	3.298	4	0.509	8.014	4	0.091	4.394	4	0.355	4.475	4	0.345	12.675	4	0.013	4.233	4	0.375	11.169	4	0.025
Education	30.382	4	0.000	2.700	4	0.609	3.410	4	0.492	4.614	4	0.329	7.935	4	0.094	0.397	4	0.983	4.765	4	0.312	5.510	4	0.239	6.508	4	0.164
Household type	14.407	8	0.072	6.110	8	0.635	7.525	8	0.481	8.151	8	0.419	5.048	8	0.752	6.221	8	0.622	9.908	8	0.272	9.514	8	0.301	10.222	8	0.250
Cars in household	6.372	6	0.383	14.215	6	0.027	9.391	6	0.153	3.834	6	0.699	8.009	6	0.237	8.159	6	0.227	12.214	6	0.057	8.664	6	0.193	3.849	6	0.697
Bicycles in household	7.973	8	0.436	2.122	8	0.977	3.331	8	0.912	6.206	8	0.624	9.100	8	0.334	5.304	8	0.725	8.735	8	0.365	6.170	8	0.628	5.529	8	0.700
Car type (2cat)	0.115	2	0.944	2.010	2	0.366	3.067	2	0.216	0.258	2	0.879	1.684	2	0.431	2.420	2	0.298	4.819	2	0.090	6.717	2	0.035	1.595	2	0.450
Frequency bicycle	13.478	4	0.009	2.291	4	0.682	8.491	4	0.075	0.157	4	0.997	3.543	4	0.471	55.065	4	0.000	4.988	4	0.289	8.656	4	0.070	2.756	4	0.600
Frequency car city	5.497	4	0.240	0.855	4	0.931	3.197	4	0.525	8.936	4	0.063	5.783	4	0.216	7.876	4	0.096	2.737	4	0.603	9.375	4	0.052	6.534	4	0.163
Frequency car total	9.233	4	0.056	5.053	4	0.282	1.910	4	0.752	3.379	4	0.496	11.437	4	0.022	8.150	4	0.086	5.448	4	0.244	2.343	4	0.673	5.814	4	0.213
Frequency shared bicycle	x	x	x	7.150	4	0.128	4.939	4	0.294	4.225	4	0.376	0.735	4	0.947	3.442	4	0.487	14.525	4	0.006	10.454	4	0.033	78.070	4	0.000
Frequency bus				x	x	x	95.726	4	0.000	2.643	4	0.619	1.073	4	0.899	1.605	4	0.808	49.983	4	0.000	11.211	4	0.024	11.989	4	0.017
Frequency tram							x	x	x	12.526	4	0.014	4.406	4	0.354	4.309	4	0.366	24.172	4	0.000	56.946	4	0.000	5.213	4	0.266
Frequency city centre										x	x	x	1.549	4	0.818	4.569	4	0.334	5.604	4	0.231	2.566	4	0.633	7.622	4	0.106
Attitude car (3cat)													x	x	x	9.771	4	0.044	9.038	4	0.060	2.658	4	0.617	4.948	4	0.293
Attitude bicycle (3cat)																x	x	x	4.369	4	0.358	3.968	4	0.410	11.423	4	0.022
Attitude bus (3cat)																			x	x	x	115.739	4	0.000	26.564	4	0.000
Attitude tram (3cat)																						x	x	x	11.752	4	0.019
Attitude shared bicycle (3cat)																									x	x	x

Table E.23: Both scenarios: correlations between interaction variables

	Gender			Age			Education			Household type			Cars in HH			Bicycles in HH			Car type (2cat)			FR bicycle			FR car city			FR car total		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	x	x	x	18.483	2	**0.000**	0.519	2	0.771	9.377	4	0.052	2.09	3	0.554	4.969	5	0.420	0.003	1	0.956	5.092	2	0.078	2.761	2	0.251	1.255	2	0.534
Age				x	x	x	12.042	4	**0.017**	30.921	8	**0.000**	8.462	6	0.206	19.434	10	**0.035**	0.928	2	0.629	4.452	4	0.348	8.630	4	0.071	3.275	4	0.513
Education							x	x	x	11.445	8	0.178	9.559	6	0.145	20.290	10	**0.027**	5.640	2	0.060	3.456	4	0.485	5.537	4	0.236	7.433	4	0.115
Household type										x	x	x	42.827	12	**0.000**	88.629	20	**0.000**	3.542	4	0.471	6.255	8	0.619	8.867	8	0.354	7.169	8	0.519
Cars in household													x	x	x	25.765	15	**0.041**	7.583	3	0.055	5.557	6	0.475	19.206	6	**0.004**	15.435	6	**0.017**
Bicycles in household																x	x	x	1.537	5	0.909	29.280	10	**0.001**	7.657	10	0.662	7.126	10	0.713
Car type (2cat)																			x	x	x	3.396	2	0.183	1.365	2	0.505	0.799	2	0.671
Frequency bicycle																						x	x	x	11.276	4	**0.024**	5.950	4	0.203
Frequency car city																									x	x	x	38.266	4	**0.000**
Frequency car total																												x	x	x
Frequency shared bicycle																														
Frequency bus																														
Frequency tram																														
Frequency city centre																														
Attitude car (3cat)																														
Attitude bicycle (3cat)																														
Attitude bus (3cat)																														
Attitude tram (3cat)																														
Attitude shared bicycle (3cat)																														

	FR shared bicycle			FR bus			FR tram			FR city centre			Att car			Att bicycle			Att bus			Att tram			Att shared bicycle		
	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value	value	df	p-value
Gender	0.380	2	0.827	1.629	2	0.443	5.843	2	0.054	1.219	2	0.544	2.499	2	0.287	1.728	2	0.422	0.919	2	0.632	0.864	2	0.649	2.055	2	0.358
Age	17.436	4	**0.002**	23.810	4	**0.000**	10.786	4	**0.029**	17.388	4	**0.002**	8.234	4	0.083	2.259	4	0.688	15.505	4	**0.004**	9.846	4	**0.043**	12.486	4	**0.014**
Education	4.040	4	0.401	6.437	4	0.169	4.826	4	0.306	1.061	4	0.900	1.412	4	0.842	0.788	4	0.940	8.490	4	0.075	4.853	4	0.303	1.304	4	0.861
Household type	27.011	8	**0.001**	14.779	8	0.064	8.317	8	0.403	4.957	8	0.762	5.823	8	0.667	4.047	8	0.853	28.248	8	**0.000**	12.718	8	0.122	16.193	8	**0.040**
Cars in household	3.796	6	0.704	14.251	6	**0.027**	8.185	6	0.225	2.880	6	0.824	15.269	6	**0.018**	3.975	6	0.680	17.221	6	**0.009**	10.171	6	0.118	6.883	6	0.332
Bicycles in household	9.626	10	0.474	7.044	10	0.721	10.032	10	0.413	5.614	10	0.847	11.326	10	0.333	10.396	10	0.406	17.946	10	0.056	9.518	10	0.484	9.521	10	0.483
Car type (2cat)	6.964	2	**0.031**	0.257	2	0.880	1.553	2	0.460	0.765	2	0.682	6.253	2	**0.044**	8.182	2	**0.017**	0.268	2	0.874	0.300	2	0.861	0.728	2	0.695
Frequency bicycle	15.932	4	**0.003**	6.713	4	0.152	7.655	4	0.105	3.209	4	0.523	4.606	4	0.330	90.860	4	**0.000**	9.398	4	0.052	10.396	4	**0.034**	7.649	4	0.105
Frequency car city	5.982	4	0.201	5.137	4	0.274	6.044	4	0.196	14.073	4	**0.007**	6.565	4	0.161	3.533	4	0.473	10.865	4	**0.028**	13.470	4	**0.009**	15.359	4	**0.004**
Frequency car total	4.704	4	0.319	4.246	4	0.374	6.477	4	0.166	9.900	4	**0.042**	15.453	4	**0.004**	6.936	4	0.139	10.415	4	**0.034**	4.637	4	0.327	12.413	4	**0.015**
Frequency shared bicycle	x	x	x	9.555	4	**0.049**	5.523	4	0.238	7.776	4	0.100	3.092	4	0.543	2.827	4	0.587	11.966	4	**0.018**	10.573	4	**0.032**	128.009	4	**0.000**
Frequency bus				x	x	x	234.407	4	**0.000**	7.479	4	0.113	2.626	4	0.622	4.184	4	0.382	92.927	4	**0.000**	30.229	4	**0.000**	10.149	4	**0.038**
Frequency tram							x	x	x	23.967	4	**0.000**	4.805	4	0.308	8.742	4	0.068	60.258	4	**0.000**	99.845	4	**0.000**	6.397	4	0.171
Frequency city centre										x	x	x	5.734	4	**0.020**	6.180	4	0.186	4.557	4	0.334	7.244	4	0.124	13.235	4	**0.010**
Attitude car (3cat)													x	x	x	15.230	4	**0.004**	6.338	4	0.175	5.414	4	0.247	3.941	4	0.414
Attitude bicycle (3cat)																x	x	x	4.097	4	0.393	2.819	4	0.589	11.730	4	**0.019**
Attitude bus (3cat)																			x	x	x	243.354	4	**0.000**	29.058	4	**0.000**
Attitude tram (3cat)																						x	x	x	20.546	4	**0.000**
Attitude shared bicycle (3cat)																									x	x	x

E.4.1 Final panel model with error component bicycle and interactions Scenario 1: 2.5 kilometer

