Exploring bicycle parking potential near public transport stops

A case study in The Hague

MSc Thesis

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Exploring bicycle parking potential near public transport stops

A case study in The Hague

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Preface

This thesis marks the end of a long and meaningful chapter in my life of seven years of being a student, filled with learning, growth and experiences that have both formed me personally and professionally. It has been quite the journey and this thesis is the final step in becoming a civil engineer.

I want to start by thanking my supervisors at the TU Delft. Starting with Nejc and Dorine, thank you for all of your supervision from thesis preparation to this end. Your advice, feedback and support have been very valuable and gave me the feeling I was able to succeed. I am grateful for the time and effort you have invested in supervising me. I loved how we could make jokes in between to not keep things too serious. Lastly, from the TU Delft, I want to thank Niels, always up for a small conversation but also always willing to help me out.

A big thanks also goes out to the Municipality of The Hague, especially to Marit and Stefan, for allowing me to conduct my research at the municipality. Specifically helping me distribute my survey with letters among residents in The Hague, this helped me tremendously and I appreciate all the support and resources you provided.

Furthermore, I want to thank all the friends I have made during my master's, thank you for being there through the ups and downs and coffee breaks. You made this journey so much more enjoyable, and I will always cherish the memories. A special shout-out to the PEPA's, to Adri, Hidde, Jorn, Kim, Sander, Tian, Tijmen, Tim and Yvar, not for only making the study more enjoyable but especially outside of our studies. From having soju evenings to sushi dinners and our recent date dinner. I am looking forward to our "burger" vacations!

I also want to thank my housemates, Fede, Louise, Amedeo and also Miłosz who moved out recently. I am thankful for all the fun house dinners and evenings we had during our studies especially when I was working on this thesis. I am happy to call you guys my housemates and to keep living with you for a while. And see you in Vancouver, Louise.

A huge thank you to my boyfriend, Jasper. Thank you for putting up with me when I was stressed and less energetic, for always being there to support me and especially for keeping me fed with all the delicious food. Your love, patience and care made all the difference. And a special thank you for your time in helping me take pictures for my thesis cover and chapter openings.

Most importantly, I want to thank my parents. You have always been there for me from the start, cheering me on and believing in me, no matter what. You have put me above everything else and I can not express how much that means to me. Your love, support and sacrifices have made everything possible and I could not have done any of this without you. Thank you for always being proud of me and for standing by my side every step of the way.

M. Lai
Delft, October 2024

Summary

Introduction

In urban areas, car usage for short-distances, up to 5 kilometres, is a prevalent issue. These trips contribute to numerous urban challenges for example traffic congestion, environmental pollution and decreased livability in neighbourhoods. As cities strive toward sustainability, there is a need to encourage more efficient and environmentally friendly transport modes. Integrating bicycles with public transport (PT) offers a promising alternative, as it combines the flexibility of cycling with the reach of public transit. However, it potentially comes with challenges and is competing with cycling a full trip instead of a car trip. This research therefore dives into the power of integration of bicycling with inner-city public transport with a focus on the exploration of bicycle parking potential and on how to reduce the reliance on cars for short-distance trips.

Research objectives

The primary focus of this research is to explore the factors influencing travel preferences and the decision to integrate bicycles as a first-mile in a trip. More specifically, this study seeks to understand how bicycle parking near bus and tram stops influences the decision-making process of travellers. It aims to identify which types of bicycle parking facilities and related attributes are most effective in encouraging the use of bicycles in combination with public transport. The study seeks to answer the following main research question:

How can the integration of bicycle parking be implemented at public transport stops to encourage bicycle-PT and discourage short-distance car trips

In answering this, the research also explores demographic and behavioural profiles of both users and non-users of the bicycle-PT combination and investigates what kind of facilities or incentives could drive a shift from cars to bicycles and public transport.

Methodology

This research applies both qualitative and quantitative methods. The qualitative approach consists of structured interviews with residents of The Hague who used the car for a short-distance car trip at that moment of time.

In the quantitative phase, findings from the qualitative interviews are incorporated in a survey that consists of a stated preference part and a questionnaire. The survey is conducted among residents of The Hague using scenarios that test different types of bicycle parking facilities, including a bicycle bracket, shedded parking and bicycle safes. Furthermore, a tyre pump is tested next to the mentioned facilities. The questionnaire includes sociodemographic questions and attitudinal statements to capture respondents' preferences and behavioural.

The collected data of the survey is analysed using a multinomial logit model, which allowed for the estimation of the probability that individuals choose a certain mode of transportation based on various attributes for example, bicycle parking facilities, travel time and travel costs. The model helps assess how much bicycle parking facilities, travel time and travel costs can shift preferences towards the bicycle-PT combination. During the modelling process, various methods and have contributed to the final model. This included a base model, a factor analysis and the incorporation of sociodemographics. The incorporation of sociodemographics happened in two approaches, separately or in interaction effects.

The last step in the quantitative approach is the determination of modal splits and how a modal shift could be achieved using the findings of the final model. This is done by using a persona-based trip

scenario analysis, where personae are undergoing imaginary trips in different scenarios.

Results

In the qualitative results, it is revealed that many residents are open to considering the bicycle-PT combination. However, there are several barriers present. The primary obstacles are a lack of secure, accessible and well-maintained bicycle parking places at PT stops. Additionally, concerns about bicycle theft prevent residents from opting for this specific mode. Moreover, unfavourable weather conditions and the perceived convenience of cars are major factors for a preference for car usage. A couple of interviewees mentioned personal limitations, for example, lack of cycling confidence as a reason for avoiding bicycle-PT as a mode of transport. Despite these challenges, many interviewees acknowledged the environmental and health benefits of cycling and expressed a willingness to use bicycles if the parking facilities are improved.

The findings of the quantitative approach support the qualitative results, and conclude a certain effectiveness of bicycle parking facilities in encouraging the use of bicycles in combination with public transport. The model results showed a clear preference for facilities as a bicycle bracket and a bicycle safe. The availability of covered parking showed mixed results. On the other hand, a bicycle pump was completely not seen as a necessary addition to encourage bicycle-PT usage.

The model revealed notable differences between sociodemographic groups. It is observed that shedded bicycle parking is viewed more positively by middle-educated individuals and those aged between 45 and 54 years old. However, people with high incomes perceived covered parking more negatively compared to the baseline traveller, while the baseline traveller already perceives it negatively. Additionally, there are notable differences regarding the bicycle-PT combination, especially in the perception of travel time between men and women and in travel costs for young adults. Women have a more negative perception of travel time when using a bicycle-PT combination, with their perception almost double as negative compared to the baseline traveller (measured per minute), while men's perception is closer to that of the baseline traveller and making them less affected by longer travel times for this specific mode. Furthermore, young adults aged 18 to 24 years old perceived the travel costs of the bicycle-PT combination very negatively. Their perception of these costs, measured per euro, is more than twice as negative compared to the baseline traveller with a value of -0.414 per euro. This makes bicycle-PT travel costs a significant barrier for this age group.

When the travel time by car is slightly longer than other alternatives for short-distance trips, people tend to switch to other modes of transport. The preference tends to shift mostly towards, bicycles or e-bikes with a slight increase in the use of a bicycle-PT combination. Furthermore, there is potential for implementing bicycle brackets and bicycle safes at public transport stops. Based solely on the implementation of these facilities, a modal shift can be achieved with a 2 percentage point increase in bicycle-PT usage and a 3 percentage point decrease in car usage. Lastly, when combining costs alternations for car and PT travel costs by making car travel more expensive and public transport cheaper larger shifts could occur. In the tested scenario, the bicycle-PT share can increase by up to 5 percentage points while car use can decrease by as much as 6.5 percentage points.

Conclusion

The results indicate that implementing bicycle parking facilities at public transport stops can play an important role in encouraging multimodal travel, in this case the bicycle-PT combination, while discouraging short-distance car trips. The qualitative research highlighted the need for secure, accessible and well-maintained bicycle parking as a key condition in order to use this specific mode. Interviewees noted that unsafe or insufficient parking facilities are a major barrier to using bicycles with public transport.

These insights are confirmed by the quantitative analysis. The role of bicycle parking facilities is important in encouraging people to adopt a bicycle-PT combination, especially the bicycle bracket and bicycle safes. Additionally, cost incentives such as reducing public transport fares or increasing car travel costs can further motivate people to shift from car use to bicycles and public transport.

The persona-based scenario trip analysis suggests potential shifts in the modal split. Depending on the measures applied, bicycle-PT usage can increase by a maximum of 2 to 5 percentage points while car use can decrease by 3 to 6.5 percentage points for short-distance car trips. Although tested within a controlled environment, these shifts can have a substantial impact on a city.

Recommendations

Based on the results and conclusion, the following recommendations are made. First, it is advised to prioritize bicycle brackets due to the ease of use and lower installation costs. The cost-effectiveness ratio of bicycle brackets is higher than that of bicycle safes. However, there is no objection to implementing bicycle safes but this facility does take up more space and is more expensive per parking place.

Further, it is recommended to evaluate potential policy changes regarding travel costs. The results show that adjusting travel costs could lead to a greater shift in mode choices beyond only implementing bicycle parking facilities. To reduce short-distance car trips and encourage the bicycle-PT combination, it is therefore advised to increase car travel costs and reduce public transport fares. The latter can be done in general or a special ticket for this combination mode.

When implementing bicycle parking facilities, whether or not combined with cost changes, it is important to raise public awareness. The more people know about new bicycle parking options, the more likely and sooner it can influence mode preferences and choices. Additionally, promoting bicycle skills and workshops among residents who lack confidence in cycling is recommended. This addresses results from the qualitative research, where respondents indicated to avoid cycling due to this reason.

This study is a case study on The Hague, however these recommendations still apply to similar cities as The Hague. It is expected that in densely populated cities with extensive public transport networks and similar population demographics, the findings of this study will be equally relevant. Therefore, the recommendations can be effectively translated to other comparable cities.

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List of Abbreviations

AIC .... Akaike information criterion
ANWB .... *Algemene Nederlandsche Wielrijders Bond*
ASC .... Alternative specific constant
BIC .... Bayesian information criterion
CBS .... *Centraal Bureau voor de Statistiek*
HTM .... *Haagsche Tramweg-Maatschappij*
IIA .... Independence of irrelevant alternatives
km .... Kilometre
MNL .... Multinomial logit
ODiN .... *Onderweg in Nederland*
PT .... Public transport
RUM .... Random utility maximisation
SBP .... Shared bicycle programs

17 Den Haag Statenkwartier 26min
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1 Introduction

In the complexity of urban life, the prevalent use of cars for short-distance trips, up to 5 kilometres, poses challenges such as traffic congestion, health and safety concerns, and environmental strain such as increased carbon emission and fuel consumption. Many of these effects are also pointed out by van Wee (2014). On the other hand, from the users' point of view, the main benefits of choosing the car are convenience, flexibility and door-to-door accessibility. However, due to the disadvantages on a city scale cities are globally at a turning point, compelled to reassess their urban transportation strategies for a more sustainable quality of life in the future (World Health Organization, 2018). Within this context, integrating active modes with public transport (PT) emerges as a promising solution, aligning with the broader global push for environmentally conscious and better connections between different neighbourhoods within a city or metropolitan area.

The foundation of this proposed shift lies in recognizing that incorporating private and/or shared bicycles into public transit should not only be practical but also attractive. This idea on private bicycles has gained traction not just from a pragmatic standpoint but also from an experiential one, as reflected in numerous studies (Kager and Harms, 2017; Kosmidis and Müller-Eie, 2023) highlighting the potential advantages of this integrated approach. However, it's important to note, as observed in research including studies conducted in The Hague (van Marsbergen et al., 2022), that shared bicycle programs (SBP) may in some instances reduce the ridership of public transport. It can function more as a substitute than a complementary. This suggests a complex relationship with SBPs, while beneficial in many aspects, but might also compete with PT for ridership.

A significant body of literature supports the need to reimagine urban mobility and a handful underscores access and egress or the synergy between bicycles and public transit. Research emphasizes the positive impact of shared bike public transit integration on overall accessibility and its potential as a sustainable alternative to car trips (Cohen and Shaheen, 2016). Similarly, studies delve into the psychological aspects, exploring the motivations behind individuals choosing biking as a mode of transportation, particularly in urban settings (Fishman et al., 2013 and Goodman et al., 2013).

Despite the recognition of benefits, the practicalities of encouraging individuals to opt for bicycles towards public transit, especially in bustling city centres, remain relatively unexplored. This research aims to explore this topic and specifically in the context of The Hague, building upon existing literature and to get a better understanding of the dynamics of the bicycle and transit combination.

Advocating for a bicycle to public transit is rooted in the recognition that discouraging short-distance car trips involves more than presenting practical alternatives. It still involves offering choices and facilities aligning the characteristics near stops. The facilities would target bicycle parking, including parking at all, secured or unsecured parking, shared mobility, hubs and more. This perspective is supported by the findings of studies conducted by Broach et al. (2012), underscoring the role of environments that enhance the attractiveness and viability of biking as an option.

Moreover, recognizing the impact of facilities near public transport stops on travellers behaviour, this research expands its scope to investigate how the presence and quality of such facilities influence the decision to opt for bicycles. This includes examining the role of bike-sharing facilities, the type of parking and other amenities in shaping commuter choices. By integrating these facets into the analysis, the study aspires to provide a comprehensive understanding of the factors and attributes influencing urban mobility choices in the context of bike and public transport integration. This examination of elements aims to contribute nuanced insights to guide urban planners and policymakers in achieving a more sustainable future and livability in cities.

Crucially, the research aims to make the first step to go beyond the conventional narrative by incorporating the characteristics of different traveller profiles and their behavioural nuances. By profiling distinct criteria based on preferences, demographics and behavioural habits, the study seeks to understand the diverse motivations that drive individuals to choose or avoid the bicycle and public transit combination. This exploration is not only intriguing from a sociodemographic point of view but also serves a practical purpose. By profiling inhabitants of urban areas by sociodemographics, informed decisions to facilitate the modal shift can be made. The research thus aspires to contribute valuable insights to guide urban planners and policy makers in making car usage less attractive and public transit in combination with cycling towards stops more tempting.

1.1. Problem description

This research addresses a critical challenge namely, understanding the complex factors influencing individuals' decisions to adopt bicycles with inner-city public transport for inner-city travel, particularly within lively urban areas with many inhabitants and events going on. In the contemporary city structure, the frequent reliance on cars for short-distance trips not only contributes to the increasing number of trips on road networks but also impacts the livability of neighbourhoods and cities. The car-dependent trips raise environmental concerns, intensify traffic and therefore congestion and diminish the overall quality of life in urban areas.

A crucial aspect of this challenge lies in acknowledging that reducing short-distance car trips holds the promise of removing pressure on road networks, thereby enhancing the livability and accessibility of neighbourhoods and cities in this aspect. Moreover, targeting short-distance trips can now be seen as just the beginning. This broader perspective emphasises the need to explore the multifaceted dynamics shaping inhabitants' choices to embrace bicycles within the context of public transit versus the reliance on cars.

Understanding these dynamics is useful in guiding policy making and urban planning strategies, aiming not only to encourage healthier travelling options but also to strategically improve the quality of urban living and accessibility by mitigating traffic congestion. Failing to find a way to start a modal shift from car usage poses a significant risk, with the potential consequence of overwhelming inner cities with increased traffic when cities tend to keep on growing. This is besides the already existing challenges that cities are facing. The urgency to initiate and guide this shift becomes important to prevent cities from becoming overloaded and to contribute to the overall sustainability and livability of urban environments.

1.2. Research scope

The focus area of the study will be directed towards understanding and enhancing bicycle-PT integration to discourage short-distance car trips within The Hague. Emphasizing a pragmatic approach, the research will delve into specific aspects of The Hague's tram and bus network, potentially narrowing down the research to select certain or more used tram and bus stops or routes to ensure a thorough exploration within the designated time frame. The focus therefore lies on only uncovering the most distinct profiles of current users of public transport and the bicycle and public transport combination, and the non-users such as car users. By using these distinct profiles, the main do's and don'ts regarding the facilities at stops are considered. Since many different and diverse factors could be of relevance and have an influence on people's behaviour, the research is only going to use the defined main factors. Accordingly, this is scoped by presenting limited scenarios in order to give an initial overview of the profiles of users and non-users.

1.3. Research objective and questions

1.3.1. Research objective

This study aims to gain a comprehensive understanding of the influences that shape public transport users as well as non-users decisions on when to incorporate the use of the mode bicycle as a first-mile option into public transit.

Firstly, the aim is to delve into the motivations that drive individuals, including users and non-users of public transport, to opt for bicycles into the public transport network of The Hague over conventional cars for short-distance trips. Understanding these motivations is key for deciphering the underlying factors that contribute to the mode shift from car to public transport.

Secondly, the research aims to explore the role of facilities near public transit stops in shaping traveller choices. This includes evaluating the presence and quality of amenities such as bike-sharing facilities, the type of parking and other facilities that can influence the ease and attractiveness of the bike into public transit integration. Understanding the influence of these facilities will contribute essential information in order to better accommodate and encourage the use of bicycles into the public transport system.

In addition to these objectives, the study will delve into profiling different traveller traits based on their preferences, demographics and commuting habits. This exploration aims to identify distinct profiles of individuals who tend to opt for the bicycle and public transit, shedding light on the diversity of commuter choices and informing targeted strategies for urban planning and policy development. These profiles will be instrumental in making informed decisions to facilitate the modal shift towards less usage of cars for short distances, ensuring that strategies are tailored to the specific needs and preferences of different profiles of travellers.

By achieving these objectives, the research seeks to offer nuanced insights and practical recommendations to policy makers and urban planners. The ultimate goal is to formulate effective strategies that not only promote alternatives to going by car but also can contribute towards the overall livability and efficiency of urban environments by strategically reducing traffic congestion by hosting certain facilities near the stops. Additionally, the study aims to determine whether a generalized configuration of facilities can be recommended to policy makers for widespread implementation.

1.3.2. Research questions

Exploring the topic of urban mobility, this research seeks to delve into the potential of optimizing the integration of bicycles with stops in The Hague's tram and bus network. Therefore the main research question is stated as follows:

How can the integration of bicycle parking be implemented at public transport stops to encourage bicycle-PT and discourage short-distance car trips?

To answer the main research question, several sub-questions have been formulated to build upon the main question. Through the sub-questions stated below, the study aspires to provide insights that can inform strategies to design for more attraction towards public transit than the usage of cars. Therefore the sub-questions are stated as follows:

- *What is the perceived level of accessibility by bike in travellers' perception at public transport stops?*
- *To what extent are there demographic or behavioural profiles that can be identified among those who opt for bicycle-PT integration and those who do not?*
- *How do these profiles influence urban mobility choices as well as their choice to integrate bicycles with city scale PT?*
- *What criteria or facilities motivate individuals to choose bicycle-PT integration over short-distance car trips?*

1.4. Scientific and societal relevance

1.4.1. Scientific relevance

Existing literature on bicycle integration in public transport is mostly dedicated to trips that include using a train. However, trips within a city are mostly not considered. Therefore, this research aspires to fill this mentioned gap. Furthermore, a conspicuous gap persists in understanding the distinct profiles of users and non-users of public transport and therefore also in the topic of bicycle-PT integration to determine the facilities that are required at tram and bus stops. The aspect of exploring travel preferences and behaviour of non-PT-users to create a modal shift and a change in PT ridership can be quite relevant. This is also opted in van Kuijk et al. (2022). This research however is more focused on shared mobility, but regardless of the focus, the relation with public transport creates a good basis for this research to base its importance on the already existing research that has been done. This includes also the specific case study on The Hague. These aspects can all be used in a broader context for societal relevance which is discussed in the next section.

1.4.2. Societal relevance

The challenge for most cities is to manage the environmental impact and congestion associated with car usage. In the particular case of The Hague, it is then interesting to look at how to reduce the shorter distance trips within the city. Mainly opted to relieve the network partly from these trips and to accommodate other trips better that include the use of highways. Due to the high potential of the public transport network to discourage car usage for inner-city trips, it is worth exploring how this can be done. The municipality's mobility transition strategy (Gemeente Den Haag, 2021b) already sets a standard on what is the desired result of overall mobility in the city. The municipality values sustainability, efficient urban mobility and enhancing the quality of life for residents. These key values strongly align with the research context.

A simple step in the right direction in achieving these values is therefore implemented by activating the public transport potential. This research investigates the integration of cycling with public transportation as a viable solution to alleviate the city's congestion and environmental concerns. By focusing on the facilitation of bicycle access to public transport nodes, the study aligns with The Hague's vision. This approach not only promises to enhance the efficiency of the city's transport network but also contributes to a significant reduction in short-distance car trips.

Moreover, the implication of the research extends beyond mere transportation logistics. It delves into the societal aspects of urban mobility, exploring how changes in transportation infrastructure can positively influence the lifestyle and well-being of The Hague's residents. The findings of this study are expected to offer practical insights into the dynamics of urban mobility. The insights guide the city's effort to develop a more integrated, sustainable and user-friendly transportation system in the end.

In conclusion, the relevance of this research to The Hague lies not only in its potential to inform and shape local mobility policies but also in its contribution to the broader discourse on sustainable urban development. By addressing the specific needs and characteristics of The Hague, the study serves as a case study for other cities struggling with similar challenges in urban mobility.

1.5. Thesis outline

The outline of all chapters in this thesis will be as follows. In Chapter 2, the methodology of this study is explained which is followed by the literature review in Chapter 3. The specific case study of The Hague in this research is going to be described in Chapter 4. In Chapter 5, the experimental setup is discussed with the results of the research in Chapter 6. The interpretation of the results are going to be elaborated on in an analysis in Chapter 7. Closing it off, the conclusions of the model and its interpretation in this research are mentioned in Chapter 8 and the discussion and recommendations in Chapter 9.


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Literature review

This chapter aims to collect and adapt the existing knowledge on integrating bicycles with public transit while focusing on urban transit and the behavioural aspects of users and non-users of public transport. The aim is to have a better grip on users' aspects regarding the first- and last-mile towards public transit within a city. Subsequently, the problem that is sketched within this research involves convincing non-regular or non-users that particularly use the car as a mode of transport for short-distances to make a mode shift towards public transport. For this study, a focus is put on the multimodal trip of a bicycle and PT is targeted. This creates many elements to be of importance. In literature, several researchers have explored different relations between different transport feeders and users or bicycle integration and users.

The literature review is divided into (non-)user characteristics, travel behaviour, mode choice factors, bicycle facilities. Based on the knowledge that is gained from this chapter a set up of the research can be determined on how to tackle the research problem and achieve the research objectives.

2.1. (Non-)user characteristics

(Non-)user characteristics, especially sociodemographics are of importance within this research. The moderating effects of these sociodemographics can all influence travel behaviour and therefore mode choice. The most commonly used sociodemographics to describe individuals in similar choice behaviour studies are gender, age, education level and income level. Furthermore, available transport mode ownership is considered.

Age

Shared bikes are less used by older age groups either as a mode for themselves or as an access/egress mode for public transport (Böcker et al., 2020). The latter is partially supported by other findings of where bike transit users are typically in the 17-27 age group (Shelat et al., 2018). However, other findings say that age is positively associated with bicycle-transit integration (Chan and Farber, 2020. There are quite some differences and contradictions in findings in literature when it comes down to the relation between age and bicycle usage towards transit.

Gender

Numerous studies have showcased that men are more likely to use the bicycle-PT combination and have higher cycling rates. It is discovered that men have a higher share (71%) of bike transit users (Sherwin et al., 2011. Additionally, cycling rate of men is higher than women (Meng et al., 2016 and Park et al., 2014). To add upon this, it is observed that men are more likely to use the bicycle-PT combination (Böcker et al., 2020). Furthermore, it has uncovered that men are willing to travel longer access/egress distances and are less discouraged from riding a bicycle during limited daylight than women (Molin and Timmermans, 2010).

Education level
Various research findings suggest that individuals with higher levels of education tend to opt more often to combine cycling with public transportation (Jonkeren et al., 2021 and Shelat et al., 2018). Contrarily, another research identified no link between educational attainment and the use of bike-transit combinations in the United States, though they observed correlations with housing status and cultural background (Wang and Liu, 2013). These results suggest that variables connected to a person's socioeconomic position such as income or place of residence may more accurately forecast their transportation choices.

Income level
A positive correlation is found between median income and the willingness to integrate biking with transit usage in Greater Toronto and the Hamilton area (Chan and Farber, 2020. Similarly, but in The Netherlands individuals who use both bikes and transit typically fall into higher income brackets (Shelat et al., 2018). Conversely, in China it is observed that the lower income groups are more inclined towards the combined use of bicycles and public transit, suggesting geographic variations in the socioeconomic dynamics of transportation choices (Yang et al., 2014).

Car ownership
Lower rates of car ownership have a positive association with the use of bicycles in conjunction with public transit (Chan and Farber, 2020. Additionally, car owners show a greater willingness to adopt e-bikes over conventional bicycles or public transport (Kroesen, 2017). Besides this a gradual decrease in car ownership among young adults is rising.This is a trend potentially linked to increased urban living and delays in starting a family, which might lead to less car ownership among this group in the future (Oakil et al., 2016).

Bicycle ownership
In the context of The Netherlands a significant decline in both car usage and public transportation when individuals own e-bikes, as opposed to conventional bicycles (Kroesen, 2017). This finding aligns with another research that noted a complex relationship between bicycle ownership and public transit use (Huang et al., 2017. Owning a private bicycle correlates with increased use of the metro whereas possession of an e-bike tends to correspond with a reduced likelihood of using the metro system. These insights suggest that e-bike ownership may serve as a substitute for other modes of transport rather than complement them. A few sociodemographic factors reveal that gender and socioeconomic status significantly influence car access, which in turn affects mode choice decisions (Ellaway et al., 2003). What else can affect mode choice decisions is elaborated on in Section 2.2. A higher proportion of males than females reported having household access to a car. These aspects highlight the diversity in travelling profiles.

2.2. Mode choice factors

Experience or even satisfaction level towards a particular mode can be a key aspect in such a choice. For example, the first and last-mile journey significantly influences satisfaction with public transit (Susilo and Cats, 2014). Adding to this, it is revealed that users frequently adopt a combined mode of cycling and public transport in their daily activities (Shelat et al., 2018 and van Mil et al., 2020). This behaviour can further be influenced by weather conditions and safety considerations (Molin and Timmermans, 2010). Additionally, they observed that adverse weather, heavy baggage and limited daylight negatively affect bike-transit usage, whereas companionship and route familiarity, can have positive effects. To add upon this, the significance of personal safety, waiting comfort and information accessibility, contribute to the perceived quality of bicycle facilities when considering physical safety (Venter, 2020).

Furthermore, the variability in mode choices between home-end and activity-end connected trips depends on the availability of mode alternatives (Hoogendoorn-Lanser et al., 2006). Additionally, different research underscores the pivotal role of bicycle travel time in having the incentive to create a mode shift (Limburg, 2021). This emphasizes the adverse impact of car reliance on urban space. Bike-transit users are prepared to cycle an additional 6 minutes to avoid transfers (van Mil et al., 2020), showcasing specific user preferences in their commuting pattern. This information can be applied towards the larger stops in the network.

On the psychological front, car drivers often require significant incentives to switch to the bike and PT mode (Arentze and Molin, 2013). This insight is complemented by another research that identified core motives for car usage, such as journey time, personal space concerns and monetary costs (Gardner and Abraham, 2007). The previous research also underpins these motives as the desire for control. This indicates the psychological barriers involved in transitioning from car to alternative modes.

2.3. Bicycle facilities

Bicycle parking facilities can differ from place to place depending on space availability or budget constraints. For inner-city scale public transport, space near stops is on many occasions quite limited. However, there are several implementation styles of bicycle parking facilities at these stops. An interesting observation arises in the catchment radius for tram stops in The Hague being roughly 1 kilometre (Rijsman et al., 2019). This geographical factor in combination with the question of how to arrange bicycle parking facilities in the city, results in an important aspect in determining how to facilitate a mode shift. The strategic placement of bicycle parking facilities plays a crucial role in the integration of cycling with public transport where the most important attributes of access to a station, is the location of bike parking facilities (Geurs et al., 2016).

Furthermore, the emergence of shared mobility can not be ignored and has so its importance regarding the facilities that can be offered. Shared mobility options have gained prominence, particularly among the younger audience (age < 26) and those bound for suburban destinations (van Kuijk et al., 2022). By having prominence within the younger population, this can be affected by the characteristics of an individual, relating to Section 2.1. Next to this, a similar correlation is found based on age and acceptance of shared mobility (Yan et al., 2020). This particular case was focused on shared bicycles in the last mile of metro trips, while another research observed shared bicycles predominantly replacing trips made on foot/private bicycles or substituting public transit trips (Bachand-Marleau et al., 2012). This last observation is therefore closely related to individuals' mode choice behaviour.


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3
Methodology

The following chapter outlines the diverse methods to use in this research. This chapter is sectioned off to the various approaches of the study, which will dive into the methods of finding existing relevant literature and the research methods to conduct and fulfil the research objective. In Section 3.1, an overview is going to be displayed on how the literature review was carried out in Chapter 2. Section 3.2 gives more detail on the methods for qualitative resident interviews. The last section, Section 3.3, describes the methodology of the quantitative approach of this research. This includes the survey design, discrete choice modelling and the model interpretation. A visualisation of the involved parts and connection to other parts of the research is shown in Figure 3.1.

3.1. Literature review

The approach aims to collect and adapt the existing knowledge on integrating bicycles with public transit while focusing on urban transit and the behavioural aspects of users and non-users of public transport. The search strategy involved using several platforms hosting research papers, namely Scopus, ScienceDirect and Google Scholar. Some keywords that can be included are ”bicycle transit integration”, ”first-mile” and ”last-mile”, ”tram” and ”bus public transport” and ”users” and ”non-users of public transport”. Using these keywords during the search for relevant literature is expected to learn what attributes are relevant to include in the research and which are less relevant. This is for both the consideration of what influences the parking facilities at tram stops but also on the sociodemographics and behavioural aspects of users and non-users of public transit. The actual keywords that are used to gather information to form Chapter 2 are shown in Table 3.1. Furthermore, the tool of Connected Papers and recommendations of supervisors was used to narrow the search for relevant literature as well. The recommended research is in Table 3.2.

Moreover, the literature search is also applied to zoom in on the city of The Hague. To find relevant literature related to The Hague. The strategy of talking to several experts within the municipality of The Hague is applied. By doing this, ongoing processes on this topic are discovered. This led to several interesting research and reports by the municipality and its partners to help adapt this study. An example of used literature from the municipality of The Hague, carried out by Motivaction is on inhabitant profiles in the city (Motivaction International, 2023).

Lastly, the bicycle facilities were specifically aimed for. In combination with the general search for literature, extra attention to bicycle facilities is given. Furthermore, it is explored what sort of bicycle parking facilities and services the market offers as of today in 2024.

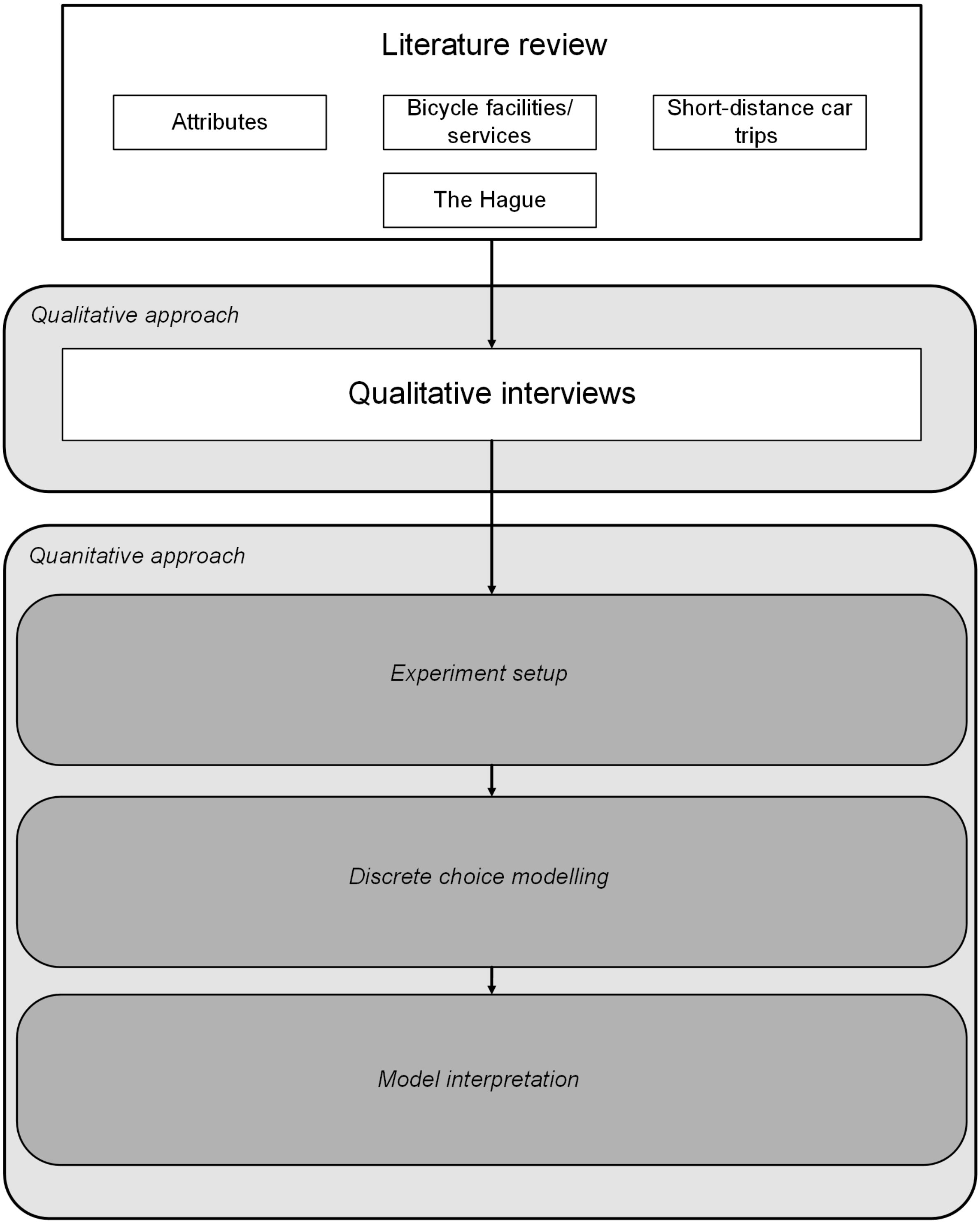


Figure 3.1: Visualisation of the research methodology

Keywords	Research
car use reasons	Gardner and Abraham, 2007
benefit cycling public transport	Kosmidis and Müller-Eie, 2023
first and last mile	van Kuijk et al., 2022
bicycle transit	Shelat et al., 2018
unsustainable car use	van Wee, 2014

Table 3.1: Used key words

Topic of recommended research	Research
Preferences for first and last mile shared mobility between stops and activity locations	van Kuijk et al., 2022
Potential for sustainable mode usage amongst cat users in mid-sized cities (The Hague)	Limburg, 2021
Walking and bicycle catchment areas of tram stops in The Hague	Rijsman et al., 2019
Insights into factors affecting the combined bicycle-transit mode	van Mil et al., 2020
Analysing the trip and user characteristics of the combined bicycle and transit mode	Shelat et al., 2018

Table 3.2: Recommended research

3.2. Qualitative approach

In this study, a qualitative approach is used in the form of interviews to get a better understanding of the motives for why residents use the car. The main purpose of this research method is to uncover potential motives that are not covered by the literature. Additionally, this method allows flexibility in responses and the opportunity to ask deeper in depth when needed.

