Exploring effective communication strategies to encourage the use of bicycle parkings

Master thesis

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Exploring effective communication strategies to encourage the use of bicycle parkings

by

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4451104

in partial fulfilment of the requirements for the degree of

Master of Science
in Civil Engineering

at the Delft University of Technology

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Preface

After a great time studying in Delft, it is with great pleasure that I present this master thesis, the end of my academic journey. I would like to express my sincere appreciation to my committee members for their guidance and feedback throughout this project. I am especially grateful to my daily supervisor Alexandra for her dedicated mentorship, and her availability to meet with me numerous times to discuss the progress and challenges of my work, especially given the challenges that this subject presented from time to time and the creativity needed to get past the problems.

I am also grateful to my fellow students, who provided a stimulating work environment in the thesis room and served as a source of inspiration and input when needed. Their insights and perspectives have contributed to my understanding of the subject, and they have helped me stay motivated throughout the process. Furthermore, the coffee breaks we had and the distractions during lunch helped me stay focused and energized during the process.

Furthermore, I would like to acknowledge the support of my roommates and friends, who have provided me with a healthy balance between working on my thesis and taking time off. Their encouragement helped me to maintain balance and perspective even in the most challenging moments.

Finally, I want to express my heartfelt appreciation to my family, whose love, guidance, and encouragement have been the foundation of my academic and personal growth over these past years. I am grateful for their unwavering belief in my abilities and their constant support throughout the challenges and successes of this journey.

In conclusion, I am grateful to have had the opportunity to undertake this research and to contribute to the advancement of knowledge in this field. It is my sincere hope that this thesis will be a valuable addition to this field of research.

R.S. Holster
Delft, June 2023

Summary

The popularity of cycling has grown worldwide, but little research focuses on bicycle parking. In the Netherlands, fly parking is a common practice in the city centers, which could cause nuisance by blocking sidewalks, while official parking spaces remain underutilized. This could be due to a lack of information being provided to cyclists. It is currently unclear what kind of communication would be effective in encouraging the use of formal parking spots, and how different people would respond to this. This study aims to identify user groups and evaluate their response to communication discouraging the use of fly parking.

To create a communication strategy, two aspects should be considered: the message that is sent, the semantics, and the way it is presented, the syntax. Communication is a very broad field, and often no clear-cut outcomes are available. In this research, it was chosen to only vary the content of the message and use the same syntax throughout. Traffic signs are the chosen syntax, as these are the most common way to present communication in traffic, and most information on how they are designed is available. By placing these signs along individuals' routes, valuable insights into the most effective communication approach can be gained. Providing an answer to the main question:

What along-route communication strategies motivate distinct user groups most to change their bicycle parking behaviour from choosing fly-parking towards parking at designated bicycle parking places?

To find an answer to this, people's choice behaviour when deciding on a parking spot needs to be researched. Furthermore, it should be investigated how this behaivour changes when communication is included and if that differs for people with certain characteristics. People's trade-offs cannot be asked for directly, as they often don't know them. Choice observation data needs to be gathered. People will be presented with choice situations for parking spots that currently do not exist, with communication added to them. So, a SP choice experiment will be developed and this will be distributed to people as an online survey.

To create the choice experiment for this survey the different alternatives, in this case parking options, people are presented with, and the attributes describing these alternatives need to be decided upon. The alternatives offered in this research are ones currently found in reality, including two formal spots, one inside and one outside, and the fly parking option, where people moor their bikes to a random object on the street.

Some other factors that influence parking behaviour are identified in the literature. There are three categories for these factors. The first are the parking characteristics, which include the walking distance, and the type of object a bike can be moored to. Perceived safety is also mentioned in literature, but it is difficult to include, as it is unclear what determines it. The next category is the trip characteristic, considered is the length of stay. Lastly, people's sociodemographics are collected. Based on these sociodemographic characteristics, it is expected

that distinct user groups will exhibit distinct choice behaviours. A person's gender, age, education level and work situation will be asked for. Furthermore, information on a person's bike will also be gathered, namely the price of a person's bike and how often they use, as these characteristics are also expected to influence people's behaviour. All these attributes can be used to identify the distinct user groups.

Communication is also one of the attributes that should be included in the choice situations. In the literature review, possible semantics for communication, or in other words, strategies are identified. The methods used in this research are no communication, hazardous communication, and educative communication, where educative communication can be neutral or negative. These semantics need to be displayed through the syntax, traffic signs. Signs to display these communication strategies do not currently exist and must be designed for this research.

Familiarity with traffic signs is important to get effective reactions. Therefore, the designs in this research are based on existing traffic signs. The netural educative communication should present people with the information formal parking options are provided. This needs to be done for both the inside and outside spots, offered in this research. The designs are shown in Figure 2, Figure 3. The negative educative communication provides the information that fly parking is forbidden in a certain area, this is shown in Figure 1. The hazardous strategy also indicates this; however, it should also alert individuals that checks are being conducted, as shown in Figure 4.

Figure 1: Custom traffic sign educative negative communication

Figure 2: Custom traffic sign educative neutral communication for inside parking

Figure 3: Custom traffic sign educative neutral communication for outside parking

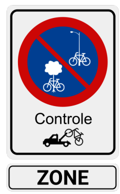

Figure 4: Custom traffic sign hazardous communication

Based on the literature review, the final overview of attributes and their attribute levels is shown in Table 1. With these, a choice experiment is designed. The trade-off that is of interest is the one between fly parking and one of the formal options. So, each choice situation should offer two parking options each time. With these requirements, a survey is developed using the software Ngene. The design will be a d-efficient design using partial choice sets, creating 12 choice situations.

These choice situations should be presented to people as realistically as possible in the survey, but it should also not overwhelm the participants with too much information. This could result in them losing interest and answering questions randomly. Since the choice situations mostly rely on visual cues, images or video clips would be the best way to present them, where clips work even better than images. However, presenting participants with a clip for each of the 12 choice situations would overwhelm them. Therefore, images are chosen as the preferred

Table 1: Final overview of attributes and attribute levels

Alternatives	Formal inside		Formal outside		Fly	
Costs	Free					
Crowdedness	Always enough space available					
Short or long stay	Max 30min	Over 2 hours	Max 30min	Over 2 hours	Max 30min	Over 2 hours
Covered/ outside	Covered		Outside		Outside	
Bike racks/ street furniture	Bike racks		Bike racks		Street furniture	
Walking distance	50m 100m	100m 150m	0m 50m	50m 100m	0m 25m	
Communication	Educative neutral		None Educative neutral	Educative neutral	None Educative negative Hazardous	

option for this research.

The choice situations in this research evaluate the effectiveness of different semantics. Although only one syntax is tested, its effectiveness can still be determined. Participants are asked whether they noticed traffic signs without explicit instructions to look for them. This approach utilizes visual cues and requires only one question, making it possible to use a single video clip. The video portrays a person's journey to the city centre, and participants are tasked with identifying the encountered signs. If a significant number of participants fail to identify these signs, it suggests that they did not notice them, indicating that presenting traffic signs alone is not an effective syntax. Finally, before people are presented with the choice situations, their understanding of the signs is tested and an explanation is presented afterwards. Initial understanding of the signs is looked into as a factor that could have an impact on parking behaviour. Lastly, also the information on people's socio-demographics is gathered to be able to identify the distinct user groups.

After a pilot survey was conducted and improvements to the design are made, the survey is sent out. The survey yielded a total of 269 useful responses. Initial analysis using descriptive statistics reveals limitations in sample representation, particularly in terms of education level and work situations. This influences the results. Especially for the categorisation of these user groups for the education level and work situation, not all groups could be composed. Furthermore, if no effect on the effectiveness is found it cannot be concluded this effect is truly not there in the entire population, only for the groups now included. Moreover, the visibility of the signs is found to be poor, with only a small percentage of participants indicating all signs shown to them. Indicating that traffic signs are not a suitable syntax for cyclists, at least if they are used exclusively. The understanding of the signs is generally good with at least 90% of respondents identifying the meaning of most signs correctly, except for the negative educative sign, as shown in Figure 1, which was identified correctly by only 58% of people. In the end, the understanding of the signs was found not to influence people's choice behaviour.

The data is further analysed using discrete choice modelling. Various models are developed, to estimate the relative importance of all attributes included in this model. The aim of this research is to identify what communication strategies are effective in reducing fly parking for distinct user groups, to explain this with modelling, interactions of communication and socio-demographics are added to the model. These identify if belonging to a certain user group brings forth a different response to a communication strategy.

A complete MNL model is created where all significant interactions are combined. In this final model, the impact of socio-demographic factors on the choice of parking is also incorporated. All variables that were found to be significant are used to create the final MNL model. Once the simple MNL model works properly, an ML model is developed. The ML model acknowledges that a single individual makes multiple choices, referred to as panel effects, which is not possible for the MNL model. However, it should be noted that an ML model requires a better dataset to perform well. But even for the current dataset, an ML model was deemed the best performing one. The results of this final model are shown in Table 2, the beta values indicate the effect of this attribute on the utility function and the Rob. p-value being smaller than 0.05 indicates the result is significant

Table 2: Final ML model with panel effects

	Value	Rob. p-value
ASC inside	0,92	0,00
ASC outsie	1,57	0,00
β hazardous comm	-2,66	0,00
β hazardous x infrequent	1,09	0,00
β negative comm	-1,66	0,00
β neutral comm	-2,91	0,00
β neutral x expensive on outside	-0,38	0,03
β neutral x infrequent	1,00	0,00
β neutral x young on inside	-0,24	0,02
β none x expensive on fly	-0,74	0,00
β Inside	0,92	0,00
β Long inside	-3,34	0,00
β Long fly	-2,40	0,00
β Rack	2,49	0,00
β WD outside	-0,03	0,00
β WDfly far	0,89	0,00
β young on inside	-0,24	0,02
Sigma_panel	-1,39	0,00

To create the context in which communication strategies operate, first, the effect of the attributes related to the parking space and the individuals using it are analysed. The alternative specific constants being significant indicates the model does not fully explain all choice behaviour. People generally prefer inside parking over outside parking. However, the model indicates that for young individuals, this positive utility for inside is slightly lower. When it comes to long-term parking, individuals are more likely to choose inside parking or fly parking compared to formal outside parking spots. The presence of bike racks positively influences the choice of parking. Moreover, the disutility of outside parking increases as the walking distance to the parking spot increases. Interestingly, having a fly parking spot placed slightly further away has a positive effect on the likelihood of choosing fly parking. The presence of sigma_panel greater than 1 indicates heterogeneity in the choices made by individuals, which aligns with expectations.

Moving on to the evaluation of communication strategies and their interactions, the neutral educative strategy, as shown in Figure 2 and Figure 3, proved to be ineffective in reducing fly parking yielding unexpected negative consequences. Promoting these parking spots increased their disutility rather than increasing their attractiveness, as intended. Therefore, this strategy is not further discussed. On the other hand, both the negative educative strategy, as shown in Figure 1 and the hazardous strategy, as shown in Figure 4 were highly effective in reducing the choice probability of fly parking, only a small choice probability for fly parking is left when these strategies are applied. Where the hazardous strategy is slightly more effective than the negative educative strategy. However, the latter is unaffected by interactions with socio-demographic factors. Indicating it is equally effective for every user group.

Next, the interactions of socio-demographics with no communication, and socio-demographics with the hazardous strategy are explained. When no communication is provided, individuals owning expensive bikes show a higher disutility for fly parking compared to those with cheaper bikes. The interaction of infrequent users and the hazardous strategy shows this communication strategy is less effective for them, making them three times more likely to choose fly parking, compared to frequent users.

There is little variation in the data for education level, with the majority of respondents having followed a higher education. As a result, it was not possible to investigate the impact of education level on individuals' responses to communication strategies. Regarding the work situation, only two groups in the dataset were large enough to estimate the model on, namely being a student/scholar or a full-time worker. The ML model did not yield significant results, the separate and combined MNL model indicated significant interaction effects. Consequently, the influence of being a student or a full-time worker on the effectiveness of communication strategies remains inconclusive. These limitations highlight the importance of better data distribution to accurately estimate results in the ML model, especially in terms of education level and work situation.

With these beta values, the utilities of each parking option can be determined. Even when communication is presented prohibiting fly parking, this indicated that if the walking distance towards outside parking becomes too long, people become more likely to choose fly parking, even for long-term parking. Apparently, after a certain distance, people are willing to accept the associated risk of fly parking, even for long-term parking. The results also showed younger individuals are more sensitive to communication strategies prohibiting fly parking when they are seeking long-term parking spots, perceiving a higher risk for such situations. Additionally, having a fly parking spot that is not placed directly next to a person's destination makes this spot much more attractive, by around 2.4 times.

In summary, the negative educative strategy and the hazardous communication strategy are both effective in reducing the choice probability of fly parking. With the hazardous strategy emerging as the most effective approach for behaviour change in bicycle parking, particularly among frequent bike users. This can be attributed to their dependence on bicycles for transportation and their prior experiences with bike removals. The perceived higher risk of their bikes being towed away enhances compliance with the rules. The neutral educative strategy, however, requires further investigation due to unexpected negative outcomes. In conclusion, the findings of this study emphasize the effectiveness of along-route communication strategies in motivating individuals to change their bicycle parking behaviour. Although interaction effects with communication strategies are present, it is important to note that most changes in choice the probability of fly parking is already achieved by implementing the negative educative or hazardous strategy. The impact of interactions is relatively marginal compared to the effectiveness of the communication strategy itself.

The presented research has several limitations, one of which is that the survey design lacked the inclusion of certain attributes, such as perceived safety. According to current literature, if formal parking options are perceived as safer than fly parking, it will likely influence women to choose the formal option more often. Furthermore, it is possible that the context in which the survey was conducted, without specifying the trip purpose and placing people in unfamiliar situations, influenced their decision-making process. The effect of a trip's purpose on communication effectiveness is currently unclear, people indicated rushing could influence their behaviour, so this could be a good aspect to study. Lastly, in familiar situations, people are likely to have more of a routine, which could be harder to change trough communication. However, these assumptions still need to be researched further in relation to the effectiveness of communication strategies.