Utility functions of final panel model scenario 1: 2.5 kilometer are shown in Equation E.25 to Equation E.28. The estimated model parameters are presented in Table E.24 and Table E.25.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{bicycle} + \sigma_{panel} + \tag{E.25}$$
$$\beta_{POS\ AT_B*TC} * POS\ AT_B * TC_A + \beta_{NEG\ AT_B*TC} * NEG\ AT_B * TC_A + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} +$$
$$\beta_{POS\ AT_B*WT} * POS\ AT_B * WT_A + \beta_{NEG\ AT_B*WT} * NEG\ AT_B * WT_A + \beta_{FR_A\ D1*TT_A} * FR_A\ D1 * TT_A + \beta_{FR_A\ D2*TT_A} * FR_A\ D2 * TT_A +$$
$$\beta_{POS\ AT_{tram}*TT_A} * POS\ AT_{tram} * TT_A + \beta_{NEG\ AT_{tram}*TT_A} * NEG\ AT_{tram} * TT_A + \beta_{POS\ AT_B*TT_A} * POS\ AT_B * TT_A +$$
$$\beta_{NEG\ AT_B*TT_A} * NEG\ AT_B * TT_A + \beta_{POS\ AT_D} * POS\ AT_D + \beta_{NEG\ AT_D} * NEG\ AT_D$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC_B} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{bicycle} + \sigma_{panel} \tag{E.26}$$
$$\beta_{POS\ AT_B*TC_B} * POS\ AT_B * TC_B + \beta_{NEG\ AT_B*TC_B} * NEG\ AT_B * TC_B + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} +$$
$$\beta_{POS\ AT_B*WT_B} * POS\ AT_B * WT_B + \beta_{NEG\ AT_B*WT_B} * NEG\ AT_B * WT_B + \beta_{POS\ AT_{tram}*WT_B} * POS\ AT_{tram} * WT_B +$$
$$\beta_{NEG\ AT_{tram}*WT_B} * NEG\ AT_{tram} * WT_B + \beta_{FR_A\ D1*WT_B} * FR_A\ D1 * WT_B + \beta_{FR_A\ D2*WT_B} * FR_A\ D2 * WT_B +$$
$$\beta_{POS\ AT_B*TT_B} * POS\ AT_B * TT_B + \beta_{NEG\ AT_B*TT_B} * NEG\ AT_B * TT_B +$$
$$\beta_{HHcars*WT_B} * HHcars * WT_B \beta_{HHtype\ D1*WT_B} * HHtype\ D1 * WT_B + \beta_{HHtype\ D2*WT_B} * HHtype\ D2 * WT_B +$$
$$\beta_{HHtype\ D3*WT_B} * HHtype\ D3 * WT_B + \beta_{HHtype\ D4*WT_B} * HHtype\ D4 * WT_B + \beta_{POS\ AT_D} * POS\ AT_D + \beta_{NEG\ AT_D} * NEG\ AT_D$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} + \tag{E.27}$$
$$\beta_{POS\ AT_B*TC} * POS\ AT_B * TC_C + \beta_{NEG\ AT_B*TC} * NEG\ AT_B * TC_C + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} +$$
$$\beta_{POS\ AT_B*WT} * POS\ AT_B * WT_C + \beta_{NEG\ AT_B*WT} * NEG\ AT_B * WT_C + \beta_{POS\ AT_D} * POS\ AT_D + \beta_{NEG\ AT_D} * NEG\ AT_D$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D + \tag{E.28}$$
$$\beta_{POS\ AT_B*TC} * POS\ AT_B * TC_D + \beta_{NEG\ AT_B*TC} * NEG\ AT_B * TC_D + \beta_{POS\ AT_B*WT} * POS\ AT_B * WT_D + \beta_{NEG\ AT_B*WT} * NEG\ AT_B * WT_D +$$
$$\beta_{FR_{city\ centre}\ D1*TC_D} * FR_{city\ centre}\ D1 * TC_D + \beta_{FR_{city\ centre}\ D2*TC_D} * FR_{city\ centre}\ D2 * TC_D + \beta_{HHtype\ D1*TC_D} * HHtype\ D1 * TC_D +$$
$$\beta_{HHtype\ D2*TC_D} * HHtype\ D2 * TC_D + \beta_{HHtype\ D3*TC_D} * HHtype\ D3 * TC_D + \beta_{HHtype\ D4*TC_D} * HHtype\ D4 * TC_D$$

Table E.24: Scenario 1: ML results with significant interactions [part 1]

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	5.360	0.967	5.550	0.000	0.961	5.580	**0.000***
Shared bicycle	0.272	0.057	4.790	0.000	0.066	4.140	**0.000***
Public transport	-0.238	0.673	-0.353	0.724	0.856	-0.278	0.781
Generic							
Crowdedness	-0.046	0.037	-1.240	0.216	0.031	-1.470	0.142
Travel costs	-0.383	0.081	-4.760	0.000	0.092	-4.180	**0.000***
Travel time	-0.055	0.050	-1.110	0.266	0.050	-1.110	0.269
Walking time	-0.086	0.036	-2.380	0.017	0.039	-2.230	**0.026****
Bicycle							
Travel time bicycle	-0.171	0.068	-2.510	0.012	0.069	-2.470	**0.013****
Shared bicycle							
1-2 bicycles available	-0.449	0.207	-2.170	0.030	0.173	-2.590	**0.009***
3+ bicycles available	-0.950	0.253	-3.750	0.000	0.224	-4.250	**0.000***
Mode type (electric SB)	0.070	0.189	0.370	0.711	0.143	0.489	0.625
Travel costs shared bicycle	-0.983	0.165	-5.970	0.000	0.197	-4.990	**0.000***
Travel time shared bicycle	0.588	0.139	4.220	0.000	0.156	3.770	**0.000***
Walking time shared bicycle	-0.982	0.163	-6.010	0.000	0.203	-4.830	**0.000***

Table E.25: Scenario 1: ML results with significant interactions [part 2]

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
Public transport							
Not quiet/not busy	-0.435	0.248	-1.750	0.080	0.226	-1.930	**0.054***
Busy	-0.352	0.259	-1.360	0.175	0.254	-1.380	0.166
Frequency PT	0.021	0.023	0.893	0.372	0.025	0.826	0.409
Mode type (tram)	-0.125	0.190	-0.661	0.509	0.168	-0.749	0.454
Car							
Parking costs car	-0.877	0.194	-4.520	0.000	0.202	-4.340	**0.000***
Sigmas							
Bicycle	5.360	0.616	8.690	0.000	0.888	6.040	**0.000***
Panel	-2.330	0.373	-6.250	0.000	0.548	-4.250	**0.000***
Interactions							
Negative attitude car	-0.775	0.585	-1.330	0.185	0.835	-0.928	0.353
Positive attitude car	-0.864	0.364	-2.380	0.018	0.558	-1.550	0.121
*Negative attitude SB * travel costs*	-0.189	0.061	-3.080	0.002	0.076	-2.490	**0.013****
*Negative attitude SB * travel costs SB*	-0.582	0.191	-3.040	0.002	0.222	-2.620	**0.009***
*Negative attitude SB * travel time bicycle*	0.078	0.052	1.480	0.139	0.063	1.230	0.220
*Negative attitude SB * travel time SB*	0.537	0.143	3.760	0.000	0.170	3.150	**0.002***
*Negative attitude SB * walking time*	-0.054	0.043	-1.250	0.212	0.046	-1.160	0.244
*Negative attitude SB * walking time SB*	-0.536	0.190	-2.820	0.005	0.219	-2.440	**0.015****
*Positive attitude SB * travel costs*	0.359	0.108	3.340	0.001	0.125	2.870	**0.004***
*Positive attitude SB * travel costs SB*	-0.399	0.264	-1.510	0.132	0.328	-1.220	0.224
*Positive attitude SB * travel time bicycle*	0.220	0.096	2.300	0.022	0.082	2.690	**0.007***
*Positive attitude SB * travel time SB*	0.590	0.235	2.510	0.012	0.239	2.470	**0.014****
*Positive attitude SB * walking time*	0.138	0.081	1.690	0.090	0.071	1.940	**0.053*****
*Positive attitude SB * walking time SB*	-0.282	0.248	-1.140	0.256	0.324	-0.870	0.384
Negative attitude tram	2.230	0.359	6.200	0.000	0.490	4.540	**0.000***
*Negative attitude tram * travel time bicycle*	-0.109	0.048	-2.290	0.022	0.063	-1.730	**0.083*****
*Negative attitude tram * walking time SB*	-0.380	0.125	-3.040	0.002	0.136	-2.790	**0.005***
Positive attitude tram	-0.247	0.394	-0.627	0.531	0.628	-0.393	0.694
*Positive attitude tram * travel time bicycle*	-0.052	0.054	-0.973	0.331	0.073	-0.715	0.475
*Positive attitude tram * walking time SB*	-0.088	0.147	-0.598	0.550	0.181	-0.487	0.626
*Frequency city centre D1 * car parking costs*	0.003	0.041	0.078	0.938	0.063	0.051	0.960
*Frequency city centre D2 * car parking costs*	-0.312	0.067	-4.620	0.000	0.094	-3.310	**0.001***
*Frequency bicycle D1 * travel time bicycle*	-0.100	0.020	-5.060	0.000	0.032	-3.160	**0.002***
*Frequency bicycle D1 * walking time SB*	-0.380	0.114	-3.350	0.001	0.184	-2.060	**0.039****
*Frequency bicycle D2 * travel time bicycle*	-0.169	0.029	-5.750	0.000	0.040	-4.250	**0.000***
*Frequency bicycle D2 * walking time SB*	-0.553	0.157	-3.530	0.000	0.195	-2.840	**0.005***
*Cars in household * walking time SB*	0.168	0.041	4.130	0.000	0.050	3.380	**0.001***
*Household type D1 * parking costs car*	0.425	0.184	2.310	0.021	0.211	2.010	**0.044****
*Household type D1 * walking time SB*	0.127	0.072	1.760	0.078	0.133	0.953	0.341
*Household type D2 * parking costs car*	0.599	0.183	3.270	0.001	0.199	3.010	**0.003***
*Household type D2 * walking time SB*	-0.270	0.080	-3.400	0.001	0.138	-1.950	**0.051*****
*Household type D3 * parking costs car*	0.678	0.181	3.750	0.000	0.186	3.650	**0.000***
*Household type D3 * walking time SB*	-0.113	0.061	-1.840	0.066	0.103	-1.100	0.273
*Household type D4 * parking costs car*	0.558	0.198	2.810	0.005	0.259	2.150	**0.031****
*Household type D4 * walking time SB*	0.138	0.110	1.260	0.208	0.142	0.972	0.331

E.4.2 Final panel model with error component bicycle and interactions Scenario 2: 5 kilometer

Utility functions of final panel model scenario 2: 5 kilometer are shown in Equation E.29 to Equation E.32. The estimated model parameters are presented in Table E.26 and Table E.27.

$$U_A = ASC_A + \beta_{TT_A} \times TT_A + \beta_{WT} \times WT_A + \beta_{CR} \times CR_A + \beta_{TC} \times TC_A + \sigma_{bicycle} + \sigma_{panel} + \\ \beta_{FR_A\ D1} * FR_A\ D1 + \beta_{FR_A\ D2} * FR_A\ D2 + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} + \\ \beta_{FR_{car\ in\ city}\ D1} * FR_{car\ in\ city}\ D1 + \beta_{FR_{car\ in\ city}\ D2} * FR_{car\ in\ city}\ D2 + \beta_{age\ D1*TC} * age\ D1 * TC_A + \\ \beta_{age\ D2*TC} * age\ D2 * TC_A + \beta_{HHcars*WT} * HHcars * WT_A \tag{E.29}$$

$$U_B = ASC_B + \beta_{TT_B} \times TT_B + \beta_{WT_B} \times WT_B + \beta_{MT_B} \times MT_B + \beta_{TC} \times TC_B + \beta_{AV1_B} \times AVB_1 + \beta_{AV1_B} \times AV2_B + \sigma_{bicycle} + \sigma_{panel} + \\ \beta_{FR_A\ D1} * FR_A\ D1 + \beta_{FR_A\ D2} * FR_A\ D2 + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} + \\ \beta_{FR_{car\ in\ city}\ D1} * FR_{car\ in\ city}\ D1 + \beta_{FR_{car\ in\ city}\ D2} * FR_{car\ in\ city}\ D2 + \beta_{age\ D1*TC} * age\ D1 * TC_B + \beta_{age\ D2*TC} * age\ D2 * TC_B + \tag{E.30}$$

$$U_C = ASC_C + \beta_{TT} \times TT_C + \beta_{WT} \times WT_C + \beta_{MT_C} \times MT_C + \beta_{TC} \times TC_C + \beta FR_C \times FR_C + \beta_{CR1_C} \times CR1_C + \beta_{CR2_c} \times CR2_C + \sigma_{panel} + \\ \beta_{FR_A\ D1} * FR_A\ D1 + \beta_{FR_A\ D2} * FR_A\ D2 + \beta_{POS\ AT_{tram}} * POS\ AT_{tram} + \beta_{NEG\ AT_{tram}} * NEG\ AT_{tram} + \\ \beta_{FR_{car\ in\ city}\ D1} * FR_{car\ in\ city}\ D1 + \beta_{FR_{car\ in\ city}\ D2} * FR_{car\ in\ city}\ D2 + \beta_{age\ D1*TC} * age\ D1 * TC_C + \\ \beta_{age\ D2*TC} * age\ D2 * TC_C + \beta_{HHcars*WT} * HHcars * WT_C \tag{E.31}$$

$$U_D = \beta_{TT} \times TT_D + \beta_{WT} \times WT_D + \beta_{TC_D} \times TC_D + \beta_{CR} \times CR_D + \\ \beta_{FR_{city\ centre}\ D1*TC_D} * FR_{city\ centre}\ D1 * TC_D + \beta_{FR_{city\ centre}\ D2*TC_D} * FR_{city\ centre}\ D2 * TC_D + \beta_{HHcars*WT} * HHcars * WT_D \tag{E.32}$$