The interviews are conducted through structured questions. However, as mentioned there is the opportunity to be flexible. In this study, qualitative data is gathered from local residents who are using the car at that moment. The questions during the interview are:

1. Where are you currently going/did you go to?
2. What are you going to do/did you do?
3. Did you consider another mode of transport for this activity?
4. Is the car your main/favourite mode of transport?
5. Did you consider the bicycle + PT option? Also in a more general case?
6. What is needed to convince you to use (more) the bicycle + PT combination?
7. What is your opinion on the current bicycle parking facilities near public transport stops?

The aim is to gather around 20 to 30 interviewees to answer these questions about their mode preferences and general opinions. The questions and specific target audience are to get a comprehensive understanding of car usage patterns and a general opinion of the bicycle + PT mode among the local population.

Prior to conducting the interviews, a risk assessment is submitted with a risk assessment through the labservant of the TU Delft. This protocol ensures the mitigation of any potential hazards associated with conducting interviews near traffic. Key to this way of researching is to precautionously use high-visibility vests with the TU Delft logo. High visibility results in more alertness of surrounding traffic and lets residents know for what institution the research is conducted. Interviews are conducted on-site and involve a second person. The presence of a second person is necessary to have immediate support in the event of any accidents or incidents. Before each interview, consent from a participant is obtained and explained that it is not mandatory. This preliminary step is crucial to prevent any unwanted situations and to respect the interviewee. The results of the residents' interview can be found in Chapter 6 which contributes in answering the main research question and the first sub-question.

3.3. Quantitative approach

In the next part, the results gathered from the qualitative resident interviews to form base knowledge to execute the quantitative research. This sequential mixed research can provide a more comprehensive understanding of the research problem. Additionally, implementing a quantitative method allows for testing findings on a larger sample to create generalizability. The methodology of the quantitative approach is discussed and broken down into partial steps. The steps consist of the survey, discrete choice modelling and the model interpretation.

3.3.1. Survey

In order to collect data on The Hague's residents' preferences, a stated preference survey is introduced. The convenience of this method and the high flexibility are preferred over a revealed preference method. The last mentioned method entails observing real-world behaviour which has a limited scope since it only captures choices that are made. This ignores the reasons behind these choices or alternatives that were considered but not chosen. Therefore, it is opted to conduct quantitative research by stated preference surveys using a digital platform named Qualtrics (Qualtrics, 2021). The stated preference part of the survey is accompanied by a questionnaire at the end of the survey.

The stated preference survey was designed using Ngene (ChoiceMetrics, 2021). Twelve choice tasks are developed with an efficient design methodology. This type of design optimizes the statistical efficiency of the survey by selecting a subset of scenarios that maximizes the information gained about the parameters of interest while minimizing redundancy.

It is chosen to present eight out of twelve choice tasks to each person who fills in the survey. These choice tasks have a two-part question structure: a base question assessing initial transport mode preferences regarding the bicycle or a combination of the bicycle and public transport. This is followed by a control question to verify consistency when compared to modes currently used by the respondent.

Furthermore, a questionnaire is designed to accompany the stated preference survey. This questionnaire includes questions regarding sociodemographics but also statement questions. Where the latter is designed into Likert scale questions. A more detailed description of the complete survey design is discussed in Chapter 5.

Survey distribution

To effectively target the specific residents within the borders of the municipality of The Hague, the survey was distributed primarily within this region using a multi-channel approach to maximize the reach to get to a satisfactory number of respondents. The distribution methods are chosen based on its potential to engage the community effectively and include both direct and indirect strategies. The forms of distribution are listed down below.

Forms of distribution:

- Municipal letter to residents in the neighbourhoods *Bouwlust en Vredelust* and *Leyenburg* (Appendix F).
- Flyering and hanging up flyers in residential buildings/supermarkets and community centres.
- The author's LinkedIn network.

3.3.2. Discrete choice modelling

The next step within the quantitative approach is the discrete choice modelling process. The survey setup leads to data that can be categorized as stated preferences, Likert scale answers and sociodemographics. This data is used to develop a final model.

To analyse the data with discrete choice modelling, a multinominal logit model (MNL model) is applied. In order to build this model, the open source freeware of Biogeme is used which is a package of the programming language Python (Bierlaire, 2023). A multinomial logit model is used for analysing mode choice behaviours and is designed to handle the discrete choice tasks that are tested in the survey and estimate probabilities that a particular mode will be selected from a set of alternatives. The model is based on the random utility maximisation (RUM) decision rule, which assumes that individuals choose the option that maximises the utility. This allows the model to predict the likelihood of a specific alternative from a set of alternatives.

The advantage of using a MNL model is that it is relatively simple to estimate parameters while keeping it computationally efficient. A multinomial logit model relies on the Independence of Irrelevant Alternatives (IIA) assumption which means that the probability ratio of a choice remains the same, even if another option is added. Choices are handled independently from each other regardless of what was chosen before. Due to the model's simplicity, multiple developed partial models are combined into a final model to capture underlying effects. The partial models are combinations of a base model, a factor analysis and sociodemographics. The methods behind the developed models will be elaborated on below.

Base model
The base model is a simple MNL model that keeps the utility function for each alternative relatively simple and is only estimated based on the made choices in the survey. The utility functions represent the preferences that individuals have for each of the available alternatives. In the base model the utility derives from choosing an alternative j can be represented as:

$$U_j = ASC_j + \sum_{k \in K} \beta_k \cdot I_{kj} \cdot X_{kj} + \epsilon, \quad \forall j \in J,\, I_{kj} \in \{0,1\}, \quad \forall k \in K \tag{3.1}$$

where:

- ASC$_j$: Alternative-specific constant for alternative j
- β_k: Coefficient for k-th attribute
- I_{kj}: Indicator if attribute k is present for alternative j
- X_{kj}: Value of k-th attribute of alternative j (either a dummy or a number i.e. for travel time)
- J: Set of alternatives
- K: Set of attributes
- ϵ: Error term

Base model combined with a factor analysis
The second model is a combination of the previously mentioned base model and the addition of a factor analysis. A factor analysis is a statistical method to explore underlying patterns of the responses. Therefore it is applied to the Likert scale questions. To keep options open, an exploratory factor analysis is used for the underlying patterns. For the extraction of factors, it is opted to limit the number of factors due to the relatively small number of Likert scale questions. The rotation in the factor analysis is the orthogonal rotation, Varimax, which is designed to make the output easier to interpret. Setting these boundaries results in factor loadings which is the correlation coefficient for the Likert scale question and the factor. This loading explains how much of the variance can be explained by a factor, ranging from -1 to 1. Eventually, a factor score can be incorporated into the base MNL model. A factor score is a numeric representation that describes an individual to a specific factor. This is implemented into the utility function in the following way:

$$\begin{gathered} U_{ij} = ASC_j + \sum_{k \in K} \beta_k \cdot I_{kj} \cdot X_{kj} + \sum_{m \in M} \beta_{mj} \cdot F_{mi} + \epsilon, \\ \forall j \in J,\, I_{kj} \in \{0,1\}, \forall k \in K,\, \forall m \in M \end{gathered} \tag{3.2}$$

where the additions:

- β_{mj}: Coefficient for m-th factor score for alternative j
- F_{mi}: m-th factor score for individual i
- M: Set of factors

Base model combined with sociodemographics and interaction effects
Lastly, the sociodemographics in the survey are implemented in utility functions. There are two explored methods on how to implement sociodemographics groups. By adding the type of sociodemographic per group sequentially per alternative j and by having interaction effects with attributes in set K.

The first method involves a sociodemographic to be divided into groups where the first group is held as a reference and is therefore not included in the utility function, which is as follows:

$$U_{ij} = ASC_j + \sum_{k \in K} \beta_k \cdot I_{kj} \cdot X_{kj} + \sum_{l \in L \setminus \{l_1\}} \beta_{lj} \cdot S_{li} + \epsilon,$$
$$\forall j \in J,\, I_{kj} \in \{0,1\},\, \forall k \in K,\, \forall l \in L, S_{li} \in \{0,1\} \tag{3.3}$$

where the additions:

- S_{li}: Indicator for individual i belonging to sociodemographic group l
- β_{lj}: Coefficient for sociodemographic group l specific to alternative j
- L: Set of sociodemographic groups

Similarly, the interaction effects are added sequentially into the utility function. Where one attribute is interacting with a sociodemographic and the utility function is modified as:

$$U_{ij} = ASC_j + \sum_{k \in K} \beta_k \cdot I_{kj} \cdot X_{kj} + \sum_{k \in K} \sum_{l \in L \setminus \{l_1\}} \beta_{kl} \cdot I_{kj} \cdot X_{kj} \cdot S_{li} + \epsilon,$$
$$\forall j \in J,\, I_{kj} \in \{0,1\},\, \forall k \in K,\, \forall l \in L, S_{li} \in \{0,1\} \tag{3.4}$$

where the additions:

- β_{kl} Coefficient for interaction effect between attribute k and sociodemographic group l

Final model
In the final model, all significant coefficients are combined into one model where a backward elimination is introduced. This method is a stepwise regression approach used to refine the statistical model by systematically removing variables that do not significantly contribute to the explanatory power. In the previous models, the coefficients are added sequentially while in this model it includes all the coefficients at once while diminishing one by one if insignificant. The utility function can now be described as:

$$\begin{aligned} U = ASC_j &+ \sum_{k \in K} \beta_k \cdot I_{kj} \cdot X_{kj} + \sum_{n \in M} \beta_{nj} \cdot F_{ni} \\ &+ \sum_{O \in L} \beta_{lj} \cdot S_{li} + \sum_{k \in K} \sum_{l \in L} \sum_{p \in P} \beta_p \cdot I_{kj} \cdot X_{kj} \cdot S_{li} + \epsilon, \end{aligned}$$

$$\begin{gathered} \forall j \in J,\, I_{kj} \in \{0,1\},\, \forall k \in K,\, \forall l \in L, \\ \forall m \in M,\, \forall n \in M,\, \forall o \in L,\, \forall p \in P,\, S_{li} \in \{0,1\} \end{gathered} \tag{3.5}$$

where:

- ASC_j: Alternative-specific constant for alternative j
- β_k: Coefficient for k-th attribute
- I_{kj}: Indicator if attribute k is present for alternative j
- X_{kj}: Value of k-th attribute of alternative j (either a dummy or a number, e.g., for travel time)
- β_{mj}: Coefficient for m-th factor score for alternative j
- F_{ni}: Factor score of factor n for individual i
- β_{lj}: Coefficient for sociodemographic group l specific to alternative j
- S_{li}: Indicator for individual i belonging to sociodemographic group l
- β_p: Coefficient for interaction effect between attribute k and sociodemographic group l
- J: Set of alternatives
- K: Set of attributes
- L: Set of all sociodemographic groups
- M: Set of factors
- N: Subset of factors variables identified as significant for testing
- O: Subset of sociodemographic identified as significant for testing
- P: Set of interactions identified as significant for testing
- ϵ: Error term

During the process of backward elimination, subsets *N* and *O* and set *P* are constantly updated when the least significant variable is deleted until all variables in the model are significant. The development of the partial models and the final model are found in Section 6.4.

3.3.3. Model interpertation

The last step in the quantitative approach is the model interpretation. This is carried out by showcasing the modal split on several occasions which is based on a persona trip scenario analysis. The scenarios explore the effects of certain attributes and where the modal split is computed based on the usage of a mode which is done according to the following formula:

$$p_{i,j}^{m} = \frac{e^{U_{i,j}^{m}}}{\sum_{m \in M} e^{U_{i,j}^{m}}} \tag{3.6}$$

where:

- U: utility
- i: origin
- j: destination
- m: mode
- M: {bicycle, bicycle + PT, car, moped, ebike}

This formula uses the utility functions that are formed out of the final model. Further details on the variables to be filled in for the mode usage in the analysis and the utility functions can be found in Chapter 7.

4
Case study: The Hague

The Hague's geographical setting contributes to its unique character. The city includes historic and political significance and a seaside to its municipality borders, namely Scheveningen. Its coastal location appeals as a tourist attraction. However, the overall city infrastructure is key to providing inhabitants and visitors a way to transport themselves in the city in daily life and for example to the attractions that the city provides. The city's transport network is a mix of highways, roadways and an extensive public transport network. Therefore Section 4.1 dives into the current situation of the city's infrastructure, Section 4.2 discusses the already known inhabitants profiles for this city, Section 4.3 showcases details on short-distance car trips in The Hague and lastly Section 4.4 goes into the resident interviews carried out in The Hague.

4.1. Current situation

Highways and roadways

The Hague is connected to the rest of The Netherlands with a network of major highways. An important highway is the A12, which reaches close to the city centre. Furthermore, the A4 and A13 are presented near the east side of the city. These highways are complemented and connected to smaller order roads and streets within the city. These roads accommodate car traffic but also balance the needs of pedestrians and cyclists. However, what makes The Hague different to other major cities in The Netherlands is that highways don't surround the city as a ring. Therefore, long distances are travelled from certain neighbourhoods before reaching a highway.

Public transport network

The city's tram and bus services, primarily operated by HTM, form the backbone of its public transport network. The operator accounts for a detailed stop typology system to understand the diverse passenger needs. This typology is outlined in HTM Personenvervoer NV, 2022 which includes three stop types (basic, plus and top stops) and four stop labels (transfer, recreation, neighbourhood and seasonal stops). The operator also accounts for differences in timetables, such as in the summer. Additionally, changes in lines can be applied for seasonal stops, especially regarding the beach at Scheveningen with the *Strandexpress*. The stop at Scheveningen is therefore a prime example of a seasonal stop. The system also integrates with the regional RandstadRail network, providing easy access to neighbouring cities like Zoetermeer and Rotterdam. Moreover, the HTM network is also well connected to The Hague Central and Holland Spoor railway stations, which connect the city via national train services. Therefore, public transportation has a high potential to increase ridership which is going to be explored in by this study.

4.2. The Hague inhabitant profiles

To explore inhabitant profiles in The Hague regarding this research topic, findings from the company Motivaction are assessed (Motivaction International, 2023). The report delineates eight distinct mobility styles among the inhabitants of The Hague providing a nuanced understanding of the underlying motivations and barriers to adopting a modal shift away from car usage. The identification of eight distinct mobility styles is included among The Hague's residents, each with unique characteristics and preferences for transportation modes. These styles range from *New Conservatives* who show a high attachment to cars but also express interest in public transport and e-bikes, to *Post-materialists* who prioritize environmental concerns and show a high willingness to use bicycles and public transport over cars.

Notably, the mobility styles *"Postmodern Hedonists" (Postmoderne Hedonisten)* and *"Cosmopolitans" (Kosmopolieten)* stand out for their distinctive attitudes towards mobility and sustainability. Postmodern Hedonist are characterized by their pioneering spirit in the culture of experience and their tendency to challenge moral and social conventions. Displaying relatively high ownership of cars but expressing openness to using public transportation more frequently. Their lifestyle suggests a potential for embracing innovative mobility solutions. These options align with their values of freedom, individualism and novelty.

Conversely, the Cosmopolitans embody open-minded and critical citizens who integrate postmodern values of self-actualization and experience with modern values of societal success and material enjoyment. Their mobility patterns reflect a lesser dependency on cars while having a stronger inclination toward cycling and public transportation. Simultaneously, these are the preferred modes of Cosmopolitans to travel within the city. This group's environmental consciousness and preference for sustainable lifestyle choices make them prime candidates for policies aimed at reducing car use in favour of greener or more space-efficient modes of transport.

However, the report also sheds light on groups such as the *"New Conservatives" (Nieuwe Conservatieven)*, *"Traditional Bourgeoisie" (Traditionele Burgerij)* and *"Modern Bourgeoisie" (Moderne Burgerij)*, who exhibit a stronger attachment to car usage and ownership. These profiles are characterized by their preference for tradition, comfort and status and therefore show less inclination toward a modal shift from car to more sustainable transport options. The New Conservatives value technological advancements yet are conservative towards social and cultural shifts, indicating potential openness to e-mobility. Albeit, with a strong preference for personal vehicle ownership. The Traditional Bourgeoisie, adhering to moralistic and duty-bound values while the Modern Bourgeoisie balances between tradition and modern consumerism. Both prioritize the convenience and status associated with car ownership, posing challenges to efforts aimed at promoting alternative modes of transport.

The report's insights into the mobility styles of The Hague's inhabitants offer valuable guidance for the course of this research. By understanding and leveraging the unique preferences and attitudes of groups such as the Postmodern Hedonists and Cosmopolitans, alongside addressing the concerns and preferences of the New Conservatives, Traditional Bourgeoisie and Modern Bourgeoisie, this research can more effectively encourage and steer with more focus towards a modal shift.

4.3. Short-distance car trips

The mobility research report of the municipality of The Hague (Gemeente Den Haag, 2022) covering the period from 2018 to 2021, provides insights into the influence of short-distance car trips within the city. This report is based on ODiN (*Onderweg in Nederland*) data. Despite a substantial proportion of trips being dominated by non-motorized transport modes such as walking and cycling, accounting for 54% of all journeys, a significant number of car trips are notably short. Specifically, 18% of car trips are limited to distances of 2.5 kilometres and an additional 19% are within 5 kilometres. This frequent use of cars for short distances indicates somewhat a notable reliance on cars even for journeys that could be feasible by other modes. Furthermore, a decline in public transportation use is seen. The drop in this, resulted in more residents opting for walking or car trips instead.

The demographic analysis within the report of the municipality of The Hague reveals that the most mobile group includes individuals aged 25 to 55, which is based on the average number of trips per person per day. On the contrary, the least mobile group are to be found in the age group 80 and above. However, gender differences in mobility are minimal, whereas the highest frequency of trips is observed among highly educated inhabitants. When comparing The Hague to other major Dutch cities such as Amsterdam, Rotterdam and Utrecht, The Hague has a higher proportion of car trips. This trend is particularly evident in inter-district travel, where cars remain an important mode of transport. Contrarily, within a neighbourhood, short-distance trips (less than 3 kilometres) are predominantly made by walking or cycling, with public transportation being less utilized. These findings highlight the complex use of short-distance car trips in The Hague.

Besides, the previously mentioned mobility report, also other research has explored the use of short-distance car trips more in depth. A large proportion of these trips are for purposes such as shopping or grocery errands. As well as picking up and dropping off passengers. There is a notable resistance to changing these habits. Interestingly, within the category of shopping or grocery errands, there is a potential to differentiate between large and small shopping trips, as well as between essential groceries and leisure shopping. The distinction provides some leverage for altering behaviour away from using the car for short-distance trips. Although, convenience and practicality often lead to the choice of car usage.

Higher educated individuals generally prefer cycling, which raises the question of which demographic should be targeted to achieve a modal shift away from car usage. Insights from the study suggest that singles and couples without children are more open to restrictions on car use, making them more adaptable to behaviour changes. However, when travelling alone, parents with children are also susceptible to using the car less. By focusing on this information specifically, it may be easier to implement strategies that encourage alternative modes of transport and reduce reliance on cars for short-distance trips.

4.4. Interviewing residents

To get a better understanding of the motivations why residents take the car, interviews are done. The method and procedures mentioned in Section 3.2 are applied to conducting this interview.

In this interview, several questions are asked to residents who were using the car at that moment. Some questions are related to the mode they were using at that moment while also including some more general questions to understand their preferences. The interviews are a good starting point to answer the first and the last subquestion.

In total 22 interviewees across two locations have been asked to answer these questions. The interviews were held in the Escamp area. The first interview location is the shopping centre Leyweg and the second location was near a supermarket but also a small shopping centre named Leyenburg. Both locations were chosen due to the high possibility of car users among the residents. Furthermore, these types of locations were chosen to understand residents' travel behaviour at that moment, even though there was a high risk of car usage due to grocery shopping or carrying goods. The chance of exposing motives that were not found in literature is worth interviewing residents at these locations. Furthermore, to ensure that not create a one-sided opinion due to the interviewees' current events, the general questions are to help to ask about general behaviour and not the at that certain time.

The original outcome of the interviews is displayed in Appendix A. The English version of the outcome of the interview can be found in Appendix B. The translation is carried out by the author and is not an official translation. The findings and results of the qualitative interview are further elaborated on in Chapter 6, specifically in Section 6.1.


RandstadRail
ELLIPTIGO

5 Experiment setup

After being able to discover some of the travel purposes for car usage instead of an alternative mode in the qualitative interviews the setup for the quantitative part of this research can be performed. The take-aways of the interviews are included in the experiment setup to have a more quantitative approach to the research. The exact results from the interviews can be found in Section 6.1. In this chapter, the aim is to explore factors by using a stated preference survey, influencing transportation preferences and behaviours among urban residents and in this case specifically in The Hague. Furthermore, the questionnaire that is included in the survey is discussed. An overview of the experiment setup is shown in Figure 5.1.

To guide this research, the following hypothesis is defined as:

Bicycle parking facilities at bus and tram stops do influence current users and non-users to use the bike + PT integration more frequently while diminishing the reliance on car usage for short distances.

This hypothesis is based on preliminary qualitative findings that indicate current deficiencies in bicycle parking infrastructure near public transport stops as a major barrier to the combined use of these modes of transport. The hypothesis is going to be tested through a detailed quantitative analysis, incorporating multiple choice tasks in a newly designed online survey, which is showcased in Appendix D. This survey targets The Hague's residents' preferences and needs regarding bicycle parking facilities.

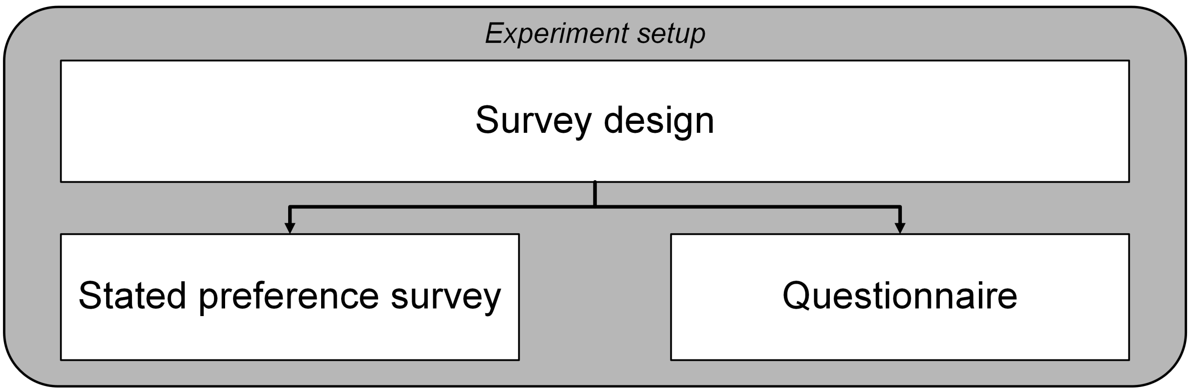


Figure 5.1: Experiment setup overview

5.1. Stated preference survey

The construction of the stated preference survey is an important component to reach the research objective. This subsection elaborates on the methodology and tools that are used in designing the stated preference part of the survey. Highlighting, the incorporated attributes, the developed choice tasks and the presentation of the stated preference survey to respondents.

The survey begins by classifying respondents according to the modes of transport sometimes used for their trips (Figure D.3 in Appendix D). This initial classification is important to understand mode access and habits. Respondents are presented with options including car, bicycle, moped, e-bike or other, to select the modes they occasionally use. Depending on the chosen modes, the respondent is assigned to a certain branch which will be discussed further in Subsection 5.1.1.

For respondents who do not select the bicycle as a used mode of transport, a follow-up question asks about bicycle ownership (Figure D.4 in Appendix D). If the response is negative, the survey further inquires whether a bicycle is ever borrowed from for example a family member or a friend (Figure D.5 in Appendix D). This sequence of questions collects data on how many respondents experience barriers to bicycle use in the form of lack of ownership or reliance on borrowed bicycles.

Respondents indicating that they neither own nor borrow a bicycle are thanked for their cooperation and informed that the remainder of the survey is primarily relevant to individuals with access to a bicycle. This approach makes sure that the survey focuses on collecting detailed information from those who are potential users of bicycle + PT combinations. Thus maintaining the relevance and quality of the data collected for the research objectives.

5.1.1. Choice sets

As mentioned before, the first question classifies a respondent. Based on the options that are given six choice sets of alternatives are decided on based on certain mode combinations, which are listed in Table 5.1. Each respondent is assigned to one of the choice sets. The modes that are considered to form these choice sets are:

- The bicycle
- The car
- The moped
- The e-bike

This research aims to assess the extent to which short-distance car trips can be reduced by implementing bicycle parking facilities near bus and tram stops. To achieve this, all mode combinations must include the bicycle and respondents who do not utilize a bicycle are excluded from the target group as defined in Section 5.1. Given the focus on short-distance car trips, respondents who indicate occasional use of a car are always assigned to a mode combination that includes the car (mode combinations A, B, and C). Additionally, when respondents possess both a moped and an e-bike, the moped is prioritized in the mode combination, whereas the e-bike is included in combinations B or E rather than combinations A and D. Mode combination F is uniquely defined to include only one mode, the bicycle, serving respondents who exclusively use or have regular access to a bicycle. Although the survey includes an option for the mode '*other*,' it is not used in the creation of any mode combination.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Choice set A	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	Car	Moped
Choice set B	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	Car	E-bike
Choice set C	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	Car	-
Choice set D	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	Moped	-
Choice set E	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	E-bike	-
Choice set F	Bicycle	Bicycle + PT option 1	Bicycle + PT option 2	-	-

Table 5.2: Survey choice sets

	Bicycle	Bicycle + PT 1	Bicycle + PT 2	Car	Moped	E-bike
Bicycle parking facility		X	X			
Tyre pump			X	X		
Parking time	X	X	X	X	X	X
Travel time	X	X	X	X	X	X
Travel costs		X	X	X	X	

Table 5.3: Overview of alternatives and to be tested attributes

	Mode 1	Mode 2	Mode 3	Mode 4
Mode combination A	Bicycle	Car	Moped	(Other)
Mode combination B	Bicycle	Car	E-bike	(Other)
Mode combination C	Bicycle	Car	(Other)	-
Mode combination D	Bicycle	Moped	(Other)	-
Mode combination E	Bicycle	E-bike	(Other)	-
Mode combination F	Bicycle	(Other)	-	-

Table 5.1: Mode combinations including the transportation modes

Using the composed mode combinations presented in Table 5.1, choice sets can be formed. The survey choice sets are displayed in Table 5.2. These choice sets are constructed by providing each available mode within a combination as an alternative. For example, mode combination A includes the bicycle, car, and moped, thereby offering each mode as an alternative in choice set A. This process is applied across all mode combinations. Additionally, to support the objective of this research, two alternatives are included to evaluate the potential of the combined mode of bicycle and public transportation.

5.1.2. Attributes

The attributes to be tested in the survey are the bicycle parking facilities, bicycle services, parking time, travel time and travel costs. This is chosen due to the research objective of discovering bicycle parking potential. Therefore some common bicycle parking facilities and services are included to be tested. Furthermore, travel time and travel costs are included to make the choice tasks in the survey more realistic such that trade-offs can be made. An overview of which attribute is considered per alternative can be found in Table 5.3.

(a) An example of no parking available

(b) A bicycle parking bracket (VelopA B.V., 2023)

(c) Shedded parking (VelopA B.V., 2023)

(d) Bicycle safes (VelopA B.V., 2023)

Figure 5.2: The levels of bicycle parking facilities

Bicycle parking facilities

The first attribute, the bicycle parking facilities, is incorporated to explore the potential of these facilities near bus and tram stops. This specific attribute consists of four levels which are shown in Figure 5.2 and are specifically tested on the bicycle + PT alternatives.

The different attribute levels represent various possibilities on how a bicycle can be parked. In Figure 5.2a, an example is given on how a bicycle can be parked without bicycle parking facilities. Next to this, one can also park a bicycle against a gate either near a house or at a PT stop. Other possibilities include parking next to a building that is not equipped with a bicycle parking facility. These are all examples of what no facilities could mean. However, the core of this is that the bicycle is not parked at an allocated place dedicated to bicycle parking and cannot be locked to something.

A common facility is the bicycle bracket which is depicted in Figure 5.2b. This facility can be found in many locations and is quite often used in The Netherlands. It provides an easy and quick way for users to park their bicycles, while the bicycle can still lean onto something or be locked against. These bicycle brackets are additionally contributing to a relatively safe and neat manner of bicycle parking. This is also reflected in lowering the chance of thefts and vandalism while also maintaining an orderly environment in neighbourhoods. The space required to have a bicycle bracket is quite minimal which makes it quite an easy facility to install and a favourable facility to municipalities due to the amount of parking spaces that can be created. Furthermore, the installation costs of this facility are relatively low compared to the other attribute levels that will be discussed further in this subsection.

The next level in this attribute is shown in Figure 5.2c. In the figure, a shedded bicycle parking facility (VelopA B.V., 2023) is displayed. As the name states, the facility ensures that parked bicycles are covered. This type of facility protects bicycles against all kinds of weather conditions which contributes to a longer lifespan of the bicycle. In comparison to the previously mentioned attribute level of bicycle parking facilities, this facility requires more space to install. This also leads to a different kind of spatial planning near tram and bus stops. Due to the shedding of the parking facility, this will also contribute to a different look in the environment than a bicycle bracket. Additionally, due to its more complex structure a shedded parking results in a more expensive facility to realise.

Figure 5.3: A tyre pump (VelopA B.V., 2023)

Lastly, bicycle safes are included in the attribute of bicycle parking facilities. An example of bicycle safes is depicted in Figure 5.2d. This specific type of bicycle safe is made by the company VelopA B.V.. There are other types on the market, however this figure depicts the general idea of a bicycle safe. Just as a shedded bicycle parking facility, a bicycle safe protects a bicycle from adverse weather conditions. The additional benefit in this case would be that the bicycle is completely enclosed resulting in better protection against weather but also theft. However, this type of facility requires the most amount of space and costs per bicycle.

Bicycle service product

Besides only parking a bicycle, maintaining it can also be an important aspect of using the bicycle as a mode or as part of a multimodal trip. Therefore, it is chosen to put the tyre pump (Figure 5.3) as a service product in the survey design specifically for the bicycle + PT alternatives. This results in the attribute to have two levels. Either a tyre pump is present when making a trip by bicycle and travelling further with public transportation or there is not.

Parking time

The parking time is defined as the time that is needed to park your vehicle. Independently of the alternatives, parking time can be applied to all possible alternatives that are offered to the respondent. Therefore, this attribute is not alternative dependent and will be incorporated into all alternatives. However, for all modes except for the bicycle + PT combinations, this means that the parking would happen at the end. While travelling by bicycle to a public transport stop would mean that the parking happens mid-travel. It is opted for a two-level attribute to keep it less complicated. The options that are presented are 1 minute or 2 minutes to park the vehicle.

Travel time

Besides parking time, travel time is another attribute that is included in the survey design. The travel time includes the time that is needed to travel from origin to destination excluding the parking time since this is taken into account already in a separate attribute. Due to the various range of modes, it is chosen to work with time differentiation. To realise this, the modes are assigned to either a faster travel time or a slower travel time. Modes that are classified as having a slower travel time are the bicycle, the bicycle + PT combination and the e-bike. In the other category, the car and moped are assigned to a faster travel time. Each category is equidistant to ensure the benefits of an equidistant attribute. Therefore, the alternatives of a slower travel time are presented with 6, 12 or 18 minutes as travel time and the alternatives with a faster travel time are presented with 4, 8 and 12 minutes.

Travel costs

Lastly, in each alternative the travel costs are included. To make it more realistic the decision is made to state for the alternative bicycle and e-bike that the costs would be zero if the alternative is chosen. All costs are expressed in euros. This leaves only the alternatives of a multimodal trip with the bicycle and public transportation, the car and the moped to be of cost. Similarly to travel time, the attribute is equidistant and the costs that are presented vary from €2, €4 and €6. For the alternative bicycle + PT this covers a public transportation ticket and for the car and moped, the costs cover fuel.

5.1.3. Choice tasks

The attributes mentioned in Subsection 5.1.2 are incorporated into choice tasks in order to be presentable to respondents. In the process of composing these choice tasks the methodology of the survey design which is mentioned in Subsection 3.3.1 is used. The corresponding syntax that is used to compose the choice tasks for the survey can be found in Appendix C.

The presented choice tasks are randomized until each respondent has seen a total of eight. How these are presented to respondents is going to be explained in Subsection 5.1.4.

5.1.4. Stated preference survey presentation

The presentation uses a sequential decision making process aimed at testing the hypothesis that bicycle parking facilities at bus and tram stops can influence both current users and non-users to integrate cycling and public transportation (PT) more frequently, thereby reducing reliance on car usage for short distances.

For each presented choice task, respondents answer two sequential questions. In part 1 of each choice task, the alternatives are limited to the bicycle, bicycle + PT option 1 and bicycle + PT option 2. This restriction is designed to isolate the effects of bicycle only options on respondents' choices. In part 2, respondents are presented with the option they chose in part 1, along with additional alternatives as defined in the choice sets outlined in Table 5.2. A visualisation of how part 1 and part 2 are presented is shown in Figure 5.4. Note that this visualisation is translated for illustration purposes and not the original visualisation that respondents got to see. This structure applies to all choice sets except for choice set 6. If a respondent only has access to a bicycle, only part 1 of each choice task will be presented.

Additionally, providing a clear and relatable context is important for obtaining reliable and realistic data. Context helps respondents envision realistic circumstances without making assumptions that could differ from one respondent to another. This reduces hypothetical bias and leads to more meaningful and precise responses. For this research, respondents are presented with a specific context that does not change during the survey where the weather is always 17 °C degrees during a spring day without rain. Furthermore, no travel companion is present, thus travelling alone, with a small backpack to a restaurant. This context was chosen to make an ideal situation since the weather can be of large influence when trading off whether travelling by bicycle is desirable. Next to this, as a result of the quantitative research in Subsection 6.1, the outcome of travelling with another person can have drawbacks. Therefore it is stated that the respondent is travelling alone.

5.2. Questionnaire design

Besides a stated preference survey, a questionnaire is included in the survey. The following subsections describe the elements incorporated into the questionnaire.

5.2.1. Statement questions

Incorporating Likert scale questions has a few advantages. First of all, these questions allow to find out a respondent's attitudes towards various factors thereby providing a better understanding of the factors influencing their choices. Moreover, Likert scale questions have a straightforward nature which also ensures respondents can easily comprehend and respond. This results in more reliable data.

In this research, a series of Likert scale questions are included to evaluate respondents' attitudes towards various transportation-related factors. These questions are going to be of use when identifying latent classes in Chapter 6. The questions, originally presented in Dutch (Figure D.13) are as follows:

1. Convenience is important to me.
2. I see public transport as an alternative to the car.
3. The environment is an important factor in my choice of transportation mode.
4. Cost is an important factor in my choice of transportation mode.
5. Owning a car is important to me.
6. I cycle because it is better for my health.