Moreover, the respondents' representation in the study is not comparable to the Dutch population, which, as discussed, limits the generalizability of the findings. Lastly, the analysis revealed limitations when assessing the neutral educative strategy. For inside and outside parking, the signs always display a distance, which could have influenced the choice for this parking more than the communication strategy itself. Further investigation is necessary to determine the influence of factors such as distance indicated on the signs of this strategy, or how it can be better compared with the baseline level of no communication using a different research method.

For practical application, the study suggests that hazardous communication was the most effective approach to deter people from fly parking, as the effect of the interactions on the choice probability is minimal compared to the effect of the communication strategy itself. However, the effectiveness of traffic signs as a communication syntax is called into question. Therefore, alternative syntaxes and communication strategies should be explored in future research. Moreover, future studies should investigate the attractiveness of specific fly parking spots and the influence of situational factors, such as trip purpose and time constraints, and perceived safety on parking behaviour. It is recommended to obtain a larger and more representative dataset, especially in terms of education level and work situations, to draw generalisable conclusions for the entire population and create more specific user groups.

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1 Introduction

Cycling has been promoted by governments all over the world (Heinen and Buehler, 2019). This increased popularity of cycling has also inspired more research in the field. Even though bikes are typically parked most of the day, much of the research has focused on infrastructure needs for cycling, with little attention given to bicycle parking facilities. A literature review found that the majority of research in this area has focused on different preferences of people for bicycle parking or the supply of parking facilities, with a focus on locations near public transportation stations and stops, and generic locations such as educational institutions (Heinen and Buehler, 2019).

In the Netherlands, it is common for bicycles to be parked next to street furniture, such as trees or lampposts. People often moor their bikes to these objects. The practice known as 'fly parking' can cause a nuisance in city centres and obstruct side walks. Research from the CROW has shown that the number of bikes removed from city centres due to incorrect parking has increased in recent years (CROW, 2020). Whilst official parking spaces at racks or designated inside parking areas are often underutilized (Larsen, 2017). The lack of use of official bicycle parking spots may not only be due to a lack of capacity, but may also be due to a lack of user information and marketing (Fujii, 2005). According to a report from the transport institution in Victoria, Canada, the lack of information can significantly impact bicycle parking behaviour (Litman, 2006). It's not clear at this point what kind of communication would effectively encourage the utilization of bicycle parking spaces and reduce fly parking, and how this might differ for different user groups.

The purpose of this study is to identify and evaluate the response of specific user groups to communication promoting bicycle parking locations, to determine the most effective communication method for promoting the use of official bicycle parking spots and reducing fly parking.

1.1. Scope

This section will provide the scoping of this research because scoring plays a crucial role in identifying, objectives, and limitations of this study. There is currently little information about bicycle parking behaviour and the effect communication might have on it. To be able to perform this research within time and with the resources available for a master thesis, certain parts of the research need to be left out of scope. Communication is a very broad field of research that offers many ways and forms to communicate messages. Furthermore, the field lacks clear-cut outcomes, and papers often disagree on outcomes and whether they are applicable to all situations. Therefore, the research will focus exclusively on one form of communication.

The way communication is expressed is called the syntax (van Erp, 2007). The most common syntax for communication in traffic is currently provided by traffic signs along the road or on the road. Although these two types are very similar, they could already influence people's parking behaviour differently. Because of this, only one of them will be included in this research. Previous research has demonstrated the effectiveness of traffic signs in conveying clear and understandable messages to road users (Zhang et al., 2013). Moreover, it has been shown that the use of traffic signs to provide information near pedestrian crossings has significantly improved drivers' yielding behaviour in the interest of pedestrian safety (Pulugurtha et al., 2010). Therefore, traffic signs presented to cyclists along their route will be used, as these are the most common communication method in traffic and more is known about how they should be designed.

Moreover, not all types of parking can be included in the research because there are many options. Because there is no consensus on the definitions and factors to consider, it is difficult to distinguish between different types of parking in the literature. Here, the parking options that will be included in the research are introduced. Firstly, the type of parking depends greatly on whether it is inside or outside. Inside parking almost usually provides bicycle racks as well. So, the assumption is that this type of parking always provides bike racks. An example of such parking is presented in Figure 1.1.

Figure 1.1: Example of inside parking with racks

Figure 1.2: Example of outside parking with racks

This distinction also provides the next option, which is to park outside. Outside, there are several types of parking available. First, a more formal option is bike racks, which are provided in the city. An example of this is presented in Figure 1.2. Different types of racks could be used, but there will be no distinction between them. The other outside parking option mentioned in the literature is fly parking. In the literature, fly parking without mooring a bike to an object is not discussed. Therefore, only fly parking where bikes get moored to an object will be considered in this research, an example of this is shown in Figure 1.3 and Figure 1.4. Fly parking where bikes get moored to an object is also the most occurring type of fly parking in practice, as it is much safer.

Figure 1.3: Example of fly parking at a lamppost

Figure 1.4: Example of fly parking at a tree (Iyaf, n.d.)

So, this research introduces three types of parking, two formal ones in bike racks inside and outside, and an informal one, outside at street furniture and trees. The parking options are presented in an overview in Table 1.1.

Table 1.1: Parking alternatives offered in this research

Alternative	Parking option A	Parking option B	Parking option C
Inside/Outside	Covered	Outside	Outside
Bike racks/Street furniture	Bike racks	Bike racks	Street furniture

It is important to acknowledge that this study has several limitations. First, the scope of the research is limited to the use of traffic signs along the road as the syntax for communication and does not explore other potential communication methods. Secondly, the study focuses on specific types of parking options, while other parking options may have different influences on bicycle parking behaviour. Finally, the study is limited to urban areas and may not be applicable to rural or suburban settings. Despite these limitations, this study aims to provide valuable insights into the influence of communication on bicycle parking behaviour in urban areas.

1.2. Research objectives and questions

The purpose of this research is to examine the response of individuals to communication strategies aimed at educating people on the correct use of bicycle parking facilities, instead of fly parking, and to determine which communication strategy would be most effective. The main research question is, therefore,

What along-route communication strategies motivate distinct user groups most to change their bicycle parking behaviour from choosing fly-parking to parking at designated bicycle parking places?

In this thesis, it is important to investigate whether communication has an effect on people's parking choices. This should provide insight into whether communication could help reduce the number of people who choose fly parking and cause nuisance. To find the best strategy, first, the different options to communicate need to be found. So, the first sub-question is:

1. What communication strategies could be used for bicycle parking?

Another important aspect to consider when people make choices for bike parking is their preference for different types of parking, as these will also influence their behaviour. The communication strategies will not determine the entire choice, but will be correlated to these other factors. To take the other characteristics into account, they should be identified first. So, the following questions should be researched:

2. What factors are known to influence parking behaviour?

Traffic signs are chosen to be the syntax to convey the different communication strategies. A clear and accurate way needs to be found to present these messages through traffic signs, therefore the following sub-question is introduced:

3. What requirements should be met to clearly present these communication strategies, through traffic signs, to cyclists?

Next, a method for researching the effects communication has on people is needed. Furthermore, the goal of this research is to find people's responses. For this, the following sub-question below can be answered.

4. What method should be used to investigate people's choices when presented with communication about bike parking?
5. What are the different user groups that can be identified?
6. What are the responses of these different user groups to the communication strategies?
7. What communication strategies are effective for bicycle parking?

1.3. Research contribution

The proposed research is expected to contribute to both the scientific literature and the practice. Current research focuses mostly on the infrastructure needed for cycling and not on parking facilities, and even if research on facilities was performed, it mostly focused on capacity. The motivation behind bicycle users choosing a certain parking spot within the city centre is unknown. This research aims to fill a gap in the scientific literature regarding bicycle parking in generic locations within cities, by investigating whether communication can aid in determining individuals' parking and how this may differ across diverse groups.

Furthermore, the research aims to address the methodological gap in the current research on bicycle parking. Heinen and Buehler, 2019 argue that the current research mostly relies on cross-sectional studies, which limits our understanding of the topic and prohibits causal conclusions on the reported relationships. In addition, parking was usually only one of the many factors included in these types of research. Since the findings in these studies are likely affected by the inclusion or absence of other factors describing parking behaviour. The proposed research should provide us with additional information about bicycle parking and how the choices for a certain spot are influenced, and lead to more valid and general findings in the future.

The research also aims to have a practical contribution. By examining how the location of bike parking can be effectively communicated to different user groups, the findings from this research could help municipalities to improve the use of bicycle parking within cities. Better insights into how people choose a bike parking spot and how to promote parking facilities help to develop a strategy that works well and helps reduce the nuisance of incorrectly and illegally parked bikes within city centres. So, this research is expected to contribute both to the practical and scientific understanding of bicycle parking in generic locations within cities.

1.4. Report outline

This report is structured as follows. Firstly, in chapter Chapter 2, a comprehensive review of the literature is provided, focusing on bike parking behaviour and its influencing attributes. Additionally, it provides information on communication strategies that could be utilized in this research. The following chapter, Chapter 3, outlines the method that will be employed to study the impact of communication on parking behaviour in this research. In Chapter 4, newly designed traffic signs that are chosen as the form of communication is discussed. The chapter covers how they were developed for the previously identified communication strategies. Moreover, how the understanding of these signs should be tested is presented in this chapter. In Chapter 5, the survey design is presented and explained for each part of the survey, and possible improvements are discussed following a pilot study. In Chapter 6, initial data analysis is conducted using descriptive statistics, presenting the sample characteristics and analysing some preliminary results. In Chapter 7, the data analysis is further explored, where an MNL model is developed. Interactions between the communication strategies and socio-demographics are examined, and an ML model is built that includes all variables to help develop the best model possible with the current dataset. Conclusions based on the data analysis are drawn in Chapter 8 and linked to the findings in the literature review. Lastly, in Chapter 9, the research's limitations are discussed, and recommendations are made for practice and future research.

2 Literature review

In this chapter, the first step of this research is presented: the literature review. In the first section, Section 2.1 theory on communication is presented, and communication strategies are introduced. Of course, communication is not the only thing influencing parking behaviour. So, Section 2.2 other factors influencing parking behaviour are discussed. Lastly, in Section 2.3 some background on the design of traffic signs is presented, since these are used to convey the communication.

2.1. Types of communication

The goal of this research is to identify the influence of communication on parking behaviour. In this section, an introduction to communication and its different aspects is given. Secondly, communication strategies are identified from the literature and are described. This section should provide answers to the following sub-question:

1. What communication strategies could be used for bicycle parking?

2.1.1. Introduction to communication

Effective communication is essential for policymakers to successfully implement new policies and effect behavioural change. When researching the effects of communication, it is important to consider some basic communication principles when choosing which communication strategy to use. In this part, these basics are presented.

Communicating can be defined as the exchange of information or messages from a sender to a receiver. The goal can vary, it can be instrumental or non-instrumental. Non-instrumental communication is seen as a form of expression or a ritual. Whilst, instrumental communication is designed to elicit a specific action or behaviour change from the receiver (van Erp, 2007). Since this change of behaviour is what is researched, only information on instrumental communication is described in the following part.

A successful communication strategy should begin with analysing the attitude, social norms, and feasibility of compliance with the policy among the target group. As individuals often interpret information differently and therefore communication could be more or less effective (Nelissen, 1997). Therefore, it is important to research these different responses from individuals to communication and the effect the communication has on their behaviour. This might help to target a specific group better in the future.

To be able to assess the effectiveness of communication on behaviour, McGuire developed a model. This consists of the following three phases:

- Orientation phase: people need to be exposed to the information, give it attention and should have an appreciation for it
- Acceptance phase: people should accept the message and change their attitude towards the situation and be willing to change their behaviour
- Integration phase: change in behaviour should solidify and should not become a one-time action (McGuire, 1989)

All these phases should be successful to have an effective communication strategy. In this thesis, the first two phases will be tested. For the first one, people are provided with information on the parking situations, which represents the orientation phase. The question is whether they change their behaviour based on the communication provided, which is the acceptance phase. Whether this change in behaviour solidifies is the last step in assessing how effective the communication is, but in the short time this research will run it will not be possible to assess this last phase.

2.1.2. Communication Strategies

Studies have identified three aspects of information: semantics, syntax and pragmatics. In other words, the content, the way it is expressed and its effect on the receiver's behaviour respectively (van Erp, 2007). Traffic signs was already determined as the syntax. The pragmatics is what is researched. What remains to be identified is the semantics. Different types of semantics are described in this section. Four categories for the semantics of the communication strategy are described. These categories are (van Erp, 2007, Fujii, 2005):

- Persuasive Communication: Processes intended to achieve specific persuasive goals
- Educative Communication: Explanation of current or new regulations
- Hazardous/Threatening Communication:
    - Using sanctions, making people aware of patrols and costs of violation
    - Making people fear the consequences to themselves
    - Threatening damage to a person's reputation
- Normative Communication: Making people aware of social norms and the legitimacy of regulations

These categories are introduced in the literature on communication in relation to the enforcement of policies (van Erp, 2007). This makes them very relevant to this research, as it is about the effectiveness of communication strategies that could be used when the new policy on bicycle parking is introduced. The communication types introduced above will be explained and how they can contribute to an overall communication strategy will be analysed in the next sections.

Persuasive Communication

Previous research has demonstrated the effectiveness of persuasive communication in changing bike parking behaviour. In a study, people were presented with advice to seek information on where they could park their bikes before making a trip. This research found that persuasive communication could contribute to reducing the amount of inappropriate bike parking (Fujii, 2005). According to other literature, this type of communication is best suited for this type of communication before a trip. The research conducted for this report only includes communication through traffic signs along the route. As persuasive communication works best through communication presented before a trip, this type of communication will not be investigated further in this research.

Educative Communication

Educative communication aims to explain regulations to the public and leaves people to make their own decisions (van Erp, 2007). The literature suggests that certain aspects are important to consider when using educative communication. These will be discussed in this section.