Table E.26: Scenario 2: ML results with significant interactions [part 1]

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC							
Bicycle	6.650	1.650	4.040	0.000	1.680	3.950	**0.000***
Shared bicycle	3.850	1.760	2.190	0.028	1.510	2.550	**0.011****
Public transport	2.680	0.526	5.090	0.000	0.518	5.170	**0.000***
Generic							
Crowdedness	0.009	0.035	0.264	0.792	0.030	0.307	0.759
Travel costs	-0.624	0.106	-5.910	0.000	0.147	-4.240	**0.000***
Travel time	-0.031	0.039	-0.796	0.426	0.036	-0.848	0.396
Walking time	0.080	0.042	1.900	0.058	0.050	1.590	0.111
Bicycle							
Travel time bicycle	-0.214	0.053	-4.060	0.000	0.065	-3.310	**0.001***
Shared bicycle							
1-2 bicycles available	0.363	0.303	1.200	0.230	0.268	1.360	0.175
3+ bicycles available	0.625	0.260	2.400	0.016	0.235	2.660	**0.008***
Mode type (electric SB)	0.041	0.293	0.139	0.890	0.259	0.157	0.875
Travel time shared bicycle	-0.179	0.111	-1.620	0.105	0.080	-2.240	**0.025****
Walking time shared bicycle	-0.163	0.182	-0.899	0.369	0.134	-1.220	0.222
Public transport							
Not quiet/not busy	-0.650	0.247	-2.630	0.009	0.277	-2.350	**0.019****
Busy	-0.507	0.181	-2.810	0.005	0.170	-2.990	**0.003***
Frequency PT	-0.035	0.020	-1.800	0.072	0.020	-1.790	**0.073*****
Mode type (tram)	0.174	0.170	1.020	0.308	0.154	1.130	0.260
Car							
Parking costs car	0.028	0.050	0.558	0.577	0.061	0.461	0.645
Sigmas							
Bicycle	4.780	0.499	9.570	0.000	0.618	7.730	**0.000***
Panel	2.350	0.318	7.410	0.000	0.447	5.260	**0.000***

Table E.27: Scenario 2: ML results with significant interactions [part 2]

Beta	**Value**	**Std err**	**t-test**	**p-value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
Interactions							
*Age D1 * travel costs*	0.334	0.089	3.780	0.000	0.155	2.150	**0.031****
*Age D2 * travel costs*	0.721	0.109	6.620	0.000	0.188	3.840	**0.000***
Negative attitude tram	3.320	0.481	6.900	0.000	0.829	4.010	**0.000***
Positive attitude tram	1.380	0.375	3.660	0.000	0.636	2.160	**0.031****
Frequency car in city D1	0.839	0.382	2.200	0.028	0.587	1.430	0.153
Frequency car in city D2	1.590	0.404	3.920	0.000	0.794	2.000	**0.046****
*Frequency city centre D1 * parking costs car*	-0.362	0.053	-6.900	0.000	0.083	-4.370	**0.000***
*Frequency city centre D2 * parking costs car*	-0.427	0.088	-4.850	0.000	0.154	-2.770	**0.006***
Frequency bicycle D1	-0.911	0.427	-2.130	0.033	0.681	-1.340	0.181
Frequency bicycle D2	-1.070	0.357	-3.010	0.003	0.629	-1.710	**0.088*****
*Cars in household * walking time*	-0.077	0.030	-2.600	0.009	0.040	-1.920	**0.055*****