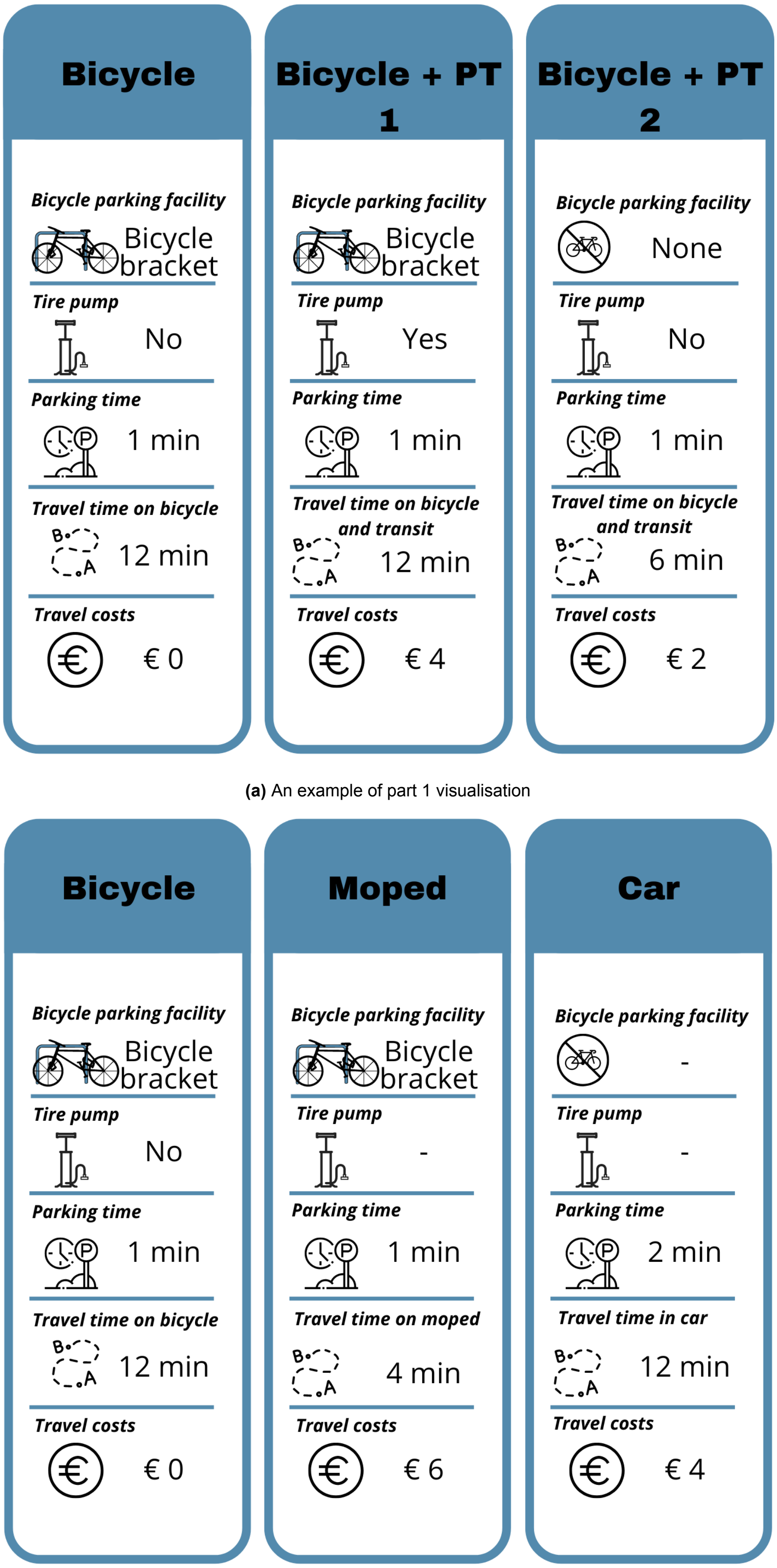
7. I know how to use a bicycle locker without problems.
8. I fear my bicycle will be stolen at a stop.
9. It is important that my bicycle is properly parked at an intended bicycle parking space.
10. I feel safe on the bicycle.

The responses to these questions are collected in a five-point Likert scale, ranging from strongly agree to strongly disagree. In this way, it allows the responses to be analysed to identify latent classes among the respondents. Each group represent similar attitudes and preferences. This demarcation is needed for the model discussed in Chapter 6.

5.2.2. Sociodemographic questions

Lastly, sociodemographic questions are included in the survey design, see Figure D.14 in Appendix D. These questions are an important component of stated preference surveys, providing essential contextual information about respondents. This data helps with making an analysis regarding individual characteristics and if it could influence preferences and choices. Therefore a series of sociodemographic questions are included to capture a profile of the respondent. The included questions, presented in Dutch, are as follows:

1. What is your age?
2. What is your gender?
3. What is your highest achieved level of education?
4. What is your (gross) annual household income?



(a) An example of part 1 visualisation

(b) An example of part 2 visualisation

Figure 5.4: Choice tasks visualisations


Centraal Station
Buitenhof -
Binnenhof -
Nobelstraat
Stadhuis
Mauritshuis -
Hollands Spoor 2
Leiden 17
HTM
3136
Kneuterdijk
Wittenburg

6 Results

This chapter elaborates on the obtained results from the qualitative and quantitative approaches where the setup of the approaches was explained in Chapter 4 and Chapter 5. In Section 6.1 the results of the qualitative interviews are discussed with its conclusions. Section 6.2 explains how the data is prepared for discrete choice modelling while Section 6.3 gives an overview of the descriptive statistics of the survey respondents. Lastly, Section 6.4 supplies a detailed explanation of the development of a discrete choice modelling model.

6.1. Qualitative results

The analysis of the interview responses revealed several highlightable insights into participants' transportation behaviours and preferences. Interviewees reported using personal vehicles for a range of activities, including commuting to work, shopping and social visits. Common destinations are workplaces and supermarkets/shopping centres with the latter being potentially the cause of the chosen interview locations.

When asked about alternative modes of transportation, the majority of interviewees indicated a reluctance to consider options other than the car. The reasons for this varied but often centred around the impracticality of using other modes for their specific needs at that moment. Interviewees highlighted challenges such as transporting heavy goods, travelling with passengers with mobility issues and ensuring comfort during adverse weather conditions. This suggests that the perceived convenience and reliability of cars play a significant role in their preference.

Despite the dominance of car usage, there was a notable openness among some participants to use bicycles and public transport for shorter journeys or when considering environmental benefits. However, significant barriers to adopting the bicycle + PT combination were identified. These barriers included inefficient public transport connections, inadequate bicycle parking facilities and the necessity for favourable weather conditions. Specifically, interviewees highlighted that the current bicycle parking facilities near public transport stops were often insufficient, poorly maintained and felt not secure. Participants expressed a need for more parking spaces, improved maintenance and enhanced security measures to make the bicycle + PT combination more viable.

Additionally, some interviewees mentioned personal limitations that hinder their use of bicycles. Several participants indicated that they are not capable of biking, some lacked confidence in their biking skills and a few did not own a bicycle. These personal barriers further complicate the adoption of bicycle-based transportation, stressing the need for supportive and accessible measures such as bike-sharing programmes and cycling education initiatives.

In addition to the previously mentioned observations, some participants mentioned the need for better cycling conditions and public awareness. For instance, enhanced safety for cyclists, more efficient and affordable public transport options and educational programmes to promote cycling were cited a potential motivators for adopting this mode of transport. The analysis also revealed a division in attitudes towards public transport itself. With some interviewees appreciating its environmental benefits but others deterred by its costs and perceived inefficiencies which prevents them to use public transport in the first place.

6.1.1. Conclusion on qualitative results

The findings indicate a clear preference for the car during the specific moment of time among the interviewees. This was driven by its convenience and ability to meet specific needs such as carrying heavy goods and travelling with passengers with mobility issues. This preference underscores that the car could play quite a central role which is influenced by practical considerations and the comfort that it provides, especially in adverse weather conditions.

However, there is a potential for increased adoption of bicycles combined with public transport, particularly for shorter journeys and among environmentally conscious individuals. Key areas for intervention include enhancing the efficiency of public transport connections and upgrading bicycle parking facilities to ensure they are secure, well-maintained and sufficient in number.

Furthermore, there is a need for broader initiatives to improve cycling conditions and public awareness. Measures such as ensuring cyclist safety, providing affordable and efficient public transport options and running educational campaigns to promote the benefits of cycling could encourage more individuals to consider alternative modes of transport. By addressing both the infrastructural and perceptual barriers, it is possible to foster a more sustainable and diversified transportation mix. Reducing the reliance on cars and enhancing the overall quality of urban mobility.

In conclusion, while the preference at that time for car usage is strong, there is a significant potential to shift towards a more integrated use of bicycles and public transport. This shift requires comprehensive strategies that address both practical and perpetual challenges, including personal limitations such as physical constraints, lack of confidence in biking skills and bike ownership.

As a next step, the research will adopt a quantitative approach to further explore these findings. This will include a detailed survey aimed at exploring the potential of different types of bicycle parking facilities. By gathering quantitative data on preferences and needs related to bicycle parking, the study aims to identify the most effective solutions to encourage the combined use of bicycles and public transport.

6.2. Data preparation

In order to use the collected data from the described survey in Chapter 5 Experiment setup, a data preparation process is performed to make the dataset suitable for the intended model. This process consists of a few steps going from an output dataset supplied by Qualtrics (Qualtrics, 2021) to a dataset which holds a respondent's choices, several dummy variables of the attributes and the information presented in each choice task presented to a respondent.

The first step in the process is only to keep completed surveys. Incomplete surveys are removed due to the fact that such responses are incomplete and might introduce bias and inaccuracies as these respondents may not have provided all necessary information.

Next, based on the initial question in D.3 respondents are assigned to the mode combination they belong to according to the mode combinations defined in 5.1 by corresponding numbers to the letters.

To ensure data quality, a minimum time spent on the survey is set. This differs for the different mode combinations. For respondents with no access to a bicycle, no minimum is set while for respondents with only a bicycle a minimum time of 3 minutes is the threshold. For all other combinations at least 5 minutes need to be recorded for filling in the survey. This helps to safeguard that respondents spent adequate time considering their answers.

By doing this complete process, the dataset is sufficient enough to be used in the model while also reporting descriptive statistics in the next section.

6.3. Descriptive statistics

The survey is completed by 387 respondents. Resulting in a response rate of 64.6% of all people (599) who have agreed with the opening statement. After processing the data, the dataset comprises 348 responses. Appendix G gives a complete overview of the dataset. The age of respondents ranged from 18 to 83 years with a mean age of 42.9 years while the mean age of The Hague's inhabitants is 39.2 years. Figure 6.1 shows the age distribution of the survey respondents which at first sight looks like a representative distribution of reality. The composition of age groups of The Hague inhabitants are displayed in the same figure (Figure 6.1) with the use of the information in *Den Haag in Cijfers* (Gemeente Den Haag, 2023). To match the same division the groups of 75-84 and 85-94 are merged together as 75+. The survey was not meant for the age group 0 - 17 years and therefore is not represented in the survey. When keeping this in mind it can be said that when comparing the survey respondents and The Hague's inhabitants' age, the sample of respondents represents The Hague's population quite well. The only side note is that the age group of 75 + is underrepresented.

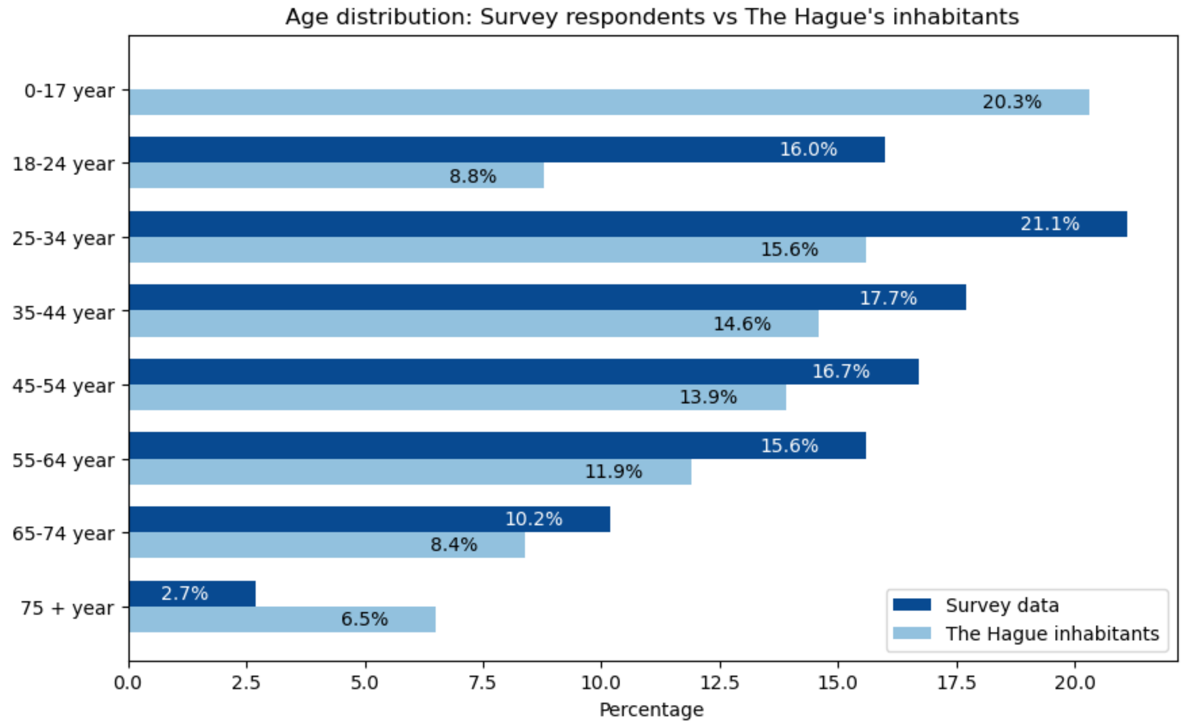


Figure 6.1: Age distribution of survey respondents and The Hague inhabitants (Gemeente Den Haag, 2023)

Furthermore, this is backed up by the absolute number of respondents in this age group. With a total of 8 respondents in this category, the age group is underrepresented.

Regarding the gender of the survey respondents, the male gender is represented by 165 people while the female is represented by 137 respondents. The remaining respondents have not indicated to be male or female. Therefore, the male gender has slightly more representation. The composition of The Hague's residents however shows a different distribution. Where women have the overhand. Nonetheless, the distribution of the survey respondents' gender in comparison to The Hague's inhabitants are sufficiently representable which can be seen in Figure 6.2.

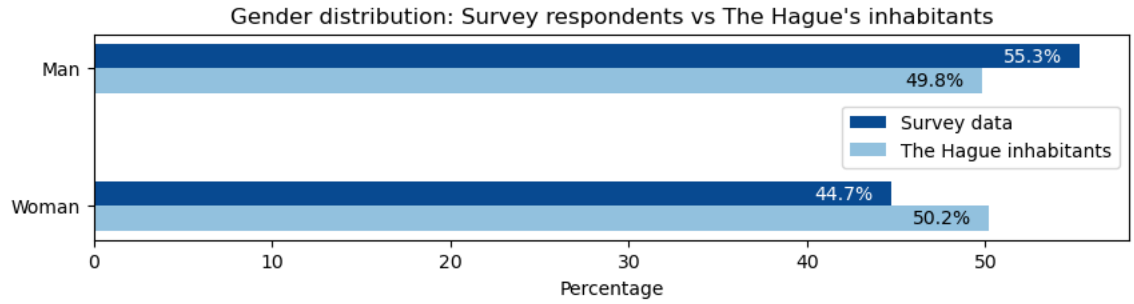


Figure 6.2: Gender distribution of survey respondents and The Hague inhabitants (Gemeente Den Haag, 2024)

Another sociodemographic that was asked of the respondents is their highest achieved education level. Hereby, it can be seen in Figure 6.3 that people with an HBO or university degree or a master's are highly represented. This figure also showcases the given answers as asked in the survey, however according to CBS (*Centraal Bureau voor de Statistiek*) a different classification is used for the Dutch population and the citizens in The Hague (Centraal bureau voor de Statistiek, 2021). The classifications include education levels CBS low, CBS middle and CBS high. Transferring the survey data to these classifications the distribution can be made and therefore is now comparable to the population statistics. As specified by the bar charts in Figure 6.4 the highly educated people are immensely overrepresented. With respect to this sociodemographic, the residents in The Hague are not represented in a balanced manner. This may lead to biased results in the model.

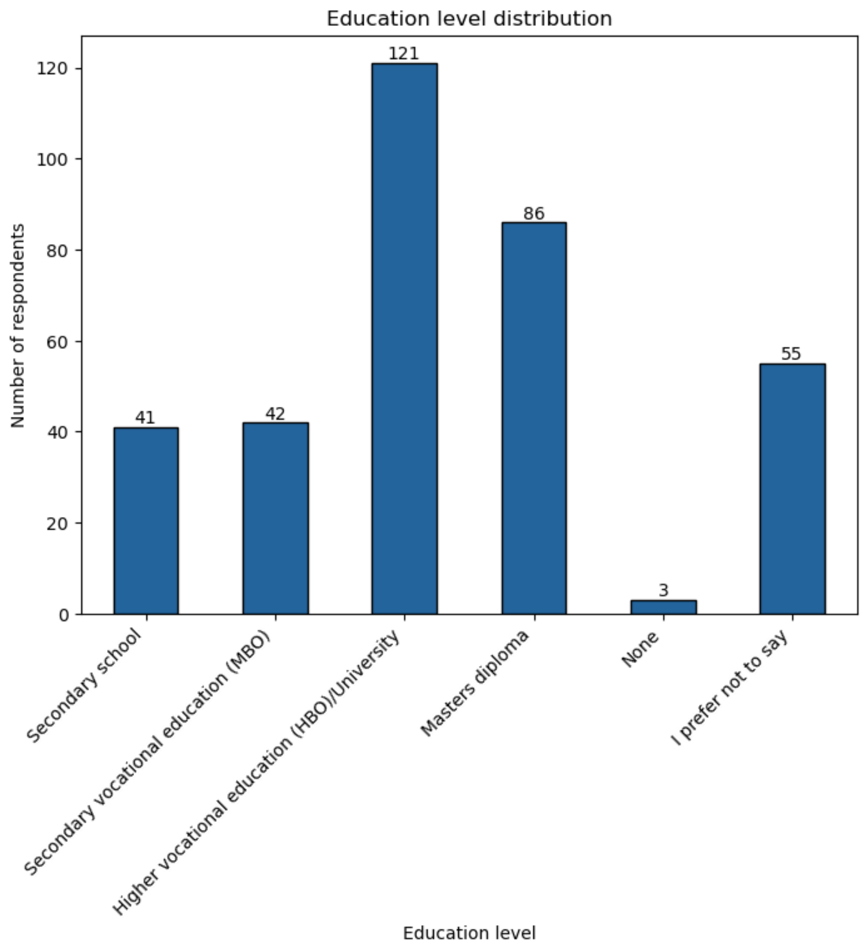


Figure 6.3: Education level distribution of survey respondents

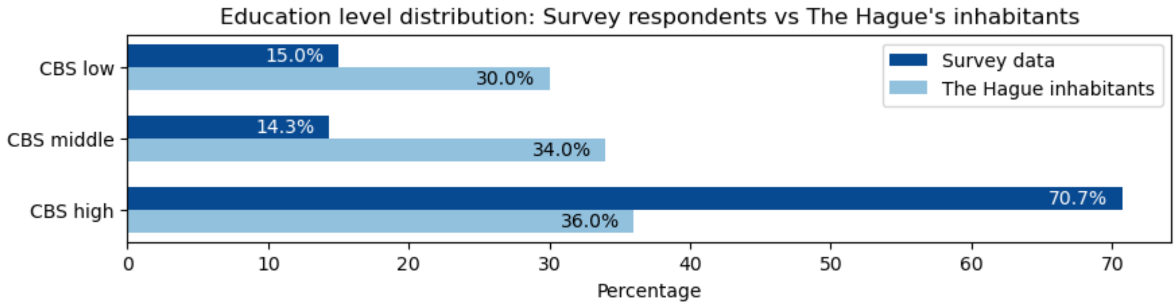


Figure 6.4: Education level distribution of survey respondents and The Hague inhabitants (Gemeente Den Haag, 2021a)

Lastly, respondents were asked to state their household gross income. Both the municipality of The Hague and the CBS keep records of net income. While the municipality used five quantiles originally, the CBS uses similarly to education level a three-level approach for income. The five quantiles are however scaled to match the three-level approach of CBS. The most recent data on The Hague's inhabitants' income dates from 2021 and can be found in Appendix H. In Table H.1 the reference levels that are used in The Hague are given and in what category this belongs to according to CBS standards. Due to the survey asking for a gross household income, an estimation is made on what this income would translate to in net income. In Table 6.1 the made assumptions are mentioned within the third column the ranges from the quantiles used by the municipality of The Hague. The thresholds of the different groups do not always match the quantiles however when accounting for the reference groups of CBS the under or upper-level net income matches closely. Given this information, a found comparison can be made.

Comparing the obtained data on income ranges, it can be said that the two levels of CBS low and CBS middle are overrepresented while CBS high is highly underrepresented. So therefore it can be stated that the respondents based on their income are out of balance and do not give a satisfactory representation of The Hague's inhabitants. The only sidenote that can be made is that the known income levels of all inhabitants in The Hague are from 2021 while the survey was carried out in 2024. So therefore the comparison is partially inaccurate.

Income gross survey	Income net estimation	Compared to net income of The Hague	CBS reference
€0 - €24.999	€0 - €22.000	< €23.500	CBS low
€25.000 - €49.999	€22.000 - €35.000	€23.500 - €34.100	CBS low
€50.000 - €89.999	€35.000 - €55.000	€34.100 - €48.600	CBS middle
€90.000 - €129.999	€55.000 - €70.000	€48.600 - €68.300	CBS middle
€130.000 - €149.999	€70.000 - €85.000	> €68.300	CBS high
More than €150.000	> €85.000	> €68.300	CBS high

Table 6.1: Assumed classifications on yearly income (Gemeente Den Haag, 2021a)

Next to sociodemographics, respondents can be described by their accessibility to certain modes. Hereby, the classification of mode combinations defined in Table 5.1 is used. The mode combination distribution of the survey respondents is depicted in Figure 6.6. Inspecting this bar chart, a few remarkable observations can be made such as that many individuals have access to a car, which is represented in mode combinations A, B and C. Within these individuals, the biggest part is covered by mode combination C, with only the car as a mode next to the bicycle. Furthermore, almost 30% of the acquired respondents only have access to a bicycle and no motorized vehicles. Lastly, 46 respondents indicated not to have a bicycle or being able to borrow one. Representing 13.2% of all respondents. A detailed breakdown in absolute numbers of modes that respondents use is in Table G.1.

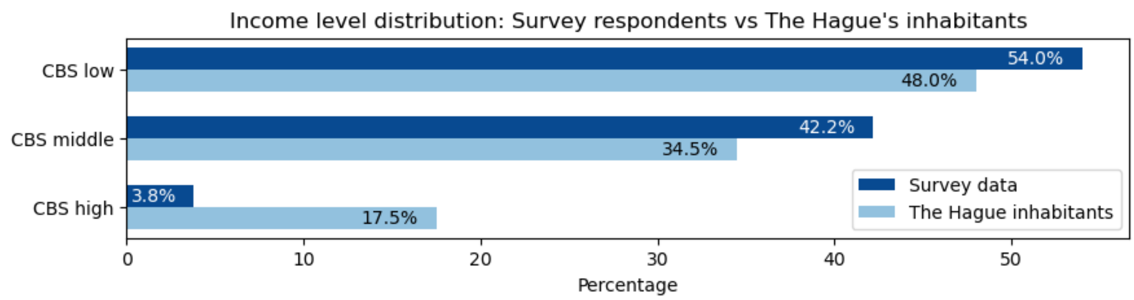


Figure 6.5: Income level distribution of survey respondents and The Hague inhabitants (Gemeente Den Haag, 2021a)

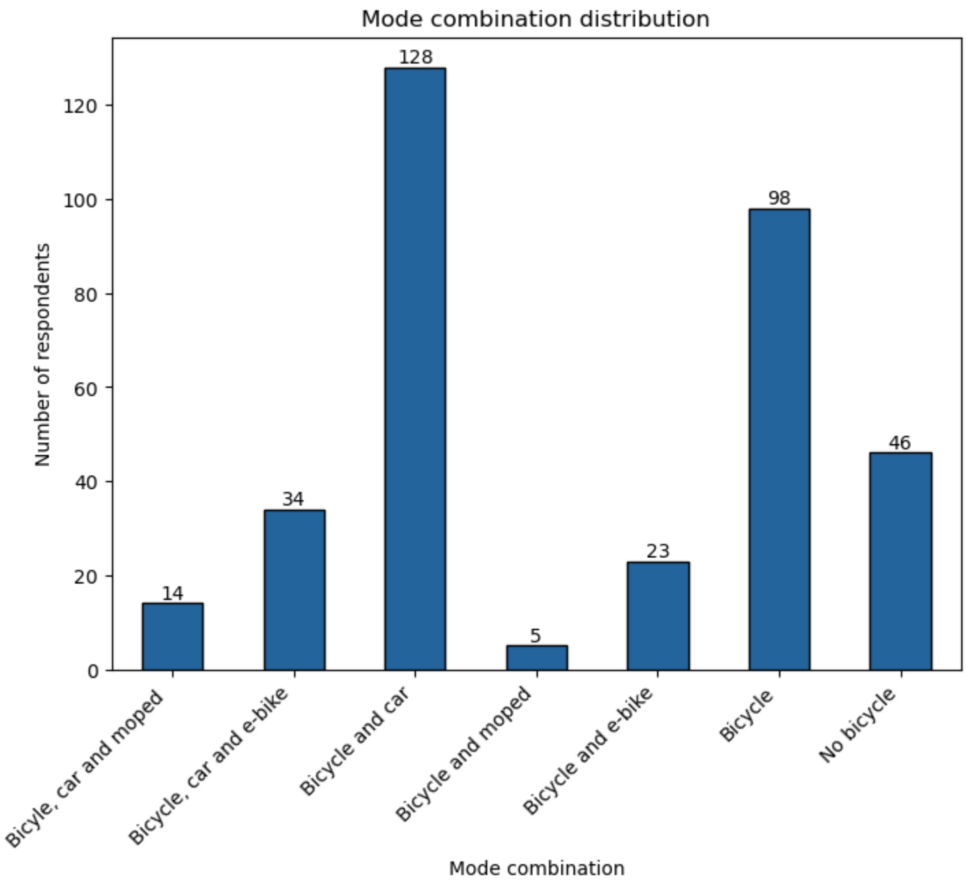


Figure 6.6: Mode combination distribution of survey respondents

The next step is to zoom out and compare the personal characteristics of the survey respondents not only to The Hague but to the Dutch population. On the national level, the age group 75 + is even more underrepresented than on The Hague's level since percentage-wise more people fall within this group. Furthermore, men are again overrepresented since the national gender distribution only differs by 0.1%. Regarding the education levels on a national level, the distribution of the Dutch population does differ from The Hague's inhabitants. Similarly, the education levels of the survey respondents did not match closely with the inhabitants of The Hague it again does not to the Dutch population due to the high overrepresentation of highly educated individuals. Lastly, the income levels of the Dutch population differ from The Hague's inhabitants. Overall in the Dutch population, the portion of high earners is less. This makes the survey more representative based on the income of The Dutch population than that of The Hague. The corresponding visualisations for the Dutch population are shown in Appendix H.

6.4. Model estimation

In this section, numerous steps are described to come to a suitable model to fit the collected data from the survey. Therefore, the following will be discussed, the base model, a factor analysis and its incorporation into the base model. Lastly, the interaction effects of sociodemographics together with other variables are going to be elaborated on which is then used to form a final model. An overview of this process and how this incorporates the outcome of the survey is illustrated in Figure 6.7. Before describing all models, the performance of the developed final model is elaborated on to showcase and justify the development of the final model.

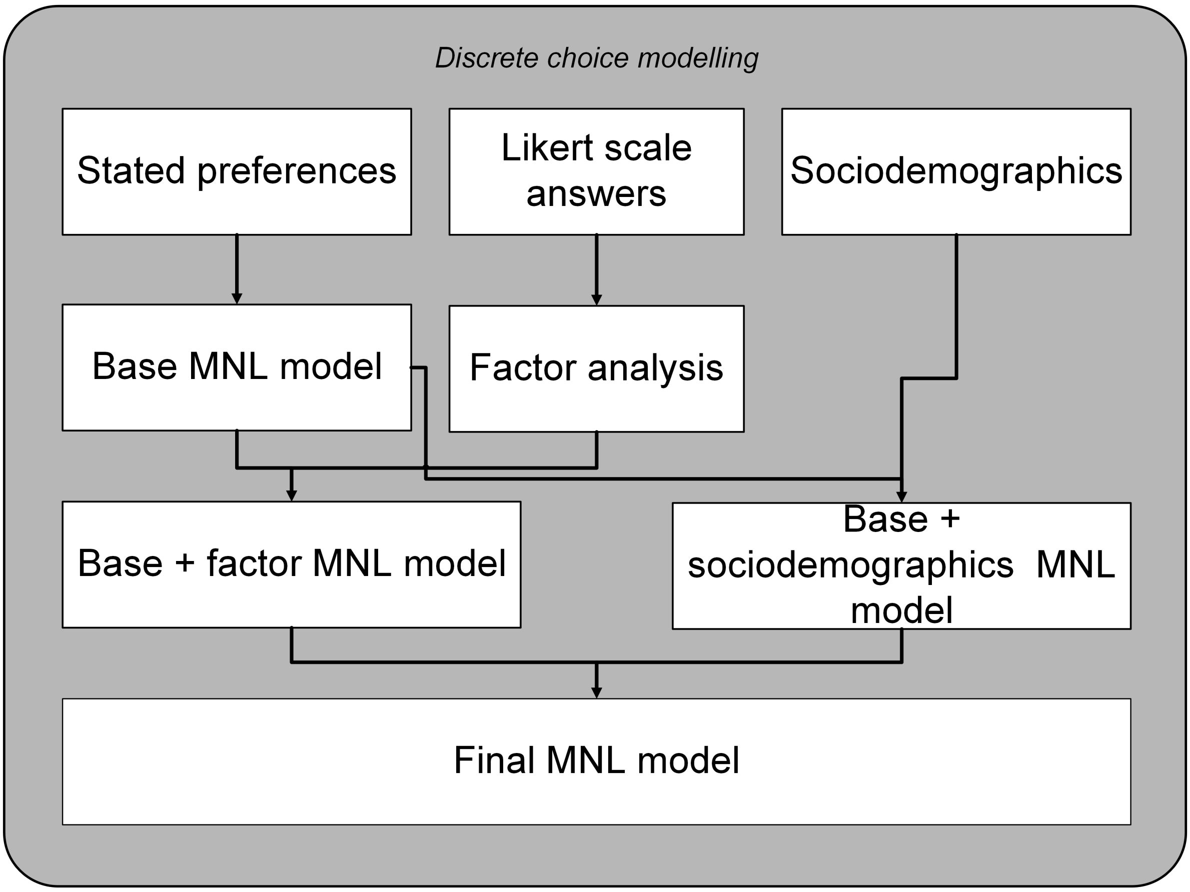


Figure 6.7: Discrete choice modelling overview

6.4.1. Performance of final model

The final model demonstrates a strong performance, as evident by several key indicators. It significantly improves the initial log-likelihood from -3184 to a final log-likelihood of -1628 with a rho-square bar of 0.478 indicating that the model explains 47.8% of the variance in mode choice behaviour. Additionally, the likelihood ratio test of 3112 further supports the improvement over the null model. The base model has a rho-square bar of 0.447 and a log-likelihood of -1751, while partial models incorporating additional factors and interactions improve the rho-square to 0.475 and the log-likelihood to -1640.

Model	Par.	ρ^2-bar	Init. LL	Final LL	AIC	BIC
Base MNL	10	0.447	-3183.68	-1751.02	3522.05	3579.88
Base MNL + factors	13	0.451	-3183.68	-1736.20	3498.41	3573.59
Base MNL + sociodemographics	32	0.475	-3183.68	-1640.16	3344.32	3529.39
Final MNL	34	0.478	-3183.68	-1627.80	3323.61	3520.24

Table 6.2: Model comparison summary

Moreover, the final model includes 34 parameters, providing a more distinct understanding of the factors and preferences influencing mode choice compared to the base model, which only includes 10 parameters. The final model also shows better performance in AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion). The base model performs with an AIC and BIC of 3522 and 3580 while the final model performs with an AIC of 3324 and a BIC of 3520. Both information criteria being lower than the base model which indicates a better balance between the model fit and complexity.

Overall, the comparisons indicate that while the base model offers a solid starting point, the final model improves upon it by providing a more accurate and comprehensive understanding of the factors influencing mode choice. This makes the outcomes more reliable for decision-making and further analysis. The stepwise improvements through intermediate models show the importance of incorporating additional variables and interactions to achieve a more robust and insightful model. Therefore it can be said that the developed final MNL model is justified to use for further use and recommendations in decision-making processes.

6.4.2. Base model

To start the process, a base model is constructed which is a basic multinominal logit model (MNL model). Due to differences in respondents' choice sets and if a sequential decision was needed per choice task, it is opted to only include a respondent's final choice for each choice task. This means that for respondents with choice sets A to D only their second choice for a choice task is considered and for respondents with choice set E all their made choices are included.

This model starts with all attributes that are used in the stated preference experiment including ASCs (alternative specific constants). Hereby, the bicycle + PT combination is chosen to be the reference due to the nature of this research. Furthermore, regarding the bicycle parking facilities, this attribute has four levels and is also in need of a reference level in the base MNL model. In this case, the attribute level of no present bicycle parking facility is used as a reference. Additionally, the attributes of parking time, travel time and travel costs are included.

According to the model, parking time is estimated to have a positive value with a very significant robust p-value. This means that according to the model, parking time is valued more positively the longer it takes which is counterintuitive. The survey design also only presented in all alternatives a parking time of one or two minutes which can be perceived as not too meaningful to respondents. For that reason, it is decided to exclude parking time in the base model.

Next to excluding parking time in the base model, also a modification to the travel time is done. In the stated preference survey, the scenarios are presented with different travel times. For the bicycle, bicycle + PT and the e-bike a slower travel time is used while for the car and the moped, a faster travel time is used. However, the two different travel time variables are merged into one common variable for travel time. This is justified because of the weak covariance (covariance of -6.71e-05) and statistically insignificant correlation (robust p-value of 0.863) between these two variables.

After these modifications, a base model is the result. The complete Biogeme code to reach this base model can be found in Appendix E in Subsection E.1.1. The values of the considered variables of the base model are depicted in Table 6.3. The statistically significant values of the variables are depicted in blue. The full estimation report of this base MNL model is shown in Appendix E Subsection E.1.2. In this base model almost all parameters are statistically significant, except for the bicycle parking bracket and the shedded bicycle parking facility. However, due to the relevance of these parameters in the research, it is opted to keep these variables in the base model even though being statistically insignificant. Regardless of keeping these parameters, the base model has a rho-square-bar of 0.447 which is relatively high and indicates that this base model explains a significant portion of the variability in the choices.

	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_bike	2.01	0.17	14.40	0
ASC_car	0.89	0.17	5.34	<0.001
ASC_ebike	2.85	0.20	14.50	0
ASC_moped	0.81	0.29	2.76	0.006
beta_bicycle_pump	-0.47	0.14	-3.50	<0.001
beta_parking_bracket	0.22	0.17	1.28	0.200
beta_parking_safes	0.59	0.17	3.51	<0.001
beta_parking_shedded	0.26	0.24	1.11	0.290
beta_travel_costs	-0.09	0.04	-2.51	0.012
beta_travel_time	-0.10	0.01	-12.20	0

Table 6.3: Base MNL model values

6.4.3. Factor analysis

The second step that leads to developing the final model is by carrying out a factor analysis and including those findings in the base model. A factor analysis may be an important aspect in researching travel preferences and heterogeneity in behaviour further which the base model does not account for. It gives the potential to uncover more individual-specific characteristics and perceptions.

By applying a factor analysis to the ten statement questions in the survey, hidden patterns are discovered. It incorporates the given answers by respondents on the ten statement questions mentioned in Section 5.2.1 into a factor analysis that uses two factors to simplify the complex dataset generated by the survey answers. All given answers on the Likert scale statement questions can be found in detail in Appendix G in Table G.4. Using two factors the large number of observed variables is simplified by a smaller set of latent factors. This leads to Figure 6.8 which shows the factor loadings of each statement question for each factor. The closer the loading in Figure 6.8 is to -1 or 1, the stronger the influence while loadings close to zero indicate a weak influence. Based on this a few observations are visible.