Firstly, the information should be presented to people who can change the behaviour in question (Magat et al., 1992). Furthermore, it was found that behaviour meant to be changed by educative communication should be easy to change and not interfere with people's daily routines too much (Goldenbeld and Wisman, 2004). Other research found that the information presented should be new and not something that reminds a person of something they already knew (Viscusi, 2007). Furthermore, the existing attitude of the receiver towards the subject is important in the decisions they make. Information can make people reconsider their position critically, but if a negative attitude already exists, just presenting information will probably not make people change their behaviour (Goldenbeld and Wisman, 2004).

Hazardous Communication

Hazardous communication includes two types: first, threatening with legal action such as sanctions or fines, and secondly, making people fear the consequences to themselves or their health (van Erp, 2007). While much research has been done on hazardous or threatening communication recently, little consensus exists on the effectiveness of this communication strategy (Peters et al., 2013).

A theory that currently prevails in this field, states that behaviour change will only occur with threatening communication when there is also enough perceived efficacy. Efficacy is one's ability to negate harm or losses (Peters et al., 2013). Only when both the perceived threat and efficacy are high, people will change their behaviour. The first type of communication, threatening with sanctions, is often used to enforce policies (van Erp, 2007). However, when designing a communication strategy, efficacy is not always considered, which could affect the effectiveness of the strategy.

Additionally, people are more likely to obey the rules when they feel the chances of getting caught for an offence are higher (Klepper and Nagin, 1989). This can be achieved by indicating that checks will be held. The chance to lose something is also always perceived as worse than the chance to win. Therefore, people often overestimate the chance to lose something, which could have a positive effect on compliance with the rules (Kahneman and Tversky, 2013). Of course, some checks should also actually be held. Otherwise, the effect will disappear over time (van Erp, 2007).

The second communication type, utilization of fear-inducing communication strategies, is often employed in situations where potential health concerns are present. For example, the depiction of possible illnesses on cigarette packages is utilized to discourage smoking. However, research suggests that this method of communication, which aims to induce fear, is ineffective at best (Peters et al., 2014). Studies that did find a positive effect of fear-inducing strategies have been criticized for methodological flaws or for only examining intentions and not actual behaviour (Peters et al., 2013). Whilst other research has proven that there is a discrepancy between intentions and behaviour. This means people's intentions do not always induce an actual change in behaviour.

Normative Communication

Many individuals comply with rules and regulations not solely due to the threat of punishment, but also due to certain norms and values. Norms play a significant role in behaviour (Fujii, 2005, Andreoni et al., 1998), however, little research has been done on how norms can be used in communication to persuade compliance with policies (van Erp, 2007).

There are two types of norms: personal norms and social norms. Both are affected by the feeling of legitimacy of the rules and regulations, and whether the government as a whole is seen as legitimate. In this research, the legitimacy of the government as a whole is not considered to be a problem, as it is not typically an issue in the Netherlands.

Social norms involve people relating their behaviour to what others, they consider equals, would do. A study on bicycle parking around stations found that an individual's choice of parking strongly depends on the decisions made by others before them (Fujii, 2005). Research shows that making people aware of the behaviour of the majority can make them more likely to follow rules as well (Peters et al., 2013). Positive values should be focused on, as research has shown that focusing on negative values and what people should not do, is ineffective (van Erp, 2007).

Personal norms involve sticking to behaviour even when no one else knows about it (Roth et al., 1989, p119). Research in law and economics found that people may only accept a norm and norm-activating information if they agree with the norm becoming a policy or law themselves (Tyran and Feld, 2005). Therefore, it is quite difficult to use this communication method to induce a change in behaviour.

2.1.3. Conclusion on communication strategies

Some requirements of communication strategies were identified, and it was also clear that these were not always considered in previous use of these communications strategies. But the effectiveness of the different communication strategies that were identified does not become apparent from the literature.

Persuasive communication was already researched and was proven to be effective, so it is not investigated in this research. Educative communication can be used to achieve a change in behaviour, but it must comply with certain requirements to be effective. For research on bicycle parking, it should comply with most of the previously mentioned requirements. Firstly, the fact that people can change their behaviour, toward bicycle parking appears to be possible for people without it interfering with their daily routine too much (Magat et al., 1992, Goldenbeld and Wisman, 2004). Next, the information that is presented to them in this research will be new. However, in real life, this may change after some time, this should be kept in mind when analysing the results (Viscusi, 2007). There is currently no clear preference for which type of message should be displayed, either positive or negative (Magat et al., 1992, Goldenbeld and Wisman, 2004).

Then there is hazardous communication. Previous research has shown that fear-inducing communication is ineffective. Therefore, this variant will not be used. Therefore, only hazardous communication involving threats of legal action or sanctions will be deployed. The focus of the message in hazardous should be on the fact that checks are being held, not on the severity of the punishment (Klepper and Nagin, 1989).

Lastly, there is normative communication. With personal norms, it is difficult to change behaviour, and therefore this strategy is not used in this research, it will only focus on social norms. The most important things here are that the regulations feel legitimate and focus on positive values (van Erp, 2007). To achieve this, it is good to assume enough bike parking spaces are provided. Because, if there is not enough space available, the regulations might not feel legitimate.

2.2. Factors influencing parking behaviour

In this section, factors that have been proven to be important to people when choosing a bike parking spot are introduced. These factors are divided into three categories: characteristics of the parking, characteristics of the trip for which a parking spot needs to be found, and users' personal characteristics. This provides an answer to the following sub-question.

2. What factors are known to influence parking behaviour?

2.2.1. Characteristics of bike parkings

In this part, characteristics of bike parkings that influence bike parking behaviour are described. There is little literature on bike parking in city centres. Therefore, literature on bike parking facilities near stations is studied (Heinen and Buehler, 2019), and research on the promotion of cycling in general, which mentions preferences for bike parking within cities.

The most important factors, which are discussed in multiple papers, are listed in Table 2.1. There are plus and minus signs in the table to indicate whether these factors have a positive or negative effect on the use of bike parking spaces.

Table 2.1: Overview of parking characteristics from literature

	Perceived safety	Stealing bikes	Walking distance to destination	Higher quality	Costs	Spaces available	Unorderly
Arbis et al., 2016		-	-				
Yuan et al., 2017	+	-		+		+	-
Molin and Maat, 2014	+	-	-	+	-		
Celis and Bolling, 2001	+	-	-	+	-	+	-
ProRail, 2005	+		-	+	-	+	-
Rietveld and Daniel, 2004	+	-			-		
Majumdar and Mitra, 2015	+	-			-	+	
der Spek and Scheltema, 2015	+		-	+	-	+	

Perceived safety is crucial to encouraging the use of bike parking facilities (Celis and Bolling, 2001, Yuan et al., 2017). However, perceived safety depends on many factors. Like the presence and type of surveillance and the amount of daylight present (Molin and Maat, 2014). Bike theft risk also affects parking choices and their perceived safety of them (Yuan et al., 2017). Surveillance can prevent theft, but people could also choose to park their bikes in view of shops and other people (Arbis et al., 2016). There is no one-size-fits-all solution, as the influence of security measures on parking behaviour varies by user group (Molin and Maat, 2014).

The next factor is the walking distance, people usually try to minimize the walking distance towards their destination as much as possible. However, people may be willing to walk a little further for a higher quality or free storage (Molin and Maat, 2014). Nonetheless, most literature shows that people prefer free storage and that, along with walking distance, costs are one of the most influential factors.

Space availability and facility appearance are also important for bike parking usage (der Spek and Scheltema, 2015, Yuan et al., 2017, Celis and Bolling, 2001). People are less likely to use a facility if they have to search for a space or if the facility looks unorganized.

There is also a factor that is not mentioned in multiple studies, but they may still be relevant to include. Having sheltering is indicated to be a benefit of a bicycle parking facility by one paper of Yuan et al., 2017. Coverage is also mentioned in some studies on parking facilities near stations. However, in these studies, it is often included as part of one description, for instance covered parking with surveillance, which you have to pay for (Molin and Maat, 2014). The result of the effect of inside parking are not presented separately, and therefore it is difficult to determine its effect.

2.2.2. Trip characteristics

In this section, the trip characteristics that could influence parking behaviour according to the literature are discussed. A factor that influences parking behaviour is the duration of stay (Rietveld and Daniel, 2004, Majumdar and Mitra, 2015). If people are planning to stay for a longer period of time, they are often willing to walk a bit further to their destination if they can park their bike in a safer, or higher quality facility. In a systematic review on bike parking, it is also suggested that the frequency of bike trips to the city centre may be an important characteristic to consider (Heinen and Buehler, 2019).

2.2.3. Personal characteristics

Lastly, personal characteristics, or socio-demographics, influencing bicycle parking behaviour that are identified in the literature will be discussed. There are several personal characteristics, or socio-demographics, that can influence bicycle parking behaviour. Again, the factors that are mentioned often, are presented in an overview in Table 2.2. Since the effect of these factors on parking behaviour is not clear from the literature, this is not indicated for these factors.

Table 2.2: Overview of personal characteristics from literature

	Gender	Age	Occupation	Price/type of bike
Majumdar and Mitra, 2015	x	x	x	
der Spek and Scheltema, 2015			x	x
Rietveld and Daniel, 2004	x	x	x	
Heinen and Buehler, 2019		x		x

Gender is one of the personal characteristics that literature has shown to influence behaviour. In the context of bicycle parking, it has been found that women place a greater emphasis on feeling safe when choosing a parking spot compared to men and thake less risks (Majumdar and Mitra, 2015, Rietveld and Daniel, 2004).

Age is another factor that can influence behaviour. Younger people tend to make a higher proportion of trips by bike compared to other age groups, possibly because they have less access to alternative modes of transportation and are therefore dependent on their bikes (Rietveld and Daniel, 2004). However, younger people may also be more likely to engage in unlawful behaviour, such as illegally parking their bikes (Kaplan et al., 2018). On the other hand, older people may have more routine behaviour and a greater need for clarity, which could make it harder for them to change their behaviour (Rietveld and Daniel, 2004).

Socio-demographics such as education level and occupation may also influence behaviour according to the literature. It is unclear what the effect of these variables will be on the effectiveness of communication and bicycle parking behaviour, as little about this is known.

Using a bike frequently or less frequently is also included as a variable to be captured, as this might have an effect on behaviour. Frequent users could have more of a routine in parking behaviour, which is harder to change. But they might also be more dependent on their bike, making them more carefull.

Finally, another characteristic which is introduced as a kind of personal characteristic is the type or price of a bike. For example, e-bikes, are becoming increasingly popular in the Netherlands with approximately 2.9 million e-bikes currently in use and an estimated 50% of new bikes being e-bikes in 2020 (BOVAG and rai vereniging, 2021). These are pricier than traditional bikes. Research has indicated that people may treat the parking of these more expensive bikes differently (Larsen, 2017, der Spek and Scheltema, 2015, Heinen and Buehler, 2019).

2.2.4. Conclusion on characteristics

The literature identified characteristics of bike parking that influence bike parking behaviour. To assess the potential impact of communication on bike parking behaviour, it is important to consider these factors.

In terms of perceived safety, the current state of knowledge regarding bike parking in the city centre is largely unexplored. There are three more influencing characteristics of parking spots introduced in the literature. The costs, crowdedness, and the walking distance from the parking to your destination. Especially the costs and walking distance are identified as very influential factors. Another factor that was also identified in the literature as having an effect on parking behaviour was the length of stay of a certain trip. According to the literature, this is an important factor to consider when looking at parking behaviour.

Lastly, the literature showed that even in similar situations, with the same options provided, people might make different decisions. According to the literature, personal characteristics like gender, age, education level and work situation could have an effect. Furthermore, the price of a person's bike and the frequency of use could have an effect. These could help identify user groups and assess the most effective communication strategies for each group. So, it is important to also collect information on these personal characteristics, nest to the choices people make in terms of parking

2.3. Traffic signs

In the previous section, the semantics of communication were discussed. The next important aspect of communication is syntax. As previously determined, the focus of this research is on along-route communication, through traffic signs. The traffic signs needed to convey the communication strategies that were introduced previously do not currently exist and need to be designed. In this section, aspects to consider when making such a design are discussed. This should provide an answer to the following sub-question:

3. What requirements should be met to clearly present these communication strategies, through traffic signs, to cyclists?

According to the literature, traffic signs should meet certain criteria to be effective, such as commanding attention, conveying a clear and simple meaning, commanding respect from road users and providing adequate time for proper response (Zhang et al., 2013). However, there is disagreement among studies regarding which factors have the greatest impact on driver performance and reactions. A more recent, study suggests that all factors, except simplicity, have a significant impact (Ou and Liu, 2012), while an older study only found a correlation with people's familiarity with the signs (Ng and Chan, 2008). So, no consensus on this exists in the literature. The only factor that is agreed upon is that familiarity is important in traffic sign designs. Therefore, the signs should be as familiar as possible. How this is incorporated in the design is discussed in Chapter 4.

An aspect that the literature does agree upon is the importance of a good understanding of signs. Poor comprehension of the sign can lead to a bad memory of sign meanings and could decrease the likelihood of effective reactions (Charlton, 2006). Additionally, socio-demographics such as age, gender, driving experience, culture, and educational background can also affect comprehension. Therefore, it is recommended to keep signs simple and familiar, without unnecessary or decorative elements (Zhang et al., 2013).

Standard attributes such as shapes and colours are used to convey specific messages in The Netherlands to help people familiarize with the meaning of signs. For example, triangular signs convey warning messages, while circular blue and white signs convey a commandment. Another factor adopted in the design of road signs in The Netherlands, that is promoted in the literature, is the use of symbols (Cominelli, 2019). Well-designed traffic signs with clear symbols can communicate instructions quickly and aid road users with reading difficulties (Kaplan et al., 2018), where some extra information is often provided by a small rectangular sign under the main sign. To ensure readability, the contrast in colour between the sign and text should be large enough (Dwiputri and Swasty, 2019).

2.4. Conclusion on literature

Some communication strategies that are promising to use in changing bicycle parking behaviour were introduced in this chapter. Along with the information on what is important when translating these strategies into traffic signs. Moreover, many characteristics in different categories that have an impact on bicycle parking behaviour. In conclusion, understanding the factors influencing parking behaviour, as well as the requirements for clear communication through traffic signs, is crucial in promoting effective bike parking and ensuring efficient communication with cyclists.