Appendix F

Additional case study information

F.1 Modal split PandasBiogeme code

The code that has been used in PandasBiogeme to model the modal splits is given below. A for-loop is used in order to be able to run combinations of interaction variables and attribute levels.

```
import pandas as pd
import numpy as np
import biogeme.database as db
import biogeme.biogeme as bio
import biogeme.models as models
import biogeme.messaging as msg
import biogeme.results as res
from biogeme import *
from biogeme.expressions import Beta, DefineVariable, bioDraws, \
    PanelLikelihoodTrajectory, MonteCarlo, log, Derive
import time
import xlsxwriter

df = pd.read_csv('BG_5_k1_2204_modalshift.txt', '\t')

#---ASC---
ASC_FIETS = Beta('ASC_FIETS',0,-1000,1000,0)
ASC_DEELFIETS = Beta('ASC_DEELFIETS',0,-1000,1000,0)
ASC_OV = Beta('ASC_OV',0,-1000,1000,0)
ASC_AUTO = Beta('ASC_AUTO',0,-1000,1000,1)

#---FIETS---
BETA_TTA = Beta('BETA_TTA',0,-1000,1000,0)
BETA_WTA = Beta('BETA_WTA',0,-1000,1000,0)
BETA_CRA = Beta('BETA_CRA',0,-1000,1000,0)
BETA_TCA = Beta('BETA_TCA',0,-1000,1000,0)

#---DEELFIETS---
BETA_TTB = Beta('BETA_TTB',0,-1000,1000,0)
BETA_WTB = Beta('BETA_WTB',0,-1000,1000,0)
BETA_MTB = Beta('BETA_MTB',0,-1000,1000,0)
BETA_TCB = Beta('BETA_TCB',0,-1000,1000,0)
BETA_AVB1 = Beta('BETA_AVB1',0,-1000,1000,0)
BETA_AVB2 = Beta('BETA_AVB2',0,-1000,1000,0)

#---OPENBAAR VERVOER---
BETA_TTC = Beta('BETA_TTC',0,-1000,1000,0)
BETA_WTC = Beta('BETA_WTC',0,-1000,1000,0)
BETA_MTC = Beta('BETA_MTC',0,-1000,1000,0)
BETA_TCC = Beta('BETA_TCC',0,-1000,1000,0)
BETA_FRC = Beta('BETA_FRC',0,-1000,1000,0)
BETA_CRC1 = Beta('BETA_CRC1',0,-1000,1000,0)
BETA_CRC2 = Beta('BETA_CRC2',0,-1000,1000,0)

#---AUTO---
BETA_TTD = Beta('BETA_TTD',0,-1000,1000,0)
BETA_WTD = Beta('BETA_WTD',0,-1000,1000,0)
BETA_TCD = Beta('BETA_TCD',0,-1000,1000,0)
BETA_CRD = Beta('BETA_CRD',0,-1000,1000,0)

#---GENERAL TIME AND COST---
BETA_TT = Beta('BETA_TT',0,-1000,1000,0)
```

```
BETA_WT = Beta('BETA_WT',0,-1000,1000,0)
BETA_TC = Beta('BETA_TC',0,-1000,1000,0)
BETA_CR = Beta('BETA_CR',0,-1000,1000,0)

#---INTERACTION VARIABLES---
BETA_FR_FIETS_D1 = Beta('BETA_FR_FIETS_D1',0,-1000,1000,0)
BETA_FR_FIETS_D2 = Beta('BETA_FR_FIETS_D2',0,-1000,1000,0)
BETA_AT_TRAM_POS = Beta('BETA_AT_TRAM_POS',0,-1000,1000,0)
BETA_AT_TRAM_NEG = Beta('BETA_AT_TRAM_NEG',0,-1000,1000,0)
BETA_FR_AUTOSTAD_D1 = Beta('BETA_FR_AUTOSTAD_D1',0,-1000,1000,0)
BETA_FR_AUTOSTAD_D2 = Beta('BETA_FR_AUTOSTAD_D2',0,-1000,1000,0)
BETA_AGE_D1_TC = Beta('BETA_AGE_D1_TC',0,-1000,1000,0)
BETA_AGE_D2_TC = Beta('BETA_AGE_D2_TC',0,-1000,1000,0)
BETA_HHCARS_WT = Beta('BETA_HHCARS_WT',0,-1000,1000,0)
BETA_FR_CENTRUM_D1_TCD = Beta('BETA_FR_CENTRUM_D1_TCD',0,-1000,1000,0)
BETA_FR_CENTRUM_D2_TCD = Beta('BETA_FR_CENTRUM_D2_TCD',0,-1000,1000,0)

# Define a random parameter, normally distributed across individuals.
# Designed to be used for Monte-Carlo simulation
Sigma_panel = Beta('Sigma_panel',0,-100,100,0)
Sigma_bicycle = Beta('Sigma_bicycle',0,-100,100,0)
Zero = Beta('Zero',0,-100,100,1)

Zero_sigma_panel = Zero + Sigma_panel * bioDraws('Zero_sigma_panel', 'NORMAL_HALTON2')
Zero_sigma_bicycle = Zero + Sigma_bicycle * bioDraws('Zero_sigma_bicycle', 'NORMAL_HALTON2')

#Defining attribute levels
value_HHcars = [1,2,3]
value_at_tram = [[0,0], [1,0], [0,-1]]
value_fr_centrum = [[0,0], [1,0], [0,1]]
value_fr_fiets = [[0,0], [1,0], [0,1]]
value_age = [[0,0], [1,0], [0,1]]
value_fr_autostad = [[0,0], [1,0], [0,1]]

value_fr_centrum_weekly = [[0,0]]
value_HHcars = [1]
value_at_tram = [[0,0]]
value_fr_centrum = [[0,0]]
value_fr_fiets = [[0,0]]
value_age = [[0,0]]
value_fr_autostad = [[0,0]]

value_TTA = [17,18,19,20,21,22,23]
value_WTA = [1,2,3,4,5]
value_TCA = [0,0.25,0.5,0.75,1,1.25,1.5,1.75,2]
value_CRA = [1,2,3,4,5,6,7,8,9,10]
value_WTB = [3,4,5,6,7]
value_TCB = [0,0.25,0.5,0.75,1,1.25,1.5,1.75,2]
value_AVB = [[0,0], [1,0], [0,1]]
value_WTC = [3,4,5,6,7,8,9]
value_TCC = [1,1.25,1.5,1.75,2,2.25,2.50,2.75,3]
value_TTC = [12,13,14,15,16,17,18]
value_FRC = [5,7.5,10,12.5,15]
value_CRC = [[0,0], [1,0], [0,1]]
value_TCD = [3,3.5,4,4.5,5,5.5,6,6.5,7,7.5,8,8.5,9]
value_TCD_1 = [9]

# Defining for what attribute levels the model is run
variable_interaction = value_fr_centrum_weekly
variable = value_TCD_1

# Creating space to save the results of MS (Modal Split) per mode
MS_A = np.zeros(len(variable) * len(variable_interaction))
MS_B = np.zeros(len(variable) * len(variable_interaction))
MS_C = np.zeros(len(variable) * len(variable_interaction))
MS_D = np.zeros(len(variable) * len(variable_interaction))
variable_interaction_print = np.zeros(len(variable) * len(variable_interaction))
variable_print = np.zeros(len(variable) * len(variable_interaction))
variable_print_1 = np.zeros(len(variable) * len(variable_interaction))
variable_interaction_print_1 = np.zeros(len(variable) * len(variable_interaction))
variable_interaction_print_2 = np.zeros(len(variable) * len(variable_interaction))
variable_interaction_print_3 = np.zeros(len(variable) * len(variable_interaction))
MS_A_stdev = np.zeros(len(variable) * len(variable_interaction))
MS_B_stdev = np.zeros(len(variable) * len(variable_interaction))
MS_C_stdev = np.zeros(len(variable) * len(variable_interaction))
MS_D_stdev = np.zeros(len(variable) * len(variable_interaction))
```

```
#STRINGS BICYCLE
TTA_sim_string = ['TTA_sim0']
WTA_sim_string = ['WTA_sim0']
CRA_sim_string = ['CRA_sim0']
TCA_sim_string = ['TCA_sim0']

#STRINGS SHARED BICYCLE
TTB_sim_string = ['TTB_sim0']
WTB_sim_string = ['WTB_sim0']
MTB_sim_string = ['MTB_sim0']
TCB_sim_string = ['TCB_sim0']
AVB1_sim_string = ['AVB1_sim0']
AVB2_sim_string = ['AVB2_sim0']

#STRINGS PUBLIC TRANSPORT
TTC_sim_string = ['TTC_sim0']
WTC_sim_string = ['WTC_sim0']
MTC_sim_string = ['MTC_sim0']
TCC_sim_string = ['TCC_sim0']
FRC_sim_string = ['FRC_sim0']
CRC1_sim_string = ['CRC1_sim0']
CRC2_sim_string = ['CRC2_sim0']

#STRINGS CAR
TTD_sim_string = ['TTD_sim0']
WTD_sim_string = ['WTD_sim0']
CRD_sim_string = ['CRD_sim0']
TCD_sim_string = ['TCD_sim0']

#STRINGS INTERACTIONS
FR_FIETS_D1_sim_string = ['FR_FIETS_D1_sim0']
FR_FIETS_D2_sim_string = ['FR_FIETS_D2_sim0']
AT_TRAM_POS_sim_string = ['AT_TRAM_POS_sim0']
AT_TRAM_NEG_sim_string = ['AT_TRAM_NEG_sim0']
FR_AUTOSTAD_D1_sim_string = ['FR_AUTOSTAD_D1_sim0']
FR_AUTOSTAD_D2_sim_string = ['FR_AUTOSTAD_D2_sim0']
AGE3_D1_sim_string = ['AGE3_D1_sim0']
AGE3_D2_sim_string = ['AGE3_D2_sim0']
HHCARS_sim_string = ['HHCARS_sim0']
FR_CENTRUM_D1_sim_string = ['FR_CENTRUM_D1_sim0']
FR_CENTRUM_D2_sim_string = ['FR_CENTRUM_D2_sim0']

for i in range(len(variable) * len(variable_interaction)):
    TTA_sim_string.append(f'TTA_sim{i+1}')
    WTA_sim_string.append(f'WTA_sim{i+1}')
    CRA_sim_string.append(f'CRA_sim{i+1}')
    TCA_sim_string.append(f'TCA_sim{i+1}')
    TTB_sim_string.append(f'TTB_sim{i+1}')
    WTB_sim_string.append(f'WTB_sim{i+1}')
    MTB_sim_string.append(f'MTB_sim{i+1}')
    TCB_sim_string.append(f'TCB_sim{i+1}')
    AVB1_sim_string.append(f'AVB1_sim{i+1}')
    AVB2_sim_string.append(f'AVB2_sim{i+1}')
    TTC_sim_string.append(f'TTC_sim{i+1}')
    WTC_sim_string.append(f'WTC_sim{i+1}')
    MTC_sim_string.append(f'MTC_sim{i+1}')
    TCC_sim_string.append(f'TCC_sim{i+1}')
    FRC_sim_string.append(f'FRC_sim{i+1}')
    CRC1_sim_string.append(f'CRC1_sim{i+1}')
    CRC2_sim_string.append(f'CRC2_sim{i+1}')
    TTD_sim_string.append(f'TTD_sim{i+1}')
    WTD_sim_string.append(f'WTD_sim{i+1}')
    CRD_sim_string.append(f'CRD_sim{i+1}')
    TCD_sim_string.append(f'TCD_sim{i+1}')
    FR_FIETS_D1_sim_string.append(f'FR_FIETS_D1_sim0{i+1}')
    FR_FIETS_D2_sim_string.append(f'FR_FIETS_D2_sim0{i+1}')
    AT_TRAM_POS_sim_string.append(f'AT_TRAM_POS_sim0{i+1}')
    AT_TRAM_NEG_sim_string.append(f'AT_TRAM_NEG_sim0{i+1}')
    FR_AUTOSTAD_D1_sim_string.append(f'FR_AUTOSTAD_D1_sim0{i+1}')
    FR_AUTOSTAD_D2_sim_string.append(f'FR_AUTOSTAD_D2_sim0{i+1}')
    AGE3_D1_sim_string.append(f'AGE3_D1_sim0{i+1}')
    AGE3_D2_sim_string.append(f'AGE3_D2_sim0{i+1}')
    HHCARS_sim_string.append(f'HHCARS_sim0{i+1}')
    FR_CENTRUM_D1_sim_string.append(f'FR_CENTRUM_D1_sim0{i+1}')
    FR_CENTRUM_D2_sim_string.append(f'FR_CENTRUM_D2_sim0{i+1}')
```

```
#creating a counter
k = 0

for i in range(len(variable_interaction)):
    for j in range(len(variable)):
        #Reset database to df
        del database
        database = db.Database('ML modal split test 2604', df)
        # They are organized as panel data. The variable ID identifies each individual.
        # database.panel("ID")

        # The Pandas data structure is available as database.data. Use all the
        # Pandas functions to invesigate the database
        #print(database.data.describe())

        # The following statement allows you to use the names of the variable
        # as Python variable.
        globals().update(database.variables)

        #excluding some observations
        exclude = (ID_EXCLUDE_SNEL == 1)
        exclude2 = (AGE3_D1 == 999999)
        database.remove(exclude)
        database.remove(exclude2)

        # case study values
        value_bicycle = [19,3,3,0]
        value_shared = [20,5,0,1,0,1]
        value_pt = [15,6,0,2,10,1,0]
        value_car = [15,4,variable[j],3]

        #alternative 1: bicycle
        TTA_sim = DefineVariable(TTA_sim_string[k],value_bicycle[0],database)