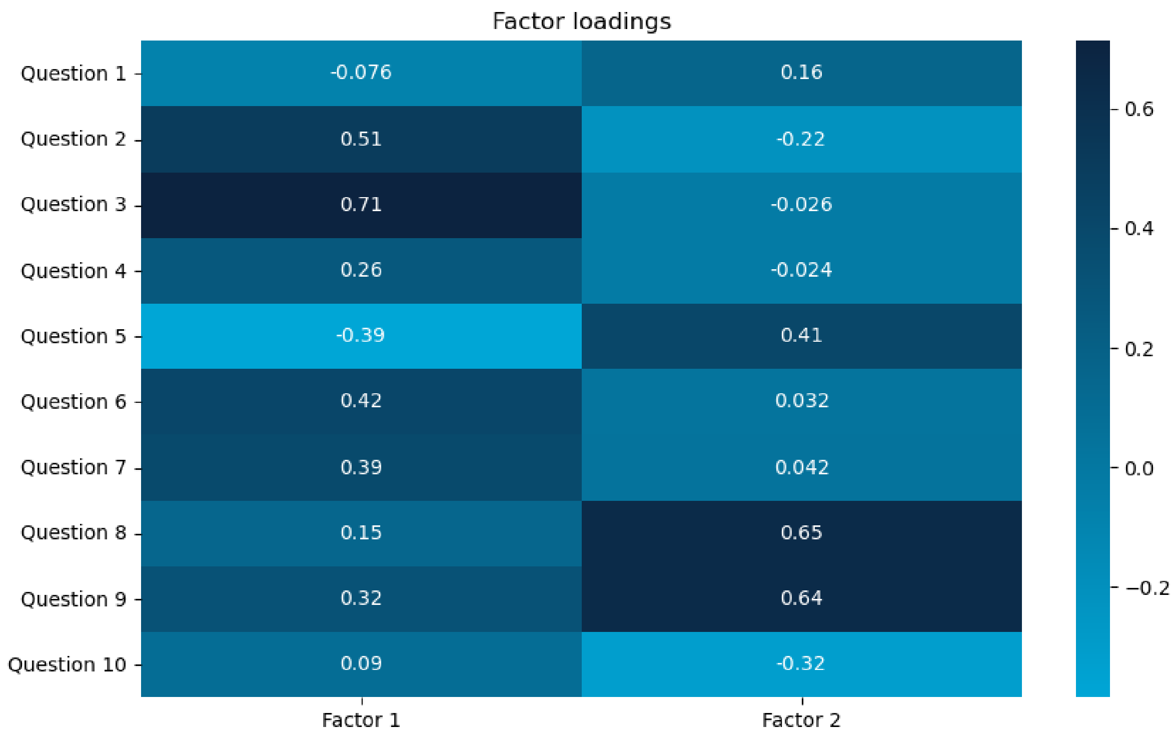


Figure 6.8: Factor loadings on Green and Healthy travellers and Safe and Secure travellers

The factor analysis results in two factors that significantly influence transportation preferences. Factor 1 appears to have high loadings in questions 2, 3 and 6. While also including moderate loadings on questions 5 and 7. To recap these statement questions are summarized in Table 6.4. It is noticeable that this factor exhibits a negative loading on the importance of car ownership. On the other hand, the positive loadings show individuals who prioritize environmental and health benefits. Therefore, factor 1 can be interpreted as representing individuals who are environmental and health conscious. Factor 1 can now be grouped as Green and Healthy travellers.

Number	Statement	Loading
2	I see public transport as an alternative to the car.	0.51
3	The environment is an important factor in my choice of transportation mode.	0.71
5	Owning a car is important to me.	-0.39
6	I cycle because it is better for my health.	0.42
7	I know how to use a bicycle locker without problems.	0.39

Table 6.4: Significant statements for Green and Healthy travellers (Factor 1)

Number	Statement	Loading
5	Owning a car is important to me.	0.41
8	I fear my bicycle will be stolen at a stop.	0.65
9	It is important that my bicycle is properly parked at an intended bicycle parking space.	0.64

Table 6.5: Significant statements for Safe and Secure travellers (Factor 2)

Besides Green and Healthy travellers, factor 2 represents another traveller profile with different factor loadings. For this factor, statement questions 5, 8 and 9 are of high relevance. This indicates that individuals who are more concerned about bicycle security are more likely to prioritize car ownership and feel less safe while cycling. Therefore, factor 2 represents security concerns related to bicycle usage and can be named Safe and Secure travellers.

After obtaining these factors, the factor scores of each individual per factor are determined. The score of each factor represents an individual's position on the factors identified during the factor analysis. These factor scores can then be incorporated into the base MNL model by introducing new variables. Both factors are added mode specific to all utility functions, which means that initially 10 new variables are introduced to the model.

In order to protect the model from overfitting, a backward elimination process is started on the 10 newly introduced variables. Each elimination is based on the least significant parameter until all parameters are statistically significant. This elimination process started with removing the beta describing the bicycle for factor 1 which has a robust p-value of 0.778. The last removed parameter represents the beta for the e-bike for factor 2, which was removed due to a robust p-value of 0.134.

At the end of the process, three variables of the initial 10 variables are kept to describe the factors. These variables include the modes bicycle + PT and the moped for factor 1 and the car for factor 2 which will be further tested in the final model. The outcome of these statistically significant parameters and its values are shown in Table 6.6. Given the values, a completely dedicated Green and Healthy traveller adds 2.44 to the utility of the alternative bicycle and PT combination. While this same individual gains 0.889 to the utility function of the alternative moped. On the other hand for factor 2, when an individual is fully pertained to be a Safe and Secure traveller only one alternative is influenced. It is the alternative car, with a gain of 2.85 in its utility function.

The full estimation report of the base model including the mentioned parameters from the factor analysis is displayed in E.2.1. This estimation report shows minor changes in values of the parameters that were statistically significant in the base MNL model. With an exception for the alternative specific constant for the moped alternative. The values for a bicycle parking bracket and shedded parking that were not statistically significant shifted proportionally more in value than the other estimated parameters.

Parameter	Value	Rob. Std err	Rob. t-test	Rob. p-value
Factor 1 bicycle + PT	2.44	0.17	14.40	0
Factor 1 moped	0.89	0.17	5.34	<0.001
Factor 2 car	2.85	0.20	14.50	0

Table 6.6: Added factor parameters and values

6.4.4. Interaction effects

Sociodemographic characteristics

Individuals' mode choices are often not only influenced by the attributes of the alternatives themselves but also personal characteristics. Sociodemographic factors can significantly affect preferences or aversion to certain alternatives. Therefore this approach leads to helping the base MNL model to capture a part of the heterogeneity.

The sociodemographic age, gender, education level and income level are one by one included based on groups and per mode with the base MNL model. Each sociodemographic is grouped in the same manner as presented in the figures of Section 6.3 Descriptive statistics. Carrying this out, all sociodemographic effects on the alternatives are obtained and reported in Section E.3 of Appendix E while the base reference is always the first mentioned sociodemographic group in the tables. Moreover, all values are displayed as the reference value of that specific group.

With completing a sequential process of incorporating sociodemographic effects into the base MNL model, 21 parameters are noted to be of interest due to its robust p-value. In Table 6.7 the mentioned parameters are summarized with the corresponding values.

While analysing this model estimation on its own numerous preferences across the different sociodemographic groups are revealed. Adults aged 35-44 show a clear preference for biking, reflecting a strong inclination towards this mode of transport and the combination together with public transportation. However, middle aged to older individuals (45-74 and 75+) are less likely to use cars. Moped usage is notably unpopular among 35 to 44 year olds.

Education levels also influence preferences in the same manner as age. Higher education is associated with a greater likelihood of choosing mopeds, as indicated by the positive coefficient, while it shows a lower likelihood for choosing e-bikes. Middle-income individuals are more prone towards biking and e-bikes, suggesting a preference for cost-effective or sustainable transport options. Additionally, women show a stronger preference for car usage. These parameters are further explored when combining all significant parameters in the final model.

Parameter	Value	Rob. Std err	Rob. t-test	Rob. p-value
Age 35-44 bicycle	1.93	0.19	10.30	0
Age 35-44 bicycle +PT	1.44	0.25	5.85	<0.001
Age 65-74 bicycle + PT	-0.61	0.30	-2.04	0.041
Age 75+ bicycle + PT	0.76	0.24	3.21	0.001
Age 25-34 car	-0.58	0.26	-2.21	0.003
Age 35-44 car	0.77	0.26	3.01	0.002
Age 45-54 car	-0.79	0.27	-2.93	0.003
Age 55-64 car	-0.61	0.23	-2.66	0.008
Age 65-74 car	-0.72	0.28	-2.57	0.010
Age 75+ car	-1.28	0.41	-3.15	0.002
Age 35-44 moped	-5.42	0.50	-10.90	0
Age 45-54 moped	1.76	0.72	2.43	0.015
Age 35-44 e-bike	1.28	0.42	3.08	0.002
Woman car	0.56	0.19	3.05	0.002
Education middle car	0.81	0.24	3.33	<0.001
Education high moped	1.82	0.83	2.20	0.028
Education middle e-bike	-0.86	0.35	-2.46	0.014
Education high e-bike	-1.63	0.36	-4.49	<0.001
Income middle bicycle	0.34	0.12	2.75	0.006
Income high bicycle + PT	1.07	0.45	2.39	0.017
Income middle car	-0.43	0.12	-3.55	0.011

Table 6.7: Statistically significant sociodemographic parameters values

Sociodemographics and attributes

Lastly, the interaction effects of sociodemographic characteristics of individuals are tested on variables. Similarly to the approach of using a factor analysis and sociodemographic characteristics, this method incorporates heterogeneity of individuals into the model and can therefore be partly captured. However, this approach is different due to its ability to capture certain effects of a sociodemographic on an attribute.

To determine which interaction effect is worth incorporating into the final model the method mentioned in Section 3.3.2 is used which starts off with testing the sociodemographics one by one into the base MNL model. As these interactions are tested sequentially, only relations within the used attributes can be made. Hereby, the sociodemographics age, gender, education and income are interacting with levels of bicycle parking of a bracket, shedded and safes and therefore are continuing to be weighed against the bicycle parking level of none. Furthermore, the attributes of a bicycle pump, travel time and travel costs are considered.

Additionally, travel time and travel costs are explored further. This is due to the fact that travel time and travel costs can be influenced per sociodemographic and per mode. All values of interaction effects of sociodemographic groups can be found in Appendix E from Table E.5 to Table E.7. The values given in these tables are computed by using a reference level, however the values indicated in the tables include the reference level. This results in the end values of the associated interaction. Nevertheless, these values maintain on being in reference of a baseline traveller.

As a result of many interaction combinations, many variables turn out to be significant. Therefore, only the highlights will be discussed further on. To be exact, 31 significant variables are observed in the interaction effects of the sociodemographics and attributes. In addition, 12 and 34 parameters are significant for the interaction effects of respectively travel costs per mode and travel time per mode interacting with sociodemographics.

The data reveals patterns in how different sociodemographic groups prefer certain bicycle parking facilities. The 45-54, 65-74 and 75+ age groups show a clear preference for the shedded option, while those others age groups are less likely to opt for this facility. However, the latter values tend not to be significant to continue testing in the final model. Middle-educated individuals have a higher preference for shedded bicycle parking (1.377), whereas high-income individuals tend to avoid the shedded option (-5.606). Furthermore, low educated and low-income individuals show a positive significant value for bicycle safes (0.6 and 0.716 respectively), meaning it accounts positively for the mode of bicycle and public transport combination. Next to this, gender differences are also apparent, with men showing a significantly low likelihood of choosing the bicycle pump service (-0.397).

While travel costs also play a role, younger adults aged 18-24 in comparison to a baseline traveller show a significant preference for reducing costs associated with the combination bicycle and PT mode, as indicated by the negative coefficient (-0.237). Similarly, adults aged 45-54 demonstrate a significant reduction in costs for the same mode, suggesting a consistent pattern of cost sensitivity in this mode across different age groups. Women also display a significant preference for minimizing costs related to the identical mode while high-income individuals show a strong preference for reducing costs in both the bicycle and PT mode and car trips.

Related to travel time, younger adults (18-24 years) show a more negative experience for travel time in the bicycle + PT mode. The 35 to 44 and 55 to 74-year-old age groups also exhibit a stronger negative experience of travel time in this mode. Meanwhile, the age group 45-54 favours travel time on the moped. Women show a worse experience related to travel times in the combination mode of bicycle and PT. Additionally, high-income individuals demonstrate having for almost all modes a more unfavourable experience of travel times relative to a baseline user.

6.4.5. Final model

The final step in developing the model that is going to be used further in this research is to combine the base model with all findings from the factor analysis and its parameters, the sociodemographic effects and the interaction effects of sociodemographics and its relations with attributes.

This is done by using the base model and including all variables at once that turned out to be significant when adding sequentially beforehand. By doing this, an initial model can be made with a total of 111 parameters. Ten from the base model, three from the factor analysis, 21 from the sociodemographic groups and a total of 77 from the interaction effects. As a result of an abundant amount of variables, a backward elimination on such a model is not preferred due to the long optimization times per elimination. Therefore, it is opted to perform the backward elimination process in parts to reduce the total number of parameters to be evaluated.

Firstly, the base model is combined with all significant parameters that came out as a result of the sociodemographic groups in Subsection 6.4.4 Sociodemographic characteristics effects. Hereby, the 21 betas are inserted all together with the base model. From here on, the backward elimination can start and it starts off with eliminating the beta coefficient for the middle income level of the mode car with a robust p-value of 0.982. Based on this, the corresponding beta coefficient is most likely the outcome due to random variation of chance. The last removed beta coefficient defines how high-education individuals experience the moped. This was the last variable out of eight variables that were removed in this partial process.

To move on in this process, parameters that are related to bicycle parking facilities and the service facility of the bicycle pump are added to the base model. This results in adding fifteen extra parameters more than the base MNL model. The first coefficient that is removed describes the effect of a bicycle pump when being a man by cause of a robust p-value of 0.923. The backward elimination in this partial process started after removing 9 more variables until all leftover variables are statistically significant.

Advancing to travel costs, all significant beta coefficients from Table E.5 and Table E.6 are tested together since all are related to travel costs. A total of 19 beta coefficients are added next to the general travel costs variable into the base MNL model. Again, a backward elimination is carried out, removing eight parameters relevant to travel time. With half of the removed beta coefficients being related to travel costs of the car.

In this last part of the partial backward elimination process, all variables associated with travel time are examined. This means an additional 49 beta coefficients are inserted next to the base MNL model. Numerous of these beta coefficients have been eliminated throughout the process. Starting off with the variable describing the travel time perception of a middle-educated person on the moped. The elimination was due to the parameter being the least significant variable in the current model with a value of 1. At the end of the procedure, another 31 variables are discarded which means seventeen variables relevant to travel time are left.

The final step after all the abovementioned partial backward elimination steps is to combine the remaining parameters and the significant factor variables into one model with the base MNL model. As a result of an interactive process where variables that were not initially in the base model were removed. A total of 34 parameters remained in the final MNL model, including the 10 that are present in the base MNL model. The values of a baseline traveller are listed in Table 6.8. Further details of the outcome of the model can be found in Appendix E in Section E.6.

Baseline traveller				
Parameter	**Estimated value**	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC bicycle	1.75	0.23	9.59	0
ASC car	-0.34	0.26	-5.86	<0.001
ASC e-bike	2.39	0.32	11.50	0
ASC moped	-2.17	0.62	-3.48	<0.001
Bicycle pump	-0.44	0.14	-3.08	0.002
Bicycle parking bracket	0.34	0.18	1.94	0.053
Bicycle parking safes	0.66	0.17	3.85	<0.001
Shedded bicycle parking	-0.38	0.30	-1.28	0.202
Travel costs	-0.18	0.05	3.94	<0.001
Travel time	-0.15	0.01	-11.3	0

Table 6.8: Baseline traveller values in final model

The estimation results reveal insights into the factors influencing mode choice, particularly for this research regarding bicycle-related facilities and services. The presence of a bicycle pump is associated with a decrease in utility for the combination mode of biking and public transport. In contrast, the availability of secure and bicycle parking bracket facilities plays a role in increasing the utility of this mode. Covered parking at public transport stops increases the utility for middle-aged individuals and those with middle-level education in comparison to the baseline traveller, making biking to a stop a more attractive option for these groups. Secure parking safes also contribute positively to the utility of biking to a PT stop and continuing a trip with PT. However, for high-income individuals, covered parking is perceived immensely negatively. These specific persons add -4.18 to the baseline users which means the value becomes -4.562. This indicates that high-income travellers have quite some aversion to this specific type of bicycle parking facility.

Beyond bicycle parking and service facilities, the final MNL model similarly reveals the effects of travel costs and time on mode choice. For example, increased travel costs consistently reduce utility across various modes and age groups, highlighting the sensitivity of users to costs. Additionally, the time spent travelling plays a crucial role, with for example age group 35 to 44 and higher educated people having an extra negative view of travel time on the moped on top of the basis of the baseline traveller. When diving into the mode of bicycle + PT, the perceived travel time of people aged over 75 comes close to zero (-0.008). Meaning, that this age group is less sensitive to increasing travel times and that travel time is a less decisive factor when travelling with this specific mode. On the contrary, women are immensely affected negatively when it comes down to travel time for the combination mode of bicycle and PT almost doubling the value in comparison to a baseline traveller. It can be said that women are very sensitive to travel time for this specific mode.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7 Model interpretation

In the previous chapter, the results have been discussed extensively. Findings and statements have been made based on the developed model. In this chapter, the interpretation of the model is going to be covered. This will be done through a persona-based trip scenario analysis which will cover personal characteristics that are of relevance in the model. An overview is shown in Figure7.1. Furthermore, the interpretation and applications of The Hague as a city are discussed.

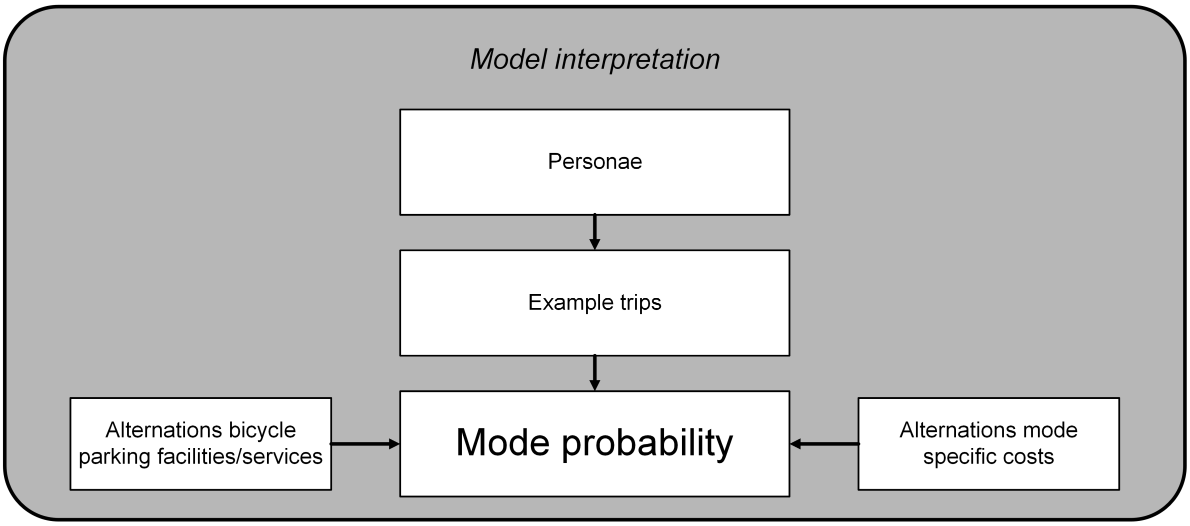

Figure 7.1: Model interpretation overview

7.1. Persona-Based trip scenario analysis

In order to get more grip on what all values exactly mean and contribute to the modal split, a persona-based trip scenario analysis is carried out. In this analysis, numerous personas are introduced with various sociodemographic characteristics to cover many of the groups that were used to develop the model. Furthermore, these personas are undergoing an imaginary trip that have realistic trip characteristics.

7.1.1. Personae and trip characteristics

To start off, different personas are created with a variety of sociodemographic characteristics who are summarized in Table 7.1. Next to this, two example trips are compiled. The first trip within The Hague originates from the Fultonstraat to the destination of De Savornin Lohmanplein 1. This trip starts from a residential area to a shopping area and has a distance by car of 3.2 km. The second trip that is generated starts in the Repelaerstraat to Laan van Meerdervoort 50B which again originates from a residential street but has a destination at a dancing school. This specific trip has a distance by car of 5.0 km. Therefore both trips can be classified as a short-distance car trip. All further trip characteristics per mode can be found in Table 7.2 and Table 7.3. The mentioned trip characteristics are computed with the help of tools from Google Maps (2024), HTM Personenvervoer NV (2024) and ANWB (2024).

	Name					
Characteristic	Fiona	David	Sara	Alex	Maria	Lucas
Age	28	45	55	35	65	24
Gender	Female	Male	Female	Male	Female	Male
Education level	High	Middle	Low	Middle	High	Low
Income level	Middle	High	Middle	Middle	Low	Low
Green and Healthy traveller score	0.8	0.3	0.6	-0.7	0.2	-0.2
Safe and Secure traveller score	-0.4	0.9	-0.1	0.2	0.5	-0.5

Table 7.1: Personae and their characteristics

Figure 7.2: Visualisation of the personae

From Fultonstraat 11-171 to De Savornin Lohmanplein 1		
Mode	**Travel time**	**Travel costs**
Bicycle	10 minutes	€0
Bicycle + PT	10 minutes	€1.50
Car	9 minutes	€2
Moped	9 minutes	€2
E-bike	9 minutes	€0

Table 7.2: Example trip 1 characteristics per mode (Google Maps (2024), HTM Personenvervoer NV (2024) and ANWB (2024))

From Repelaerstraat 1-84 to Laan van Meerdervoort 50B		
Mode	**Travel time**	**Travel costs**
Bicycle	9 minutes	€0
Bicycle + PT	15 minutes	€1.50
Car	15 minutes	€2
Moped	10 minutes	€2
E-bike	8 minutes	€0

Table 7.3: Example trip 2 characteristics per mode (Google Maps (2024), HTM Personenvervoer NV (2024) and ANWB (2024))

7.1.2. Scenario development and implementation

The analysis incorporates the created personas, the trip characteristics and changes in bicycle parking facilities while also taking the availability of modes into account. It is unlikely that every inhabitant owns all considered modes, therefore it is chosen to explore the mode choice probability between the bicycle, bicycle + PT and the car and the mode choice probability between all considered modes. The first decision is based on the fact this research dives into shifting short-distance car trips and secondly the likelihood of an individual owning an e-bike or a moped are lower. The latter is based on the percentage of survey respondents indicating access to these modes. With 19% for the e-bike and 5.5% for the moped. The share is smaller than the modes where the biggest interest lies, namely the bicycle and the car. A big note in the computation of the mode choice probabilities in the different scenarios is that modes such as walking and PT on itself are not considered. Nonetheless, both compositions are by any means going to be explored.

To have reference mode choice probabilities for all personas and trips, it is decided upon to work assuming that there are no bicycle parking facilities and no bicycle pump present at PT stops such that the effect can be captured of all additions. As a result of this, scenarios are introduced where facilities are added and even increased costs are explored. The tested scenarios are summarized in Table 7.4. In creating the scenarios, the bicycle pump is not added in any way due to the unfavourable effect on the bicycle + PT mode. This decision is supported by the fact there are no interaction effects present to showcase differentiation between personas for the preference of a bicycle pump. The mode choice probabilities outcomes of the scenarios per persona per trip are presented in Appendix I. Below, the highlights are going to be discussed per scenario with respect to the research objective of shifting short-distance car trips to the bicycle + PT mode. A sidenote that can be made is that in some scenarios a combination of bicycle parking is made. Hereby, a sum of utility is assumed while in reality, this might differ and underlying interaction effects between facilities can be of presence.

Scenario	**Modication(s)**		
Base scenario	-	-	-
Scenario 1	Add brackets		
Scenario 2	Add brackets	Add shedded parking	-
Scenario 3	Add brackets	Add bicycle safes	-
Scenario 4	Add brackets	Add shedded parking	Add bicycle safes
Scenario 5	Increase car costs by €2	-	-
Scenario 6	Increase car costs by €2	Add brackets	-
Scenario 7	Increase car costs by €2	Decrease PT costs by €0.50	Add brackets

Table 7.4: Tested scenarios with all modifications

Base scenario

In the base scenario, where no bicycle parking facilities and no bicycle pump are available at the bus and tram stops, the outcomes reveal a strong preference for the bicycle, especially for trip 2, with splits as high as 92.5% among certain personas (Figure 7.4). However, the e-bike when considered as an available mode reaches high shares (Figures 7.5 and 7.6). On the contrary, the bicycle + PT mode shows low usage across all personas, with percentages generally below 8% and as low as 0.4% when considering five modes at once. In contrast, car usage remains relatively high in some cases, particularly for personas such as David. Car usage in this case reaches 37.4% for trip 1 and 27.5% for trip 2 while other personas range from 5.6% to 22.8% in case of 3 available modes and from 1.4% to 10.8% for 5 available modes. Below the mode choice probability of all personas for trips 1 and 2 with 3 and 5 available modes are depicted where percentages smaller than 2% are not shown. For the exact percentage it is referred to TableI.1 in Appendix I.

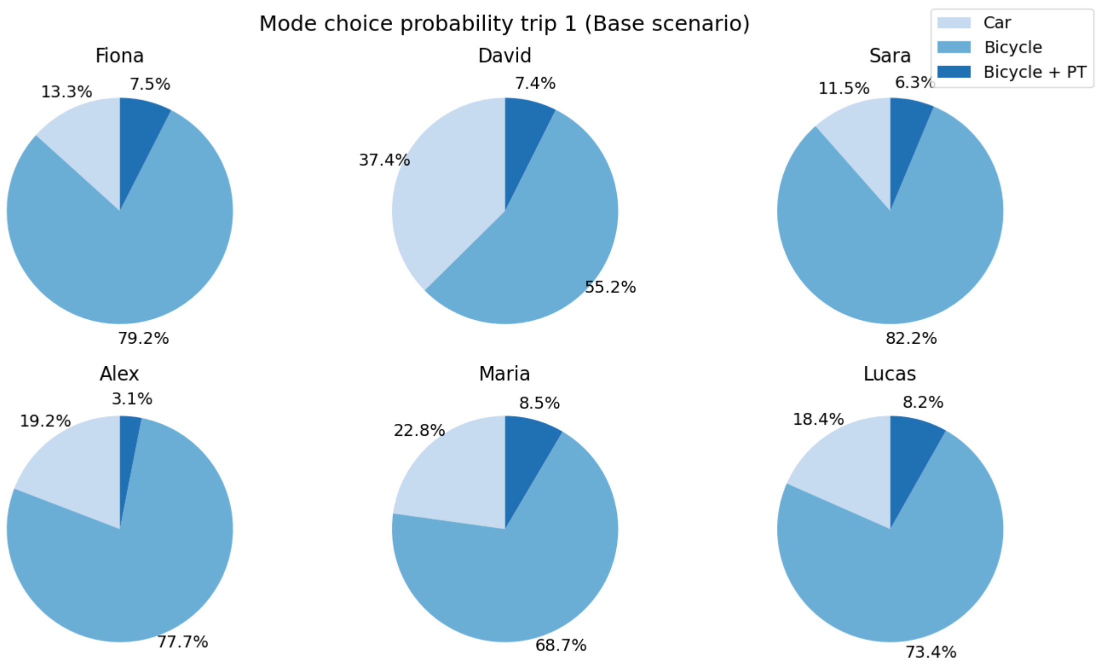

Figure 7.3: Mode choice probability for personae for trip 1 with three available modes in the base scenario

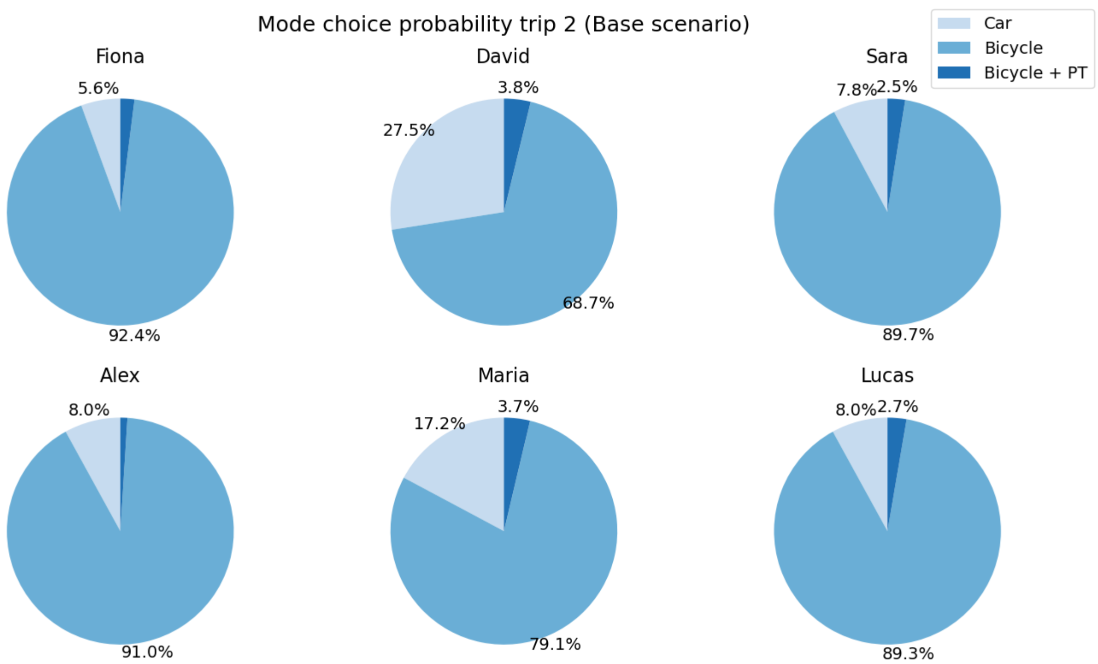

Figure 7.4: Mode choice probability for personae for trip 2 with three available modes in the base scenario

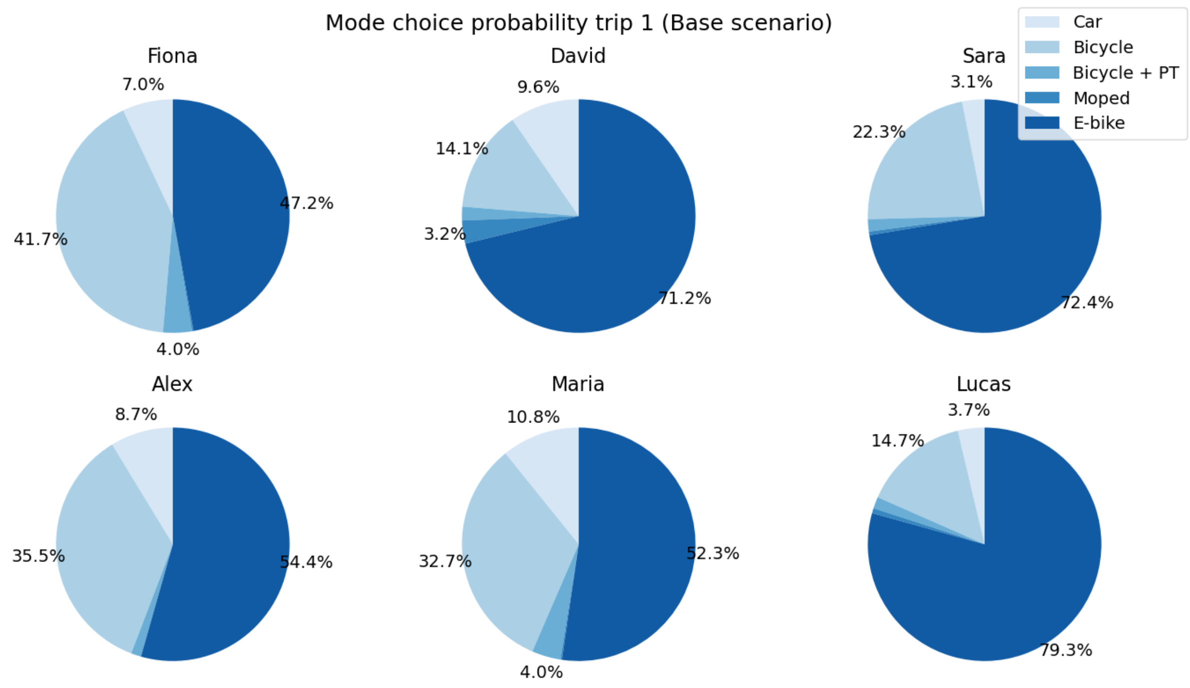

Figure 7.5: Mode choice probability for personae for trip 1 with five available modes in the base scenario

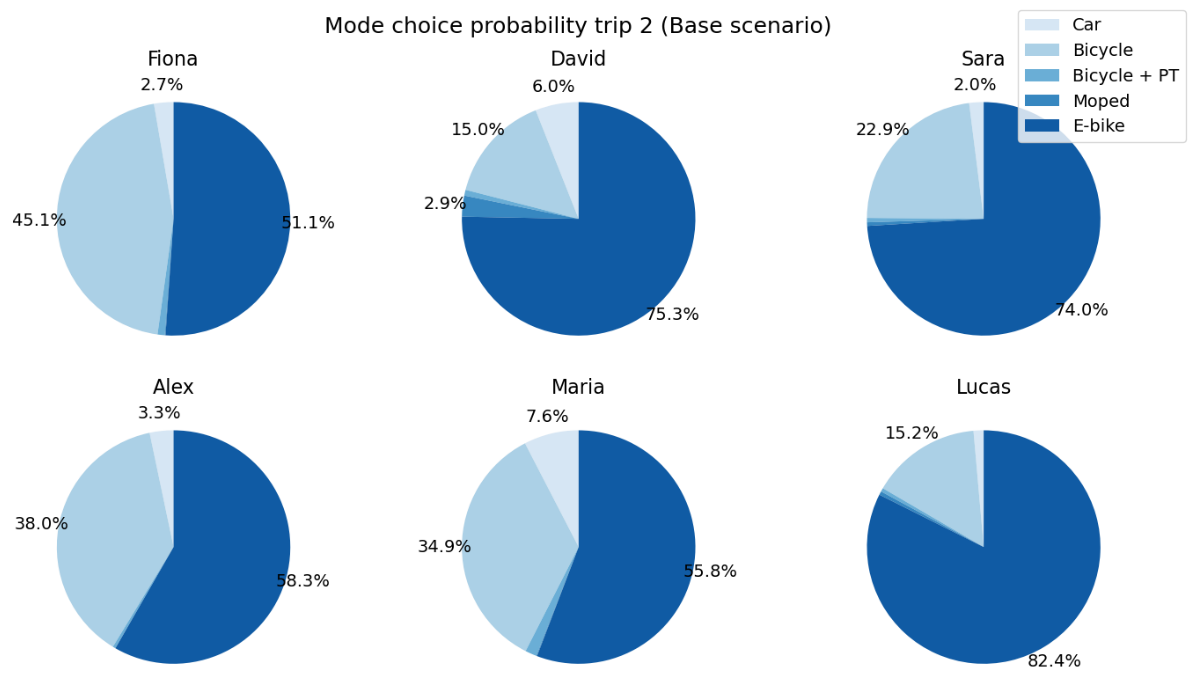

Figure 7.6: Mode choice probability for personae for trip 2 with five available modes in the base scenario

Scenario 1
In the first scenario, only the presence of a bicycle parking bracket at public transport stops is added to the situation. Bicycle usage in this scenario remains high across both trips but also shares the biggest usage with e-bikes. A key highlight in this scenario is the increase in bicycle + PT adoption in comparison to the base scenario. This increase suggests a positive effect of adding a bicycle parking bracket on this specific mode. On the other hand, car usage shows a small reduction in comparison to the base scenario, although the change is more pronounced for a few personas than others. For example, David's car probability when having access to three modes for trip 1 decreases from 37.4% to 36.4% and Lucas's car choice probability drops from 18.4% to 17.8%.