Consequently, the factors introduced in this chapter will be considered in the continuation of this research. The information on the communication strategies and traffic sign design will be used to design the traffic signs needed for clear communication. This is done in Chapter 4. Moreover, when determining the research method, it should be kept in mind that the characteristics that impact bike parking behaviour, should also be included, alongside the communication strategies.

3 Methodology

The literature review showed the factors important to consider. This chapter will describe how these could be researched. The method that will be used to collect data is presented in Section 3.1. Next, in Section 3.2 the way a choice experiment is set up is given. Lastly, in Section 3.3 the way the data can be analysed is explained. Figure 3.1 shows an overview of all steps taken in the research. This should provide an answer to the following sub-question:

4. What method should be used to investigate people's choices when presented with communication about bike parking?

3.1. Data collection method

This research is meant to find out how different user groups respond to communication strategies that encourage people to use bicycle parking facilities instead of fly parking. As presented in the literature, not only the communication strategies determine people's parking behaviour.

To assess the influence of these factors on people's choices, observation data on their choices must be collected. However, people's trade-offs cannot be asked for directly, as people often don't know their trade-offs when they are making decisions (Chorus, 2021). To gather inside into their trade-offs, a choice experiment should be used. Respondents are presented with a series of choice situations in which they are asked to choose between different options. It is possible to estimate the relative importance of different factors and how they influence a person's decision-making by analysing the responses to these choice tasks.

To perform a choice experiment, choice observation data is needed. If more trade-offs are included, this also means more observation data is needed to analyse the responses to the choice tasks and get statistically significant results (Molin, 2018). Observation data can be gathered in different ways. Three approaches for this research are discussed below: a real-life experiment where people are recruited to participate, in a simulation environment where the situations are simulated, or through an (online) survey.

Firstly, the real-life experiment, a major advantage of this technique is that the answers received will be very true to the actual choices people would make. But it would be very difficult to set up such an experiment within the limited time and resources of a master thesis project. Permission by the municipality to carry out such a test would be needed, which could take a lot of time. It's hard to account for all the variables in a real-life experiment because a lot is still unknown about bicycle parking in the city centre and how communication affects it. This makes it hard to account for all the variables.

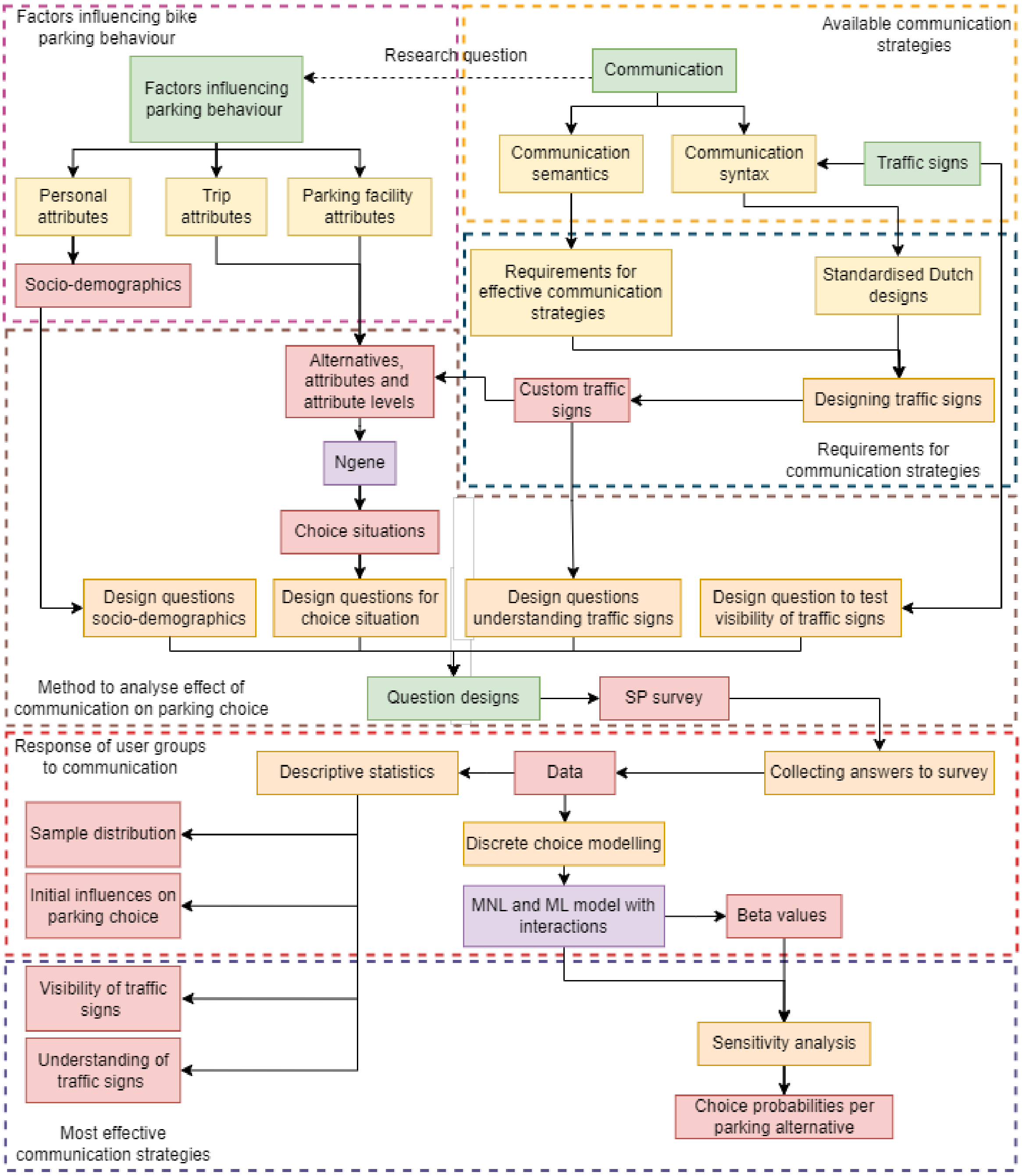

Figure 3.1: Research approach overview

Next, there is the simulation option. According to the literature, this type of experiment should provide results that are very similar to the real-life choices people would make. However, this type of experiment runs the risk of becoming repetitive if multiple scenarios are asked. The participants could be overloaded with too much information and choices, which could lead to a lack of focus and interest in the entire choice situation. Therefore, many participants would need to be recruited to gather enough data. Since using simulation also requires people to be present at a certain time and place, this will be difficult to achieve within the limited time span.

Lastly, there is the option of an online survey. An online survey can be distributed easily, which makes gathering responses easier. The choices in a survey can be observed in two ways: through revealed preference (RP) and stated preference (SP). The pros and cons of both methods are discussed below.

Revealed preference

The main advantage of RP data is that it contains people's actual choices (Train, 2009). However, the downside of this method is largely the same as for a real-life experiment. According to Train, many respondents are needed for this type of research, as only one choice from each respondent is known. This limited data set could also have insufficient variation, which could make it hard to estimate important factors (Train, 2009). Furthermore, this method is only suitable to research alternatives and attributes that exist currently or have existed in the past (Molin, 2018).

Stated preference

In an SP experiment, hypothetical choices, presenting new alternatives or attributes can be introduced (Train, 2009). This also means multiple attribute combinations, which might not exist in real life, can be introduced in the survey. Furthermore, a much smaller sample size is needed for reliable estimates, since multiple-choice situations can be presented to the respondents (Molin, 2018).

However, for an SP survey, one should always keep in mind that the answers people give might not represent what people would actually do in real life (Train, 2009). This can be due to three different things. The first reason is that a respondent may give an answer he or she thinks is the expected answer (Train, 2009). Secondly, respondents don't experience the consequences of the choices they make. Lastly, a reason for not getting people's actual choice in an SP survey is that they have perfect information about the situation, based on which they decide, this might not be the case in real life (Molin, 2018).

Conclusion on data collection method

In conclusion, this research aims to test hypothetical situations that can be created through a real-life experiment, simulation, or a stated preference survey. However, the inclusion of unknown factors in a real-life experiment and the demanding nature of collecting multiple responses in both a real-life experiment and simulation make a stated preference survey the preferred alternative for this research.

To improve on the drawbacks of a stated preference experiment, the design needs some attention. To address the fact that people might give other answers than they would in real life, the questions should be developed in such a way that they represent the situation as realistically as possible in a survey. This is discussed further in Section 5.2. The other two points: people not experiencing the consequences and people having perfect information, should always be kept in mind when analysing the results, meaning the effect of the communication in the results might be slightly more positive than it will be in real life.

3.2. Choice experiment

A choice experiment must be developed with the choice situations that should be included to design an SP survey. This section describes the different parts of a choice experiment and describes how the choice sets are developed.

3.2.1. Alternatives, attributes, and attribute levels

Choice sets consist of alternatives, attributes, and attribute levels. If more alternatives, attributes, and attribute levels are included, this gives a more complete picture of the trade-offs people make. However, an excessive number of attributes could result in a high number of trade-offs, which could lead to people focusing on a few dominant attributes or even random selection (Train, 2009, de Dios Ortúzar, 2011). Therefore, it is important to find a balance between including enough choice sets to provide a comprehensive understanding of trade-offs, while also avoiding overwhelming individuals.

3.2.2. Experimental design

Apart from the number of attributes and levels, the experimental design also influences the number of questions. There are different ways in which a survey can be designed: *full factorial design, fractional factorial design, and efficient design*. The full factorial design means including every alternative with all the combinations of attributes and attribute levels (ChoiceMetrics, 2021). This is only possible when a small number of attributes and attribute levels are included. It is also possible to create a survey with fewer choice sets. These designs can be made using the survey software Ngene. When the number of attributes and attribute levels is decided upon in Chapter 5 it can be decided if a full factorial design is feasible or if the design explained below should be used.

The designs including fewer choice sets that are feasible to use also depend on other design choices. The aim of this research is to investigate the impact of communication on the choice of formal parking options versus fly parking. So, a comparison between two alternatives in each question should provide the needed information. Limiting each choice set to two alternatives also has another benefit. It simplifies the task of choosing for the respondents. To create such a design, partial choice sets are used. This design strategy and the requirements to use it are discussed in the next part.

Partial choice sets and design choices

It is only possible to use partial choice sets in the survey design if an efficient design strategy is used. To accomplish this, a function is created for each alternative, including all attributes. This allows Ngene to generate a design with added constraints. For an efficient design, prior knowledge, even limited knowledge of the sign of the attribute, is sufficient (ChoiceMetrics, 2021).

The Modified Federov algorithm is commonly used to create designs with partial choice sets.

This algorithm creates a design based on a candidate set for each iteration and calculates the efficiency error, referred to as the D-error. If the error of the new design is smaller than that of the previous design, the new design is saved and the next design is now compared to this design (ChoiceMetrics, 2021). So, a d-efficient design with partial choice sets is used for this research.

The candidate set is generated by creating a list of all possible combinations where one alternative's attribute level is given a very high or low value based on the prior's sign. Attributes with a non-linear relationship, such as trip length, parking alternatives, and communication, are dummy-coded to be able to estimate them The partial choice set value can only be added to a non-dummy-coded variable, so this is added to the walking distance. The candidate list of partial choice sets was created using Python, this is included in the appendix (Section A.1). One more important aspect is that not all combinations of attribute levels exist. This can be accounted for when creating the candidate list for the partial choice sets.

Generic or alternative specific

In the design of a survey, parameters can be added to the functions as alternative specific or generic. Designs, where the parameters are considered generic, can be smaller than designs with all the alternative-specific parameters. This helps to limit the number of choice sets needed. Each parameter that needs to be estimated requires an extra degree of freedom (Rose et al., 2008). To find a model that performs best, one should work with a hybrid model, combining generic and alternative specific variables. In this research, a hybrid model will be used. How this is constructed should be determined by how well a model performs. The performance measures are discussed at the end of this chapter, and if the variables included are significant.

3.2.3. Number of choice sets

The previous sections introduced ways that help to limit the number of choice sets. Now, the way the number of choice sets needs to be determined for a choice experiment is presented. As Ngene needs to be given the number of choice sets, it should develop a design for. The number of choice sets to be included in the survey is determined by two criteria. The first criterion is based on the minimum number of choice sets required based on the number of parameters included in the research. The second criterion is the attribute level balance.

Starting with the number of parameters included in the research, so the number of betas that need to be estimated based on this minimum number of questions that should be included in the survey is determined as follows. The calculation of the number of choice sets required for a model is shown in Equation 5.1.

$$\text{number of choice sets} > \frac{\text{number of parameters}}{\text{number of alternatives per choice sets} - 1} \tag{3.1}$$

The second criterion is attribute level balance in survey designs. This indicates all levels of different attributes appear an equal number of times in the choice sets included in the design. While attribute level balance is not a requirement, it is considered desirable for better coverage over the whole dataset (ChoiceMetrics, 2021). However, achieving attribute level balance can only happen when the number of choice sets and the number of attribute levels match, so this should be achieved when choosing the number of attributes and attribute levels. However, when using partial choice sets, attribute level balance cannot be fully achieved because some attribute levels occur less in the candidate sets or do not occur at all for certain alternatives. While constraints can be added to better achieve attribute level balance, only a few constraints can be added to the design, or it may prevent Ngene from finding a working design.

Lastly, apart from these design criteria, one should consider how many questions participants of a survey are able and willing to answer before a survey becomes too repetitive and people lose focus. Which may cause them to only focus on a small number of attributes or select an answer at random (Train, 2009, de Dios Ortúzar, 2011). 10 questions is often seen as the maximum desired.

3.3. Data analysis

Choice data is gathered using the SP survey. To analyse this data, two methods are used. The first one is some basic statistical analysis. These results will be presented in Chapter 6. The other method is using discrete choice modelling, how this should be done is discussed first in Section 3.3.2, below.