        WTA_sim = DefineVariable(WTA_sim_string[k],value_bicycle[1],database)
        CRA_sim = DefineVariable(CRA_sim_string[k],value_bicycle[2],database)
        TCA_sim = DefineVariable(TCA_sim_string[k],value_bicycle[3],database)
        #alternative 2: shared bicycle
        TTB_sim = DefineVariable(TTB_sim_string[k],value_shared[0],database)
        WTB_sim = DefineVariable(WTB_sim_string[k],value_shared[1],database)
        MTB_sim = DefineVariable(MTB_sim_string[k],value_shared[2],database)
        TCB_sim = DefineVariable(TCB_sim_string[k],value_shared[3],database)
        AVB1_sim = DefineVariable(AVB1_sim_string[k],value_shared[4],database)
        AVB2_sim = DefineVariable(AVB2_sim_string[k],value_shared[5],database)
        #alternative 3: public transport
        TTC_sim = DefineVariable(TTC_sim_string[k],value_pt[0],database)
        WTC_sim = DefineVariable(WTC_sim_string[k],value_pt[1],database)
        MTC_sim = DefineVariable(MTC_sim_string[k],value_pt[2],database)
        TCC_sim = DefineVariable(TCC_sim_string[k],value_pt[3],database)
        FRC_sim = DefineVariable(FRC_sim_string[k],value_pt[4],database)
        CRC1_sim = DefineVariable(CRC1_sim_string[k],value_pt[5],database)
        CRC2_sim = DefineVariable(CRC2_sim_string[k],value_pt[6],database)
        #alterantive 4: car
        TTD_sim = DefineVariable(TTD_sim_string[k],value_car[0],database)
        WTD_sim = DefineVariable(WTD_sim_string[k],value_car[1],database)
        TCD_sim = DefineVariable(TCD_sim_string[k],value_car[2],database)
        CRD_sim = DefineVariable(CRD_sim_string[k],value_car[3],database)

        #interaction variables
        # used if not commendted (#), otherwise commented
        # FR_FIETS_D1_sim = DefineVariable(FR_FIETS_D1_sim_string[k],variable_interaction[i][0],
            database)
        # FR_FIETS_D2_sim = DefineVariable(FR_FIETS_D2_sim_string[k],variable_interaction[i][1],
            database)
        # AT_TRAM_POS_sim = DefineVariable(AT_TRAM_POS_sim_string[k],variable_interaction[i][0],
            database)
        # AT_TRAM_NEG_sim = DefineVariable(AT_TRAM_NEG_sim_string[k],variable_interaction[i][1],
            database)
        # FR_AUTOSTAD_D1_sim = DefineVariable(FR_AUTOSTAD_D1_sim_string[k],variable_interaction[i
            ][0],database)
        # FR_AUTOSTAD_D2_sim = DefineVariable(FR_AUTOSTAD_D2_sim_string[k],variable_interaction[i
            ][1],database)
        # AGE3_D1_sim = DefineVariable(AGE3_D1_sim_string[k],variable_interaction[i][0],database)
        # AGE3_D2_sim = DefineVariable(AGE3_D2_sim_string[k],variable_interaction[i][1],database)
        # HHCARS_sim = DefineVariable(HHCARS_sim_string[k],variable_interaction[i],database)
        FR_CENTRUM_D1_sim = DefineVariable(FR_CENTRUM_D1_sim_string[k],variable_interaction[i][0],
```

```
        database)
    FR_CENTRUM_D2_sim = DefineVariable(FR_CENTRUM_D2_sim_string[k], variable_interaction[i][1],
        database)

#utility functions SC2 simulated values
    Alt1 = ASC_FIETS + BETA_TTA * TTA_sim + BETA_WT * WTA_sim + BETA_CR * CRA_sim + BETA_TC *
        TCA_sim + Zero_sigma_panel + Zero_sigma_bicycle \
        + BETA_FR_FIETS_D1 * FR_FIETS_D1 \
        + BETA_FR_FIETS_D2 * FR_FIETS_D2 \
        + BETA_AT_TRAM_POS * AT_TRAM_POS \
        + BETA_AT_TRAM_NEG * AT_TRAM_NEG \
        + BETA_FR_AUTOSTAD_D1 * FR_AUTOSTAD_D1 \
        + BETA_FR_AUTOSTAD_D2 * FR_AUTOSTAD_D2 \
        + BETA_AGE_D1_TC * AGE3_D1 * TCA_sim \
        + BETA_AGE_D2_TC * AGE3_D2 * TCA_sim \
        + BETA_HHCARS_WT * HHCARS * WTA_sim
    Alt2 = ASC_DEELFIETS + BETA_TTB * TTB_sim + BETA_WTB * WTB_sim + BETA_MTB * MTB_sim +
        BETA_TC * TCB_sim + BETA_AVB1 * AVB1_sim + BETA_AVB2 * AVB2_sim + Zero_sigma_panel +
        Zero_sigma_bicycle \
        + BETA_FR_FIETS_D1 * FR_FIETS_D1 \
        + BETA_FR_FIETS_D2 * FR_FIETS_D2 \
        + BETA_AT_TRAM_POS * AT_TRAM_POS \
        + BETA_AT_TRAM_NEG * AT_TRAM_NEG \
        + BETA_FR_AUTOSTAD_D1 * FR_AUTOSTAD_D1 \
        + BETA_FR_AUTOSTAD_D2 * FR_AUTOSTAD_D2 \
        + BETA_AGE_D1_TC * AGE3_D1 * TCB_sim \
        + BETA_AGE_D2_TC * AGE3_D2 * TCB_sim
    Alt3 = ASC_OV + BETA_TT * TTC_sim + BETA_WT * WTC_sim + BETA_MTC * MTC_sim + BETA_TC *
        TCC_sim + BETA_FRC * FRC_sim + BETA_CRC1 * CRC1_sim + BETA_CRC2 * CRC2_sim +
        Zero_sigma_panel \
        + BETA_FR_FIETS_D1 * FR_FIETS_D1 \
        + BETA_FR_FIETS_D2 * FR_FIETS_D2 \
        + BETA_AT_TRAM_POS * AT_TRAM_POS \
        + BETA_AT_TRAM_NEG * AT_TRAM_NEG \
        + BETA_FR_AUTOSTAD_D1 * FR_AUTOSTAD_D1 \
        + BETA_FR_AUTOSTAD_D2 * FR_AUTOSTAD_D2 \
        + BETA_AGE_D1_TC * AGE3_D1 * TCC_sim \
        + BETA_AGE_D2_TC * AGE3_D2 * TCC_sim \
        + BETA_HHCARS_WT * HHCARS * WTC_sim
    Alt4 = ASC_AUTO + BETA_TT * TTD_sim + BETA_WT * WTD_sim + BETA_TCD * TCD_sim + BETA_CR *
        CRD_sim \
        + BETA_FR_CENTRUM_D1_TCD * FR_CENTRUM_D1_sim * TCD_sim \
        + BETA_FR_CENTRUM_D2_TCD * FR_CENTRUM_D2_sim * TCD_sim \
        + BETA_HHCARS_WT * HHCARS * WTD_sim


    choiceset = {1: Alt1,2: Alt2,3: Alt3,4: Alt4}

    availability = {1: 1,2: 1,3: 1,4: 1}


    prob1 = MonteCarlo(models.logit(choiceset,availability,1))
    prob2 = MonteCarlo(models.logit(choiceset,availability,2))
    prob3 = MonteCarlo(models.logit(choiceset,availability,3))
    prob4 = MonteCarlo(models.logit(choiceset,availability,4))

    simulate = {'01 Prob. Alt1': prob1,
                '02 Prob. Alt2': prob2,
                '03 Prob. Alt3': prob3,
                '04 Prob. Alt4': prob4}

    # Create the Biogeme object
    biogeme = bio.BIOGEME(database, simulate, numberOfDraws = 100)
    biogeme.modelName = 'ML SC2 modal split'

    # Read the estimation results from a file
    results = res.bioResults(pickleFile = 'ML panel + error component bicycle halton SC2 k1 1804
          interactions 100 draws iteration 8~00.pickle')

    # Simulate the formulas using the nomial values
    # simulated Values is a Panda data frame with the same number of rows as
    # the database, and as many columns as formulas to simulate.
    simulatedValues = biogeme.simulate(results.getBetaValues())

    # Retrieve the names of the betas parameters that have been estimated
    betas = biogeme.freeBetaNames
```

```
        # Draw 100 realization of the distribution of the estimators
        b = results.getBetasForSensitivityAnalysis(betas, size = 100)
        # print(b)

        ModalSplit_A = simulatedValues['01 Prob. Alt1'].mean()
        ModalSplit_A_stdev = simulatedValues['01 Prob. Alt1'].std()
        # ModalSplit_A_left = left['01 Prob. Alt1'].mean()
        # ModalSplit_A_right = right['01 Prob. Alt1'].mean()
        print(f'Market share for A: {100*ModalSplit_A:.1f}%')
    #           f'Std dev A: {100*ModalSplit_A_stdev:.1f}%')
        #       f'[{100*ModalSplit_A_left:.1f}%,{100*ModalSplit_A_right:.1f}%]')
        ModalSplit_B = simulatedValues['02 Prob. Alt2'].mean()
        ModalSplit_B_stdev = simulatedValues['02 Prob. Alt2'].std()
        # ModalSplit_B_left = left['02 Prob. Alt2'].mean()
        # ModalSplit_B_right = right['02 Prob. Alt2'].mean()
        print(f'Market share for B: {100*ModalSplit_B:.1f}%')
    #           f'Std dev B: {100*ModalSplit_B_stdev:.1f}%')
        #       f'[{100*ModalSplit_B_left:.1f}%,{100*ModalSplit_B_right:.1f}%]')
        ModalSplit_C = simulatedValues['03 Prob. Alt3'].mean()
        ModalSplit_C_stdev = simulatedValues['03 Prob. Alt3'].std()
        # ModalSplit_C_left = left['03 Prob. Alt3'].mean()
        # ModalSplit_C_right = right['03 Prob. Alt3'].mean()
        print(f'Market share for C: {100*ModalSplit_C:.1f}%')
    #           f'Std dev C: {100*ModalSplit_C_stdev:.1f}%')
        #       f'[{100*ModalSplit_C_left:.1f}%,{100*ModalSplit_C_right:.1f}%]')
        ModalSplit_D = simulatedValues['04 Prob. Alt4'].mean()
        ModalSplit_D_stdev = simulatedValues['04 Prob. Alt4'].std()
        # ModalSplit_D_left = left['04 Prob. Alt4'].mean()
        # ModalSplit_D_right = right['04 Prob. Alt4'].mean()
        print(f'Market share for D: {100*ModalSplit_D:.1f}%')
    #           f'Std. dev D: {100**ModalSplit_D_stdev:.1f}%')
        #       f'[{100*ModalSplit_D_left:.1f}%,{100*ModalSplit_D_right:.1f}%]')

        #store results
        MS_A[k] = ModalSplit_A
        MS_B[k] = ModalSplit_B
        MS_C[k] = ModalSplit_C
        MS_D[k] = ModalSplit_D

        MS_A_stdev[k] = ModalSplit_A_stdev
        MS_B_stdev[k] = ModalSplit_B_stdev
        MS_C_stdev[k] = ModalSplit_C_stdev
        MS_D_stdev[k] = ModalSplit_D_stdev

        variable_print[k] = variable[j]
        # variable_print_1[k] = variable[j][1]
        variable_interaction_print[k] = variable_interaction[i][0]
        variable_interaction_print_1[k] = variable_interaction[i][1]
        # variable_interaction_print_2[k] = variable_interaction[i][2]
        # variable_interaction_print_3[k] = variable_interaction[i][3]

        k += 1
        print(k)

ModalSplit2 = np.array([variable_print, variable_interaction_print, MS_A, MS_B, MS_C, MS_D,
    MS_A_stdev, MS_B_stdev, MS_C_stdev, MS_D_stdev])

## convert your array into a dataframe
df2 = pd.DataFrame (ModalSplit2)#, columns = ['MS_A', 'MS_B', 'MS_C', 'MS_D'])

## save to xlsx file

filepath = 'C:/Users/Babette/OneDrive/Afstuderen/casestudy_modalspit_scenario2.xlsx'

df2.to_excel(filepath, index=False)
```