Scenario 2
In this scenario, another modification is added next to the bicycle parking bracket, namely shedded parking places. This specific addition caused some changes compared to the base scenario and the first scenario. With respect to the base scenario, the bicycle + PT mode shows mixed results. While some personas, Fiona, see a decrease in probability, others, such as Alex experience a relatively high increase in utility for the bicycle-PT mode. This is due to the different interaction effects on these personas. A gain or lost probability in bicycle + PT often does not result in a net shift from the car. In relation to the first scenario, this scenario is only effective for individuals similar to Alex when using the indicator of shifting away from car trips. Resulting in a general disadvantage to implementing shedded parking together with a bracket.

Scenario 3
Similarly to the previous scenario, another bicycle parking facility is added next to the bicycle parking bracket. However, this scenario combines it with bicycle safes instead of shedded parking. In this scenario, the bicycle and the e-bike continue to be popular modes, but there are some reductions in mode choice probability compared to the base scenario. This decline is similar to the mode choice of the car. For the persona of David, the decline can be as big as 4.2 percentage points. If the mode choice e-bike is available, a decrease is again witnessed. On the contrary, the bicycle + PT mode has higher probabilities in this scenario, resulting in trips having higher chances of shifting from other modes towards the bicycle + PT mode. This includes relatively high reductions of choice probability away from car trips and this scenario performs better than scenario 2 concerning shifting away car choice probability to a higher bicycle + PT probability.

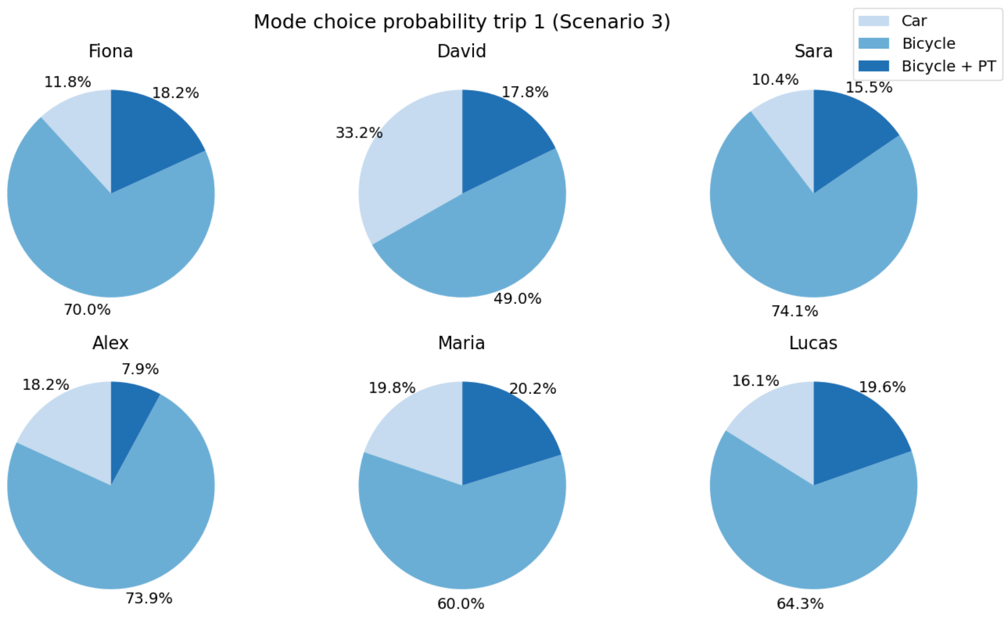

Figure 7.7: Mode choice probability for personae for trip 1 with three available modes in scenario 3

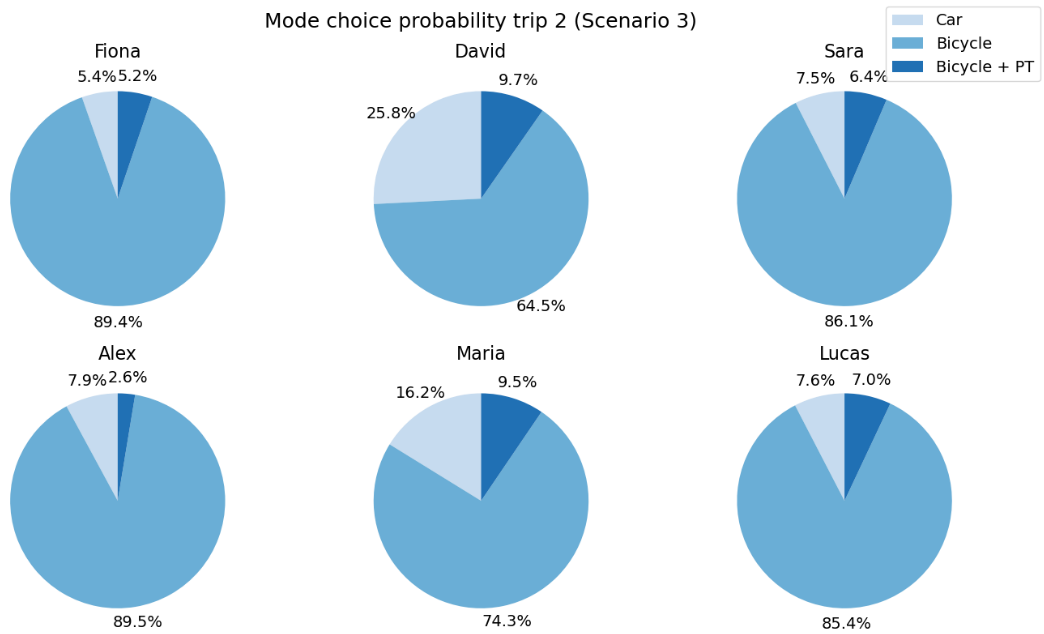

Figure 7.8: Mode choice probability for personae for trip 2 with three available modes in scenario 3

Scenario 4

The different bicycle parking facilities that are dealt with within this research are added to the base scenario, involving all bicycle parking facilities to be present at once. The bicycle + PT mode continues to show higher probabilities compared to the base scenario. However, the probabilities are not as high as in scenario 3 and for personas such as David, this scenario is not beneficial at all with only a mode choice probability of 1.9% for the bicycle-PT combination while others do show positive effects towards the mode. Overall this scenario performs well while considering reducing short-distance car trips but is not as effective as the previous scenario where only a bicycle parking bracket is combined with bicycle safes.

Scenario 5

This scenario does not explore the potential of bicycle parking facilities but analyses the effect of increasing car costs by €2. This implementation leads to higher choice probabilities towards bicycle, bicycle + PT and e-bike usage. Out of these three modes, the bicycle + PT mode experiences a more modest increase. Car usage probabilities are reduced based on the cost increase. For most personas, the reduction is around 4 to 5 percentage points. for trip 1 and a bit less for trip 2. David's car usage probability stands out in this scenario, the biggest difference is witnessed for trip 1 decreasing from 37.4% in the base scenario to 21.4%. With his high income, an extra negative perception of travel costs is experienced which caused this drop in usage.

Scenario 6

Scenario 6, as a combination of scenarios 1 and 5, combines the addition of a bicycle parking bracket and an increase in costs for the car trip. In this scenario, the bicycle + PT mode sees increased mode choice probability in comparison with scenarios 1 and 5 while the alternative car experiences the opposite. The biggest change in probability with respect to the modes car and bicycle-PT happened to David, this persona underwent a bicycle + PT increase of around 5 percentage points and a car usage decrease of almost 17 percentage points. Lucas only experiences an increase of 0.5 percentage points for the bicycle + PT and a decrease of 1.9 percentage points in car usage probability. However, the effect might differ between all personas, on average this scenario performs effectively regarding the car trip reduction by increasing choice probability towards a bicycle + PT option.

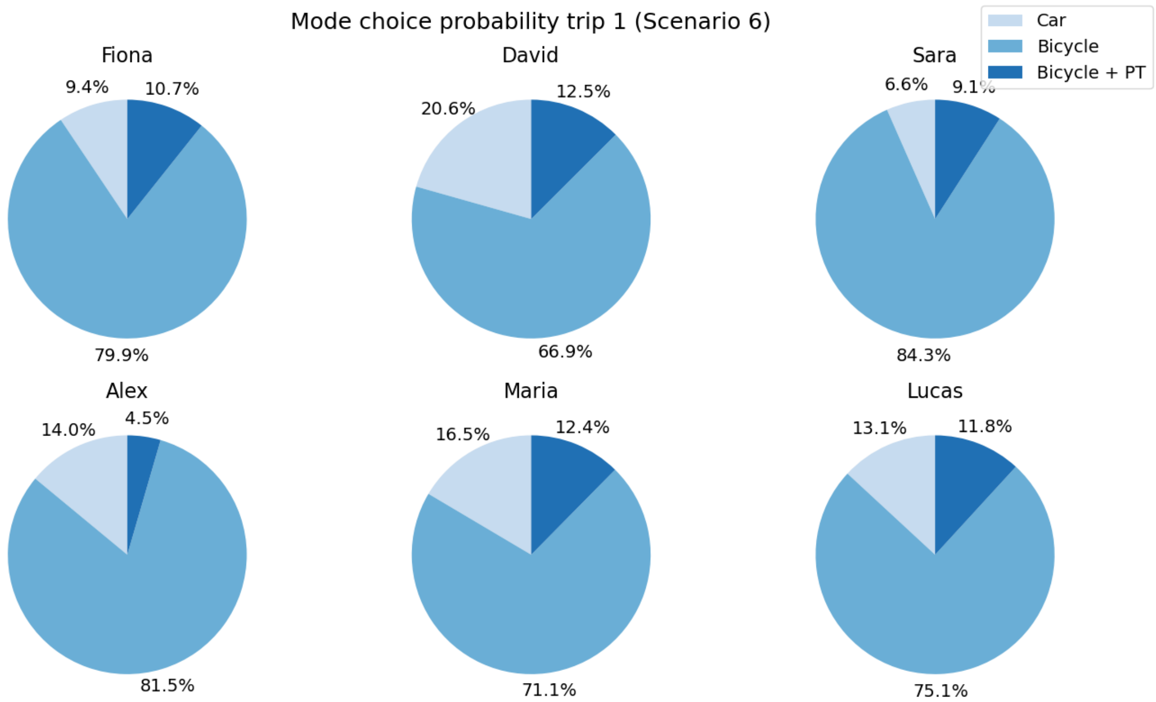

Figure 7.9: Mode choice probability for personae for trip 1 with three available modes in scenario 6

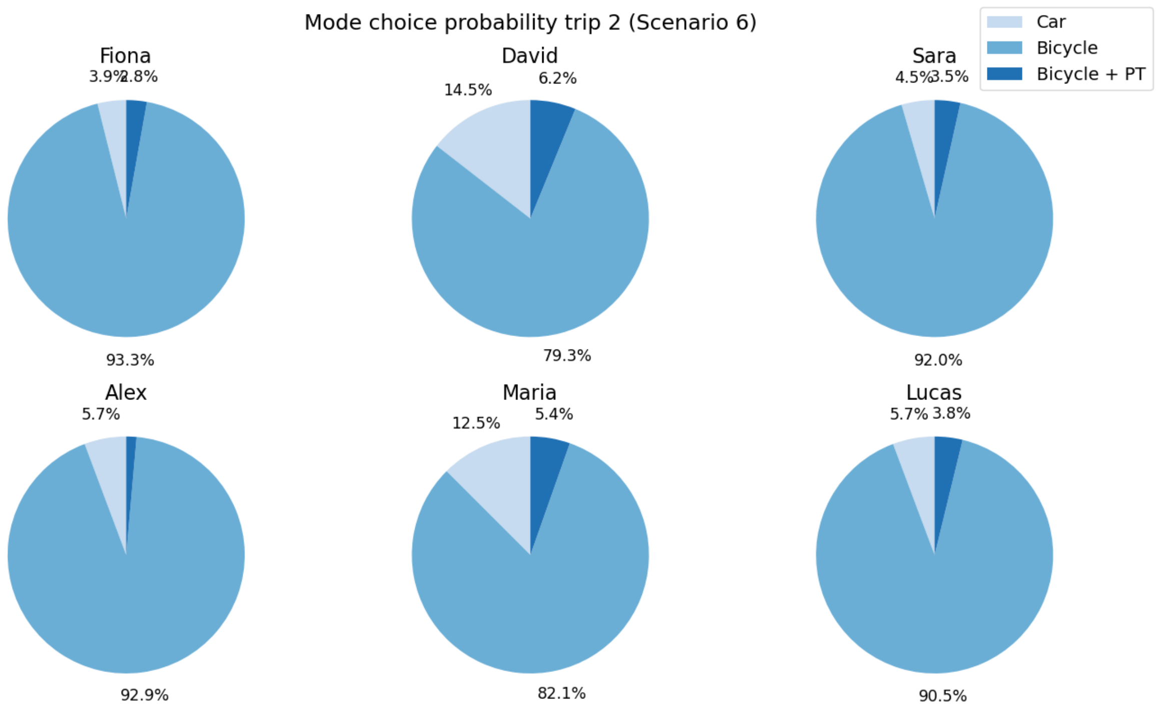

Figure 7.10: Mode choice probability for personae for trip 1 with three available modes in scenario 6

Scenario 7
The last scenario goes further on scenario 6 but adds a decrease in PT costs of €0.50 to make the bicycle + PT mode less costly. In this scenario, a slight decrease in probability is witnessed for the bicycle and e-bike modes while still being quite popular. Nevertheless, the bicycle + PT mode shows an increase across all personas in comparison to the previous scenario. This suggests that the PT cost reduction encourages users to switch from other modes. In comparison to scenario 6 where already an increase in car costs was introduced, the impact of this specific scenario is relatively small but still leads to minor reductions in car usage probabilities. The largest change is witnessed for David, the probability of choosing the car is 0.5 percentage points less for trip 1 while Sara is not willing to shift from the car when PT costs decrease for trip 2 when compared to scenario 6.

7.1.3. Persona-Based trip scenario conclusions

After analysing several scenarios, a couple of general conclusions can be made regarding the mode choice probability in these scenarios and across the personas. First of all, quite some differences can be spotted whether three modes or five modes are considered. In the case of five modes, the e-bike and moped are added, resulting mostly in the moped being used very little while the e-bike is quite popular. However, the ratio between the already considered modes does not change when the extra modes are added. Since the moped is throughout all scenarios low in choice probability, it was barely mentioned as a highlight. Next to this, the e-bike has also not been mentioned many times, however this is due to its consistent popularity. Therefore the focus is more on the three other considered modes.

Furthermore, the difference between the two example trips in Table 7.2 and Table 7.3 can be formulated. Trip 1 has travel times that are close together while trip 2 is more spread out while the travel costs of the two imaginary trips are identical. It can be seen that variations in travel time per mode influence preferences and therefore the mode choice probability across the personas. In trip 2, the travel time for the car is less beneficial and therefore it can be said that when this is the case the willingness to use this mode becomes lower.

To the research objective, adding bicycle parking brackets, adding bicycle safes, an increase in travel costs of the car and a decrease of PT costs are all in general viable measures to take on reduce short-distance car trips while trying to shift the trips to the bicycle + PT mode. Shedded bicycle parking is more questionable due to mixed performance. Depending on the persona, shedded bicycle parking either increases the utility of the bicycle + PT mode or decreases it which does not have a clear positive effect.

Zooming into the specific modes of the bicycle + PT and the car, the biggest increase in bicycle + PT choice probability in comparison to the base scenario can be witnessed for David in scenario 3 with 10.4 percentage points. Also, the biggest decrease in car usage probability can be found for individuals like David but this time in scenario 7 with 17.3 percentage points. However, these are only the extreme cases. Solely based on bicycle parking facilities and considering the three modes of bicycle, bicycle + PT and the car, an increased probability of up to 2 percentage points is normally achieved for the bicycle + PT mode and a decrease of up to 3 percentage points is observed for car trips for the shorter short-distances. Whereas, taking modifying travel costs into account the desired effects differ in magnitude. Regarding the bicycle + PT mode, an increase of around 0.5 to 5 percentage points is seen while for the car a decrease from 1.5 to 6.5 percentage points is reached. This excludes some of the outliers that are witnessed for some personas to give an overview. Trip 2, the longer short-distance trip reaches lower shifts than trip 1. Nevertheless, a mode choice probability change still occurs. with only implementing bicycle parking facilities an increase of around 4 percentage points is the maximum for the bicycle + PT mode and a decrease of around 1 percentage point in car usage probability. Taking the tested price changes into account around 2 percentage points probability shifts to the bicycle + PT mode and 4.5 percentage points shift away from the car.

To conclude, based on the model that is developed in Chapter 6, several scenarios and measures can be taken to cause a change in mode choice probability and therefore stimulate a modal shift. Adding bicycle parking brackets, adding bicycle safes, an increase in travel costs of the car and a decrease in PT costs resulted in desired effects and adding shedded parking caused mixed effects among the population. Moreover, for a few scenarios, certain personas have large shifts away from using the car for short-distance trips. However, these outliers are only applicable when all sociodemographics of a traveller match the persona. Nevertheless, a decrease of up to 6.5 percentage points in the probability of car usage and an increase of 5 percentage points in the probability of bicycle-PT usage can be achieved with the tested scenarios

7.2. Effect on The Hague

The analysis carried out in Section 7.1 is based on very controlled scenarios. Furthermore, the context that is used in the survey setup as mentioned in Section 5.1.4 causes an extra controlled environment for the results to be displayed in while in reality, it is more complex. However, these results can regardless be translated into what it could mean for The Hague as a city. The illustrated break down of car trips in The Hague is depicted in Figure 7.11. Next to that, the translation into cancelled car trips by solely implementing bicycle parking facilities at PT stops are given in Figures 7.12 and 7.13.

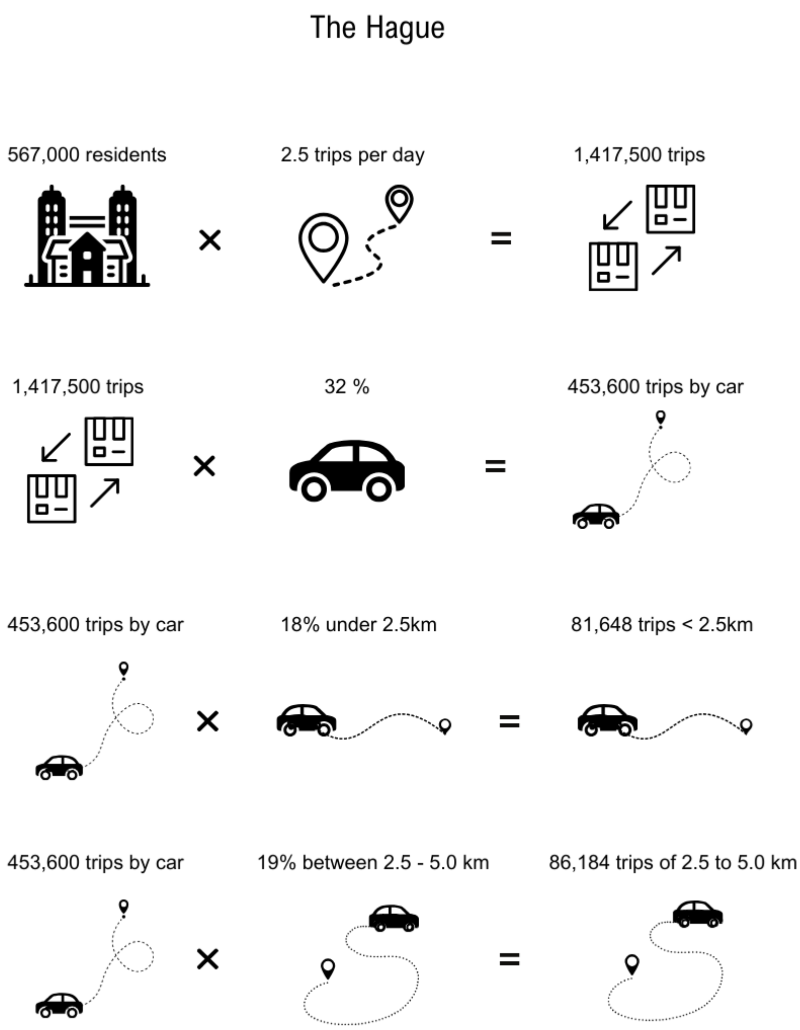

Figure 7.11: Short-distance car trips in The Hague break down per day

In the context of the city of The Hague with 567,000 residents (Gemeente Den Haag, 2024) that undergo 2.5 trips a day (Centraal bureau voor de Statistiek, 2024). With 32% of these trips by The Hague's residents are done by car whereas 18% of car trips are shorter than 2.5 kilometres as mentioned in Section 4.3. This distance is slightly shorter than the distance that is tested in trip 1. However, it functions in giving a rough estimate of the number of trips shifted according to the mode choice probabilities but can be seen as an overestimation. Given this information and that by solely implementing bicycle parking facilities a maximum decrease of 3% in car usage of the 18% can be established. This results in a rough estimate of 2450 trips per day that can be shifted away from car usage by implementing bicycle parking facilities. This simultaneously means that bicycle-PT usage increases by around 1630 trips a day out of those diminished car trips.

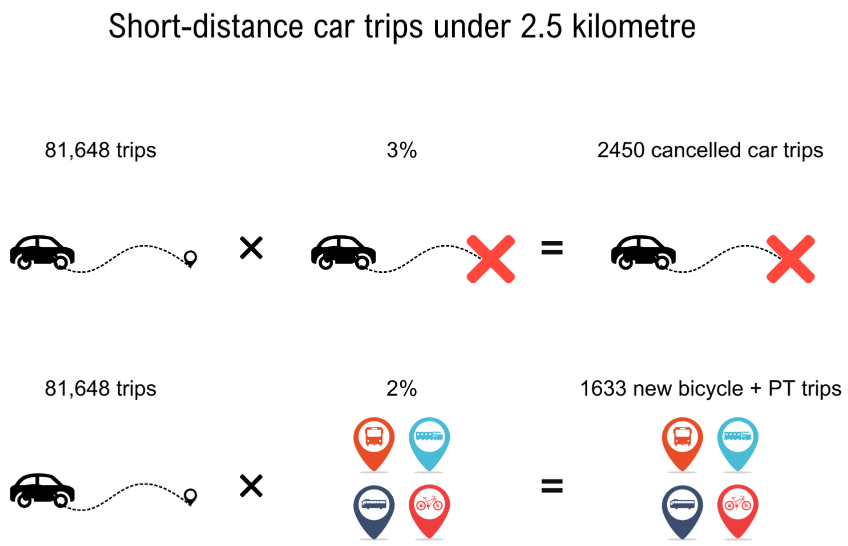

Figure 7.12: Shifts in short-distance car trips under 2.5 kilometre by implementing bicycle parking

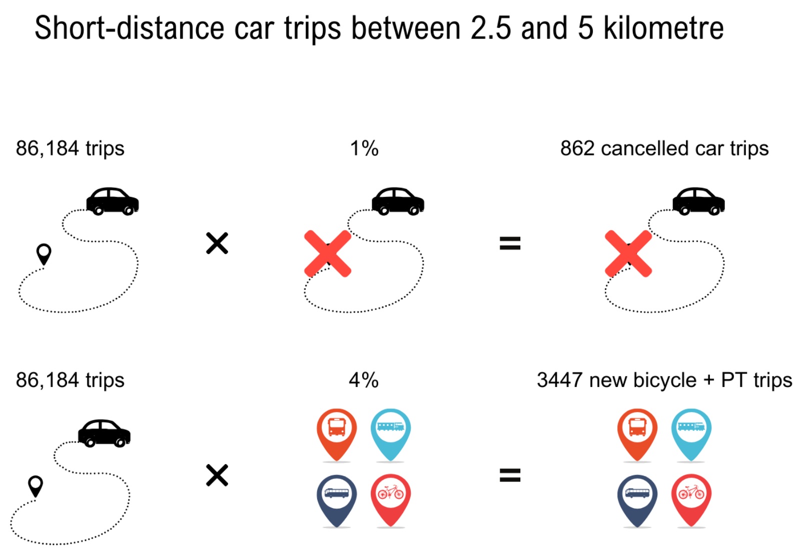

Figure 7.13: Shifts in short-distance car trips between 2.5 and 5 kilometre by implementing bicycle parking

Relating the previously mentioned information to the longer short-distance car trips up to 5 kilometres, the current car usage for distances between 2.5 and 5 kilometres is 19% of all car trips made in The Hague as mentioned in 4.3. Therefore the results from trip 2 in the analysis resemble best to the longer short-distance car trips. Hereby, another estimated 860 car trips are shifted which leads to 3450 additional bicycle-PT trips.

Translating these numbers when taking price changes into account that are tested in scenario 7 in Section 7.1, this results in different estimates. For shorter short-distance car trips, the implementation of scenario 7 means an estimated maximum of 5300 trips are diminished from the car while 4100 corresponding trips are encouraged to take the bicycle + PT mode. For longer short-distance car trips, an additional maximum of 3900 car trips are shifted away with 1700 of those trips changing modes to bicycle + PT.


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8 Conclusion

This research dived into the exploration of different types of bicycle parking facilities and one bicycle service, namely the tyre tump. Research is done if these additions to an inner city public transport stop contribute to more willingness to travel by a combination of bicycle and PT and/or short-distance car trips can be reduced. A conclusion is given by circling back to the research questions in Subsection 1.3.2.

What is the perceived level of accessibility by bike in travellers' perception at public transport stops within The Hague?

Many interviewees expressed a willingness to consider cycling as a mode of transport to reach public transport stops, particularly for shorter trips. However, significant barriers diminish the perceived accessibility. Inadequate and insecure bicycle parking facilities near public transport stops were frequently cited as a major disincentive. Participants reported that parking facilities are often insufficient in number, poorly maintained and perceived as unsafe. These factors contribute to a reluctance to cycle to public transport stops.

Furthermore, the quality and efficiency of public transport connections play a crucial role in shaping perceptions of accessibility. Inefficient or unreliable connections make the combines use of bicycles and public transport less attractive, particularly when compared to the convenience of car use. Weather conditions also emerged as a factor that negatively impacts the perceived accessibility by bike, as adverse weather makes cycling a less appealing option.

In conclusion, while there is some openness to the idea of integrating cycling with public transport, the perceived accessibility by bike is hindered by practical challenges. To explore the willingness further, the insights made in the qualitative resident interviews are taken into the quantitative research of this study.

To what extent are demographic or behavioural profiles within The Hague's inhabitants that can be identified among those who opt for bicycle-PT integration and those who do not?

Age and gender are determinants in the use of bicycle-PT integration. Studies have shown that men are generally more likely to use this combination than women, who are more sensitive to factors such as travel time (Sherwin et al., 2011; Böcker et al., 2020). The model's findings support this, with women showing a pronounced sensitivity to travel time in the context of bicycle-PT integration. Women perceive travel time for this integration as close to twice as negative as travel time for a baseline traveller. This is in contrast for individuals aged 75 and over, the impact of travel time on the choice to use a bicycle and PT is negligible (close to zero). It suggests that this age group is less deterred by increased travel times when opting for this mode. Younger individuals aged 18 to 24 experience travel costs for the bicycle and PT mode to be relatively more negative than general travel costs, making the individuals more deterred from using this specific mode.

Higher levels of education typically correlate with a preference for sustainable transportation options, driven by increased environmental awareness and health consciousness (Jonkeren et al., 2021; Shelat et al., 2018). However, this study found that individuals with higher education levels are less likely to prefer e-bikes, suggesting the influence of other factors. The factor analysis identified two profiles, where the ”Green and Healthy” travellers prioritize environmental and health benefits and ”Safe and Secure travellers” who are more concerned with safety and security and have more reliance on cars.

Income level can significantly influence transport mode decisions. Higher-income individuals are more likely to own cars, which reduces their reliance on bicycle-PT combination (Chan and Farber, 2020. The factor analysis has found similar findings, however not related to income level. The profile identified for such behaviour is the ”Safe and Secure travellers”. The concerns that this profile shows impact the likelihood of choosing a bicycle-PT combination, especially if safety perception is compromised during a trip. This is consistent with the literature which emphasizes the importance of safety and convenience in shaping mode choices (Geurs et al., 2016).

How do these profiles influence urban mobility choices as well as their choice to integrate bicycles with city scale PT?

The study reveals that sociodemographic profiles have different influences on urban mobility choices, particularly concerning the integration of bicycles with public transportation. Younger individuals, from late teens to mid-20s, are not necessarily more inclined to integrate bicycles with inner city PT. In fact, this group is particularly sensitive to the travel costs that come along with this mode, which diminishes the likelihood of choosing this mode. This pattern is similar for women regarding travel time for this mode.

Individuals with lower and higher education levels do not show a strong preference for bicycle-PT integration. However, those with middle education levels display a notable preference for car use, which reduces their likelihood of opting for bicycle-PT. For higher-educated individuals, mopeds and e-bikes are viewed negatively and the perceived travel time on mopeds is more unfavourably compared to the baseline traveller which further discourages these individuals from choosing this option. Middle-income individuals show some tendency towards bicycle use, but this does not strongly extend to bicycle-PT integration. Furthermore, high-income individuals have a strong negative association with travel costs, meaning that the preference goes to a mode that is more cost-effective, which may not always align with bicycle-PT use.

What criteria or facilities motivate individuals to choose bicycle-PT integration over short-distance car trips within The Hague?

The decision to integrate bicycles with public transport rather than opt for short-distance car trips can be discussed on the basis of the qualitative approach and the quantitative approach. Influences by a combination of parking facilities, costs and perceived convenience are elaborated on to reveal several key factors that could influence mode choice.

One of the extensively researched factors is the availability of bicycle parking facilities at PT stops. Adding bicycle parking facilities can substantially increase the likelihood of the use of the bicycle and PT combination. Facilities that cause a clear positive impact are the bicycle parking bracket and the bicycle safe. This was particularly the case when bicycle safes were included. This suggests that secure parking options address key concerns around bicycle theft which is supported by the qualitative interviews. On the contrary, shedded parking facilities have more mixed effects, with groups as ages 45 to 54 or middle-educated individuals perceiving these facilities as useful and as an addition. However, a baseline traveller and high-income individuals perceive the presence of shedded parking to be negative.

Additionally, the added value of the presence of a bicycle tyre pump is discovered in the final model. The availability of a tyre pump is perceived to be of negative value. Therefore, it can be said that adding a bicycle tyre pump is not going to contribute in any positive way in every possible scenario.

Cost consideration also plays a valuable role in mode choice. Increasing car travel costs by €2 (as seen in various scenarios) led to a shift towards the bicycle and PT combination. Similarly, reducing PT costs further promotes this shift. These findings indicate that financial incentives can effectively encourage individuals to opt out of short-distance car trips and to travel by bicycle-PT. With cost alterations in mind, choosing different modes of transport is stimulated.

Convenience, particularly related to travel time, is another criterion. The qualitative interviews revealed that car are perceived as more convenient due to quick access and comfort which makes short-distance car trips more preferable, especially when carrying goods or during adverse weather conditions. However, when the travel time for car trips becomes less beneficial the willingness to shift to bicycles, bicycle-PT and e-bikes increases as long as the travel times for these alternatives remains competitive.

Several participants from the qualitative interviews expressed an openness to bicycle and PT integration for its environmental and health benefits, making these participants suitable for the ”Green and Healthy traveller”. However, these individuals highlighted serious barriers, such as inefficient public transport connections and inadequate bicycle facilities. Addressing these barriers, could motivate a greater shift away from car use, the latter is seen in the quantitative findings that improved bicycle parking facilities such as added brackets and safes can positively influence bicycle-PT choice. This stresses the importance of aligning facility improvements to encourage modal shifts.

How can the integration of bicycle parking be implemented at public transport stops to encourage bicycle-PT and discourage short-distance car trips?

The availability and quality of bicycle parking facilities at PT stops are a major factor in encouraging the use of bicycle and PT combination. Secure and convenient parking options, such as a bicycle parking bracket and bicycle safes, dive into important concerns about theft and accessibility, making this specific mode more favourable.

The integration of bicycle parking can be further supported by using cost incentives with the objective of reducing short-distance car trips. Adjustments in the costs can be related to reducing PT fares or slightly increasing the costs associated with short car trips. This outlines some boundaries where the bicycle-PT options become financially a more attractive option and alternative. These cost measures have proven to be effective in encouraging individuals to reconsider mode choices, resulting in expected modal shifts.

For the combination of bicycle and PT to be successful, the user experience must be seamless and convenient. This includes ensuring that bicycle parking facilities are user-friendly, secure and well-maintained.

In summary, the integration of bicycle parking at city scale public transport can be effectively implemented by focusing on which facility to place and the quality of it, cost measures and enhancing the overall convenience and user experience. These elements collectively contribute to making the combination of bicycle and public transport a more attractive mode of transport, making it a viable alternative to short-distance car trips.

How these insights can be implemented into practical solutions is going to be discussed in Chapter 9 alongside the research limitations and further research recommendations.

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9 Discussion and recommendations

This chapter elaborates on the research itself and the limitations of the research and therefore on the findings. Furthermore, recommendations are given in Section 9.3 to supply policy makers with advice on how to tackle short-distance car usage while stimulating bicycle-PT combinations in practice. Moreover, recommendations for further research that adds to this study are given in Section 9.5.

9.1. Reflection on research

During the process of this research on the potential of bicycle parking at urban public transport stops, the results from the quantitative method yielded a few counterintuitive results that seem odd with expected behaviour patterns. Rather than undermining the validity of the entire research a couple of explanations are given.

To start with parameters being insignificant which is particularly the case with the coefficient for shedded parking. This parameter turns out to be of insignificance but is not disregarded due to the importance of the research objective. This insignificance indicates that the effect of shedded bicycle parking on the utility function cannot be confidently distinguished from zero, based on the obtained data. It suggests that there is no strong statistical evidence that shedded parking has either a positive or negative influence on individuals' utility in choosing the bicycle and PT combination.

Despite trying to account for heterogeneity as much as possible, often correlations between the observed parameters or unobserved preferences are still present. There may be unobserved attributes that can affect respondents' choices. Additionally, correlations between the observed factors and unobserved factors can play a role in the partial counterintuitive outcome. This can for example be the case with the result of that the bicycle pump has a negative contribution in opting for the bicycle-PT mode.

Regardless of a few counterintuitive results, that can be explained, the research remains valid and meaningful for several reasons. To start with the findings contribute to the knowledge and reveal new insights into travel behaviour, especially towards interactions between cycling and PT use for shorter distances. Furthermore, this study can function as a basis for future work which is going to be discussed in detail in Section 9.5. Lastly, the overall trend identified remains relevant for policy discussions. The research supports the notion that improving bicycle parking at public transport stops can reduce short-distance car trips, aligning with urban mobility goals.

9.2. Research limitations

While this research provides an understanding of the factors of influence regarding the bicycle and PT combination and the effectiveness of various bicycle parking facilities, several limitations need to be acknowledged.

First of all, the study primarily relies on a select number of qualitative interviews and stated preference data. The latter is quite useful for the intended research but it may not capture all decisive factors when it comes down to mode choice. Additionally, it relies on hypothetical scenarios and behaviour that can be of influence in the answers given. This can be different from the actual choice when presented in a real life situation.