3.3.1. Descriptive statistics

It is important for the research to have a representative sample that is comparable to the Dutch national average in terms of socio-demographic characteristics. To assess the similarity of the study participants to this average, descriptive statistics are used. The survey results are compared to the official statistics from CBS, the national statistical agency, to verify representativeness. This will be done using a Chi-square test, comparing the counts in the sample to the entire population. To indicate the sample is comparable to the Dutch population, the p-value of this test should be 0.95 or higher for a confidence interval of 5%, 0.90 or higher for a confidence interval of 10%. For the chi-square test to be valid, it is important to ensure that the expected frequency in each cell exceeds 5 for at least 80% of the cells. Additionally, the minimum expected frequency in each cell should be greater than 1 (Field, 2013). Before the chi-square test is applied, these criteria should be checked.

Preliminary results regarding the parking choice are also presented. This should show how socio-demographics and other characteristics in the design affect the choice of parking, and which should be included in a model that best describes the choices of the different parking options with the current data. This influence is tested by comparing the counts per parking choice of a certain group, identified by the socio-demographics, to the counts of the overall sample using a Chi-square test. If the p-value of the Chi-square test is smaller than 0.05 this means, there is a significant difference between the sample and the population for a confidence level of 5%, again also a confidence interval of 10% could be used. The p-value should then be 0.10 or smaller.

3.3.2. Discrete choice modelling

The goal of this research is to identify what effect individual attributes have on the choice that is made, discrete choice modelling is a method that can be used to achieve this (Train, 2009). Based on trade-offs observed in the data, people's future choices are estimated. To create a discrete choice model, currently random utility maximisation (RUM) is most often used in transport (Heinen and Buehler, 2019, Ben-akiva and Bierlaire, 1999). It is also often applied in research on bicycle parking. The underlying assumption for this is that travellers exhibit rational behaviour and possess clearly defined preferences.

The utility could be described as the potential costs and benefits of an alternative for an individual. The utility of each attribute can be estimated using a model. Using these estimates, it is possible to predict the future decisions of different user groups in terms of bike parking behaviour. The utility U can be described by a systematic part V and a random part ϵ for each alternative i,Equation 3.2. Where V_i is described by the attributes x_{ik} combined with their weights β_k, which need to be estimated. The equations to calculate the utilities are shown in Equation 3.2 and Equation 3.3.

$$U_i = V_i + \epsilon_i \tag{3.2}$$

$$V_i = \sum \beta_k * x_{ik} \tag{3.3}$$

Since only the systematic part of a utility function can be known, only the probability of an alternative being chosen can be estimated, this formulation is shown in Equation 3.4. Python-Biogeme will be used to estimate the parameters β of the models that are described in the next part (Bierlaire, 2020).

$$P_i = Prob(U_i > U_j, \forall i \neq j) \tag{3.4}$$

It should be determined whether alternative specific constants (ASCs) need to be added to the function. ASCs account for the unobserved factors that influence choices and are not captured by the included variables in the utility functions. Previous literature suggests that adding ASCs is particularly important in labelled experiments. This is an experiment where one can associate many things with the name of an alternative. This experiment could be seen as a labelled experiment, as the parking option can be identified as formal parking, either inside or outside and fly parking. Therefore, ASCs will be added to the estimation of the models.

In this research, the β that will be estimated for the communication strategies describe their impact on the parking choice and indicate what communication strategies are effective. Along with other estimated βs for various characteristics and ASCs, these coefficients enable the estimation of the probability of selecting a particular parking alternative. Which characteristics are included based on the literature study is described in Chapter 5. The utility functions incorporating these variables are provided in the discrete choice modelling part, Chapter 7, which outline the steps involved in constructing the models.

Additionally, interaction terms between attributes and socio-demographic characteristics can be considered to assess whether the effect of a certain attribute varies across specific socio-demographic groups. This analysis provides insights into how belonging to particular user groups influences the effectiveness of communication strategies.

3.3.3. Model specification

To estimate the weights, β_k, shown in Equation 3.3, different models could be used. The Multinominal Logit (MNL) model and the Mixed Logit (ML) model will be used in this research. A comparison is made to evaluate the performance and quality of these models.

However, over the last few years, ML models have been used more often than MNL models. As it is more flexible and, according to McFadden and Train, 2000, it can approximate any random utility model.

Multinominal logit model

The MNL model is the simplest and most widely used one (Train, 2009). It assumes that the random term ϵ_i is independently and identically distributed (iid), which means that the variance of the random term is similar for each alternative, but they are uncorrelated. If alternatives share common factors, this assumption might not be correct. In this study, the formal parking option might be correlated.

Another drawback of the MNL model is that it does not recognise that multiple choice sets could be filled in by the same person. Therefore, it is not possible to capture the variations across individuals (Train, 2009, Ben-akiva and Bierlaire, 1999). In this study, people will be asked to indicate their preference for multiple choice situations, and it would be better to be able to capture these variations. Despite its limitations, the MNL model is often used because it is the simplest model and is a good starting point for estimating results. It also requires a much shorter computation time than the ML model. Therefore, the MNL model will be used as a base model.

Mixed logit model

The mixed logit (ML) model provides a solution to the limitations of the MNL model. The ML model can take on various forms, one of which is the panel model that considers all choices made by a single respondent. Since participants indicate their preference for different choice situations, panel effects will be added to the model to test if this improves the model.

Additionally, the ML model can handle situations where alternatives share common characteristics and are thus correlated. To account for this nesting effect, an additional error component is introduced for alternatives with shared features (Train, 2009). In the context of this study, the formal parking options may possess similar characteristics and could potentially form a nest.

Consequently, the model will examine the presence of this effect and determine whether it enhances model fit.

The model determines the significance of all variables as well as their value. However, when testing for a nest the value of mu that is obtained needs to be tested against 1, which is not the case in the estimation done. Only the standard deviation of the sample is known, therefore a sample t-test is used. It calculates the t-statistic by comparing the difference in mean from the sample ($\overline{x}$) and population (μ) using the variation of the sample (s) and the number of respondents (n).

$$t = \frac{\overline{x} - \mu}{\frac{s}{\sqrt{n}}} \tag{3.5}$$

The t-statistic is then used to compare to the critical value from the t-distribution with degrees of freedom based on the sample size. If the calculated t-statistic exceeds the critical value, it suggests that there is a statistically significant difference between the means of the two groups.

The ML model has one disadvantage compared to the MNL model, it requires a better dataset to achieve better performance (Train, 2009). Therefore, it should be tested if the ML model indeed performs better for the data collected in this research.

3.3.4. Goodness of fit

After the models have been computed, the performance of the model should be assessed. For discrete choice models, the likelihood ratio index is most often used (Train, 2009). This index, ranging from 0 to 1, indicates how well the model fits the data. To do so, the estimated model is compared to a base model. The closer the index is to 1 the better the fit of the model (Chorus, 2021). The equation to estimate the likelihood ratio index is given below:

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \tag{3.6}$$

Where:
ρ^2 = McFadden's rho-square
$LL(\hat{\beta})$ = Final log-likelihood; log likelihood of the estimated model
$LL(0)$ = Null log-likelihood

However, this number will always become higher when more parameters are added to the model. Therefore, another formula can be used where ρ^2 can be adjusted for the number of parameters (K) and penalises for including an excessive number of variables, that do not significantly improve the performance of a model. This equation is shown below.

$$adjusted\, \rho^2 = 1 - (LL(\hat{\beta}) - K)/LL(0) \tag{3.7}$$

If different models need to be compared, three other statistical tests can be used: the likelihood ratio test, shown in Equation 3.8, the Akaike Information Criterion (AIC), shown in Equation 3.9, and the Bayesian Information Criterion (BIC), presented in Equation 3.10. The higher the value for the likelihood ratio test, the better the model performs. For the AIC and BIC, this is the other way around, the lower the values, the better the model performs. The AIC value is primarily used to compare models that are nested, or in other words, when one model is a subset of the other. The BIC, on the other hand, is more appropriate for selecting models when the number of parameters in each model is different. The equations of these parameters are presented below, where K is the number of parameters to be estimated and N is the number of observations.

$$LR = -2(LL_A - LL_B) \tag{3.8}$$

$$AIC = -2LL + 2K \tag{3.9}$$

$$BIC = -2LL + K \ln(N) \tag{3.10}$$

3.3.5. Validation

Once a model is created that performs well according to the performance indicators, the model will be validated. Model validation is a crucial step in the process of developing a model, as it serves to assess its reliability and generalizability. By conducting validation, the performance, and accuracy of the model in predicting outcomes on independent data can be tested. Validation should ensure the findings from the estimations are not coincidental and would change for every other dataset the model is applied to, and should identify potential overfitting issues.

To ensure that the estimates of a model are not random and are independent of the specific dataset utilized for parameter estimation, a model should be able to consistently produce similar estimates for different datasets. When the model is found to be robust, it means, the findings are applicable to general situations, not just to the specific data it was estimated with.

Only one dataset is available, which is the one obtained for this research. So, to validate the model, sample enumeration will be used to create subsets of the entire dataset. The estimated betas obtained from the model estimated based on the entire dataset are compared to other models that were estimated using a random sample consisting of 80% of the entire dataset. These should provide similar estimates for different subsets of the data for the model to be robust. These values are compared to each other using a one sample t-test. When the estimates from partial samples are significantly different from the estimates from the entire sample, this indicates that the variable is not robust and therefore not representative of the entire population.

To address the issue of overfitting, the adjusted rho square value can be used. This is a measure that indicates how well a model fits the observed data. Therefore, the adjusted rho square of the models is also looked at to indicate model how well the model performs in explaining the variability in the dataset, based on the number of estimators included in the model.

3.3.6. Sensitivity analysis

Lastly, a sensitivity analysis on the model will be performed. Sensitivity analysis can help identify the attributes that have the greatest influence on choice behaviour and prioritize interventions or policy changes accordingly. In this research, it is interesting which attributes of communication or interactions with it reduce the use of fly parking most (Train, 2009). To conduct a sensitivity analysis, utilities for different scenarios are computed and compared. To create a scenario, the attribute values should be changed, so there could for instance be a scenario keeping all variables the same except the walking distance. By varying the attribute values, the corresponding utilities can be recalculated, and subsequently, the choice probabilities can be derived.

In the final step of the model assessment, a sensitivity analysis will be performed. The effect of the variation of different attributes on the choice probability for fly parking is studied, and what is most effective in reducing it. This should also provide an answer to the main research question about how different user groups might be affected differently by communication strategies.

4 Design of traffic signs

The chosen syntax for communication is traffic signs. Requirements for these signs were discussed in the literature review in Section 2.3. For the communication strategies identified in the literature review, these signs do not exist currently. So, these need to be designed. This chapter will explain how they will be designed. Answering the following sub-question:

3. What requirements should be met to clearly present these communication strategies, through traffic signs, to cyclists?

According to the literature review, it is important to be familiar with signs to achieve effective responses. Therefore, existing traffic signs are used as much as possible in the new designs. The goal of this research is to investigate how people could be moved away from fly parking towards the formal options through communication. So, all communication strategies should either encourage the use of the inside and outside parking options or discourage the use of fly parking. In each section, the requirements for the strategy are repeated, and the design made for each of the strategies is elaborated upon.

4.1. Educative

For the educative strategy, the literature indicated people should be able to change their behaviour, without it interfering with their routine too much, and the information needs to be new. Furthermore, the literature does not suggest a preference for a negative or neutral approach. To address this, two designs will be created, one utilizing a negative approach and the other utilizing a neutral approach. Both these designs are explained below.

4.1.1. Educative negative

A negative strategy discourages something and should therefore be applied to fly parking. This strategy will comply with the requirements for the educative strategy as it presents new information that fly-parking is forbidden. Furthermore, it is assumed that this strategy also does not interfere with a person's daily routine too much.

A sign prohibiting parking currently exists and is shown in Figure 4.1. There is also a variation of this sign indicating bikes and scooters should not be parked in a certain area, as shown in Figure 4.2. What needs to be clarified is that only fly parking is not allowed. This is done by adding a tree and lamppost with a bike placed against it. These were chosen as they should be identifiable, even from a distance, and cover most of the fly parking options in the city centre. To indicate a certain policy applies to an entire area, the word 'zone' is added in The

Netherlands. This is also done for the design of this traffic sign, as it should indicate fly parking is prohibited in the entire city centre. To include extra information, a small grey rectangular sign with black text on it is often added. This creates the final design shown in Figure 4.7.

Figure 4.1: Traffic sign forbidden to park

Figure 4.2: Traffic sign forbidden to park for bicycles and scooters

Figure 4.3: Traffic sign end of a parking zone

To indicate that the traffic signs no longer apply to a certain area, the same sign is displayed in grey tones with stripes through it, as shown in Figure 4.3. This design can be utilized to denote the end of a zone; however, it is not necessary to incorporate it in this study, as only the area where fly parking is prohibited is of interest.

4.1.2. Educative neutral

The neutral educative sign could inform participants of possible parking options, directing them to inside and outside parking spots offered. Again, this provided people with new information on where to park their bikes, at least initially, and the assumption is this does not interfere with people's daily routine too much.

Usually, a blue sign presenting a P is used to indicate a parking spot. A pictogram can be added to this to indicate for which type of vehicle the sign is meant for, as shown in Figure 4.4. Inside parking is often indicated with a sort of roof that is drawn on it. This sign is shown in Figure 4.6. These signs are combined to make a neutral educative sign for inside parking. The sign should also indicate which direction the parking spots are located. This is usually done using an arrow as shown in Figure 4.5, so an arrow is placed on the sign. Lastly, additional information should be provided with these signs, indicating the distance to the parking places. Currently, on traffic signs, this is done by indicating the number of meters a person should travel. Therefore, again a small sign is added at the bottom with the distance to the parking on it. The complete sign is shown in Figure 4.8.

Figure 4.4: Traffic sign bike parking

Figure 4.5: Traffic sign direction of parking

Figure 4.6: Traffic sign inside parking

The basis for the outside parking design is the same, but another way needs to be used to indicate there is outside parking at a rack available. In The Netherlands, a bike rack called a 'nietje' is often used to create parking spots in the city centre. Therefore, a pictogram of this will be used to indicate outside parking spots. Again, the direction where the parking spot is available, and the walking distance need to be indicated. This is done the same way as inside parking is done. The traffic sign for outside parking is presented in Figure 4.9.