F.2 Case study graphs

This section contains graphs that visualize changes in modal split due to changes in attribute levels.

F.2.1 Bicycle

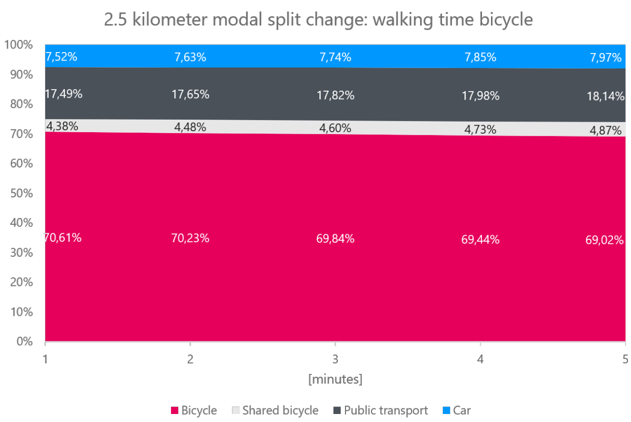

Figure F.1: Scenario 2.5 km: bicycle walking time

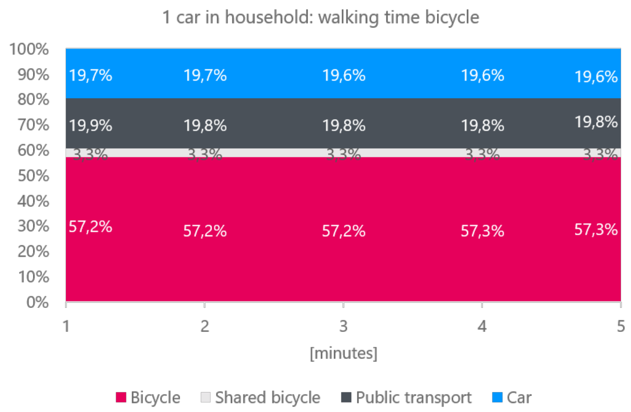

Figure F.2: Scenario 5 km: bicycle walking time * 1 car in household

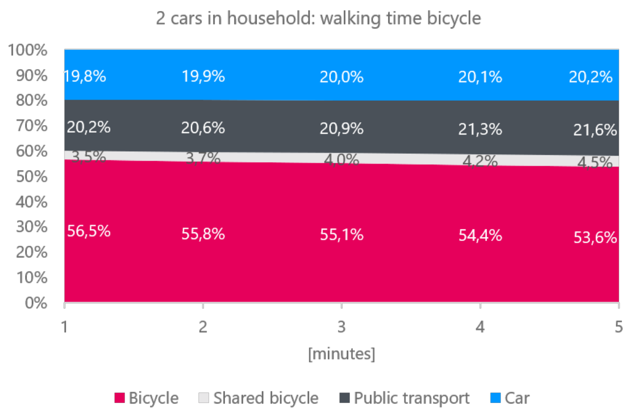

Figure F.3: Scenario 5 km: bicycle walking time * 2 cars in household

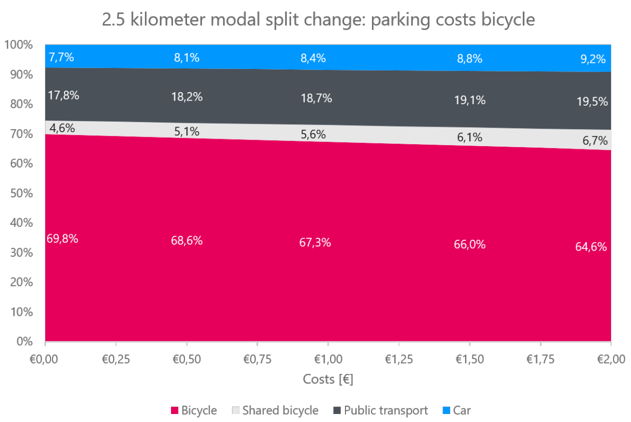

Figure F.4: Scenario 2.5 km: bicycle parking costs

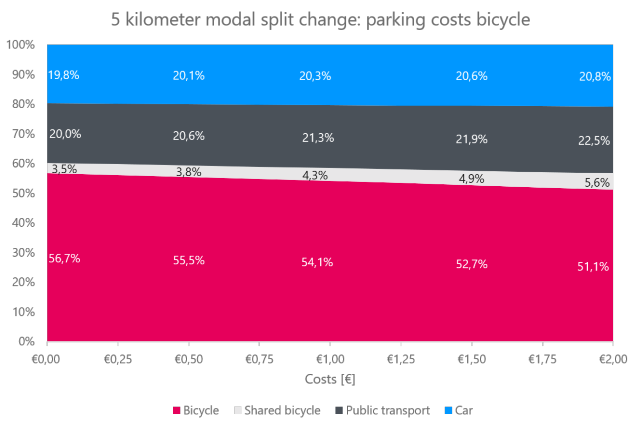

Figure F.5: Scenario 5 km: bicycle parking costs

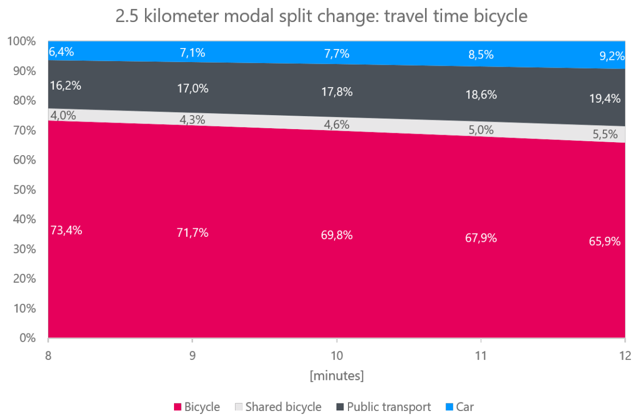

Figure F.6: Scenario 2.5 km: bicycle travel time

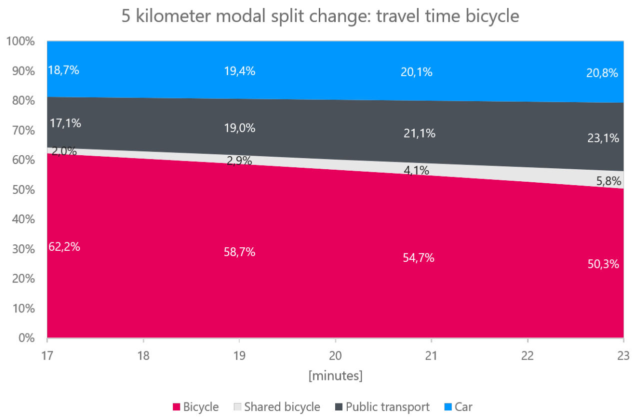

Figure F.7: Scenario 5 km: bicycle travel time

F.2.2 Shared bicycle

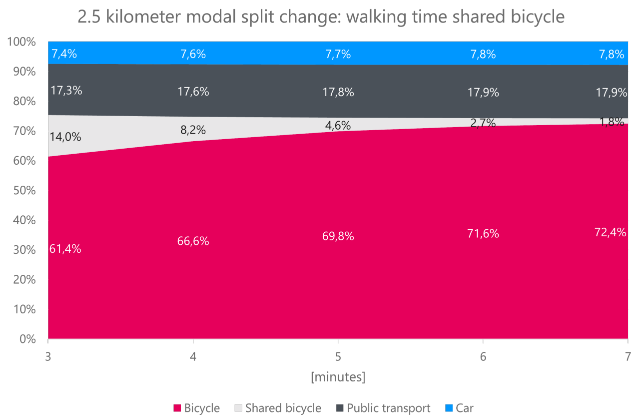

Figure F.8: Scenario 2.5 km: shared bicycle walking time

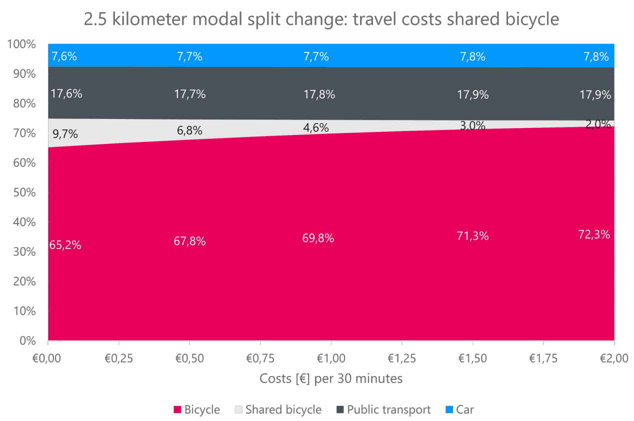

Figure F.9: Scenario 2.5 km: shared bicycle travel costs

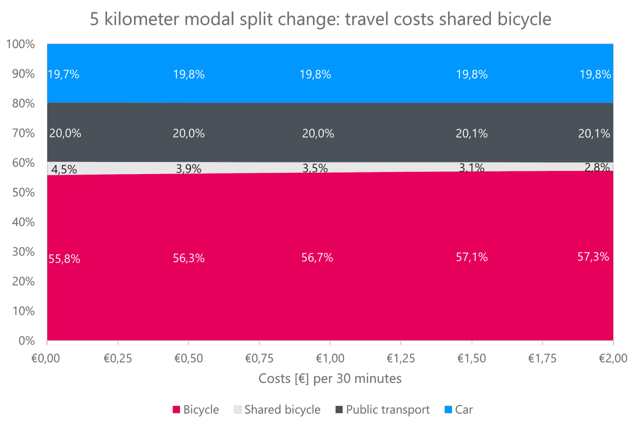

Figure F.10: Scenario 5 km: shared bicycle travel costs

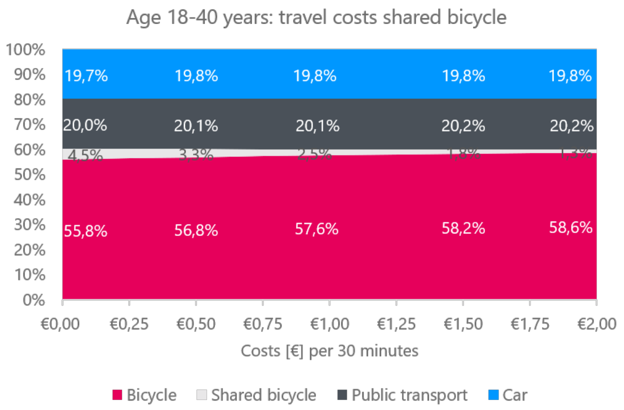

Figure F.11: Scenario 5 km: shared bicycle travel costs * age group 18-40 years

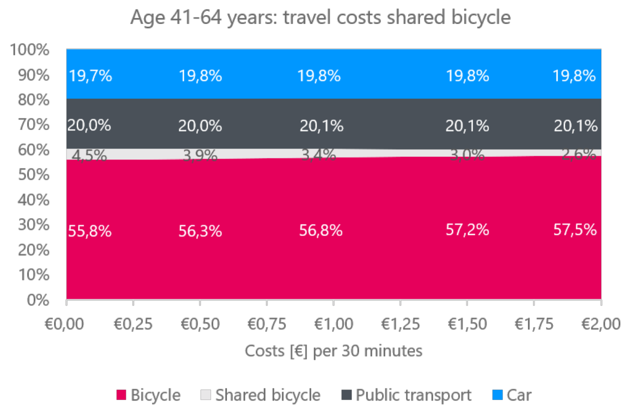

Figure F.12: Scenario 5 km: shared bicycle travel costs * age group 41-64 years

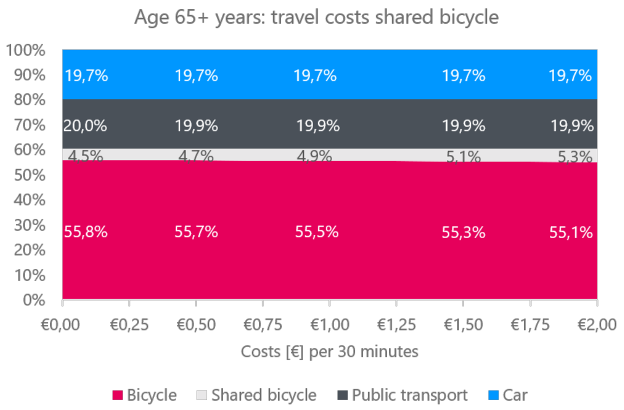

Figure F.13: Scenario 5 km: shared bicycle travel costs * age group 65+ years

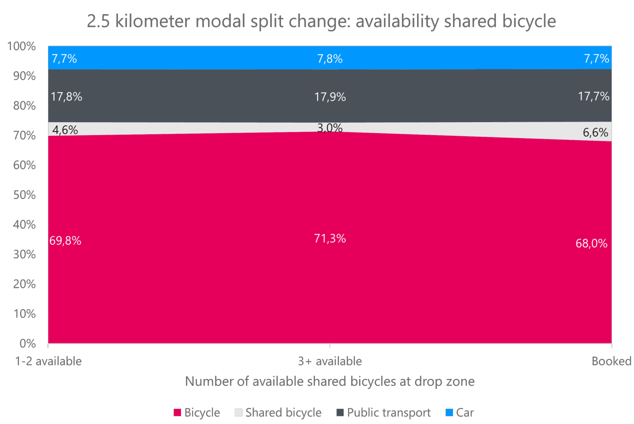