Additionally, the study's sociodemographic scope may not fully account for the diversity within the population. The detailed composition of sociodemographics of the survey respondents is given in Section 6.3. There it can be seen that the representation based on education level was not representative. Therefore it could mean that the findings do not comprehensively represent all user groups.

Furthermore, the study focuses on specific types of bicycle parking facilities, for example bicycle brackets and safes. However, the evaluation of these facilities did not incorporate other potentially relevant options. This may be for example a double-layered bicycle parking rack or a bicycle parking carousel. Moreover, this research relies on residents to use a private bicycle, while nowadays shared mobility in the form of bike-sharing systems or mobility hubs is emerging. The exclusion of other alternatives limits the scope of the recommendations.

Regarding the method used for the discrete choice modelling, the use of a multinomial logit model presents specific limitations. While the MNL model is simplistic and quite efficient, it assumes that the choices made are homogeneous across all individuals, which may not be the case. This assumption might not hold true for choices, leading to biased estimates if unobserved factors correlate with choices. Additionally, as mentioned in Section 3.3, a MNL model relies on the IIA property which means that the probability ratio of a choice remains the same and is not accounting for correlations. Besides this, a MNL model does not incorporate the panel effect and therefore each observation is seen as a different person which is not always the case. These limitations could mean that the model might have oversimplified the outcome.

Another limitation is the set context used in the survey, where respondents were asked to make decisions based on the specific scenario of it being a spring day with 17°C, no rain, and travelling alone to a restaurant with a small backpack. This is a controlled context to help standardize responses and reduce variability. However, it does not fully represent the diverse range of conditions under which individuals make mode choices. Factors such as adverse weather, varying trip purposes or different luggage requirements can significantly alter preferences and therefore eventually a choice which this study may not have uncovered.

Lastly, the incorporated attribute of parking time is not further explored in this study due to positive perceptions when parking time increases. This is probably because the options for parking time were close to each other and low in time which can be seen as neglectable by respondents.

9.3. Recommendations for policy makers

The findings from this research provide considerations for policy makers on how to effectively integrate bicycle parking at local public transport stops with an incentive to reduce short-distance car trips. A key focus should be on implementing the most effective bicycle parking facilities, which are the bicycle bracket and the bicycle safe. The bicycle bracket is suitable for implementation in quantity due to its low cost and space efficiency. On the other side, a bicycle safe is valued twice as much as a bicycle bracket. Therefore it comes with extra costs and occupying more space per parking place but it contributes more to opting for a bicycle-PT trip. Additionally, these facilities are not bound to any specific sociodemographic group to be of less value or added value. Therefore, these facilities perform uniformly across the population which can without specifically targeting any sociodemographic group be implemented for positive outcomes. With respect to the cost-effectiveness ratio, the bicycle bracket is recommended over a bicycle safe.

In contrast to the previously mentioned facilities, shedded parking gives mixed effects and a tyre pump results in a negative outcome toward the bicycle-PT mode. Despite offering weather protection, shedded parking requires more space and is more costly to install in comparison to a bicycle parking bracket, with a limited positive impact on user preferences it is therefore not recommended to consider implementing shedded bicycle parking. This advice is similar to considering a tyre pump, while the space is not the biggest constraint, there is no added value to be seen by including it next to a public transport stop.

Costs incentives can be quite interesting for policy makers, while it does not go into placing any facility it can have effects in shifting away from car usage. It is recommended to work closely with the local transport operator to develop plans that reduce PT costs for users, making the bicycle-PT integration more financially attractive. Collaborating on initiatives such as discounted PT fares for cyclists, or bundled pricing that encourages a shift away from car pricing. Furthermore, increasing car-related costs, for example parking fees, can complement by making car travel less preferable for short-distance trips.

Furthermore, making an effort to create a positive user experience at PT stops is essential. Creating an environment where users feel convenience, secure and easy-to-use facilities should encourage people to go by bicycle-PT instead of by car. This can be achieved by tactical campaigns promoting the new instalments of additional facilities and parking places at PT stops. On the other end, tackling car usage and stimulating bicycle usage on its own or in combination with PT is another approach. For instance, by promoting it as more environment-friendly and getting partial daily exercise, biking can be stimulated. Since some interviewees have said not to be comfortable on the bicycle, campaigns to help these individuals get over this fear and feel confident on the bicycle could stimulate this group to use the bicycle over the car.

To maximize the effectiveness of increasing bicycle-PT trips, policy makers should adjust strategies to address the specific preferences and needs of different demographic groups identified in the research. Younger adults, from 18 to 24 years, experience travel costs as a high barrier to using the combination mode of bicycle and PT in comparison to other modes. Therefore, offering solutions to tackle this with the reduced PT fares, could help mitigate this barrier. Moreover, middle-aged individuals, from 35 to 44 years, showed no strong preference for bicycle-PT integration. However, this group did show a high preference for the bicycle on its own and a dislike towards mopeds. Therefore, encouraging these individuals that the bicycle is a good option could lead to a tipping point of more bike rides instead of car trips. However, supplying bicycle parking facilities can also result in this group considering this option.

Another sociodemographic group that can be specifically targeted to reduce short-distance car trips are the middle-educated individuals. This group have demonstrated to have a higher preference for car usage than other sociodemographic groups and is more of a challenge regarding the objective. However, the measure of increasing car travel costs should be effective for this group. Especially, if these individuals frequently travel by car, a thought will be given to carrying some of the trips out by other forms of transportation. Furthermore, higher-income individuals tend to have a stronger association with negative perceptions of increased travel costs and may favour modes that are perceived as more cost-effective or time-efficient and therefore also a group that can be encouraged to depend less on car usage by alternating car and PT travel costs.

All in all, the mentioned measures contribute to the objective of reducing short-distance car trips by trying to shift it mainly to the bicycle-PT combination. To have good coverage, a combination of the recommendations accommodates most of the population.

9.4. Context for The Hague and similar cities

The results of this research are particularly relevant to The Hague, as the study was conducted as a case study specifically focused on this city. In the qualitative part of the research, residents of The Hague were interviewed to gain insights for this study. Additionally, the quantitative analysis was based on the travel choices of The Hague inhabitants.

In The Hague, the success of bicycle-PT integration hinges on several key factors, including the availability and quality of bicycle parking facilities near public transport stops. Additionally, the sociodemographic characteristics of the population and the specific needs of different user profiles play a role. The results show distinct traveller profiles who are more likely to combine cycling with public transport and the effects of different bicycle parking facilities. By using these profiles and their preferences, The Hague can better target its efforts to encourage a modal shift.

The impact of bicycle parking at public transport stops directly addresses workflows within the municipality. This is because decisions about where and how to install bicycle parking and how to integrate cycling with public transport are typically made by municipal bodies. The municipality of The Hague, for example, has a clear responsibility for local infrastructure and mobility planning, making it the most relevant stakeholder for implementing the findings of this study making The Hague the key actor for implementing the study's findings. At the regional level, coordination sees to it that bicycle parking and PT routes connect logically across municipal boundaries, supporting a robust network. While at the national level, policies and funding frameworks provide support for local efforts, helping The Hague align its initiatives with broader national sustainability and mobility goals.

Furthermore, this research can be of high relevance to the municipality of The Hague, which is already actively promoting cycling and reducing car usage as part of its broader urban mobility strategy. The municipality has been investing in infrastructure improvements and engaging residents in sustainable transportation options to encourage less reliance on cars, which aligns with the findings and objective of this study. The research provides insights into how bicycle parking at public transport stops can further support these goals by making cycling more convenient and attractive for short trips, reducing the need for car use in the city. The recommendations for policy makers discussed in Section 9.3 can help the municipality refine its strategies for promoting cycling as part of its sustainable mobility agenda, supporting local objectives like reducing car trips and improving public transport use within the city.

For cities similar to The Hague, particularly those with dense urban areas, well-established public transport networks and a population composition comparable to The Hague's, the findings offer valuable insights too. These cities can lift of on the experiences of The Hague to implement strategies based on this study's results that promote bicycle-PT integration.

The key takeaway is the importance of understanding local sociodemographics and user behaviour, which can vary significantly from city to city but often show similarities in cities with comparable population compositions. Additionally, the role of urban design in facilitating or hindering bicycle access to public transport is important. Cities must make sure that bicycle parking is not only available but also secure and conveniently located to encourage its use.

9.5. Recommendations for further research

While this research has provided insights into the factors influencing bicycle-PT integration and the effectiveness of various bicycle parking facilities, further research is needed to explore several topics more in depth. First of all, the exploration of other types of discrete choice models besides a multinomial logit model. This is due to the imperfections as mentioned in Section 9.2. An example of tackling the IIA property is a nested logit model. Furthermore, the panel effect can explored by a mixed logit model.

A possible direction for future research is to conduct this study under varying contexts. This research worked with a set context, therefore exploring various weather conditions is of relevance. Additionally, varying the trip purpose or companionship composition can change the willingness to cycle toward a PT stop even if there are sufficient bicycle parking facilities present.

Future studies are recommended to investigate the long-term impact of implementing specific bicycle parking facilities on user behaviour and mode choice across different sociodemographic groups. Additionally, more extensive research is required to understand specific barriers and preferences regarding mode choice. Only a handful of factors were tested in this research while there are many other criteria that are of influence determining on how to go from origin to destination. Moreover, potential alternatives that were not in the research scope can be examined for example the emergence of shared mobility. Does this alternative play a role in the effectiveness of the parking facilities or can it also stimulate reducing car usage, the outcome is of relevance to put this study in context.

Strategic placement of these facilities is another interesting topic for further research. Understanding where different types of bicycle parking facilities should be located. This can for example be at transfer points, high-traffic locations or neighbourhood stops. The placement can have influence in the effectiveness of bicycle-PT integration. Research into the optimal placements of these facilities across a city's PT network can help maximize usage and impact.

In the context of the mobility transition, further research has to focus on how the bicycle-PT integration contributes to the shift towards more sustainable and multi-modal trips. This includes exploring the role of public policies in facilitating this transition. The coordination to integrate this mode is to be researched while keeping the long-term impacts in mind.

Another direction for future research involves, analysing revealed preference data to observe actual user behaviour in response to implemented changes. This research uses a stated preference survey as a quantitative method. A revealed preference approach can provide insights into how users make real choices, as opposed to stated preferences or hypothetical scenarios. These tests can be useful in understanding how different sociodemographic groups respond to specific interventions in familiar and unfamiliar settings.

Given the unique biking culture in the Netherlands, it is also important to extend this research to other cities or regions, both within and outside of the Netherlands. Especially, where biking may not be used extensively. Comparable studies could explore how different settings and policy contexts affect bicycle-PT integration. This includes researching urban areas with less established cycling cultures or more car-dependent populations to identify other viable strategies.

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A

Residents interview in Dutch (Original)

Persoon	Waar naar toe?	Wat doen?	Andere vervoersmiddel overwogen?
1	Naar het werk	Belangrijke presentatie vandaag	Nee, te onhandig
2	Naar het werk	Werken	Ja, maar auto is comfortabeler (vooral met slecht weer).
3	Ziekenhuis	Afspraak	Nee, onhandig met passagier die slecht ter been is.
4	Winkelcentrum	Winkelen	Nee, door spullen.
5	Supermarkt (winkelcentrum)	Boodschappen doen	Nee, door de zware boodschappen
6	Supermarkt (winkelcentrum)	Boodschappen doen	Ja, maar vandaag net iets meer boodschappen dan normaal.
7	Familiebezoek	Visite	Nee, heb wat cadeaus gekocht in het winkelcentrum.
8	Winkelcentrum	Pakketje ophalen	Nee, ik verwacht een groot pakketje.
9	Naar het werk	Werken	Nee, fiets is kapot.
10	Restaurant	Lunchen met vrienden	Nee, hierna gelijk door
11	Kinderopvang	Kinderen ophalen	Nee, met drie kinderen niet te doen.
12	Sportschool	Sporten	Ja
13	Sportschool	Sporten	Nee
14	Supermarkt	Boodschappen doen	Nee, ik ga meerdere winkels af
15	Naar het werk	Werken	Nee, lunch gehaald voor kantoor
16	Oma	Kinderen afzetten	Nee, met kinderen is iets lastiger
17	Winkelcentrum	Winkelen/boodschappen	Nee, onhandig
18	Restaurant	Lunchen met oma	Nee, oma slecht te been.
19	Supermarkt	Boodschappen doen	Nee
20	Winkelcentrum	Winkelen	Ja, maar voor het geval ik veel spullen ga kopen.
21	Sportschool	Sporten	Ja, maar ik moet gelijk door hierna.
22	Boodschappen doen/kinderopvang	Boodschappen en kinderen ophalen	Nee

Figure A.1: Residents interview in Dutch (Part 1)

Persoon	Hoofd/favoriete vervoersmiddel?	Fiets + OV overwogen? (Algemeen)
1	Nee, maar ik loop wel op korte afstanden	Nee, vaak haast
2	Nee, OV is beter voor het milieu.	Ja, maar niet als ik haast heb.
3	Ja, maar overweeg fietsen voor gezondheidsvoordelen en deze situatie is net anders.	Ja
4	Nee, voor deze activiteit wel handiger.	Ja, voor andere bestemmingen.
5	Soms, afhankelijk wat goedkoper lijkt om te gebruiken	Nee, OV is te duur.
6	Nee, voorstander van OV.	Ja
7	Vaak wel.	Nee, ik kan niet zo goed fietsen en niet comfortabel.
8	Soms, ligt aan het gemak.	Nu niet, normaal soms.
9	Fiets	Ja, als niet het regent.
10	Auto	Nooit, maar interessant.
11	Auto	Ja, als de kinderen ouder zijn.
12	Auto	Soms
13	Auto/lopen	Ik heb geen fiets.
14	OV	Ja, maar niet voor dit.
15	Auto	Nee, is teveel om voor mij.
16	Persoonlijk, fiets en met kinderen auto	Niet vaak overwogen
17	Auto	Nee, OV is te ver.
18	OV	Gebruik is soms.
19	Auto	Nee, ik kan niet fietsen.
20	Auto	Nee, vind ik best vermoeiend.
21	OV	Niet vaak overwogen
22	Auto	Ja, bij uitstapjes met de kinderen.

Figure A.2: Residents interview in Dutch (Part 2)

Persoon	Wat is er nodig om fiets + ov te overtuigen?	Wat vind u van de fietsparkeergeleden bij haltes?
1	Efficiëntere OV-verbindingen	Te weinig plekken en het onderhoud kan beter.
2	Betere stallings mogelijkheden.	Oké, maar zou veiliger kunnen met meer toezicht.
3	Betere veiligheid fietsers	Voldoende
4	Mooi weer	Vaak vol
5	Veel, OV is te duur en de auto heb ik al.	Niet echt opgelet.
6	Niet veel, voorkeur als het weer meezit.	Goed, maar behoefte aan overdekte plekken.
7	Fietscursus	Onoverzichtelijk
8	Betere stalling en OV-verbindingen.	Oke, maar dus betere stallingen.
9	Zodra het sneller is dan de auto of de fiets.	Achterstallig/onderhoud nodig.
10	Snellere verbinding, minder drukte	Geen mening.
11	Goedkoper OV	Te weinig plekken bij mijn opstaphalte
12	Mooi weer	Onoverzichtelijk
13	Eerst een fiets.	Geen mening.
14	Snellere verbinding en weinig spullen mee	Oogt onveilig.
15	Snellere verbinding en toegankelijkheid.	Weinig onderhoud.
16	Meer parkeerplaatsen als ik met de kinderen wegga.	Vol, te weinig plekken.
17	Een nabijere halte.	Geen mening.
18	Voor meer: Snellere verbinding.	Te weinig zekerheid op plek
19	Leren fietsen en een fiets aanschaffen.	Achterstallig/onderhoud nodig.
20	Eerst een betere conditie dan denk ik er misschien over na.	Onverzorgd --> achterstallig
21	Betere stalling	Oogt onveilig.
22	Voor meer: Betere stallingen	Achterstallig/karig.

Figure A.3: Residents interview in Dutch (Part 3)

B

Residents interview in English (Translated)

Person	Where to?	To do what?	Considered another mode?
1	To work	Important presentation today	No, too unpractical
2	To work	Work	Yes, but the car is more comfortable (especially with bad weather).
3	Hospital	Appointment	No, too unpractical with a passenger that is less mobile (difficulties to walk).
4	Shopping centre	Shopping	No, due to the stuff from shopping.
5	Supermarket (Shopping centre)	Groceries	No, due to heavy groceries.
6	Supermarket (Shopping centre)	Groceries	Yes, but more groceries than normal today.
7	Family visit	Visit family	No, I just bought some presents at the shopping centre.
8	Shopping centre	pick up a package	No, I'm expecting a big package.
9	To work	Work	No, bike is not working.
10	Restaurant	Lunch with friends	No, after this I need to be somewhere else.
11	Daycare	Picking up kids	No, it's not doable with three kids.
12	Gym	Sports	Yes
13	Gym	Sports	No
14	Supermarket	Groceries	No, I'm going to multiple stores.
15	To work	Work	No, I picked up lunch for the office.
16	Grandma	Dropping off kids	No, it's more difficult with the kids.
17	Shopping centre	Shopping/groceries	No, unpractical.
18	Restaurant	Lunch with grandma	No, grandma has difficulties walking.
19	Supermarket	Groceries	No
20	Shopping centre	Shopping	Yes, but in case I'm buying many things.
21	Gym	Sports	Yes, but I have to go directly after this to somewhere else.
22	Supermarket/daycare	Groceries/ picking up kids	No

Figure B.1: Residents interview in English(Part 1)

Person	Main/favourite mode of transport?	Considered bicycle + PT? (General)
1	No, but I do walk shorter distances.	No, often in a hurry.
2	No, PT is better for the environment.	Yes, but not when I'm in a hurry.
3	Yes, but I'm considering biking for the health benefits and this situation was a bit different.	Yes
4	No, for this activity it was more practical to use the car.	Yes, for other destinations.
5	Sometimes, dependent on what seems to be cheaper to use.	No, PT is too expensive.
6	No, in favour of public transport.	Yes
7	Most often.	No, I can't bike that well and it's uncomfortable.
8	Sometimes, dependent on conveniece.	For now not, normally sometimes.
9	Bicycle	Yes, if it's not raining.
10	Car	Never, but sounds interesting.
11	Car	Yes, when the kids get older.
12	Car	Sometimes.
13	Car/Walking	I don't have a bike.
14	Public transport	Yes, but not for this situation.
15	Car	No, it's too big of a detour for me.
16	Personally the bicycle, when with kids the car.	Did not consider that often.
17	Car	No, PT is too far.
18	Public transport	I use it sometimes.
19	Car	No, I can't bike.
20	Car	No, I find it exhausting.
21	Public transport	Did not consider that often.
22	Car	Yes, with trips with the kids.

Figure B.2: Residents interview in English (Part 2)

Person	What is needed to convince for bicycle + PT?	What is your opinion on current bicycle parking facilities at stops?
1	More efficient PT connections.	Too little parking places and maintainance can be better.
2	Better parking opportunities.	OK, but can be more secure with surveillance.
3	More safety for cyclists.	Sufficient
4	Nice weather.	Often full.
5	A lot, PT is too expensive and the car I already own.	Did not really pay attention.
6	Not a lot, preference is when the weather is favourable .	Good, but in need of shedded parking.
7	Cycling class.	Unclear
8	Better parking and PT-connections.	OK, but better parkings needed.
9	As soon as it is faster than the car or the bike.	Overdue/Maintainance needed.
10	Faster connections, less crowdiness.	No opinion.
11	Cheaper PT.	Too little parking places at my access stop.
12	Favourable weather.	Unclear
13	First having a bike.	No opinion.
14	Faster connections, less stuff to carry.	Seems unsecure.
15	Snellere verbinding en toegankelijkheid.	Little maintainance.
16	More parkingplaces when I'm going with my kids.	Full, too little parking places.
17	A closerby stop.	No opinion.
18	For more: Faster connection.	Too little guarantee on a parking place.
19	Learning to bike and owning/buying one.	Overdue/Maintainance needed.
20	Firstly, better stamina then I will maybe think about it.	unprovided --> overdue
21	Better parking.	Seems unsecure.
22	For more: Better parking.	Overdue/scanty.

Figure B.3: Residents interview in English (Part 3)

C

Ngene syntax for survey scenarios

```
Design
;alts = Bike+PT1, Bike+PT2, Bike, E-bike, Moped, Car
;rows = 12
;eff = (mnl,d)


;model:


U(Bike+PT1) = b1[0.00001] * BicycleParkingFacility.dummy[0,1,2,3] + b2[0.00001] * BicyclePump.dummy[0,1] + b3[-0.00001] * ParkingTime[1,2] + b41[-0.00001] * TravelTimeSlow[6, 12, 18] + b5[-0.00001] * TravelCosts[2,4,6] /

U(Bike+PT2) = b1[0.00001] * BicycleParkingFacility + b2[0.00001] * BicyclePump + b3[-0.00001] * ParkingTime + b41[-0.00001] * TravelTimeSlow+ b5[-0.00001] * TravelCosts /

U(Bike) = b3[-0.00001] * ParkingTime + b41[-0.00001] * TravelTimeSlow /

U(E-bike) = b3[-0.00001] * ParkingTime + b41[-0.00001] * TravelTimeSlow /

U(Moped) = b3[-0.00001] * ParkingTime + b42[-0.00001] * TravelTimeFast[4, 8, 12] + b5[-0.00001] * TravelCosts /

U(Car) = b3[-0.00001] * ParkingTime + b42[-0.00001] * TravelTimeFast + b5[-0.00001] * TravelCosts

$
```

D

Survey (Dutch)

Je bent uitgenodigd om mee te doen aan een onderzoek: verminderen van korte afstandsritten met de auto door het maken van fietsparkeergelegenheid bij de haltes van het openbaar vervoer (OV).

Dit onderzoek wordt uitgevoerd door Madeline Lai van de TU Delft, in samenwerking met de gemeente Den Haag.

Wij onderzoeken met welke vervoersmiddelen er in Den Haag korte afstandsritten worden gemaakt. Centrale vraag hierbij is of het parkeren van je fiets bij de halte van invloed is op je keuze om met het openbaar vervoer te reizen.

Voor dit onderzoek vul je een aantal basisgegevens in. We beschrijven een aantal situaties waarin we je vragen om een keuze te maken. Mocht een vraag te persoonlijk zijn dan hoeft deze niet beantwoord te worden.

Je deelname aan dit onderzoek is vrijwillig. Je mag op elk moment stoppen.

Meedoen aan het onderzoek duurt **ongeveer 10 minuten**.

*Hierbij ga ik akkoord met de openingsverklaring en woon ik in Den Haag.

- [ ] Ja, ik ga akkoord.

Figure D.1: Dutch opening statement

Introductie

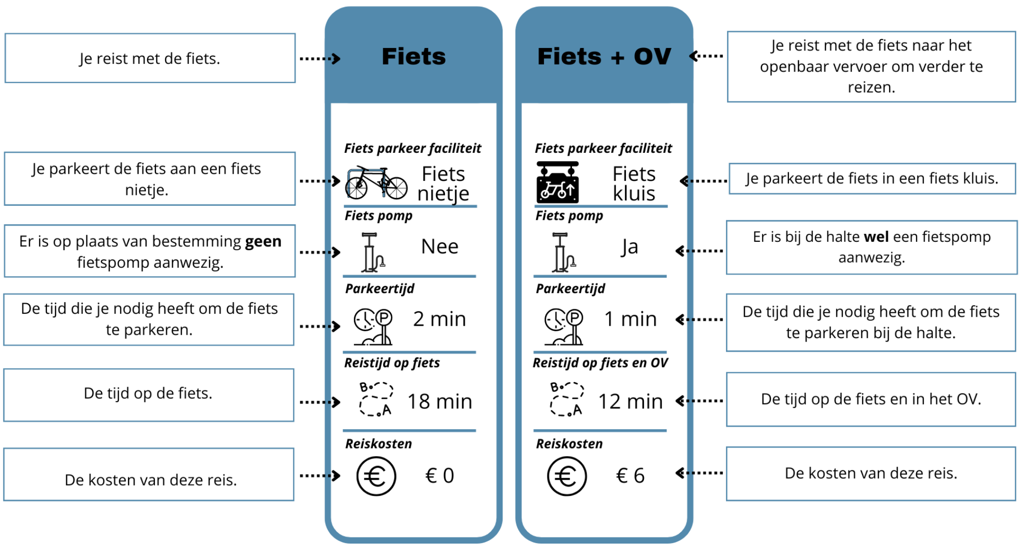
We gaan je een paar vragen stellen. Bij een aantal vragen heb je standaard 3 keuzes om te reizen. Dit zijn de volgende keuzes:

- Fiets
- Fiets + openbaar vervoer combinatie 1
- Fiets + openbaar vervoer combinatie 2

Kies wat je het fijnst vindt. *Wat zal jij doen?* Een aantal vragen gaan uit van jouw antwoord op de eerste vraag die hierna volgt. In deze vraag geef jij je eigen gebruikte vervoersmiddelen aan. Ook bij deze vraag kies je wat het fijnst is voor jou. Dit wordt in totaal 8 keer gedaan en 2 keer herhaald met verschillende getallen om genoeg informatie uit jouw reisvoorkeuren te halen.

Zie hieronder een voorbeeld waarin uitgelegd is wat we bedoelen. In het voorbeeld heb je twee keuzes, namelijk *Fiets* en *Fiets + OV*. Als je reist met de fiets parkeer jij de fiets bij een fiets nietje. Verder is er geen fiets pomp beschikbaar en heb je 2 minuten nodig om jouw fiets te parkeren. Daarnaast ben je 18 minuten aan het fietsen en kost de reis je €0. Zo lees je de keuze fiets af en doet dit vervolgens ook voor de keuze *Fiets + OV*.

Kies je nu voor de *fiets*, of voor een combinatie van *fiets en openbaar vervoer*?



Als voorbeeld een aantal fietsparkeer/service faciliteiten (met bijpassend icoon) die benoemd zullen worden in het vervolg van de enquête.

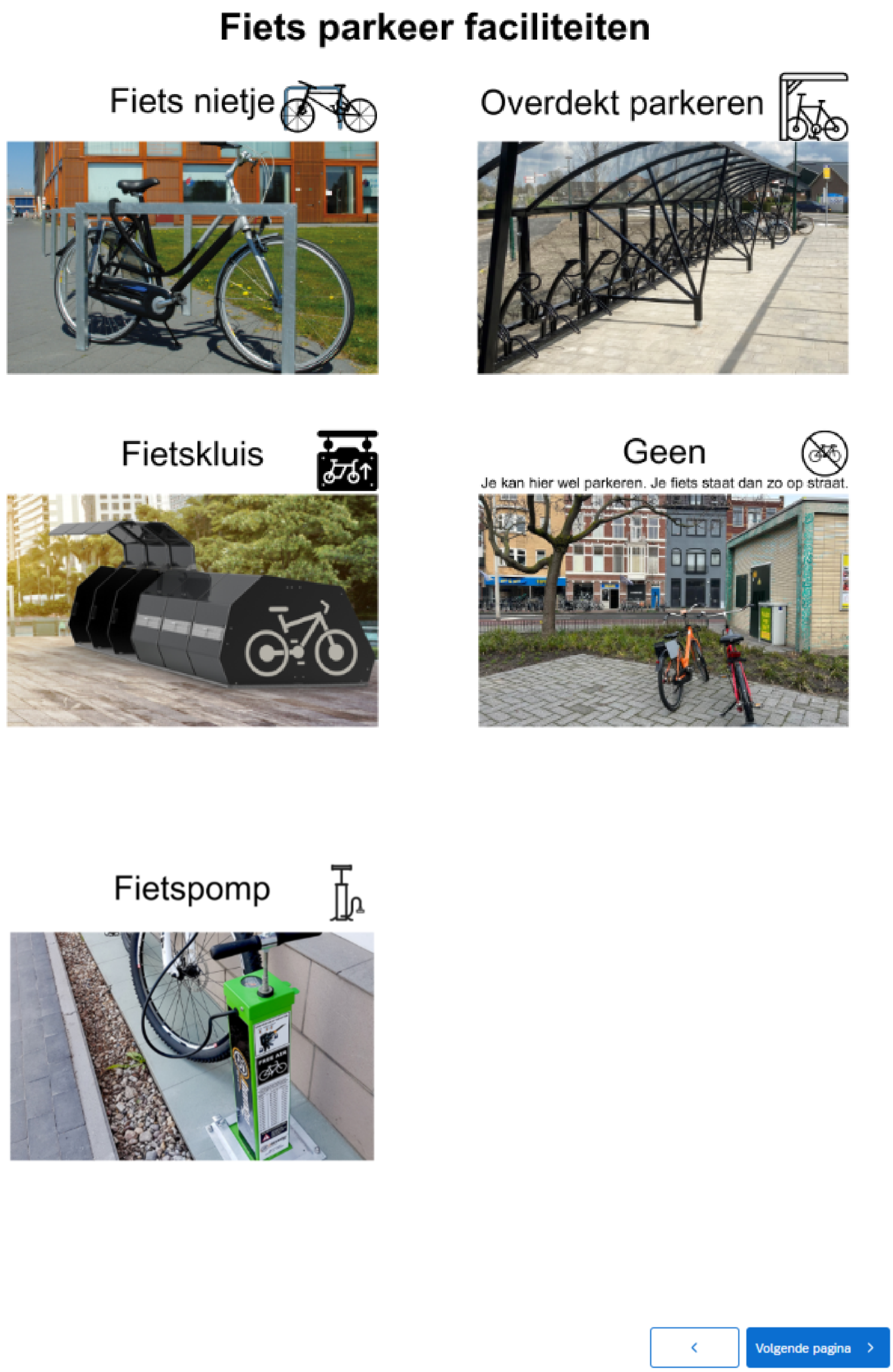
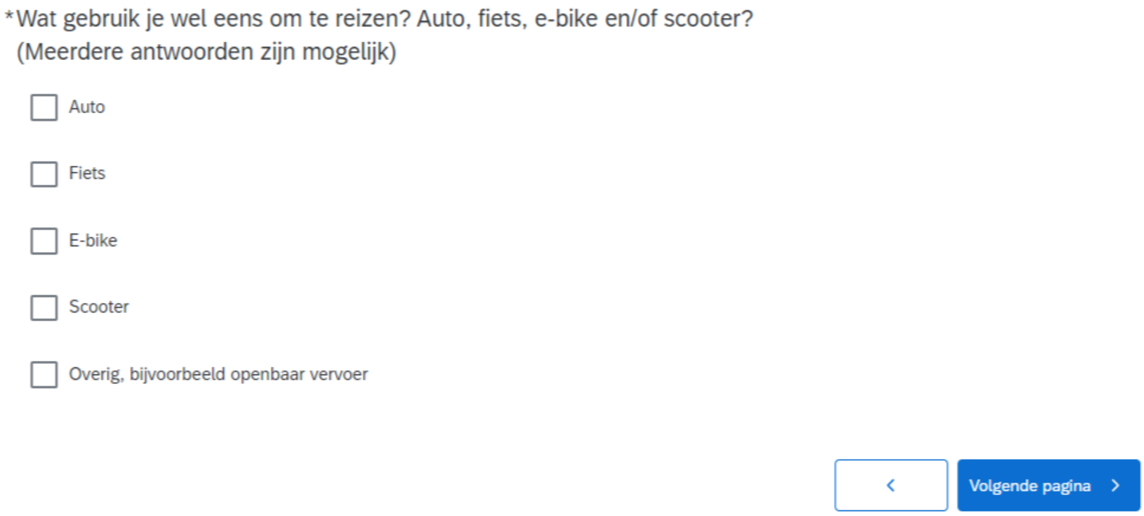


Figure D.2: Dutch introduction to survey

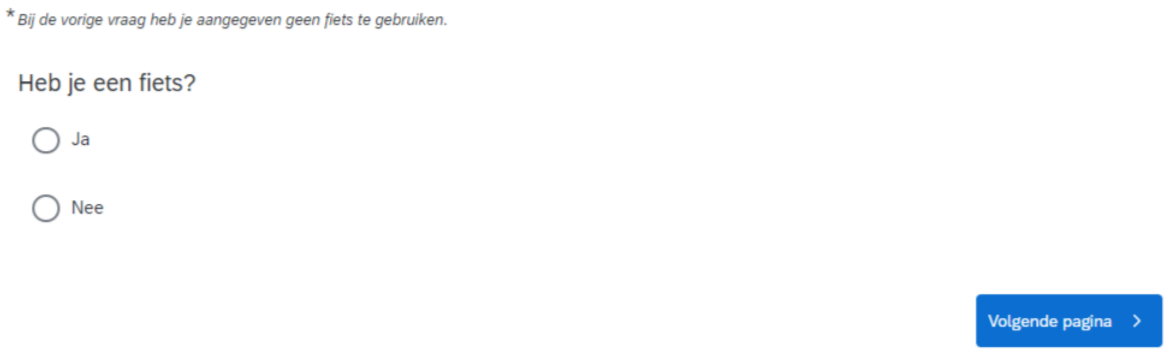


*Wat gebruik je wel eens om te reizen? Auto, fiets, e-bike en/of scooter? (Meerdere antwoorden zijn mogelijk)

- Auto
- Fiets
- E-bike
- Scooter
- Overig, bijvoorbeeld openbaar vervoer

Volgende pagina

Figure D.3: First question on modes that are used sometimes



*Bij de vorige vraag heb je aangegeven geen fiets te gebruiken.

Heb je een fiets?

- Ja
- Nee

Volgende pagina

Figure D.4: First follow-up question when respondent did not select a bicycle

Bij de vorige vraag heb je aangegeven geen fiets te hebben.

Leen je wel eens een fiets? Bijvoorbeeld van vrienden of familie?

- Ja
- Nee

Volgende pagina

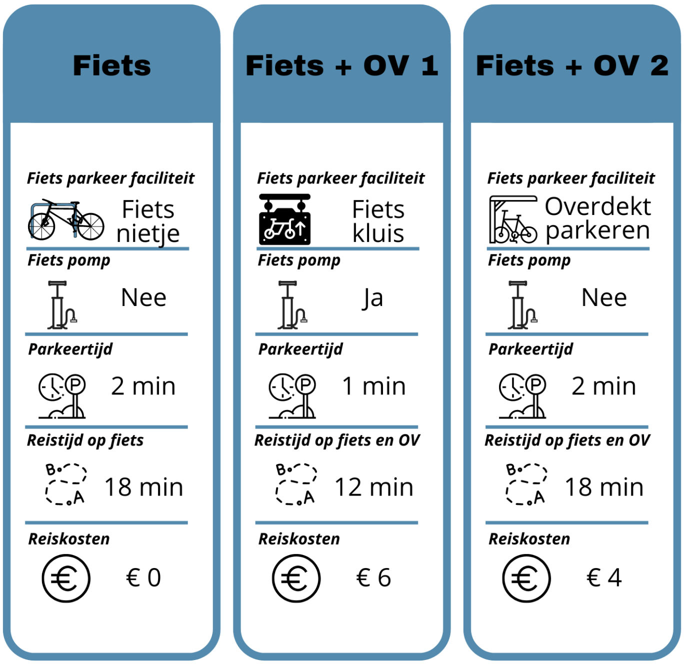
Figure D.5: Second follow-up question when respondent did not select a bicycle

Je hebt aangegeven in ieder geval een fiets, scooter en auto te hebben. Nu komen er **twee voorbeeldvragen** die hierover gaan. Deze antwoorden worden niet opgeslagen.

In dit voorbeeld en in **alle vervolgvragen**. Het is **17 °C** en een lentedag **zonder regen**. Je reist **alleen** naar een **restaurant met een kleine rugtas**.

* *Voorbeeldvraag 1*

Welke optie kies jij?