Figure 4.7: Custom traffic sign educative negative communication

Figure 4.8: Custom traffic sign educative neutral communication for inside parking

Figure 4.9: Custom traffic sign educative neutral communication for outside parking

4.2. Hazardous

The hazardous strategy will indicate something is forbidden. Therefore, it should be applied to fly parking. The message displayed on the signs should focus on the fact that checks are being held, not necessarily on the punishment. Furthermore, the efficacy should be high according to the literature. It is assumed this is the case for this research as picking another parking spot, which is always available in this research, will negate harm or losses (Peters et al., 2013).

In order to make the sign familiar, the design for this strategy is based on an existing sign that indicates that parking in a specific spot is not allowed, as shown in Figure 4.10. This sign includes a forbidden to park sign. In the case of this research, it should present a specific type of bike parking, fly parking, is not allowed. To convey this message, the design of the original forbidden to park sign is replaced with the design of the negative educative strategy, as presented in Figure 4.7.

Making people aware of checks is also done in traffic signs indicating cameras are placed along the road to check the sped limit. This sign is shown in Figure 4.11, here the word 'Controle' is used to indicate this check. Therefore, this will also be used in the hazardous traffic sign. This sign now includes the necessary elements for a hazardous strategy. However, it will not look familiar to people in this way. Therefore, it is decided to add the pictogram of being towed away, as this makes the sign more similar to an existing sign such as in Figure 4.10. This picogram is altered slightly, replacing the car with a bike. Lastly, to indicate that the sign applies to the entire area and not just one spot, the word 'zone' is added using a small rectangular sign underneath the main sign.

Figure 4.10: Traffic sign do not block driveways

Figure 4.11: Traffic sign speed checks

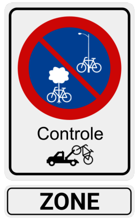

Figure 4.12: Custom traffic sign hazardous communication

4.3. Normative

Lastly, there is the normative communication strategy. In this research, the focus is on communication through social norms. The literature indicates that focusing on positive values is more effective than paying attention to negatives. So stating others, in people's eyes equals, also comply with the regulations makes people more likely to comply with the regulations as well. There is currently no traffic sign that translates a normative message that can be used as a basis.

Two designs were made, in Figure 4.13 the first design is shown. Both the correct and incorrect way of parking are shown, with similar pictograms as described for the communication strategies before. Text is also included to indicate most others park their bike correctly. Another design was made, shown in Figure 4.14. In this design, it was attempted to translate the fact that most others park their bikes correctly in a sort of pie-chart form on a round traffic sign with a red border, where part of that border was made green.

These designs contain a lot of information not only through pictograms but also through text, which makes them difficult to interpret in the short time a cyclist has in real life. Furthermore, these signs are very unfamiliar to people, which makes interpreting them even harder. It is concluded that it was not possible to create a clear sign that conveys a normative message. So, this communication strategy cannot be tested in this research.

Figure 4.13: Attempt at custom normative design 1

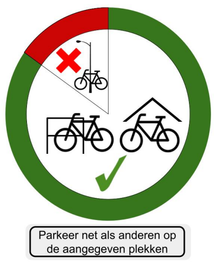

Figure 4.14: Attempt at custom normative design 2

Normative communication could also be conveyed differently, namely through the parking behaviour of others. This is an entirely different way of communication. One could include the normative strategy as a separate factor, by including a dummy variable showing whether others use the fly parking options, or not. However, this type of communication is provided to people differently. This could make it hard to analyse if people made this choice based on the normative effect this form of communication has, or simply based on the crowdedness of a certain parking spot. Since very little is known about the effect of communication and this factor cannot be interpreted in the same way as the other communication factors, it is not considered for this research. So for this research, the images that are shown with the possibility of fly parking, will not have bikes parked by other people in the images.

4.4. Conclusion on traffic signs

Based on the requirements for the design of traffic signs and for the communication strategies to be effective, traffic sign designs were made. The literature also indicated that people's understanding of traffic signs possibly influences people's reactions to them. Therefore, this understanding should be tested in the survey. Each sign is based on different aspects. Some of these aspects might not be intuitive to people and should be tested. Each of the aspects that should be tested is broken down below.

For the neutral educative strategy, most of the design is assumed to be intuitive, namely the rectangular blue sign with a P indicating parking in a certain direction at a certain distance. These parts will therefore not be tested. The only part that is new is the part indicating inside and outside parking. It should be tested if these additions are clear to people.

Next for the negative educative strategy, the forbidden to park sign is basic information, needed to understand this sign, so the meaning of this sign should be repeated. The part that was added to this sign is a tree and lamppost, next to which a bike is parked. It should be tested whether people understand this indicates fly parking. It is also not entirely certain if everyone is familiar with the addition of a zone for this sign and the hazardous sign. So, this should be tested.

For the hazardous strategy, the understanding of the forbidden to use fly parking sign was already tested in the negative educative strategy. It should be checked for this sign if people understand checks are being held and that wrongly parking a bike will result in being towed away.

To assess if this understanding has an influence on the parking choices people make, survey questions should be created to test the understanding of the signs. The question that will be created are discussed in Section 5.2.2, in the next chapter.

5 Survey design

Chapter 3 introduced an SP as the method used to identify choice behviour. The attributes that could be included in the choice sitautions were identified in Chapter 2 on the literature review. In this chapter, the design of the choice situations. First, the design of the choice situations is discussed in Section 5.1. These aim to identify preferences in parking behaviour and responses to communication of different user groups. To be able to identify the most effective communication strategy for distinct user groups.

Next, for each part of the survey, the questions need to be developed. That is discussed in Section 5.2. First, how the visibility of the signs is tested is described. To test how effective traffic signs are as a communication syntax. Next, questions for understanding the different parts of the signs are developed. This understanding could influence people's behaviour in the choice situations and is therefore captured. Then questions for the choice situations that were developed using images are explained. Lastly, to identify different user groups, the survey will also contain a part where information about the participants and their bikes is gathered, also called socio-demographics. These questions are combined, and a pilot survey is held, from this improvements for the final survey are gathered these are discussed in Section 5.3.

5.1. Design of choice experiment

To design the choice experiment, two steps need to be taken. Firstly, the attributes and their attribute levels need to be decided upon. This will be done in the following part. Furthermore, the experimental design needs to be determined, describing which type of survey design is chosen and how many choice sets need to be created. This is done in Section 5.1.2.

5.1.1. Deciding on attributes and attribute levels

For communication, the attribute levels that should be included were decided upon in the previous chapter, Chapter 4. For other characteristics identified in the literature, it should also be decided which alternatives, attributes, and attribute levels need to be incorporated.

Perceived safety

Starting with the first attribute, perceived safety. As indicated in the literature, perceived safety could introduce many variables. This might, for example, differ depending on what time of the day it is and whether there are other people there. Since these variables are highly subjective and different for everyone, it is difficult to alter them intentionally. Therefore, perceived safety is not considered as a variable in this research, since it introduces too many variables for which too little is known. To present similar situations in terms of safety, only situations in daylight will be presented and people need to always be offered a place to moor their bike to, so also the chances of a bike being stolen are similar throughout the situations.

Costs

Then, on to the costs. In The Netherlands, most bicycle parking facilities in the city centre are free. So, the assumption for this research is all costs will be zero. The walking distance needs to be varied because this will change when choosing between different parking options in the city centre. Therefore, this will also be a variable in this research. Lastly, crowdedness will not vary much for the different parking options, as for the normative communication strategy it is important to always provide a parking spot.

Attribute levels walking distance

Next, there is walking distance from a parking spot to a person's final destination. Since the length of stay is likely to influence the choice of parking and the willingness to walk further, a distinction between the walking distances included for short-term and long-term parking will be made. Little scientific information on bike parking in city centres is available. Therefore, practical information from the municipality of Delft's bike parking strategy and literature on parking near stations is used.

According to the practical information from Delft, for short-term parking, people are willing to walk a maximum of 50 meters, and for long-term parking, they are willing to walk a maximum of 100 meters from a parking spot to their destination (Gemeente Delft, 2021, Delft, 2017). Studies on parking near stations indicate that people are willing to walk anywhere between 80 and 160 meters for inside parking with surveillance, and ProRail sets the maximum walking distance for guarded, inside bike parking facilities at 200 meters. Based on the combination of these two for short-term inside parking, attribute levels should be tested at 50, 100, and 150 meters, and long-term parking should include the covered parking option at 200 meters. In the pilot, people will be asked if there are options they would not consider, and these will be excluded from the final survey.

For the outside parking, the assumption is that people are willing to walk a little bit less towards an outside parking spot. For outside parking in racks, a minimum distance of 0 meters is assumed, since the rack could be placed right in front of the destination. For short-term parking, people are willing to walk a maximum of 50 meters, and for long-term parking, they are willing to walk up to 100 meters. For fly parking, a distance as close as possible to a person's destination is deemed realistic, as they would otherwise probably be willing to walk a bit further for a formal parking option. So, fly parking also assumes a minimum distance of 0 meters. Offering one more attribute level slightly further away at 25 meters from the destination, assuming that the distance between lampposts in the city is 25 meters.

Attribute level availability

By assuming people might need to pick a spot for fly parking further from their destination because it might be full, crowdedness is indirectly included in fly parking. For the other option's availability could be introduced as a variable. However, it is unknown how many parking places should be available for people to find it an attractive alternative. Furthermore, if it is indicated no space is available, people are likely to not consider the option at all. This means that even though communication is presented, the option cannot be seriously considered by the participants. Therefore, availability is skipped as a variable in this research. The assumption is enough places will always be available. This is also likely to be true in reality, since, as mentioned in the introduction, formal indoor parking places are often underutilised.

Attribute levels length of stay

The next attribute that was identified was the length of stay of a trip. This could be included in two ways, as an attribute level, or by designing two separate surveys. However, creating two surveys would also mean one would need twice as many participants. Therefore, the choice is made to include the length of stay for a certain trip as an attribute level.

To determine the attribute levels for this, the distinction that the municipality of Delft uses for their bike parking strategy is used. This means two levels are used which is either a short stay of 30 minutes maximum and a longer stay, of over an hour (Gemeente Delft, 2021, Delft, 2017). No other scientific data was found that indicates what a long or short stay is. Therefore, in the pilot study, it should be investigated whether these levels distinguish the situations enough for people.

Attribute levels communication

Lastly, there is the attribute communication, different semantics were identified in the literature. These can be used for the attribute levels. The options that could be translated to traffic signs, as shown in Chapter 4, are: educative, hazardous, and normative communication. Furthermore, there is a base option to consider where no communication is presented to the respondents. An overview of all attribute levels is presented in Table 5.1.

What should be noted is that not all combinations of communication and parking options are included, this is because not all of them are logical. Presenting participants with communication on fly parking when no fly parking options are offered is, for instance, not logical. So, not all combinations of attribute levels will be included in the design.

Table 5.1: Initial overview of attributes and attribute levels

Alternatives	A	B	C
Costs	Free		
Availability	Always enough space available		
Short or long stay	Short: max 30 minutes Long: 1 hour or longer		
Covered/outside	Covered	Outside	Outside
Bike racks/ street furniture	Bike rack	Bike rack	Street furniture
Walking distance	50m 100m 150m 200m	0m 50m 100m	0m 25m
Communication	None Educative neutral Educative negative Hazardous		

5.1.2. Determining experimental design

Now an experimental design needs to be chosen. Based on the number of attributes and their levels, a full factorial design would need 108 choice situations. This is too much, therefore, a survey design with fewer choice sets is preferred for this research. The design should be generated using partial choice sets. Therefore, the d-efficient design using partial choice sets will be developed.

5.1.3. Priors

As described in Section 3.2.2, an efficient design needs priors to estimate a design. Priors for the model could be searched for in the literature. However, hardly any research on bike parking in city centres has been performed. For this reason, we examined information from bike parking near stations. However, getting priors from these reports is difficult. Often, combinations of attributes were researched. For instance, Molin and Maat, 2014 estimated a value for walking distance, but in their research, these are correlated to whether the parking was free, outdoors and not guarded or, paid, indoors and guarded. No separate value of the influence of walking time was included in this report, making it impossible to get an uncorrelated estimation for the influence of walking distance. Furthermore, these values are estimated in relation to each other in one model and need to be related to a

Table 5.2: Priors pilot survey

Parameter	Prior
Short or long	
Short	0
Long	0
Inside or outside	
Inside	0.001
Outside	0
Racks or furniture	
Racks	0.001
Furniture	0
Walking distance	
all	-0.001
Communication	
None	0
Educative neutral	0.001
Educative negative	-0.001
Hazardous	-0.001

standardised value, like the value of time, to be comparable throughout different research. In the experiments performed for bicycle parking, such a value is often not indicated. So, no specific priors could be identified.

Whether the effect of an attribute is positive or negative could, however, be determined, so the signs of the priors will be determined. The attribute of a short or long stay was added to avoid having to create two surveys. Furthermore, this attribute likely has a different effect on the parking choices for the two attribute levels. For fly parking, it is likely positive for a short stay and negative for a longer stay. This cannot be incorporated in the design. So, it was decided this attribute should not influence the design. Therefore, its prior is chosen to be zero. The literature showed that parking in racks will probably have a positive effect on parking. For having a shelter, the same could be true, however, not all research that has been carried out found having sheltering significantly improved people's perception of the parking places (Molin and Maat, 2014, Hoskam, 2021). However, other researchers did, and it was never found to have a negative effect on the parking choice. So, these are both assumed to be positive. Walking distance is also indicated to have a negative effect in literature (Molin and Maat, 2014).

Lastly, there is attribute communication. The hypothesis of this research, having communication in place, should increase people's preference for formal parking and reduce the choice of fly parking. The neutral educative communication is applied to the formal inside and outside parking spots and should promote these. Therefore, the prior for this communication strategy should be positive. The negative educative and hazardous strategy are applied to fly parking and should have a negative effect. So, this prior will be negative. No communication should not have an effect and should therefore be 0. The priors shown in Table 5.2 are chosen for the design. For now, these are only minuscule values with the correct sign that was either found in literature or assumed with the reasoning presented in this section. This should provide enough prior information to create a proper, efficient design.