Figure F.14: Scenario 2.5 km: shared bicycle availability

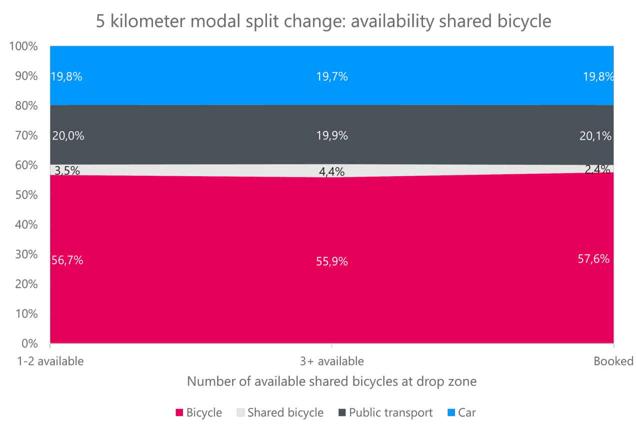

Figure F.15: Scenario 5 km: shared bicycle availability

F.2.3 Public transport

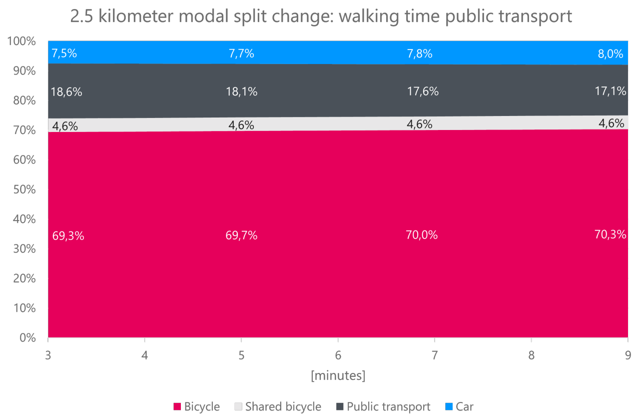

Figure F.16: Scenario 2.5 km: public transport walking time

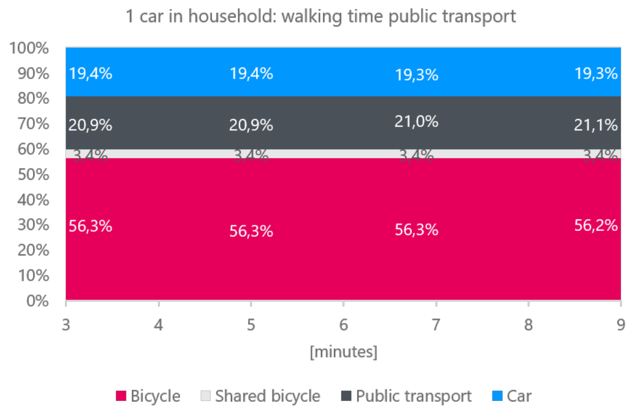

Figure F.17: Scenario 5 km: public transport walking time * 1 car in household

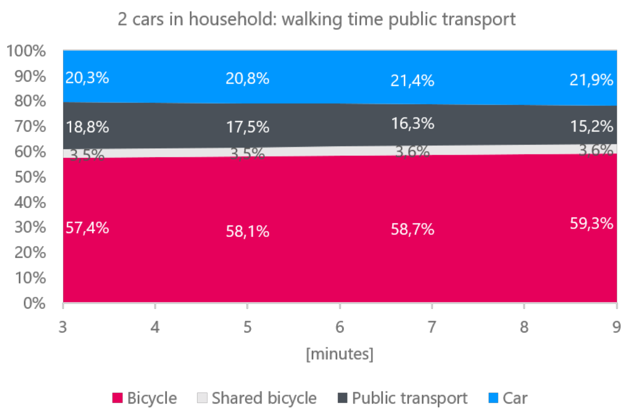

Figure F.18: Scenario 5 km: public transport walking time * 2 cars in household

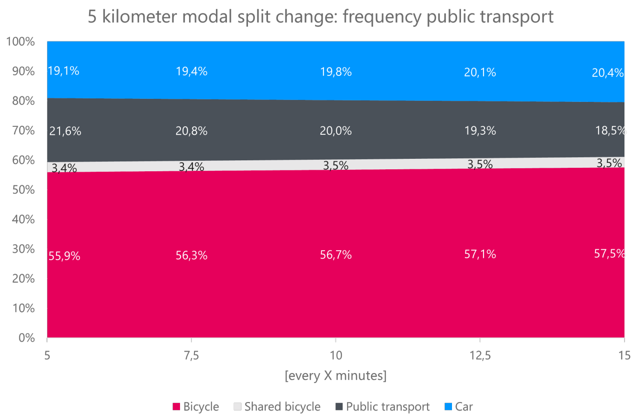

Figure F.19: Scenario 5 km: public transport frequency

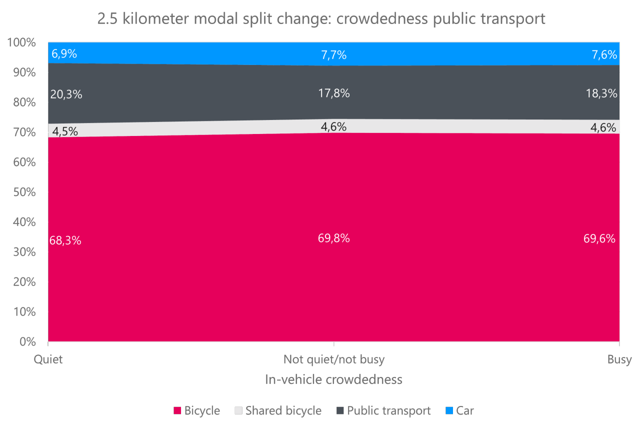

Figure F.20: Scenario 2.5 km: public transport in-vehicle crowdedness

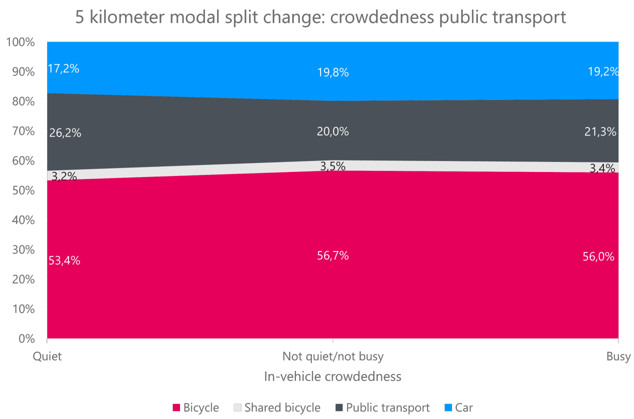

Figure F.21: Scenario 5 km: public transport in-vehicle crowdedness

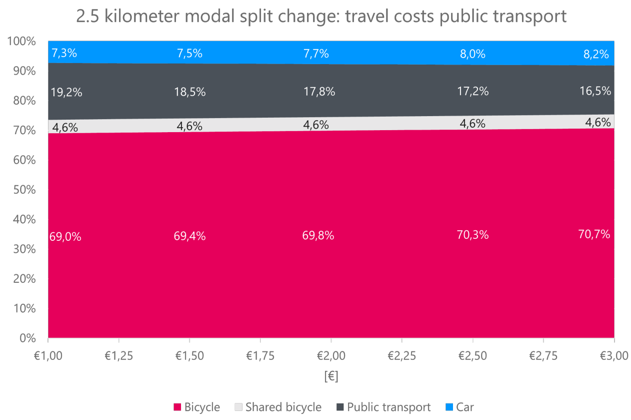

Figure F.22: Scenario 2.5 km: public transport travel costs

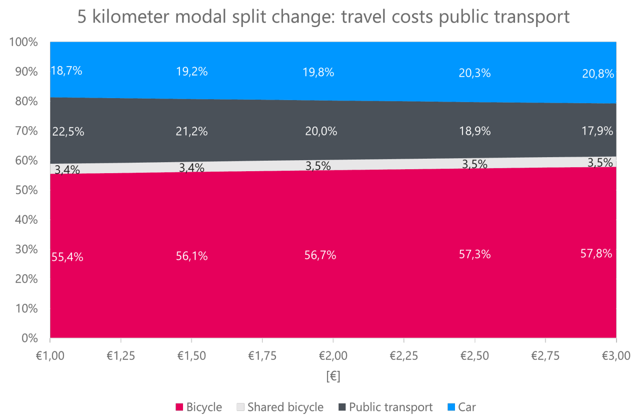

Figure F.23: Scenario 5 km: public transport travel costs

F.2.4 Car

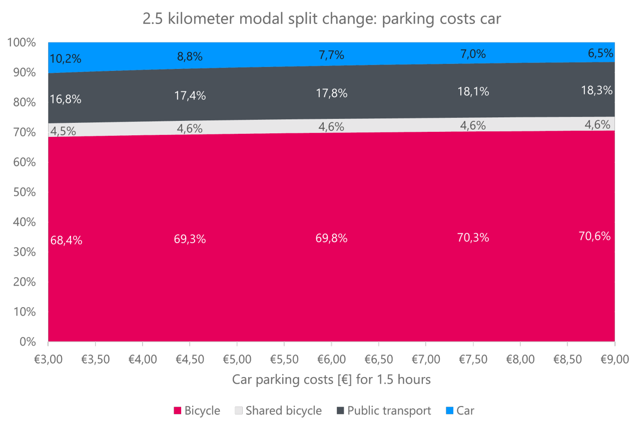

Figure F.24: Scenario 2.5 km: car parking costs

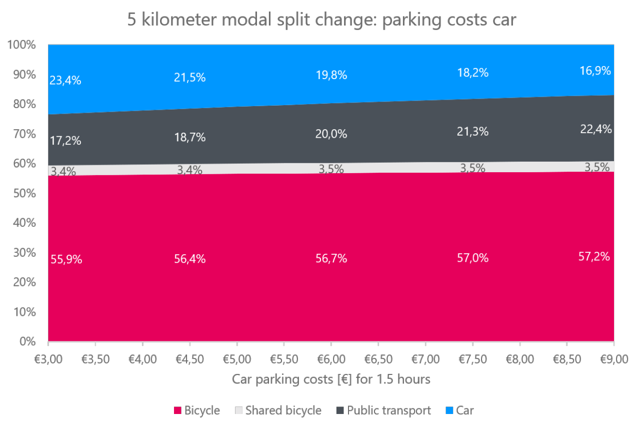

Figure F.25: Scenario 5 km: car parking costs

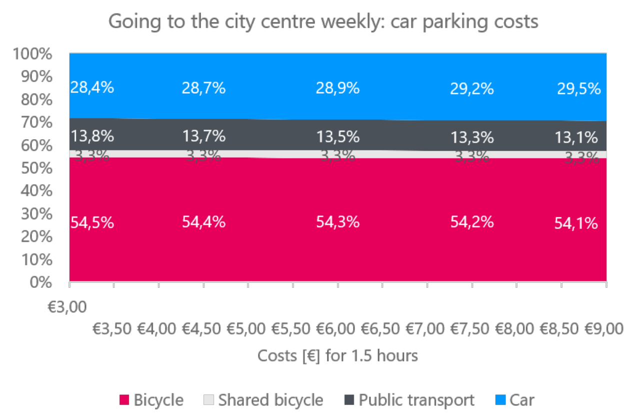

Figure F.26: Scenario 5 km: car parking costs * weekly city centre visitors

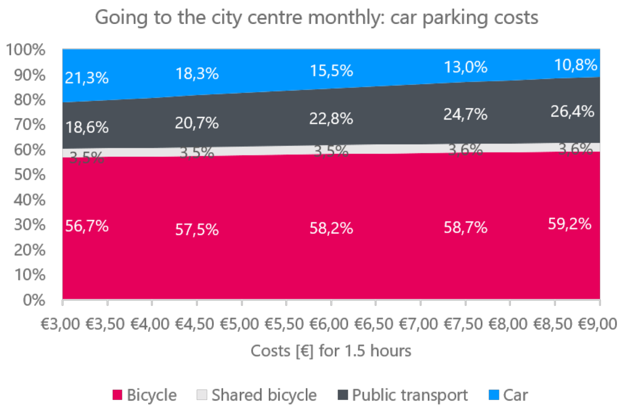

Figure F.27: Scenario 5 km: car parking costs * monthly city centre visitors

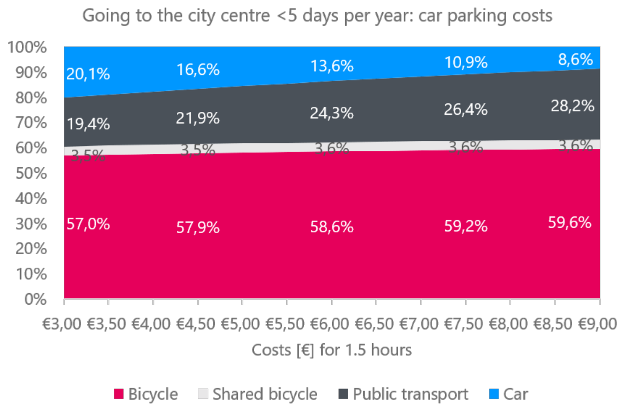

Figure F.28: Scenario 5 km: car parking costs * <5 days per year city centre visitors