- ○ Fiets
- ○ Fiets + OV 1
- ○ Fiets + OV 2

Volgende pagina >

Figure D.6: Sample question part 1 in mode set 1

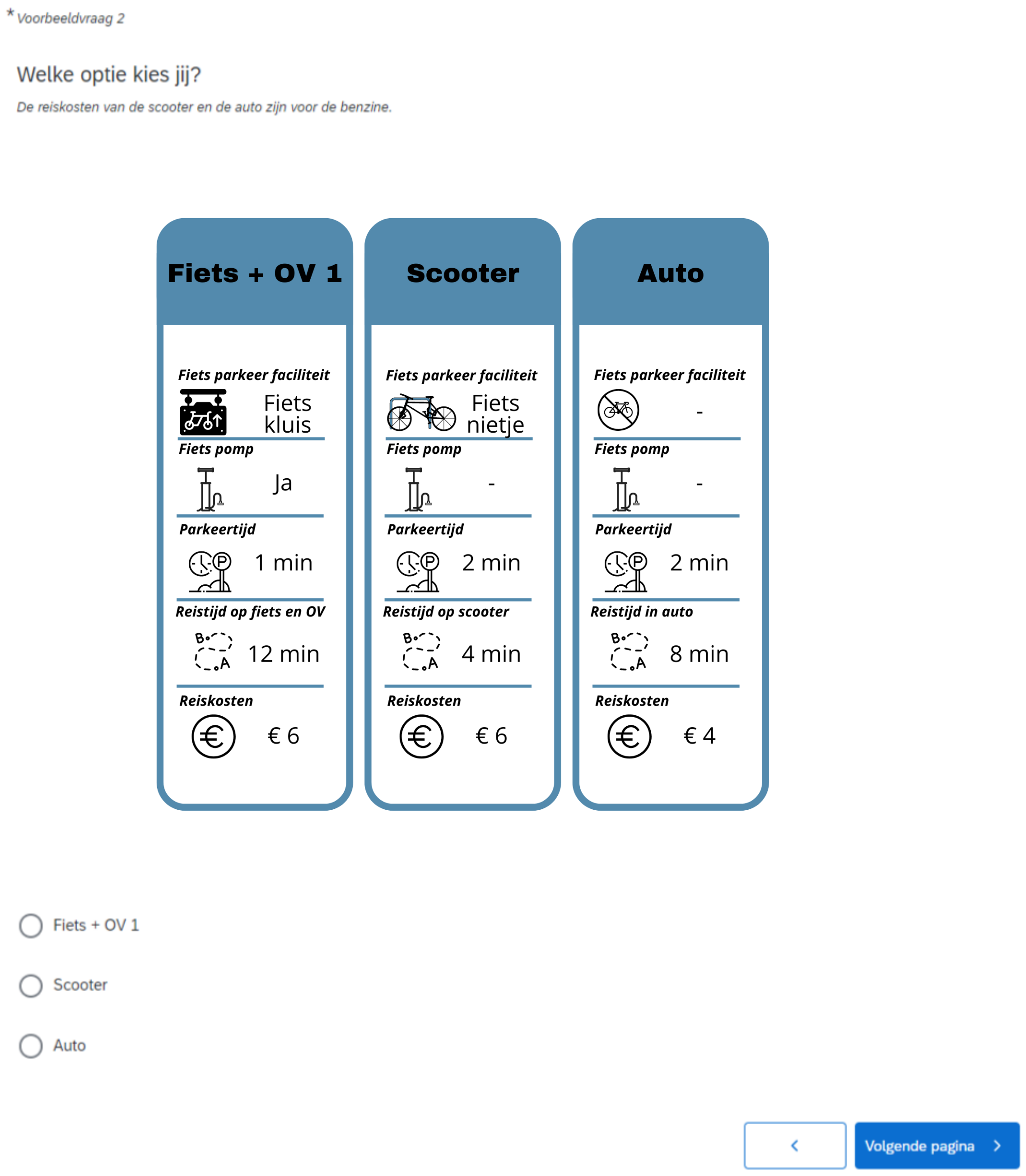


Figure D.7: Sample question part 2 in mode set 1

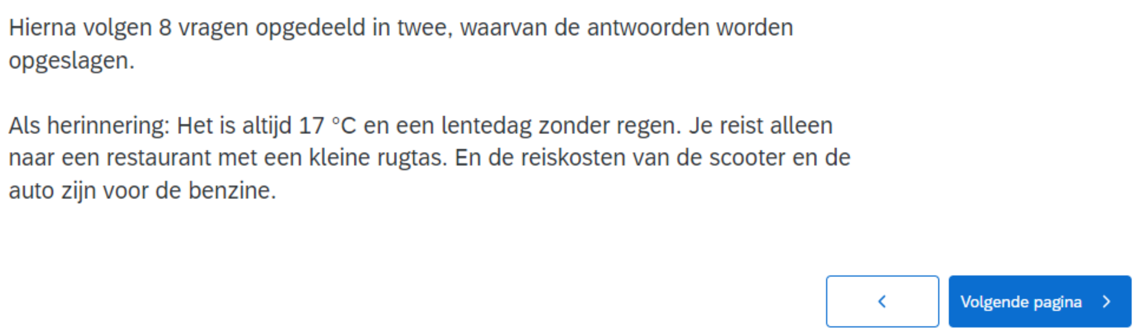
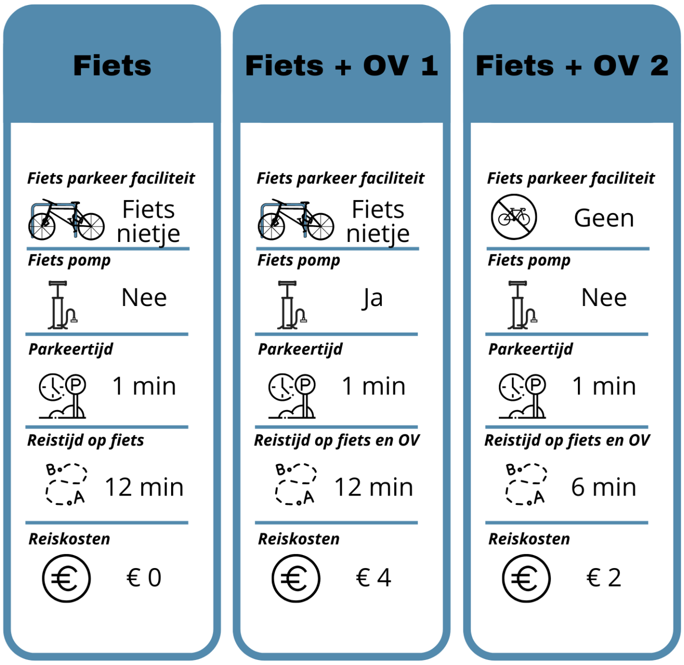


Figure D.8: Final explanation

*Welke optie kies jij?

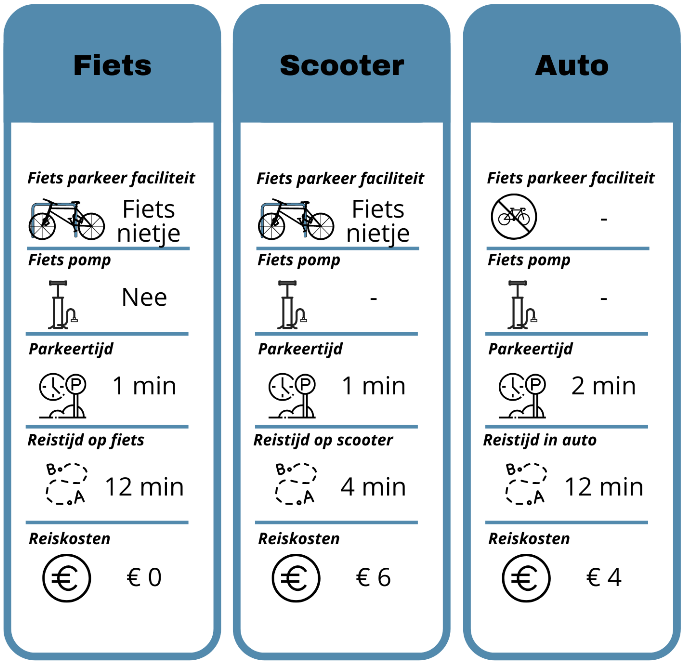


- Fiets
- Fiets + OV 1
- Fiets + OV 2

Volgende pagina >

Figure D.9: Scenario 1 out of 12 part 1

*Welke optie kies jij?

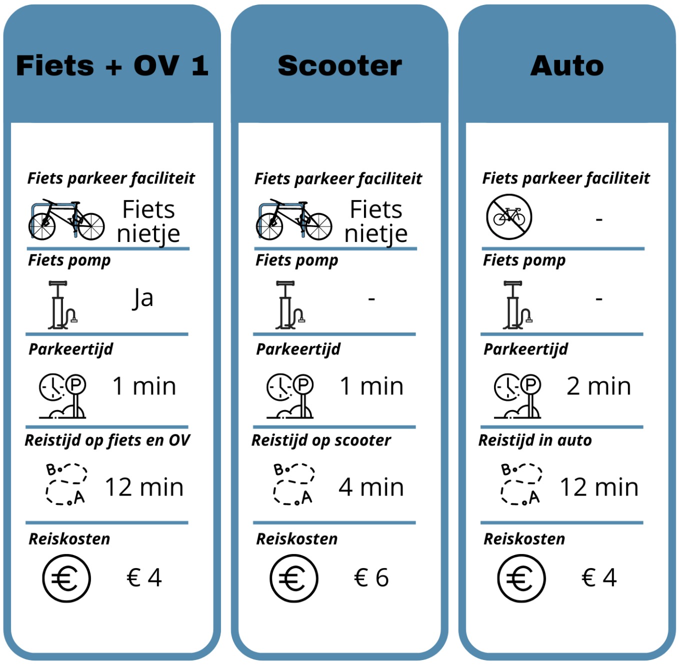


- Fiets
- Scooter
- Auto

‹ Volgende pagina ›

Figure D.10: Scenario 1 out of 12 part 2 in mode set 1 with *Fiets* as answer on part 1

*Welke optie kies jij?



- Fiets + OV 1
- Scooter
- Auto

Volgende pagina

Figure D.11: Scenario 1 out of 12 part 2 in mode set 1 with *Fiets + OV 1* as answer on part 1

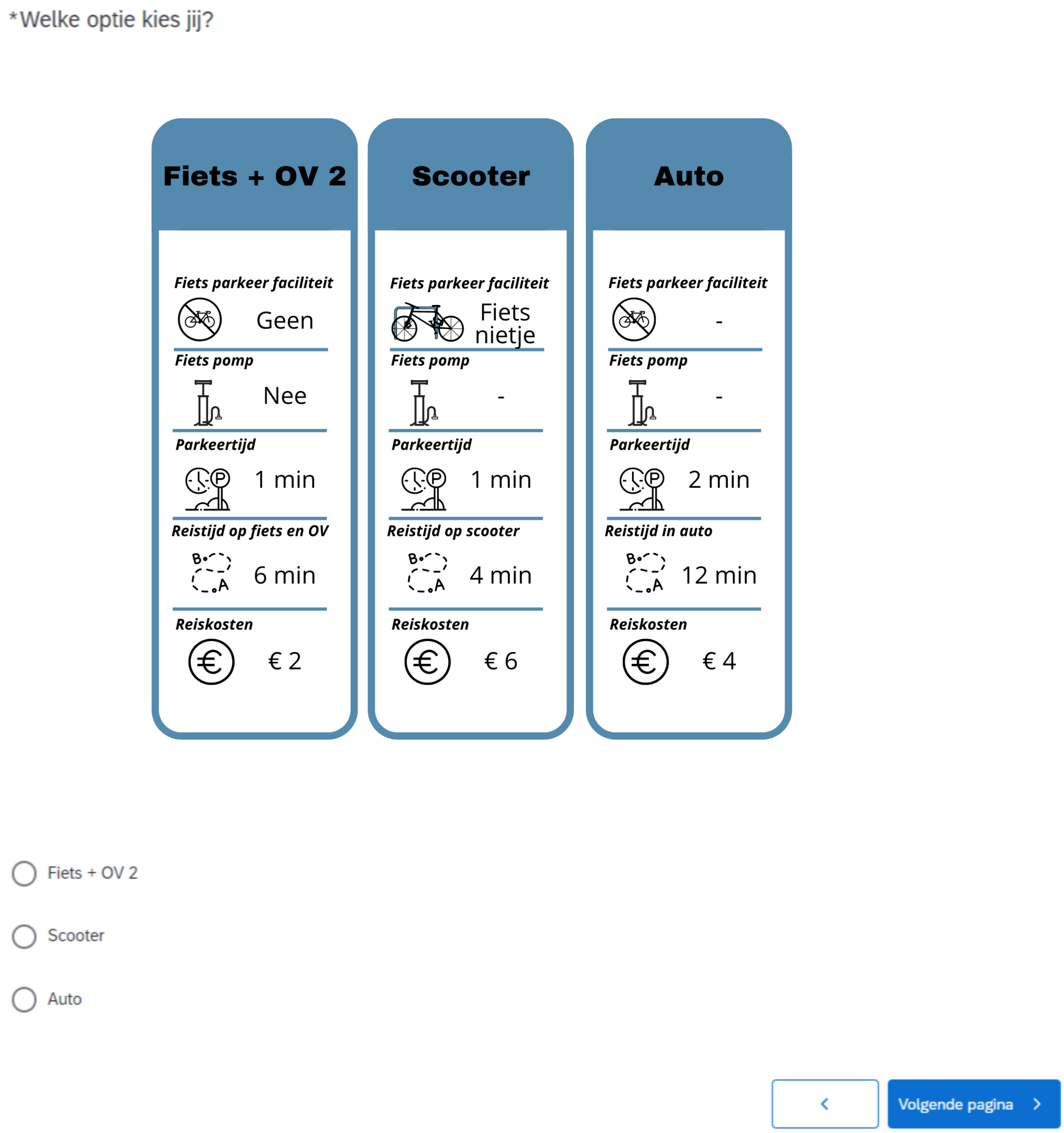


Figure D.12: Scenario 1 out of 12 part 2 in mode set 1 with *Fiets + OV 2* as answer on part 1

Om jouw antwoorden beter te kunnen verwerken, volgen er nu een aantal stellingen.

*Ben jij het eens met de volgende stellingen?

	Zeer mee eens	Mee eens	Neutraal	Oneens	Zeer oneens
Gemak is belangrijk voor mij	○	○	○	○	○
Ik zie het openbaar vervoer als alternatief voor de auto.	○	○	○	○	○
Het milieu is een belangrijke factor bij mijn vervoersmiddelkeuze.	○	○	○	○	○
Kosten is een belangrijke factor bij mijn vervoersmiddelkeuze.	○	○	○	○	○
Een auto bezitten is voor mij belangrijk.	○	○	○	○	○
Ik fiets omdat het beter is voor mijn gezondheid.	○	○	○	○	○
Ik weet hoe ik een fietskluis gebruik zonder problemen.	○	○	○	○	○
Ik ben bang dat mijn fiets gestolen wordt bij een halte.	○	○	○	○	○
Het is belangrijk dat mijn fiets juist op een fietsparkeerplaats staat.	○	○	○	○	○
Ik voel mij veilig op de fiets.	○	○	○	○	○

Volgende pagina >

Figure D.13: Statement questions

Als laatste onderdeel van de enquête zijn basisgegevens nodig voor een betere verwerking van uw antwoorden.

Wat is je leeftijd?

Wat is je geslacht?

- Man
- Vrouw
- Overig
- Ik geef liever geen antwoord

Wat is jouw hoogst behaalde opleidingsniveau?

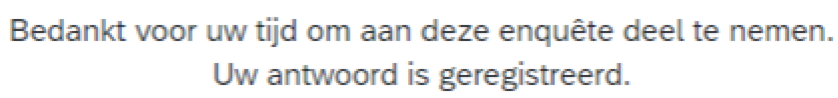
- Middelbare school diploma
- MBO diploma
- HBO/Universiteit Bachelor diploma
- Masters diploma
- Doctor/PhD
- Geen
- Ik geef liever geen antwoord

Wat is jouw (bruto) huishoudelijk jaarlijks inkomen?

- €0 - €24.999 per jaar
- €25.000 - €49.999 per jaar
- €50.000 - €89.999 per jaar
- €90.000 - €129.999 per jaar
- €130.000 - €149.999 per jaar
- Meer dan €150.000 per jaar
- Ik geef liever geen antwoord

Volgende pagina

Figure D.14: Sociodemographic questions



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

Figure D.15: Closing statement

E

Biogeme model

E.1. Base MNL model

E.1.1. Biogeme code of base MNL model

```
#Importing packages
import biogeme.database as db
import biogeme.biogeme as bio
from biogeme import models
import biogeme.tools as tools
from biogeme.expressions import Beta, Variable, log, exp , PanelLikelihoodTrajectory
import pandas as pd
import numpy as np
import math
import datetime
import os

#loading data frame
df = pd.read_csv('Filtered_Data_dummy.csv')

#Only selecting the last choice
df_filtered = df[(df['mode_set_id'] == 5) | ((df['mode_set_id'] != 5) & (df['part'] == 2))].
    copy()

#Creating general database
database = db.Database('Survey_answers', df_filtered)

#Defining variables
globals().update(database.variables)

# Defining betas
ASC_bike = Beta('ASC_bike', 0, None, None, 0)
ASC_ebike = Beta('ASC_ebike', 0, None, None, 0)
ASC_car = Beta('ASC_car', 0, None, None, 0)
ASC_moped = Beta('ASC_moped', 0, None, None, 0)

beta_parking_bracket = Beta('beta_parking_bracket', 0, None, None, 0)
beta_parking_shedded = Beta('beta_parking_shedded', 0, None, None, 0)
beta_parking_safes = Beta('beta_parking_safes', 0, None, None, 0)
beta_bicycle_pump = Beta('beta_bicycle_pump', 0, None, None, 0)

beta_travel_costs = Beta('beta_travel_costs', 0, None, None, 0)

beta_travel_time_slow = Beta('beta_travel_time_slow', 0, None, None, 1)
beta_travel_time_fast = Beta('beta_travel_time_fast', 0, None, None, 1)
beta_travel_time = Beta('beta_travel_time', 0, None, None, 0)

beta_parking_time = Beta('beta_parking_time', 0, None, None, 1)

#Defining utility functions
V_bike =       (ASC_bike +
```

```
                beta_travel_time * bike_travel_time +
                beta_parking_time * bike_parking_time)

V_ebike =       (ASC_ebike +
                beta_travel_time * ebike_travel_time +
                beta_parking_time * ebike_parking_time)

V_bike_PT1 =    (beta_parking_bracket * bike_PT1_parking_facility_bracket +
                beta_parking_safes * bike_PT1_parking_facility_safe +
                beta_parking_shedded * bike_PT1_parking_facility_shedded +
                beta_bicycle_pump * bike_PT1_tire_pump +
                beta_travel_costs * bike_PT1_travel_costs +
                beta_travel_time* bike_PT1_travel_time +
                beta_parking_time * bike_PT1_parking_time)

V_bike_PT2 =    (beta_parking_bracket * bike_PT2_parking_facility_bracket +
                beta_parking_safes * bike_PT2_parking_facility_safe +
                beta_parking_shedded * bike_PT2_parking_facility_shedded +
                beta_travel_costs * bike_PT2_travel_costs +
                beta_bicycle_pump * bike_PT2_tire_pump +
                beta_travel_time * bike_PT2_travel_time +
                beta_parking_time * bike_PT2_parking_time)

V_car =         (ASC_car + beta_travel_costs * car_travel_costs +
                beta_travel_time * car_travel_time +
                beta_parking_time * car_parking_time)

V_moped =       (ASC_moped  + beta_travel_costs * moped_travel_costs +
                beta_travel_time * moped_travel_time +
                beta_parking_time * moped_parking_time)

# Associate utility functions with the alternatives
V = {0: V_bike, 1: V_bike_PT1, 2: V_bike_PT2, 3: V_car, 4: V_moped, 5: V_ebike}

# Assign availability of the alternatives
av = {0: availability0, 1: availability1, 2: availability2, 3: availability3, 4:
    availability4, 5: availability5}

# The choice model is a logit model with availability conditions
logprob = models.loglogit(V, av, choice)

# Define the Biogeme object
biogeme = bio.BIOGEME(database, logprob)

#Setting reporting files
biogeme.generate_pickle = False
biogeme.generate_html = True
biogeme.saveIterations = True

#Naming and estimating the model
biogeme.modelName = "Base model"
results = biogeme.estimate()

# Get general statistics and estimated parameters
print(results.printGeneralStatistics())
pandasResults = results.getEstimatedParameters()
display(pandasResults)
```

E.1.2. Estimation report of base MNL model

Number of estimated parameters: 10
Sample size: 2400
Excluded observations: 0
Init log likelihood: -3183.681
Final log likelihood: -1751.023
Likelihood ratio test for the init. model: 2865.315
Rho-square for the init. model: 0.45
Rho-square-bar for the init. model: 0.447
Akaike Information Criterion: 3522.046
Bayesian Information Criterion: 3579.878
Final gradient norm: 6.4373E-04
Nbr of threads: 12
Relative gradient: 1.8820514953842104e-07
Cause of termination: Relative gradient = 1.9e-07 <= 6.1e-06
Number of function evaluations: 6
Number of gradient evaluations: 6
Number of hessian evaluations: 5
Algorithm: Newton with trust region for simple bound constraints
Number of iterations: 5
Proportion of Hessian calculation: 5/5 = 100.0%
Optimization time: 0:00:00.274275

Estimated parameters

	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC_bike	2.01	0.169	14.4	0
ASC_car	0.889	0.166	5.34	9.11e-08
ASC_ebike	2.85	0.196	14.5	0
ASC_moped	0.81	0.293	2.76	0.00572
beta_bicycle_pump	-0.474	0.136	-3.5	0.000467
beta_parking_bracket	0.217	0.169	1.28	0.2
beta_parking_safes	0.59	0.168	3.51	0.000444
beta_parking_shedded	0.257	0.243	1.106	0.29
beta_travel_costs	-0.0938	0.0374	-2.51	0.0122
beta_travel_time	-0.1	0.00821	-12.2	0

E.2. Base MNL + factors

E.2.1. Estimation report of base MNL + factors model

Number of estimated parameters: 13
Sample size: 2400
Excluded observations: 0
Init log likelihood: -3183.681
Final log likelihood: -1736.204
Likelihood ratio test for the init. model: 2894.953
Rho-square for the init. model: 0.455
Rho-square-bar for the init. model: 0.451
Akaike Information Criterion: 3498.408
Bayesian Information Criterion: 3573.59
Final gradient norm: 3.2171E-04
Nbr of threads: 12
Relative gradient: 6.675947150494609e-08
Cause of termination: Relative gradient = 6.7e-08 <= 6.1e-06
Number of function evaluations: 6
Number of gradient evaluations: 6
Number of hessian evaluations: 5
Algorithm: Newton with trust region for simple bound constraints
Number of iterations: 5
Proportion of Hessian calculation: 5/5 = 100.0%
Optimization time: 0:00:00.341781

Estimated parameters

	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC_bike	2.07	0.171	14.5	0
ASC_car	0.847	0.17	4.98	6.46e-07
ASC_ebike	2.89	0.198	14.6	0
ASC_moped	0.554	0.316	1.75	0.0797
beta_bicycle_pump	-0.474	0.136	-3.49	0.00049
beta_factor1_bike_PT	0.311	0.0844	3.68	0.000231
beta_factor1_moped	-0.652	0.23	-2.84	0.00458
beta_factor2_car	0.31	0.107	2.91	0.00366
beta_parking_bracket	0.226	0.17	1.33	0.182
beta_parking_safes	0.598	0.169	3.53	0.00041
beta_parking_shedded	0.267	0.244	1.09	0.274
beta_travel_costs	-0.0937	0.0376	-2.5	0.0126
beta_travel_time	-0.101	0.00822	-12.3	0

E.3. Base MNL + sociodemographics

In this section, several interaction effects of various sociodemographics are displayed in the following tables. Significant values are highlighted in blue numbers.

E.3.1. Age

	Bicycle			
Age	Value*	Rob.Std err	Rob. t-test	Rob. p-value
18 - 24 year				
25 - 34 year	-0.0584	0.192	-0.304	0.761
35 - 44 year	1.93	0.188	10.3	**0**
45 - 54 year	-0.399	0.22	-1.81	0.0703
55 - 64 year	0.154	0.167	0.923	0.356
65 - 74 year	-0.338	0.221	-1.53	0.126
75 + year	0.112	0.191	0.587	0.557
	Bike+PT			
18 - 24 year				
25 - 34 year	-0.156	0.234	0.666	0.505
35 - 44 year	1.44	0.246	5.85	**4.91e-09**
45 - 54 year	-0.391	0.282	-1.39	0.166
55 - 64 year	-0.153	0.232	-0.658	0.51
65 - 74 year	-0.606	0.297	-2.04	**0.0412**
75 + year	0.759	0.237	3.21	**0.00134**
	Car			
18 - 24 year				
25 - 34 year	-0.576	0.26	-2.21	**0.0269**
35 - 44 year	0.774	0.257	3.01	**0.0026**
45 - 54 year	-0.79	0.27	-2.93	**0.00341**
55 - 64 year	-0.606	0.228	-2.66	**0.00784**
65 - 74 year	-0.716	0.279	-2.57	**0.0103**
75 + year	-1.28	0.407	-3.15	**0.00165**
	Moped			
18 - 24 year				
25 - 34 year	-0.241	0.564	-0.427	0.669
35 - 44 year	-5.42	0.498	-10.9	**0**
45 - 54 year	1.76	0.722	2.43	**0.0149**
55 - 64 year	0	1.8e+308	0	1
65 - 74 year	0.914	0.611	1.5	0.135
75 + year	0	1.8e+308	0	1
	E-bike			
18 - 24 year				
25 - 34 year	0.719	0.413	1.74	0.0819
35 - 44 year	1.28	0.417	3.08	**0.00208**
45 - 54 year	-0.177	0.401	-0.44	0.66
55 - 64 year	0.605	0.365	1.66	0.0975
65 - 74 year	0.746	0.417	1.79	0.0734
75 + year	0.411	0.479	0.859	0.391

*Value is given in reference to base category

Table E.1: Sociodemographic age effects on alternatives

E.3.2. Gender

	Bicycle			
Gender	Value*	Rob.Std err	Rob. t-test	Rob. p-value
Man				
Woman	0.267	0.149	1.79	0.0734
	Bike+PT			
Man				
Woman	-0.0766	0.176	-0.436	0.663
	Car			
Man				
Woman	0.564	0.185	3.05	**0.00229**
	Moped			
Man				
Woman	-0.483	0.533	-0.906	0.365
	E-bike			
Man				
Woman	-0.271	0.222	-1.22	0.223

*Value is given in reference to base category

Table E.2: Sociodemographic gender effects on alternatives

E.3.3. Education level

	Bicycle			
Education Level	Value*	Rob.Std err	Rob. t-test	Rob. p-value
Low				
Middle	-0.0245	0.136	-0.18	0.857
High	0.0181	0.223	0.081	0.935
	Bike+PT			
Low				
Middle	0.0739	0.204	0.363	0.717
High	-0.182	0.251	-0.727	0.468
	Car			
Low				
Middle	0.809	0.243	3.33	**0.000875**
High	-0.0255	0.291	-0.0875	0.93
	Moped			
Low				
Middle	0	1.8e+308	0	1
High	1.82	0.827	2.2	**0.0281**
	E-bike			
Low				
Middle	-0.858	0.349	-2.46	**0.014**
High	-1.63	0.363	-4.49	**7.23e-06**

*Value is given in reference to base category

Table E.3: Sociodemographic education level effects on alternatives

E.3.4. Income level

	Bicycle			
Income Level	Value*	Rob.Std err	Rob. t-test	Rob. p-value
Low				
Middle	0.338	0.123	2.75	**0.00592**
High	0	1.8e+308	0	1
	Bike+PT			
Low				
Middle	-0.216	0.16	-1.35	0.177
High	1.07	0.447	2.39	**0.0169**
	Car			
Low				
Middle	-0.433	0.122	-3.55	**0.0108**
High	-1.25	0.793	-1.57	0.116
	Moped			
Low				
Middle	0.445	0.405	1.1	0.271
High	0	1.8e+308	0	1
	E-bike			
Low				
Middle	-0.135	0.207	-0.654	0.513
High	-1.06	0.872	-1.22	0.224

*Value is given in reference to base category

Table E.4: Sociodemographic income level effects on alternatives

E.4. Base MNL + interaction effects

	Bracket				**Shedded**			
Age	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
18 - 24	0.0755	0.33	0.229	0.819	-1.36	1.01	-1.35	0.178
25 - 34	0.4735	0.378	1.05	0.293	-0.34	1.12	0.908	0.364
35 - 44	0.0953	0.423	0.0469	0.963	-0.758	1.23	0.489	0.625
45 - 54	0.2235	0.445	0.332	0.74	1.12	1.05	2.35	**0.0185**
55 - 64	0.2145	0.432	0.322	0.748	-0.616	1.23	0.605	0.545
65 - 74	-0.1385	0.553	-0.387	0.699	0.9	1.11	2.05	**0.0408**
75 +	0.3015	0.498	0.453	0.651	1.42	1.08	2.56	**0.0104**
	Safe				**Bicycle pump**			
Age	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
18 - 24	0.404	0.338	1.2	0.232	-0.838	0.329	-2.55	**0.0108**
25 - 34	0.803	0.381	1.05	0.296	-0.634	0.4	0.51	0.61
35 - 44	0.1	0.466	-0.652	0.514	-0.8143	0.443	0.0535	0.957
45 - 54	0.693	0.418	0.691	0.49	-0.049	0.393	2.01	**0.0448**
55 - 64	0.4672	0.44	0.144	0.886	-0.8768	0.466	-0.0832	0.934
65 - 74	0.09	0.567	-0.553	0.58	-0.322	0.471	1.1	0.273
75 +	1.414	0.457	2.21	**0.0274**	0.352	0.43	2.77	**0.00567**
	Travel time				**Travel costs**			
Age	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
18 - 24	-0.179	0.0192	-9.34	**0**	-0.0258	0.0224	-1.15	0.248
25 - 34	-0.17033	0.0234	0.371	0.71	-0.0578	0.0417	-0.769	0.442
35 - 44	-0.074	0.0242	4.32	**1.54e-05**	-0.1978	0.0502	-3.43	**0.00061**
45 - 54	-0.081	0.0234	4.18	**2.86e-05**	-0.0209	0.0456	0.108	0.914
55 - 64	-0.069	0.025	4.42	**9.72e-06**	-0.1428	0.0501	-2.33	**0.02**
65 - 74	-0.055	0.0277	4.45	**8.49e-06**	-0.0536	0.0556	-0.499	0.618
75 +	-0.066	0.0347	3.25	**0.00114**	0.0279	0.0651	0.825	0.41
	Bracket				**Shedded**			
Gender	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Man	0.338	0.191	1.77	0.0774	0.519	0.262	1.98	**0.0476**
Woman	0.043	0.241	-1.23	0.22	0.229	0.418	-1.89	0.0586
	Safe				**Bicycle pump**			
Gender	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Man	0.644	0.191	3.37	**0.000765**	-0.397	0.159	-2.5	**0.0125**
Woman	0.513	0.23	-0.569	0.569	-0.586	0.221	-0.854	0.393
	Travel time				**Travel costs**			
Gender	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Man	-0.1	0.011	-9.13	**0**	-0.0875	0.0398	-2.2	0.0281
Woman	-0.1	0.0134	-0.00205	0.98	-0.1026	0.0277	-0.546	0.585
	Bracket				**Shedded**			
Education	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	0.284	0.285	0.997	0.319	0.367	0.418	0.877	0.38
Middle	-0.079	0.456	-0.797	0.426	1.377	0.491	2.06	**0.0394**
High	0.2465	0.29	-0.129	0.897	-0.321	0.49	-1.4	0.16
	Safe				**Bicycle pump**			
Education	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	0.6	0.279	2.15	**0.0313**	-0.328	0.241	-1.36	0.174
Middle	0.5117	0.404	-0.218	0.827	0.1	0.327	1.31	0.192
High	0.604	0.286	0.0124	0.99	-0.699	0.271	-1.37	0.171

	Travel time				Travel costs			
Education	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	-0.0858	0.0167	-5.13	**2.86e-07**	-0.0994	0.0501	-1.99	**0.047**
Middle	-0.0759	0.026	0.379	0.704	0.0496	0.0479	3.12	**0.00179**
High	-0.1089	0.018	-1.28	0.201	-0.1318	0.0376	-0.862	0.388
	Bracket				**Shedded**			
Income	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	0.346	0.189	1.83	0.0667	0.194	0.136	1.43	0.153
Middle	-0.027	0.255	-1.46	0.143	-0.095	0.391	-0.739	0.46
High	0.242	0.68	-0.153	0.879	-5.606	0.293	-19.8	**0**
	Safe				**Bicycle pump**			
Income	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	0.716	0.185	3.87	**0.000108**	-0.283	0.151	-1.87	0.0617
Middle	0.29	0.256	-1.67	0.0957	-0.974	0.26	-2.65	**0.00795**
High	0.968	0.552	0.457	0.648	-0.037	0.509	0.484	0.628
	Travel time				**Travel costs**			
Income	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Low	-0.112	0.0105	-10.7	**0**	-0.0406	0.038	-1.07	0.284
Middle	-0.0816	0.0137	2.21	**0.0269**	-0.1946	0.0309	-5	**5.74e-07**
High	-0.1329	0.0381	-0.549	0.583	-0.3366	0.0933	-3.17	**0.00152**

*Value is given as end value

Table E.5: Interaction effects of sociodemographic groups

	Travel costs							
Age	**18 - 24**				**25 - 34**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.237	0.0754	-3.14	**0.00169**	-0.139	0.0641	1.53	0.126
Car	0.0741	0.0623	1.19	0.234	-0.0221	0.0558	-1.72	0.0847
Moped	-0.26	0.209	-1.25	0.212	-0.3255	0.163	-0.401	0.688
Age	**35 - 44**				**45 - 54**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.2916	0.0834	-0.655	0.513	-0.084	0.0729	2.09	**0.0362**
Car	-0.1669	0.0592	-4.06	**4.86e-05**	-0.0299	0.055	-1.89	0.0585
Moped	-3.14	0.33	-8.73	**0**	0.157	0.248	1.68	0.0925
Age	**55 - 64**				**65 - 74**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.2388	0.0826	-0.0213	0.983	-0.1644	0.0997	0.728	0.466
Car	-0.1199	0.059	-3.28	**0.00102**	-0.0519	0.0651	-1.93	0.0537
Moped	-0.26	1.8e+308	0	1	-0.008	0.172	1.46	0.143
Age	**75 +**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle + PT	0.083	0.0726	4.41	**1.03e-05**				
Car	-0.1769	0.108	-2.33	**0.0197**				
Moped	-0.26	2.63e-13	0	1				
Gender	**Man**				**Woman**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.0988	0.0674	-1.47	0.143	-0.2278	0.0444	-2.91	**0.00361**
Car	-0.0864	0.0572	-1.51	0.131	-0.0211	0.0347	1.88	0.0599
Moped	-0.148	0.152	-0.974	0.33	-0.367	0.171	-1.28	0.202
Education	**Low**				**Middle**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.102	0.0795	-1.28	0.199	-0.0108	0.067	1.36	0.174
Car	-0.0806	0.0682	-1.18	0.237	0.0984	0.0595	3.02	**0.00257**
Moped	-0.449	0.327	-1.37	0.169	-0.449	0	1.8e+308	0
Education	**High**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle + PT	-0.1988	0.0517	-1.87	0.0609				
Car	-0.087	0.0491	-0.129	0.897				
Moped	-0.146	0.257	1.18	0.239				
Income	**Low**				**Middle**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle + PT	-0.0922	0.0664	-1.39	0.165	-0.2422	0.0502	-2.98	**0.00286**
Car	0.0101	0.0541	0.186	0.852	-0.1639	0.0378	-4.61	**4.12e-06**
Moped	-0.196	0.164	-1.2	0.231	-0.1829	0.112	0.116	0.907
Income	**High**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle + PT	-0.2392	0.102	-1.44	0.15				
Car	-0.4539	0.231	-2.01	**0.0445**				
Moped	-0.196	2.97e-16	0	1				