5.1.4. Selecting number of choice sets

The next step in the design is deciding upon the number of choice sets. Two criteria were introduced and will be discussed in the following paragraphs. Starting with the number of choice sets based on the number of parameters that need to be estimated, followed by the criterium for attribute level balance.

The model estimation procedure will employ a hybrid approach, but it is currently unattainable to determine which parameters should be included as generic and which ones as specific. Therefore, when determining the number of choice sets needed, all parameters are assumed to be generic. This implies that the utility functions include nine parameters: two for the ASCs, one for the length of stay, inside or outside parking against either street furniture or a rack, walking distance, and 4 parameters for communication as this has 4 dummy coded levels of which 3 need to be estimated. Each choice set consists of two alternatives. For the MNL model, the number of choice sets needed is 9. For the ML model, two additional parameters might need to be added for the panel effects. So, at least 11 choice sets are needed based on this criterium.

$$\text{number of choice sets for MNL model} > \frac{9}{2-1} = 9 \quad (5.1)$$

$$\text{number of choice sets for ML model} > \frac{11}{1} = 11 \quad (5.2)$$

Now for attribute level balance. In this research, to achieve attribute level balance, at least 20 questions would be needed. Reducing the number of levels for the walking distance of inside parking by one can result in achieving attribute level balance with 12 questions. Which is a bit high in terms of how many questions participants are willing to answer, but still acceptable. Since the literature on which the choices for the walking distance were based was not unambiguous, the pilot survey could be used to test which level of the walking distance could be dropped. People might think 200 meters walking to covered parking is too long, or 50 m could be considered so short that it becomes a dominant alternative.

5.1.5. Conclusion on choice situations using Ngene

So, the choice experiments should be designed using a d-efficient design with partial choice sets. The attribute levels and priors are combined to create the functions used in the Ngene script. Furthermore, the script includes all other design choices. For the pilot survey, 20 questions should be used to achieve attribute level balance. However, this would be far too many questions to ask a participant. Attribute level balance is not a requirement, but is desired for the estimation of the model. The data from the pilot survey is only used to improve the survey design, not for estimation. Therefore, a design of 12 questions, which will also be used for the final design, was created for the pilot survey. One constraint was added to this design to create 6 questions on both the short and long-stay trips.

Based on the pilot survey, one attribute level of the walking distance will be removed. This makes it possible to have a design with 12 choice situations for the final survey, complying with the first requirement for the number of choice set, and achieving as much attribute level balance as possible. This number is slightly high for the number of questions people are willing and able to answer intentionally and focussed, but is deemed acceptable with the way the questions are asked with the use of images. Since these will be designed to capture all information in one single image, making it easy and quick to process.

5.2. Design of questions

The study includes multiple components to investigate the effectiveness of communication strategies for bike parking. The choice situations, described before, will be used to assess the effect of the communication strategies on parkin behaviour. But to be able to assess communication for bike parking overall, the effectiveness of the syntax used for the communication, in this case, traffic signs, should be tested as well. Furthermore, the literature highlights the importance of understanding and familiarity with signs. Therefore, data on the understanding of the sign designs needs to be collected to determine their influence on participants' decisions. Additionally, personal characteristics that influence choices are also considered and included in the survey.

When information on a situation in which a participant should make a decision or assess the situation needs to be provided, the use of videos, text, or images is common in surveys. Some pros and cons of the different ways to present questions are discussed in this section. After this, the decision for the design of the questions for each part of the survey is explained.

The first option is providing information through text. Text can provide all the necessary information to participants, describing the entire situation or answer, but it can be unrealistic. As presenting information in text provides the respondent with perfect information.

Videos and images are particularly useful when visual cues are the primary source of information. Videos provide a realistic representation of information and situations. However, after reviewing several clips, participants may lose focus or interest in the survey (Lim et al., 2020). Therefore, there should not be too many questions, including a clip.

Images are slightly worse at presenting situations realistically to participants than videos, but they are more realistic than text. The advantage of images over videos is that respondents can review them more quickly, and participants are less likely to lose focus (Hurtubia, 2020). A balance between realistic representation and keeping focus needs to be found in the design of the question. The choices for the different ways to design questions are presented in the following sections.

5.2.1. Questions on the visibility of signs

Starting with testing the syntax, traffic signs. The question that should be answered is whether people notice the traffic signs when they are not explicitly made aware of them. This indicates how well this type form of communication works for bicycle users by itself. Traffic signs are visual cues and only a single question, whether people notice traffic signs, needs to be answered. Therefore, a single clip can be used to answer this.

In this clip, it looks like people are on a bike. They are told that they are looking for a parking spot on their way to the centre. The video will include multiple signs to check if people noticed them. One existing sign and two new signs will be included in the clip. In the question, they will be asked which signs they noticed. They will be presented with answers, including the signs included in the clip and one more already existing and the two other newly designed signs, which were not included in the clip. They will also get the option that they did not notice any signs at all.

To not make people aware of the signs before watching the video, this part should be done in the survey first. Followed by the interpretation questions on the signs and their explanation, next the choice situations are presented and lastly, the questions on the socio-demographics are asked.

5.2.2. Understanding and explanation of signs

People's understanding of different parts of the newly designed signs must be tested. These parts were identified in Section 4.4. In this part of the survey, multiple-choice questions are used to gather this information. Instead of asking people questions and asking them to describe the sign, each question presents answers for the part of the sign that is tested with that question.

Starting with the signs of educative negative and hazardous communication, participants are first familiarized with the forbidden to park sign. For educative negative signs, bikes parked against trees and lampposts are added to indicate that fly parking is prohibited. In the first question, participants are presented with different answers about what type of bike parking is indicated to be forbidden according to this sign, shown in Figure 5.4. Next, the forbidden to park sign is shown, and the small zone sign is added, this is shown in Figure 5.5. People are asked to answer to which area this sign applies. Now the hazardous sign without the small zone sign, as shown in Figure 5.3, is presented, and participants are asked if they understand the part of the sign that describes the possibility of checks being held and being towed away.

Figure 5.1: Traffic sign first question

Figure 5.2: Traffic sign second question

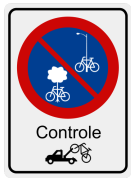

Figure 5.3: Traffic sign third question

For neutral educative signs, participants' comprehension of the difference between covered and outside parking is tested. To test whether people understand the difference between covered and outside parking, a question for each sign where the type of parking is varied is asked.

Figure 5.4: Traffic sign first question

Figure 5.5: Traffic sign second question

Lastly, as discussed before, familiarity with signs is important for the effect they have on people's behaviour. Therefore, at the end of this section, an explanation of each sign is included. Although it should be kept in mind that people some people might not read the entire explanation, or do not read it intentionally, and therefore still do not feel familiar with the signs. Therefore, their initial understanding could also affect their answers in the choice situations, and the influence of this factor on the parking should be tested for.

5.2.3. Design of questions in choice situations

Ngene will generate 12 choice situations for the final survey. Once the choice situations are generated by Ngene, they must be presented in the survey in some way. Text, like the one shown in Table 5.3, provides people with perfect information and provides a very unrealistic description of the choice situation. Furthermore, it always provides communication to the respondents, as people are always presented with all options.

Visual cues are the primary source of information, with the newly designed traffic signs used as communication. Therefore, either videos or images will give a more realistic representation of the choice situation in reality. 12 choice situations are generated and should be presented to participants. This is too much when one wants to avoid repetitiveness and keep people focu throughout. Therefore, videos should not be used in this part of the research.sed

Table 5.3: Example of a choice situation in table

A	B
Outside	Outside
Bike rack	Street furniture
50m	0m
	

Making images the preferred option for this research. However, when designing the images for this survey, there are some drawbacks to consider. To indicate parking places, they should be visible in the image, or extra information needs to be provided. To avoid overloading participants with information, this is not preferred. Furthermore, using one single image per question is also preferred to avoid overloading participants with information.

To facilitate this, a person's destination should be included in the image to avoid additional information being required. In this way, fly parking and outside parking close to the destination can be indicated within the image without providing extra information. To be able to provide fly parking without communication on it, the distance to fly parking, will not be explicitly indicated in the images. There will be the option right next to the destination and further away. In the pilot, participants will be asked to indicate the difference between these situations.

Open answers to what choices people make would give the most realistic results. However, inside and outside parking already need to be indicated explicitly through the signs. To not get a distinction between the answers, the other options will also be identified and presented to people in some form of multiple choices. This also makes the processing of the data easier, which is convenient for the limited time available in this research.

There are two ways these questions can be created using pictures, using hot spot questions, like the one shown in Figure 5.6, or where the options are edited in using coloured boxes Figure 5.7. In the hotspot questions, the destination still needs to be indicated using a coloured box. In (paid) survey software by Qualtrics, so-called hot spot questions could be created. In the back end, a few areas can be identified within the images, indicating parking options. These options are only visible to people when they move their mouse over the images. If they came across an indicated spot, a black box appears in the image. This could mean people make their choices more freely, as they do not see all options provided. However, the question is if people use the questions like this. They could also be confused by the lack of options presented to them. Or first, look up all options in the image, which would mean they still do not choose their options freely, which was precisely the point of this design.

The other option is using coloured boxes and indicating multiple-choice options for each. For the coloured boxes, different designs will be tested. Like the ones shown in Figure 5.7 and Figure 5.8 with different colours. In the pilot survey, it is identified which option works best, if the images are clear, and whether this gives data that can be processed.

Figure 5.6: Example of hotspot question

Figure 5.7: Example choice situation: box with border

Figure 5.8: Example choice situation: semi-see-through box

5.2.4. Questions on socio-demographic information

In addition to external attributes, people's personal characteristics also play a significant role in shaping their behaviour. Important factors that likely influence people's bicycle parking behaviour were introduced in the literature, in this part the questions on these socio-demographics that need to be included in the survey are described. These questions do not need to describe a certain situation and can therefore simply be asked for using text only.

According to the literature, women are less likely to take risks than men. This could lead to women choosing fly parking less often, especially if communication prohibits it. Younger people are expected to be more reckless than older people and are therefore expected to respond less to communication on fly parking and choose it more often than older people would. Age is not requested explicitly, but only the age group to which an individual belongs is asked for. These age categories were established based on the categories employed by the CBS to classify individuals.

Furthermore, education level, occupation, and income have been found to be important factors. However, listing every occupation can result in a lengthy list and will not give a clear outcome. Instead, respondents are asked to indicate to which of the proposed groups they belong in terms of education level and work situation. These groups are also based on the CBS's statistics. What belonging to these user groups has means for the effectiveness of communication strategies for bike parking is not currently known. But, little is known about bicycle parking behaviour in general and these factors are often associated with predicting people's behaviour and are therefore also collected in this research.

In bike parking, not only people's own characteristics could influence their parking behaviour, but also the price of bike they are using and the way they use it could be important. So, this is also asked for in the survey. People are likely more careful with an expensive bike, and therefore take less risks with it. Frequent bicycle users could be affected by communication in different ways according to the literature. Either their routine is harder to change through communication, or they might be more sensitive to it because they might be dependent on their bike and be more careful with it. For the cost of a bike and frequency of use, no previous statistics are found. So, the price categories were created based on retail prices of different types of bikes that could be found. For the frequency of use, the categories were inspired by other research where this topic was included.

5.2.5. Conclusion on design

All these parts should be incorporated into the survey. To avoid people being very focussed on traffic signs already, the survey should start with the clip, testing the visibilities of the signs. Next, people need the explanation of the traffic signs before moving onto the choice situations. So, this part on the understanding should be the second part of the survey. Then the choice situations will be presented to people and lastly the information on their socio-demographics is asked.

5.3. Improvements from pilot survey

The elements that should be included in the survey and how they were designed at first were described in the previous section. To determine the last two attribute levels that still need to be chosen, namely the furthest walking distance for formal parking and the time of a short or long stay, a pilot survey was held. This pilot will also aid in identifying potential obstacles participants may encounter while completing the survey. In the pilot, around 15 people from different age groups and genders are consulted. They were asked to think out loud and comment on the different parts of the survey. In this part, some improvements and comments from participants are discussed and improvements to the survey are indicated. The major improvements are indicated in bold.

Part on the visibility of signs

- Interest in the clip drops off when it takes too long. So, a shorter version of the video was created by taking a slightly different part of the clip where the signs could be included more compactly and speeding up a part of the clip slightly where no traffic signs can be seen.
- Participants in the study reported feeling more confident about recognizing certain signs compared to others. However, the survey software used does not allow for questions that can capture this information, so, unfortunately, this is a limitation of the questionnaire.

Part on the understanding and explanation of signs

- It is important to state in the survey that some signs used in the survey were specifically developed for the study. This was not indicated at first, which initially caused confusion among participants.

Part on the choice situations

- People wanted a bit more assistance when answering the first-choice situation. Therefore, an example question is added to the choice situations.
- **People indicated that the distinction between short-term and long-term parking was too small. So, this was adjusted to at least 2 hours to make the difference more noticeable.**
- Some people missed the change from short-term parking to long-term parking situations. Therefore, bold fonts and large letters were used to emphasize this change.
- **Hot spot questions caused confusion among participants. Furthermore, people indeed first looked up all options before making their choice, taking away the advantage of this method. Therefore, coloured boxes are chosen.**
  - The best way to use the coloured boxes turned out to be using a border only. Orange and yellow turned out to be the best options for the colour, as these contrast with almost every background, but people do not associate it with good or bad like green and red do.
- **Based on the pilot survey, the maximum walking distance was adjusted to 150 meters for covered parking, as the previous distance of 200 meters, was deemed too far by most participants.**
- As described, the distance towards a fly parking option cannot be expressed as an absolute number. So, it is either indicated immediately next to the destination or further away. People did indicate this difference between the different choice situations, this indicates this difference is clear enough to people.

Some additional variables are introduced when creating images, and these were indicated by people when filling out the pilot survey. These variables could be important for explaining certain choices and are therefore introduced here. Firstly, in the images, some fly parking options are offered right underneath a sign. The pilot survey showed some people would still choose these spots. Therefore, these options will still be included in the final design, but the effect on the choice this might have should be investigated in the data analysis.

There were not many types of street furniture included, as there were no usable situations to be photographed. For example, benches and trash bins were not included. There are however situations with parking options at a tree included. In the pilot, it was indicated by some people they would rather not park at a tree, so this variable should also be investigated.