F.2.5 Interaction variables

Scenario 1: 2.5 kilometer

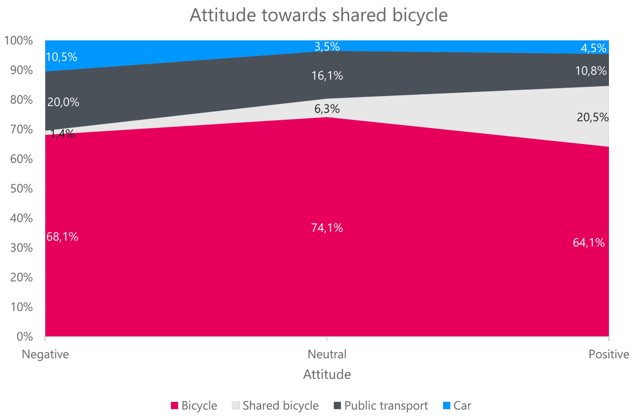

Figure F.29: Scenario 2.5 km: attitude towards shared bicycle

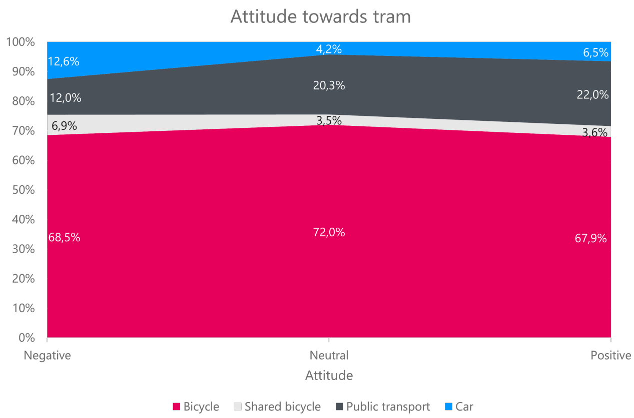

Figure F.30: Scenario 2.5 km: attitude towards tram

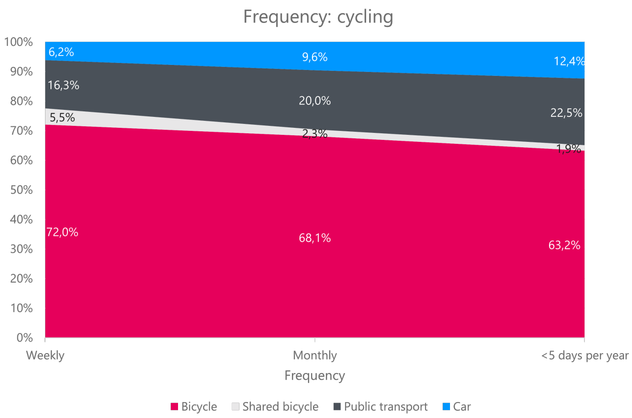

Figure F.31: Scenario 2.5 km: frequency bicycle usage

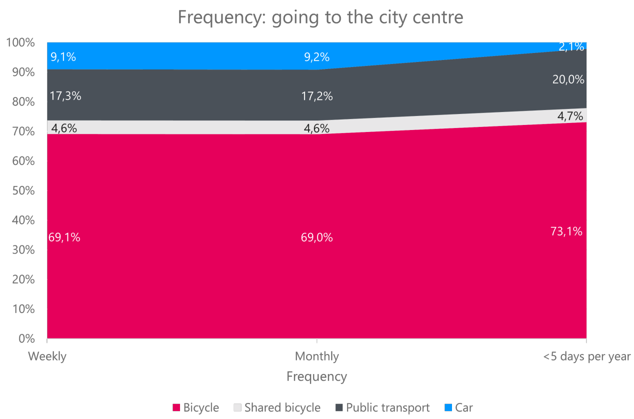

Figure F.32: Scenario 2.5 km: frequency going to the city centre

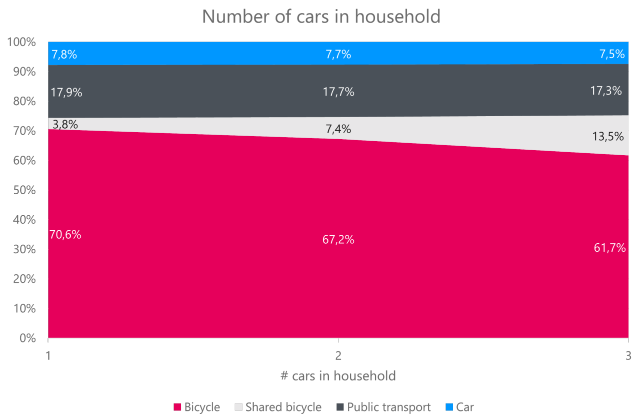

Figure F.33: Scenario 2.5 km: number of cars in household

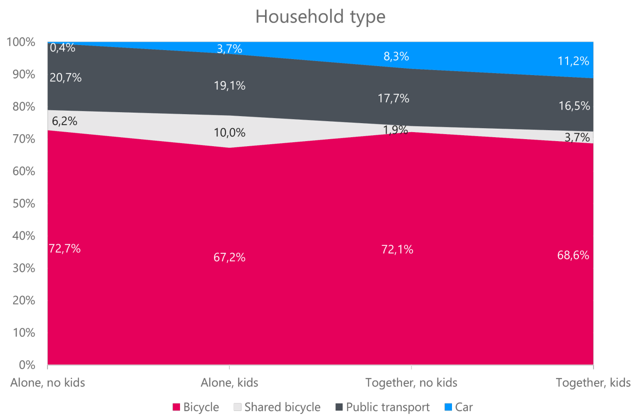

Figure F.34: Scenario 2.5 km: household type

Scenario 2: 5 kilometer

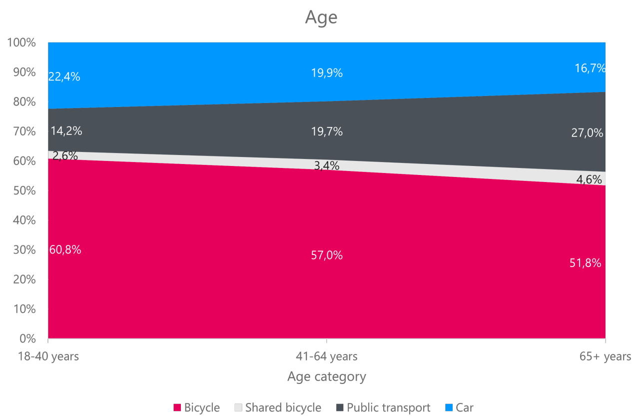

Figure F.35: Scenario 5 km: age

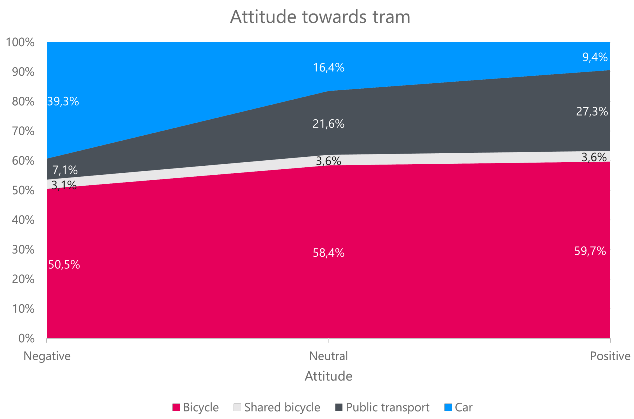

Figure F.36: Scenario 5 km: attitude towards tram

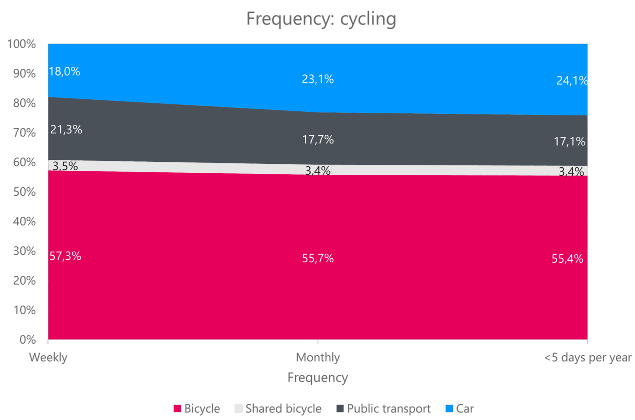

Figure F.37: Scenario 5 km: frequency bicycle usage

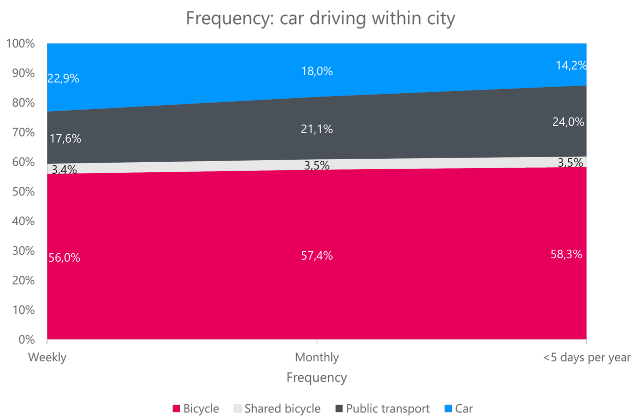

Figure F.38: Scenario 5 km: frequency of car driving within the city

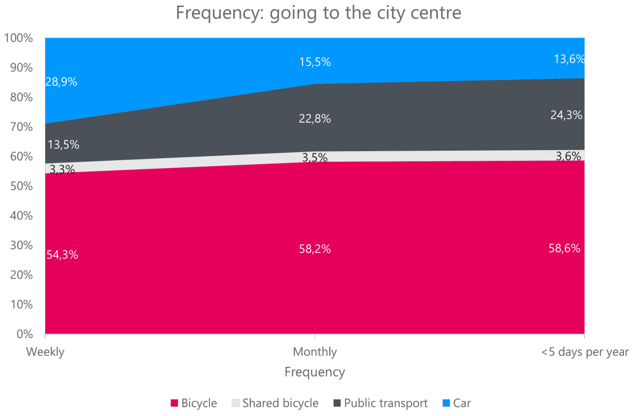

Figure F.39: Scenario 5 km: frequency of going to the city centre

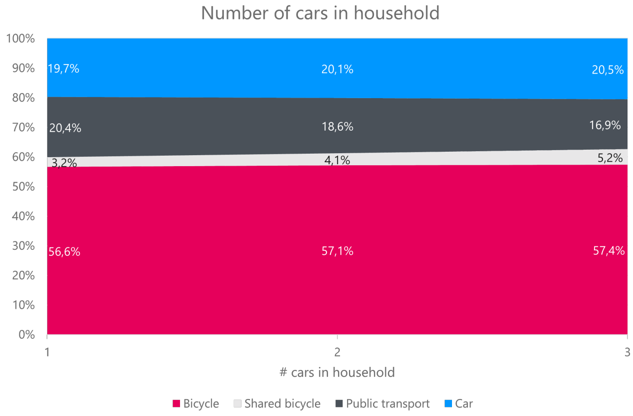

Figure F.40: Scenario 5 km: number of cars in household

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