*Value is given as end value

Table E.6: Interaction effects of sociodemographic groups with travel costs per mode

	Travel time							
Age	**18 - 24**				**25 - 34**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.197	0.0244	-8.08	**6.66e-16**	-0.18934	0.0281	0.272	0.785
Bicycle + PT	-0.283	0.0458	-6.19	**6.18e-10**	-0.234	0.0482	1.02	0.309
Car	-0.109	0.0541	-2.02	**0.0437**	-0.171	0.0571	-1.09	0.278
Moped	-0.12	0.125	-0.958	0.338	-0.11226	0.105	0.074	0.941
E-bike	-0.142	0.0475	-2.99	**0.00275**	-0.1052	0.0501	0.734	0.463
Age	**35 - 44**				**45 - 54**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.088	0.0295	3.7	**0.000212**	-0.083	0.0264	4.32	**1.55e-05**
Bicycle + PT	-0.163	0.0474	2.52	**0.0116**	-0.094	0.0432	4.38	**1.17e-05**
Car	-0.0798	0.0552	0.529	0.597	0.024	0.0487	2.73	**0.00627**
Moped	-1.34	0.174	-7.01	**2.43e-12**	0.28	0.125	3.19	**0.0014**
E-bike	-0.0842	0.0506	1.14	0.253	-0.0438	0.0461	2.13	**0.0333**
Age	**55 - 64**				**65 - 74**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.084	0.0291	3.89	**0.0001**	-0.086	0.0314	3.54	**0.000397**
Bicycle + PT	-0.144	0.0469	2.96	**0.00304**	-0.118	0.0531	3.11	**0.00185**
Car	-0.018	0.0536	1.7	**0.0898**	0.019	0.0548	2.34	**0.0193**
Moped	-0.12	1.8e+308	0	1	0.185	0.107	2.85	**0.00434**
E-bike	-0.019	0.048	2.56	**0.0103**	0.018	0.0481	3.32	**0.000895**
Age	**75 +**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle	-0.088	0.0315	3.47	**0.000527**				
Bicycle + PT	-0.045	0.046	5.17	**2.3e-07**				
Car	-0.1543	0.0746	-0.608	0.544				
Moped	-0.12	1.8e+308	0	1				
E-bike	-0.059	0.0574	1.45	0.148				
Gender	**Man**				**Woman**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.117	0.0135	-8.62	**0**	-0.11507	0.0142	0.136	0.892
Bicycle + PT	-0.134	0.027	-4.96	**7.05e-07**	-0.1803	0.0223	-2.08	**0.0378**
Car	-0.0782	0.0449	-1.74	0.0818	-0.044	0.0277	1.23	0.218
Moped	0.0101	0.0818	0.123	0.902	-0.0507	0.0811	-0.75	0.453
E-bike	-0.013	0.0235	-0.551	0.582	-0.051	0.0188	-2.02	**0.0435**
Education	**Low**				**Middle**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.12	0.0188	-6.37	**1.92e-10**	-0.0882	0.0238	1.33	0.182
Bicycle + PT	-0.136	0.0346	-3.91	**9.05e-05**	-0.0831	0.0353	1.5	0.134
Car	-0.083	0.0518	-1.6	0.109	0.063	0.0439	3.33	**0.000869**
Moped	-0.313	0.167	-1.87	**0.061**	-0.313	0	1.8e+308	**0**
E-bike	0.0429	0.0305	1.41	0.159	0.0177	0.0333	-0.757	0.449
Education	**High**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle	-0.1244	0.0187	-0.234	0.815				
Bicycle + PT	-0.1792	0.0292	-1.48	0.139				
Car	-0.085	0.0394	-0.0491	0.961				
Moped	0.005	0.153	2.08	**0.0376**				
E-bike	-0.0701	0.027	-4.19	**2.77e-05**				

	Travel time							
Income	**Low**				**Middle**			
Mode	Value*	Std. Err.	t-test	p-value	Value*	Std. Err.	t-test	p-value
Bicycle	-0.127	0.0132	-9.6	**0**	-0.0983	0.015	1.91	0.0563
Bicycle + PT	-0.14	0.0273	-5.14	**2.73e-07**	-0.1613	0.0241	-0.883	0.377
Car	-0.0457	0.0416	-1.1	0.273	-0.074	0.0301	-0.942	0.346
Moped	-0.0305	0.0896	-0.34	0.734	0.0335	0.0615	1.04	0.298
E-bike	-0.0312	0.0214	-1.45	0.146	-0.0454	0.0199	-0.716	0.474
Income	**High**							
Mode	Value*	Std. Err.	t-test	p-value				
Bicycle	-0.289	0.0651	-2.49	**0.0128**				
Bicycle + PT	-0.445	0.114	-2.67	**0.00763**				
Car	-1.0757	0.302	-3.39	**0.000687**				
Moped	-0.0305	1.8e+308	0	1				
E-bike	-0.3942	0.161	-2.25	**0.0245**				

*Value is given as end value

Table E.7: Interaction effects of sociodemographic groups with travel time per mode

E.5. Base MNL + sociodemographics and interactions

E.5.1. Estimation report of base MNL + significant effects

Number of estimated parameters: 32
Sample size: 2400
Excluded observations: 0
Init log likelihood: -3183.681
Final log likelihood: -1640.161
Likelihood ratio test for the init. model: 3087.04
Rho-square for the init. model: 0.485
Rho-square-bar for the init. model: 0.475
Akaike Information Criterion: 3344.321
Bayesian Information Criterion: 3529.385
Final gradient norm: 2.1845E-02
Nbr of threads: 12
Relative gradient: 5.737483178682076e-06
Cause of termination: Relative gradient = 5.7e-06 <= 6.1e-06
Number of function evaluations: 82
Number of gradient evaluations: 82
Number of hessian evaluations: 81
Algorithm: Newton with trust region for simple bound constraints
Number of iterations: 81
Proportion of Hessian calculation: 81/81 = 100.0Optimization time: 0:05:52.598705

Estimated parameters

	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_bike	1.72	0.223	9.5	0
ASC_car	-0.56	0.258	-5.67	1.47e-08
ASC_ebike	2.33	0.317	11.4	0
ASC_moped	-2.14	0.626	-3.42	0.000627
beta_bicycle_pump	-0.44	0.143	-3.08	0.00207
beta_bike_age35_44	0.801	0.165	4.84	1.27e-06
beta_education_high_ebike	-1.11	0.252	-4.39	1.12e-05
beta_education_middle_car	0.966	0.204	4.74	2.19e-06
beta_income_middle_bike	0.449	0.108	4.16	3.24e-05
beta_moped_age35_44	-0.167	0.0135	-12.4	0
beta_moped_age45_54	2.03	0.745	2.73	0.00642
beta_parking_bracket	0.326	0.175	1.87	0.0616
beta_parking_facility_shedded_age45_54	0.914	0.414	2.21	0.0274
beta_parking_facility_shedded_education_middle	1.33	0.391	3.41	0.000654
beta_parking_facility_shedded_income_high	-4.44	0.58	-7.65	2.02e-14
beta_parking_safes	0.654	0.171	3.83	0.000131
beta_parking_shedded	-0.394	0.299	-1.32	0.187
beta_travel_costs	-0.155	0.0451	-3.43	0.000597
beta_travel_costs_age18_24_bike_PT	-0.209	0.0695	-3.02	0.00256
beta_travel_costs_age35_44_moped	-0.925	0.138	-6.72	1.88e-11
beta_travel_costs_age55_64	-0.108	0.0486	-2.22	0.0265
beta_travel_costs_income_high	-0.203	0.0965	-2.1	0.0354
beta_travel_time	-0.146	0.0132	-11.1	0
beta_travel_time_age35_44_moped	-0.828	0.0888	-9.32	0
beta_travel_time_age45_54	0.0695	0.0175	3.97	7.27e-05
beta_travel_time_age55_64	0.0793	0.0229	3.47	0.000518
beta_travel_time_age65_74	0.0872	0.0234	3.73	0.00019
beta_travel_time_age75_bike	0.0913	0.0179	5.09	3.58e-07
beta_travel_time_age75_bike_PT	0.146	0.0242	6.03	1.6e-09
beta_travel_time_education_high_moped	-0.235	0.0663	3.54	0.0004
beta_travel_time_man_bike_PT	-0.0857	0.0209	-4.09	4.28e-05
beta_travel_time_woman_bike_PT	-0.125	0.0227	-5.51	3.52e-08

E.6. Final model

E.6.1. Estimation report of final model

Number of estimated parameters: 34
Sample size: 2400
Excluded observations: 0
Init log likelihood: -3183.681
Final log likelihood: -1627.803
Likelihood ratio test for the init. model: 3111.756
Rho-square for the init. model: 0.489
Rho-square-bar for the init. model: 0.478
Akaike Information Criterion: 3323.605
Bayesian Information Criterion: 3520.235
Final gradient norm: 1.4067E-02
Nbr of threads: 12
Relative gradient: 5.968884817996204e-06
Cause of termination: Relative gradient = 6e-06 <= 6.1e-06
Number of function evaluations: 77
Number of gradient evaluations: 77
Number of hessian evaluations: 76
Algorithm: Newton with trust region for simple bound constraints
Number of iterations: 76
Proportion of Hessian calculation: 76/76 = 100.0%
Optimization time: 0:05:46.876892

Estimated parameters

	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_bike	1.75	0.225	9.59	0
ASC_car	-0.34	0.263	-5.86	4.71e-09
ASC_ebike	2.39	0.321	11.5	0
ASC_moped	-2.17	0.624	-3.48	0.000506
beta_bicycle_pump	-0.442	0.143	-3.08	0.00206
beta_bike_age35_44	0.826	0.164	5.04	4.61e-07
beta_education_high_ebike	-1.13	0.255	-4.44	8.87e-06
beta_education_middle_car	0.986	0.205	4.81	1.51e-06
beta_factor1_bike_PT	0.289	0.0852	3.4	0.000686
beta_factor2_car	0.365	0.116	3.14	0.00171
beta_income_middle_bike	0.433	0.109	3.99	6.7e-05
beta_moped_age35_44	-0.165	0.0135	-12.2	0
beta_moped_age45_54	2.05	0.743	2.76	0.00574
beta_parking_bracket	0.34	0.175	1.94	0.0526
beta_parking_facility_shedded_age45_54	0.844	0.412	2.05	0.0404
beta_parking_facility_shedded_education_middle	1.32	0.389	3.39	0.000711
beta_parking_facility_shedded_income_high	-4.18	0.598	-6.99	2.67e-12
beta_parking_safes	0.663	0.172	3.85	0.000119
beta_parking_shedded	-0.382	0.299	-1.28	0.202
beta_travel_costs	-0.179	0.0455	3.94	8.23e-05
beta_travel_costs_age18_24_bike_PT	-0.235	0.0706	-3.32	0.000888
beta_travel_costs_age35_44_moped	-0.91	0.138	-6.62	3.59e-11
beta_travel_costs_age55_64	-0.109	0.0481	-2.26	0.0235
beta_travel_costs_income_high	-0.215	0.0978	-2.2	0.0279
beta_travel_time	-0.147	0.0133	-11.1	0
beta_travel_time_age35_44_moped	-0.816	0.088	-9.27	0
beta_travel_time_age45_54	0.0717	0.0176	4.08	4.47e-05
beta_travel_time_age55_64	0.0789	0.0232	3.4	0.000674
beta_travel_time_age65_74	0.0873	0.0233	3.75	0.000178
beta_travel_time_age75_bike	0.086	0.0179	4.8	1.62e-06
beta_travel_time_age75_bike_PT	0.139	0.0247	5.65	1.64e-08
beta_travel_time_education_high_moped	-0.238	0.0662	3.59	0.000326
beta_travel_time_man_bike_PT	-0.0859	0.0211	-4.08	4.59e-05
beta_travel_time_woman_bike_PT	-0.123	0.0227	-5.42	6.11e-08

F

Residents letter

Den Haag

VREDE EN RECHT

040

Retouradres Postbus 12655, 2500 DP Den Haag

Aan bewoners in Den Haag

Contactpersoon
Madeline Lai
Dienst
Dienst Stedelijke Ontwikkeling
Afdeling
Mobiliteit

Datum
16 mei 2024

Onderwerp
Uitnodiging voor deelname aan een onderzoek naar reisgedrag

Geachte bewoner,

Gemeente Den Haag en student Madeline Lai van Technische Universiteit Delft doen een onderzoek. Wij willen weten hoe mensen in Den Haag reizen? Wij willen vooral weten of mensen vaker het openbaar vervoer gaan gebruiken als er een fietsenstalling bij de bushalte of tramhalte is.

Waarom is jouw mening belangrijk?
Jouw ervaringen helpen ons om te ontdekken wat voor fietsenstallingen nodig zijn.

Hoe kan jij helpen?
Vul de online vragenlijst in. Invullen duurt ongeveer 10 minuten. Jouw antwoorden blijven anoniem. Als je een vraag te persoonlijk vindt, mag je deze overslaan.

Start de vragenlijst:
Stap 1: Scan de QR die hiernaast staat
Stap 2: Start de vragenlijst

Of gebruik deze link:
https://tudelft.fra1.qualtrics.com/jfe/form/SV_6LtQOZMjPCdcFnM

Deelnemen is vrijwillig. Jouw mening is belangrijk voor ons. Als je vragen hebt of meer informatie over het onderzoek wilt, mail dan naar Madeline Lai.

Dank voor je tijd!

Met vriendelijke groet,

Madeline Lai
Afstudeerder Technische Universiteit Delft/Gemeente Den Haag

Gemeente Den Haag
Spui 70
Den Haag

Postbus 12655
2500 DP Den Haag

T 14070
www.denhaag.nl

Figure F.1: Residents letter

G
Data set

Introduction questions	Option	Absolute number	Percentage*
What do you sometimes use to travel?	Car	176	50.6%
	Bicycle	254	73.0%
	E-bike	66	19.0%
	Moped	19	5.5%
	Other	274	78.7%
	Total **	789	
Do you own a bicycle?	Yes	43	45.7%
	No	51	54.3%
	Total	94	
Do you sometimes borrow a bicycle?	Yes	5	9.8%
	No	46	90.2%
	Total	51	

* Percentage of respondents for whom the question was visible
** Multiple answers are possible per respondent

Table G.1: Given answers by respondents in the introduction block

Choice set	Absolute number	Percentage
Choice set A	14	4.0
Choice set B	34	9.8
Choice set C	128	36.8
Choice set D	5	1.4
Choice set E	23	6.6
Choice set F	98	28.2
No bicycle	46	13.2

Table G.2: Choice set distribution

Sociodemographic	Option	Abs. number	Pct.	The Hague	Dutch pop.
Age	0 - 17 year	0	0	20.3%	18.6%
	18 - 24 year	47	16.0%	8.8%	9.0%
	25 - 34 year	62	21.1%	15.6%	13.1%
	35 - 44 year	52	17.7%	14.6%	12.2%
	45 - 54 year	49	16.7%	13.9%	13.1%
	55 - 64 year	46	15.6%	11.9%	13.7%
	65 - 74 year	30	10.2%	8.4%	11.0%
	75 + year	8	2.7%	6.5%	9.2%
	Unknown*	54			
	Total	348			
Gender	Man	165	56.1%	49.8%	49.7%
	Woman	137	45.4%	50.2%	50.3%
	Other*	2			
	Unknown*	44			
	Total	348			
Education	Secondary school	41	14.0%		
	MBO	42	14.3%		
	HBO/university bachelor	121	41.3%		
	Masters diploma	86	29.4%		
	None	3	1.0%		
	Unknown*	55			
	Total	348			
Education (classified)	CBS low	44	15.0%	30.0%	26.0%
	CBS middle	42	14.3%	34.0%	42.0%
	CBS high	207	70.7%	36.0%	32.0%
	Unknown*	55			
	Total	348			
Income (gross)	€0 - €24.999 a year	69	26.0%		
	€25.000 - €49.999 a year	74	27.9%		
	€50.000 - €89.999 a year	86	32.5%		
	€90.000 - €129.999 a year	26	9.8%		
	€130.000 - €149.999 a year	4	1.5%		
	More than €150.000 a year	6	2.3%		
	Unknown*	83			
	Total	348			
Income (classified)	CBS low	143	54.0%	48.0%	56.2%
	CBS middle	112	42.2%	34.5%	39.6%
	CBS high	10	3.8%	17.5%	4.2%
	Unknown*	83			
	Total	348			

* Not included in percentage column

Table G.3: Sociodemographic characteristics summurized

Statement	Agreement	Abs. number	Percentage
Convenience is important to me	Strongly agree	82	27.2%
	Agree	143	47.3%
	Neutral	58	19.2%
	Disagree	15	5.0%
	Strongly disagree	4	1.3%
	Total*	302	
I see public transport as an alternative to the car	Strongly agree	101	33.4%
	Agree	127	42.1%
	Neutral	38	12.6%
	Disagree	26	8.6%
	Strongly disagree	10	3.3%
	Total*	302	
The environment is an important factor in my choice of transportation mode	Strongly agree	58	19.2%
	Agree	104	34.4%
	Neutral	79	26.2%
	Disagree	38	12.6%
	Strongly disagree	23	7.6%
	Total*	302	
Cost is an important factor in my choice of transportation mode	Strongly agree	104	34.4%
	Agree	120	39.8%
	Neutral	48	15.9%
	Disagree	26	8.6%
	Strongly disagree	4	1.3%
	Total*	302	
Owning a car is important to me	Strongly agree	46	15.2%
	Agree	79	26.2%
	Neutral	52	17.2%
	Disagree	55	18.2%
	Strongly disagree	70	23.2%
	Total*	302	
I cycle because it is better for my health	Strongly agree	94	31.1%
	Agree	129	42.7%
	Neutral	49	16.2%
	Disagree	25	8.3%
	Strongly disagree	5	1.7%
	Total*	302	
I know how to use a bicycle locker without problems	Strongly agree	18	6.0%
	Agree	47	15.6%
	Neutral	94	31.1%
	Disagree	96	31.7%
	Strongly disagree	47	15.6%
	Total*	302	
I fear my bicycle will be stolen at a stop	Strongly agree	70	23.2%
	Agree	104	34.4%
	Neutral	53	17.6%
	Disagree	68	22.5%
	Strongly disagree	7	2.3%
	Total*	302	
It is important that my bicycle is properly parked at an intended bicycle parking space.	Strongly agree	62	20.5%
	Agree	143	47.4%
	Neutral	59	19.5%
	Disagree	32	10.6%
	Strongly disagree	6	2.0%
	Total*	302	
I feel safe on the bicycle	Strongly agree	90	29.8%
	Agree	149	49.3%
	Neutral	40	13.3%
	Disagree	20	6.6%
	Strongly disagree	3	1.0%
	Total*	302	

*Excluding *no bicycle* users

Table G.4: Attitudes towards statements

H

Sociodemographic graphs and statistics

H.1. Income statistics

H.1.1. Municipality five-level income range

	Income range	Percentage of residents	CBS reference
Quantile 1	< €23.500	27.0%	CBS low
Quantile 2	€23.500 - €34.100	21.0%	CBS low
Quantile 3	€34.100 - €48.600	18.8%	CBS middle
Quantile 4	€48.600 - €68.300	15.7%	CBS middle
Quantile 5	> €68.300	17.5%	CBS high

Table H.1: Yearly net income quantiles of The Hague (Gemeente Den Haag, 2021a)

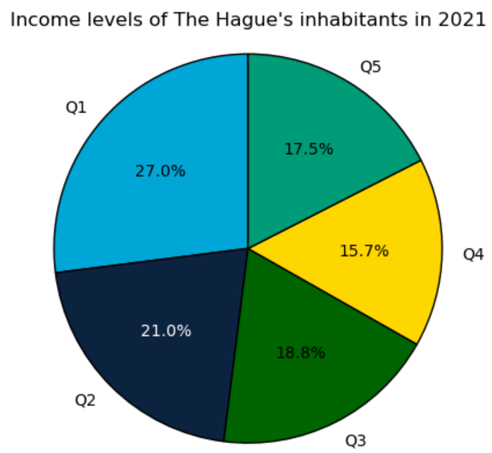
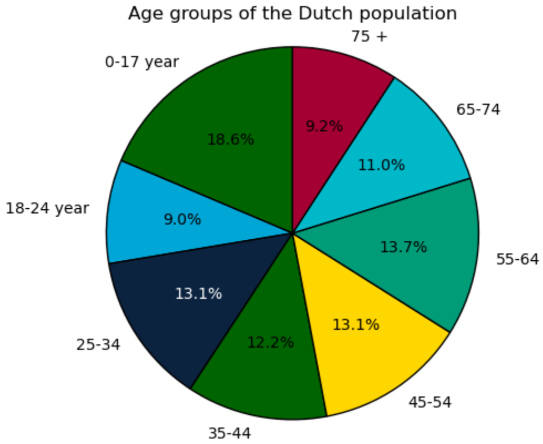
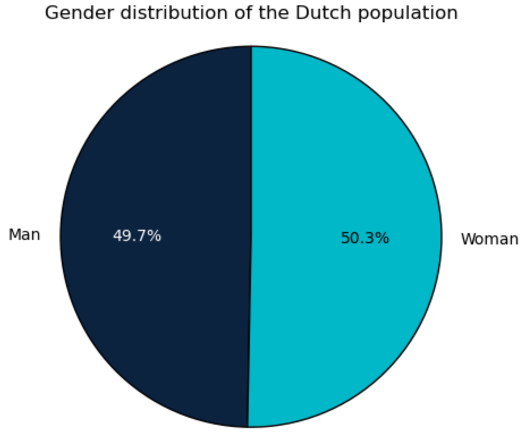


Figure H.1: Income level distribution of The Hague's inhabitants

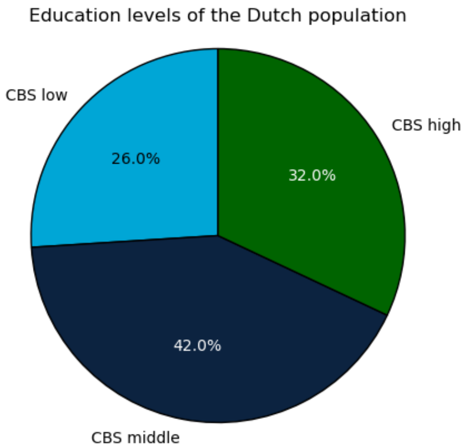
H.2. Descriptive statistics on Dutch population



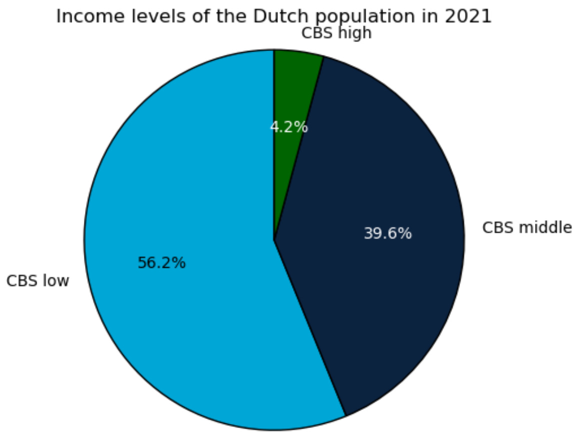
(a) Age distribution of the Dutch population 2023



(b) Gender distribution of the Dutch population in 2023



(c) Education level distribution of the Dutch population in 2021



(d) Income distribution of the Dutch population in 2021

Figure H.2: Sociodemographic distribution of the Dutch population

I

Persona-Based trip scenario outcomes

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	79.1%	55.2%	82.2%	77.8%	68.7%	73.4%
	Bicycle + PT	7.5%	7.4%	6.3%	3.1%	8.5%	8.2%
	Car	13.3%	37.4%	11.5%	19.2%	22.8%	18.4%
Trip 1	Bicycle	41.7%	14.1%	22.3%	35.5%	32.7%	14.7%
	Bicycle + PT	4.0%	1.9%	1.7%	1.4%	4.0%	1.6%
	Car	7.0%	9.6%	3.1%	8.7%	10.8%	3.7%
	Moped	0.2%	3.2%	0.5%	0%	0.2%	0.7%
	E-bike	47.2%	71.2%	72.3%	54.4%	52.3%	79.3%
Trip 2	Bicycle	92.5%	68.7%	89.7%	91.0%	79.1%	89.3%
	Bicycle + PT	2.0%	3.8%	2.5%	1.0%	3.7%	2.7%
	Car	5.6%	27.5%	7.8%	8.0%	17.2%	8.0%
Trip 2	Bicycle	45.1%	15.0%	22.9%	38.0%	34.9%	15.2%
	Bicycle + PT	1.0%	0.8%	0.6%	0.4%	1.6%	0.5%
	Car	2.7%	6.0%	2.0%	3.3%	7.6%	1.4%
	Moped	0.1%	2.9%	0.5%	0%	0.1%	0.5%
	E-bike	51.1%	75.3%	74.1%	58.3%	55.8%	82.4%

Table I.1: Base scenario outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	76.8%	53.6%	80.2%	76.8%	66.5%	71.0%
	Bicycle + PT	10.3%	10.1%	8.6%	4.2%	11.5%	11.2%
	Car	12.9%	36.4%	11.2%	18.9%	22.0%	17.8%
Trip 1	Bicycle	41.0%	14.0%	22.2%	35.3%	32.2%	14.6%
	Bicycle + PT	5.5%	2.6%	2.4%	1.9%	5.6%	2.3%
	Car	6.9%	9.5%	3.1%	8.7%	10.6%	3.7%
	Moped	0.2%	3.2%	0.5%	0%	0.2%	0.7%
	E-bike	46.4%	70.6%	71.8%	54.1%	51.4%	78.8%
Trip 2	Bicycle	91.7%	67.7%	88.9%	90.7%	77.9%	88.3%
	Bicycle + PT	2.7%	5.3%	3.4%	1.3%	5.1%	3.8%
	Car	5.5%	27.1%	7.7%	8.0%	17.0%	7.9%
Trip 2	Bicycle	45.0%	14.9%	22.8%	37.9%	34.6%	15.2%
	Bicycle + PT	1.3%	1.2%	0.9%	0.6%	2.3%	0.6%
	Car	2.7%	6.0%	2.0%	3.3%	7.5%	1.4%
	Moped	0.1%	2.9%	0.5%	0%	0.1%	0.5%
	E-bike	50.9%	75.0%	73.9%	58.2%	55.4%	82.2%

Table I.2: Scenario 1 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	79.4%	59.0%	82.4%	72.1%	69.0%	73.6%
	Bicycle + PT	7.3%	1.0%	6.0%	10.1%	8.2%	7.9%
	Car	13.4%	40.0%	11.5%	17.8%	22.8%	18.5%
Trip 1	Bicycle	41.7%	14.4%	22.3%	34.2%	32.7%	14.7%
	Bicycle + PT	3.8%	0.2%	1.6%	4.8%	3.9%	1.6%
	Car	7.0%	9.8%	3.1%	8.4%	10.8%	3.7%
	Moped	0.2%	3.3%	0.5%	0%	0.2%	0.7%
	E-bike	47.3%	72.3%	72.4%	52.5%	52.4%	79.3%
Trip 2	Bicycle	92.5%	71.0%	89.9%	88.8%	79.2%	89.4%
	Bicycle + PT	1.9%	0.5%	2.4%	3.4%	3.5%	2.6%
	Car	5.6%	28.4%	7.8%	7.8%	17.3%	8.0%
Trip 2	Bicycle	45.1%	15.1%	22.9%	37.6%	34.9%	15.2%
	Bicycle + PT	0.9%	0.1%	0.6%	1.4%	1.6%	0.4%
	Car	2.7%	6.0%	2.0%	3.3%	7.6%	1.4%
	Moped	0.1%	2.9%	0.5%	0%	0.1%	0.5%
	E-bike	51.1%	75.8%	74.1%	57.7%	55.8%	82.4%

Table I.3: Scenario 2 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	70.0%	49.0%	74.2%	73.9%	60.0%	64.2%
	Bicycle + PT	18.2%	17.8%	15.5%	7.9%	20.2%	19.6%
	Car	11.8%	33.2%	10.4%	18.2%	19.8%	16.1%
Trip 1	Bicycle	39.0%	13.7%	21.7%	34.6%	30.6%	14.3%
	Bicycle + PT	10.1%	5.0%	4.5%	3.7%	10.3%	4.4%
	Car	6.6%	9.3%	3.0%	8.5%	10.1%	3.6%
	Moped	0.1%	3.1%	0.5%	0%	0.2%	0.7%
	E-bike	44.1%	68.9%	70.3%	53.1%	48.9%	77.1%
Trip 2	Bicycle	89.4%	64.5%	86.1%	89.5%	74.3%	85.3%
	Bicycle + PT	5.2%	9.7%	6.4%	2.6%	9.5%	7.0%
	Car	5.4%	25.8%	7.5%	7.9%	16.2%	7.6%
Trip 2	Bicycle	44.4%	14.8%	22.6%	37.7%	33.9%	15.1%
	Bicycle + PT	2.6%	2.2%	1.7%	1.1%	4.3%	1.2%
	Car	2.7%	5.9%	2.0%	3.3%	7.4%	1.4%
	Moped	0.1%	2.9%	0.5%	0%	0.1%	0.5%
	E-bike	50.3%	74.2%	73.3%	57.9%	54.3%	81.7%

Table I.4: Scenario 3 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	74.3%	58.4%	78.0%	65.8%	64.1%	68.5%
	Bicycle + PT	13.2%	1.9%	11.1%	18.0%	14.7%	14.3%
	Car	12.5%	39.6%	10.9%	16.2%	21.2%	17.2%
Trip 1	Bicycle	40.3%	14.4%	22.0%	32.7%	31.6%	14.5%
	Bicycle + PT	7.1%	0.5%	3.1%	8.9%	7.3%	3.0%
	Car	6.8%	9.7%	3.1%	8.1%	10.5%	3.6%
	Moped	0.1%	3.3%	0.5%	0%	0.2%	0.7%
	E-bike	45.6%	72.2%	71.3%	50.2%	50.5%	78.2%
Trip 2	Bicycle	90.9%	70.7%	87.9%	86.1%	76.6%	87.3%
	Bicycle + PT	3.6%	1.0%	4.5%	6.3%	6.7%	4.9%
	Car	5.5%	28.3%	7.6%	7.6%	16.7%	7.8%
Trip 2	Bicycle	44.8%	15.1%	22.7%	37.1%	34.4%	15.2%
	Bicycle + PT	1.8%	0.2%	1.2%	2.7%	3.0%	0.9%
	Car	2.7%	6.0%	2.0%	3.3%	7.5%	1.4%
	Moped	0.1%	2.9%	0.5%	0%	0.1%	0.5%
	E-bike	50.7%	75.8%	73.7%	56.9%	55%	82.1%

Table I.5: Scenario 4 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	82.4%	69.3%	86.6%	82.5%	73.8%	77.7%
	Bicycle + PT	7.9%	9.3%	6.6%	3.2%	9.1%	8.7%
	Car	9.7%	21.4%	6.8%	14.2%	17.1%	13.6%
Trip 1	Bicycle	42.6%	14.9%	22.6%	36.4%	33.8%	14.8%
	Bicycle + PT	4.1%	2.0%	1.7%	1.4%	4.2%	1.7%
	Car	5.0%	4.6%	1.8%	6.3%	7.8%	2.6%
	Moped	0.2%	3.4%	0.5%	0%	0.2%	0.7%
	E-bike	48.2%	75.1%	73.3%	55.9%	54.0%	80.2%
Trip 2	Bicycle	94.0%	80.8%	92.9%	93.3%	83.4%	91.5%
	Bicycle + PT	2.0%	4.5%	2.6%	1.0%	3.9%	2.8%
	Car	4.0%	14.7%	4.5%	5.7%	12.7%	5.7%
Trip 2	Bicycle	45.5%	15.5%	23.1%	38.4%	35.7%	15.3%
	Bicycle + PT	1.0%	0.9%	0.6%	0.4%	1.7%	0.5%
	Car	1.9%	2.8%	1.1%	2.4%	5.4%	1.0%
	Moped	0.1%	3.0%	0.5%	0%	0.1%	0.6%
	E-bike	51.5%	77.8%	74.7%	58.9%	57.1%	82.7%

Table I.6: Scenario 5 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	79.9%	66.8%	84.3%	81.5%	71.2%	75.0%
	Bicycle + PT	10.7%	12.5%	9.1%	4.5%	12.4%	11.8%
	Car	9.4%	20.6%	6.6%	14.0%	16.5%	13.1%
Trip 1	Bicycle	41.9%	14.8%	22.5%	36.2%	33.2%	14.7%
	Bicycle + PT	5.6%	2.8%	2.4%	2.0%	5.8%	2.3%
	Car	4.9%	4.6%	1.8%	6.2%	7.7%	2.6%
	Moped	0.2%	3.4%	0.5%	0%	0.2%	0.7%
	E-bike	47.4%	74.5%	72.8%	55.6%	53.1%	79.6%
Trip 2	Bicycle	93.3%	79.4%	92.0%	92.9%	82.1%	90.5%
	Bicycle + PT	2.8%	6.2%	3.5%	1.4%	5.4%	3.8%
	Car	3.9%	14.5%	4.5%	5.7%	12.5%	5.7%
Trip 2	Bicycle	45.3%	15.4%	23.0%	38.3%	35.4%	15.3%
	Bicycle + PT	1.4%	1.2%	0.9%	0.6%	2.3%	0.6%
	Car	1.9%	2.8%	1.1%	2.4%	5.4%	1.0%
	Moped	0.1%	3.0%	0.5%	0%	0.1%	0.5%
	E-bike	51.3%	77.6%	74.5%	58.8%	56.7%	82.6%

Table I.7: Scenario 6 outcome

Trip	Mode	Fiona	David	Sara	Alex	Maria	Lucas
Trip 1	Bicycle	79.1%	65.1%	83.2%	81.1%	70.4%	73.0%
	Bicycle + PT	11.6%	14.9%	10.3%	4.9%	13.4%	14.2%
	Car	9.3%	20.1%	6.5%	14.0%	16.3%	12.8%
Trip 1	Bicycle	41.7%	14.7%	22.4%	36.1%	33.0%	14.7%
	Bicycle + PT	6.1%	3.4%	2.8%	2.2%	6.3%	2.8%
	Car	4.9%	4.5%	1.8%	6.2%	7.6%	2.6%
	Moped	0.2%	3.3%	0.5%	0%	0.2%	0.7%
	E-bike	47.2%	74.0%	72.5%	55.5%	52.9%	79.2%
Trip 2	Bicycle	93.0%	78.3%	91.5%	92.8%	81.7%	89.7%
	Bicycle + PT	3.0%	7.4%	4.1%	1.5%	5.9%	4.7%
	Car	3.9%	14.3%	4.5%	5.7%	12.4%	5.6%
Trip 2	Bicycle	45.3%	15.4%	23.0%	38.3%	35.4%	15.3%
	Bicycle + PT	1.5%	1.5%	1.0%	0.6%	2.5%	0.8%
	Car	1.9%	2.8%	1.1%	2.4%	5.4%	0.9%
	Moped	0.1%	3.0%	0.5%	0%	0.1%	0.5%
	E-bike	51.2%	77.4%	74.4%	58.7%	56.6%	82.4%

Table I.8: Scenario 7 outcome