5.4. Final survey design

From the pilot survey, the final decision on all attribute levels is made. These are presented in an overview in Table 5.4. Including the final decision on walking distance for the formal parking options and how long a short or long-term stay is. These were used to create the final survey design in Ngene. This design is included in Section A.2, including all the final changes mentioned in the improvements for the pilot.

The final survey is distributed online. LinkedIn is used to reach as many people as possible. However, since people are asked to fill out the survey voluntarily, there might be a self-selection bias, of only people that found the topic interesting filling out the survey.

Table 5.4: Final overview of attributes and attribute levels

Alternatives	Formal inside		Formal outside		Fly	
Costs	Free					
Crowdedness	Always enough space available					
Short or long stay	Max 30min	Over 2 hours	Max 30min	Over 2 hours	Max 30min	Over 2 hours
Covered/ outside	Covered		Outside		Outside	
Bike racks/ street furniture	Bike racks		Bike racks		Street furniture	
Walking distance	50m 100m	100m 150m	0m 50m	50m 100m	0m 25m	
Communication	Educative neutral		None Educative neutral	Educative neutral	None Educative negative Hazardous	

6 Descriptive statistics

The previous chapters described how the data for this research was gathered. Now, the analysis on this data will be carried out. This chapter will cover the descriptive statistics of the observations obtained in the final survey. These can be used to summarize and describe data in a clear and concise way. First, some steps to prepare the data are described. In Section 6.2 the distribution of gender, age, education level and work situation are analysed and compared to the Dutch population. It is researched if these characteristics have an effect on the effectiveness of communication, so it is important to get an overview of the distribution of the sample to see if the findings are generalisable. In this section also the frequency of use of bicycles and the price of these bicycles are reported. This provides an answer to the following sub-question:

5. What are the different user groups that can be identified?

In Section 6.5 statistics on the choice of parking spots based on different socio-demographics are presented. These statistics do not directly show the effectiveness of the communication strategies, but can show how many chose a certain type of parking when presented with the different communication strategies. Or, for example, what socio-demographics affected people's parking behaviour, such as whether a certain group of people chose to fly park more often. The interaction of socio-demographics and communication strategies cannot be captured in descriptive statistics and is researched further in Chapter 7.

But the statistics should help provide some initial insights for the following sub-question:

6. What are the responses of different user groups to the communication strategies?

6.1. Data preparation

In total, 276 respondents filled in the complete survey. Of which 262 respondents answered the Dutch survey and 16 the English version. Before processing it, the data is checked and prepared. Only surveys that were filled out are captured by the software, so no incomplete surveys exist in the data file. The following criteria were applied to the data:

- The survey has a video of around 50 seconds in it, and 3 parts with questions which each take at least 1 minute to complete, so people need at least 03:50 to answer questions and not randomly answer. Everyone who answered in under 03:50 is removed from the sample.

- It is checked if people gave only one single answer for the choice situations, for instance only 'A', as this could indicate people randomly answered the multiple choice questions. If this was the case, these respondents are removed from the sample.

In total, 7 people answered more quickly than in 03:50 minutes, and these answers were removed. Two of these people only filled in a single answer, but these were already filtered out by the first criterium, so in total, the answers of 7 respondents were removed from the dataset. A total of 269 responses were left. Each respondent was presented with 12 choice situations. This means 12 times 269 is, 3228 choice observations were collected.

6.2. Socio-demographics and types of bikes

The dataset will be analysed in different ways. First, the socio-demographic characteristics of these respondents will be discussed. This will give an idea of the composition of the sample and indicates what should be kept in mind when analysing it. The socio-demographics can be used to divide people into user groups, for instance, based on their age and education level. Depending on how the characteristics are spread out in the sample, it can be determined what groups can be formed that are big enough to get statistically significant results. Furthermore, if certain groups are overrepresented or underrepresented, this indicates some findings of this study might not be generalisable.

In Table 6.1 the percentages and counts of the sample for the socio-demographics that were asked for are presented. Moreover, the percentages of these socio-demographics representing the entire Dutch population are presented. These statics were gathered through the CBS for the year 2021 (CBS, 2022). This year was chosen as these statistics are the most recent year that provides data on all needed statistics. To test whether the sample significantly differs from the entire population, a Chi-square test is conducted. The results of these tests are shown in Table 6.2. In the survey, people also had the option to indicate they would rather not provide information on their socio-demographics, these groups were small each time. So, no separate group was made for these respondents, their answers were kept in the entire sample.

For the sample, only the gender does not vary a lot from the entire population, for a confidence interval of 10% the distribution of gender is not significantly different from the entire population.

The group of individuals in the age group of 20 to 40 years is over-represented massively, whilst the older groups and people under 20 are underrepresented. This could influence the results of the model. It is expected from the literature that young people behave differently compared to the elderly. To investigate the effect of age in the rest of the research, the groups are aggregated, so the sample sizes of the groups are large enough (N>30), to give statistically significant results. The data on age was gathered in terms of age groups the CBS also uses, and the group between 20 and 40 was split into two groups in the survey of 20–29 years and 30–39 years.

Usually, people under 25 are considered young, but this group cannot be derived from the data. Under 20 is too small a group, so the younger group was chosen to be people under 30, so up to and including 29-year-olds, this includes 156 respondents. The next two age groups that could be distinguished are the middle-aged group between the ages of 30 and 65 and the elderly group of 65 and over. However, the group of 65 or older, is too small. No other distinction could be made between middle-aged and elderly, as a group of 40-64 year olds was captured in the data and the group of 30–39 years old was too small to investigate independently. So, these groups are aggregated in the data analysis.

For education, the groups also needed to be aggregated to get large enough groups. Therefore, 3 levels of education: low, middle and high education, as also used by the CBS are used for education. However, for the so-called lower education, the group is still too small. So, only the behaviour of middle and higher education can be compared to the entire sample. This means the effect of a lower education level on the parking choice and the interaction with communication cannot be identified with this dataset.

Table 6.1: Socio-demographics from respondents and Dutch population

	Respondents		Population	
	Count	%	Count	%NL
Gender				
Female	135	50.19	8788879	50.3
Male	131	48.70	8686536	49.7
Other/not indicated	3	1.12	-	-
Age				
Under 20	2	0.74	3739739	21.4
20 - 40 years	183	68.03	4421280	25.3
40 - 65 years	75	27.88	5854264	33.5
65 - 80 years	8	2.97	2621312	15
80 or older	1	0.37	838820	4.8
Education				
Low	10	3.72	4071772	23.3
Middle	104	38.66	5364952	30.7
High	152	56.51	4910592	28.1
None or other	3	1.12	104853	0.6
Work				
Fulltime	137	50.93	4805739	27.5
Parttime	28	10.41	4456231	25.5
Unemployed	12	4.46	401935	2.3
Self-employed	21	7.81	2079574	11.9
Student/scholar	52	19.33	3652362	20.9
Pensioner	10	3.72	2079574	11.9
Ohter/not indicated	9	3.35	-	-

Lastly, there is the working situation. These cannot be aggregated, as each group has their characteristics. Only the group of full-time workers and students/scholars is large enough to research. Therefore, these are the only groups whose behaviour can be compared to the behaviour of the entire sample. It should be kept in mind that especially the full-time workers comprise a large part of the entire sample, and therefore their behaviour also influences the overall results a lot.

Table 6.2: Chi-square test for socio-demographics

	Chi-square	df	P-value
Gender	0.007	1	0.930
Age	287.218	4	0.000*
Education level	97.835	2	0.000*
Work situation	105.653	5	0.000*

Some other information was also gathered: the price of a person's bike and what frequency with which they use it. These statistics cannot be compared to the entire population, since no data is available on this. The results for frequency of use are presented in Figure 6.1 and for the cost of bikes in Figure 6.2.

The counts of these groups are also too small to include them all separately. So for the frequency of bike use, people will be divided into frequent, in between, and infrequent users, as these groups show the most variation in behaviour and the data varies enough to make large enough groups. Infrequent users will be people who indicated to never use a bike or 1 time a month or less, this group includes 46 respondents. The users in between will be the group that uses their bike 1 a week or less. The frequent users include bike use less, 1–3 times a week and 4 times a week.

For the cost of a bike, the group owning an expensive bike versus a cheaper bike showed the most variance in behaviour when the following groups are combined for people with an expensive bike: 'My bike is solid and quite new (€300-€1500)', 'My bike is expensive (€1500 or more)' and 'My bike is irreplaceable, it has emotional value to me'. The group of cheap bikes consists of: 'My bike could break down at any moment and needs to be replaced any moment now', 'My bike is cheap and/or second hand (€300 or less)'. It would be interesting to investigate the behaviour of people that rent their bikes, but this group of respondents consists of only 11 people, so that will not be possible with the current dataset.

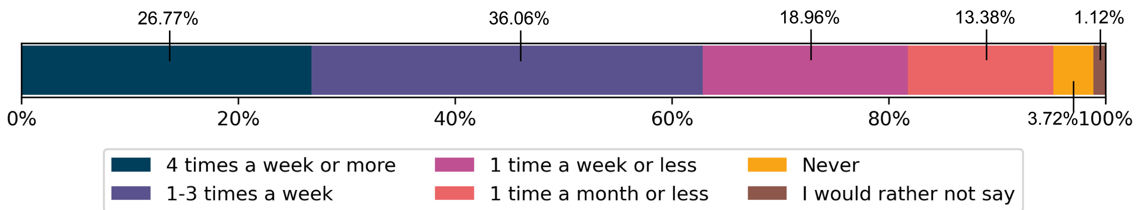

Figure 6.1: Statistics on the frequency of bicycle use

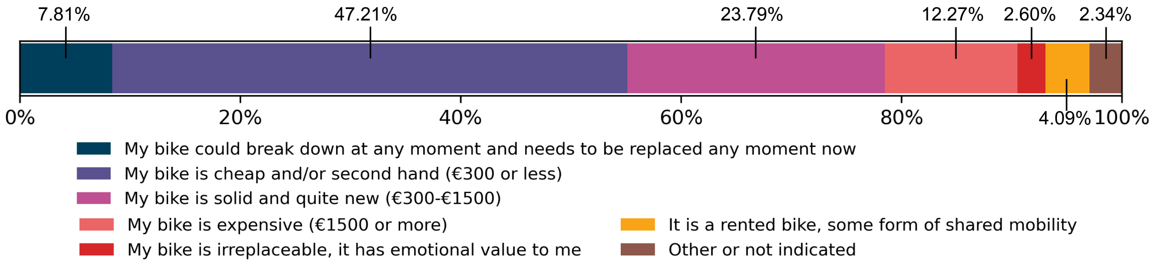

Figure 6.2: Statistics on the cost of bikes

6.3. Testing the syntax traffic signs

To help determine if traffic signs are a good syntax, the survey also included a clip that tested the visibility of traffic signs during a bike trip. The results of this are shown in Table 6.3. As can be seen, the majority of people answered incorrectly or indicated not to have seen the signs at all. This could indicate that if people are not aware, they need to look for traffic signs, they also will not spot them during their journey. This is important to note when looking for the most effective way of communicating with cyclists. Only using the syntax of traffic signs is probably not the most effective way to reach cyclists. People will first need to be made aware of the signs being there in another way.

Table 6.3: Indicated correct signs in clip

	Count	Percentage
Identified all signs that occurred in the clip	17	6.32
Identified 2 out of 3 signs correctly (and no wrong signs identified)	59	18.22
Identified 1 out of 3 signs correctly (and no wrong signs identified)	49	21.93
Answered not to have identified any sings in the clip	99	32.71
Answered incorrectly for all signs	56	20.82

6.4. Testing understanding of traffic signs

People's understanding of each part of the newly designed signs was tested in the survey as well. Since, the understanding and familiarity of signs could affect people's behaviour. The results are shown in Table 6.4. Only the first sign, which is also indicated in, was badly understood. Only 58%of people answered correctly what the meaning of this sign is. Whilst the others were answered correctly by 97% of people or more. Even though an explanation was given of all signs, it should be kept in mind that the negative educative sign is not completely intuitive to people and that this is included in the hazardous sign as well. According to the survey, the familiarity, and understanding of the sign are low for many people. Therefore, it should be tested if the group that indicated the meaning of the sign incorrectly makes different decisions in the choice situation than the group that did understand this sign.

Table 6.4: Percentage of people correctly identifying the meaning of the signs

	Percentage of people identifying the sign correctly
Educative negative sign, without zone	58%
Zone sign	97,40%
Hazardous strategy, without zone	98,88%
Parking inside	100%
Parking outside	98,51%

6.5. Choice of parking options

In this part, the effect of the different characteristics on the parking choice is investigated. Firstly, the effect on the parking choices of the short or long stay is identified. Furthermore, the influence of the other variables, the socio-demographics, types of bike and bike use, communication, the understanding of the signs and the design of the images in the survey on parking behaviour is tested in this section.

6.5.1. Influence of length of stay on parking choices

One of the assumptions made in this research is that the length of stay of a trip influences the parking choices made. But this factor is expected to have an influence on the parking choice. If it indeed does, this is a good indication that this factor should be included as an alternative specific variable.

In Figure 6.3 the percentages of people choosing a certain parking spot are presented for different lengths of stay. These indicate that, indeed, people make slightly different choices for a parking spot when the length of stay varies. For a longer stay, people park inside more often. But what is interesting is that also the number of people choosing fly parking increases. This is probably due to the other factors expressed in these scenarios, like the walking distance. However, no conslusion can yet be drawn from these results, as the different influences on parking choice are better explained by discrete choice modelling. These models are developed in Chapter 7. This is, however, an indication that the effect of certain attributes on the parking choice is stronger than the communication strategies are. The thing that differs for the long stay, is the walking distance. Therefore, these results indicate people's parking choices are likely influenced a lot by walking distance.

The results of the Chi-square test are shown in Table 6.5. The p-value is so small it is estimated to be approximately 0 and the Chi-square value is worth considering. This indicates there is indeed a significant difference in parking choice for the length of stay, and this variable should be included as alternative specific. The complete results of all Chi-square tests can be found in Appendix D.

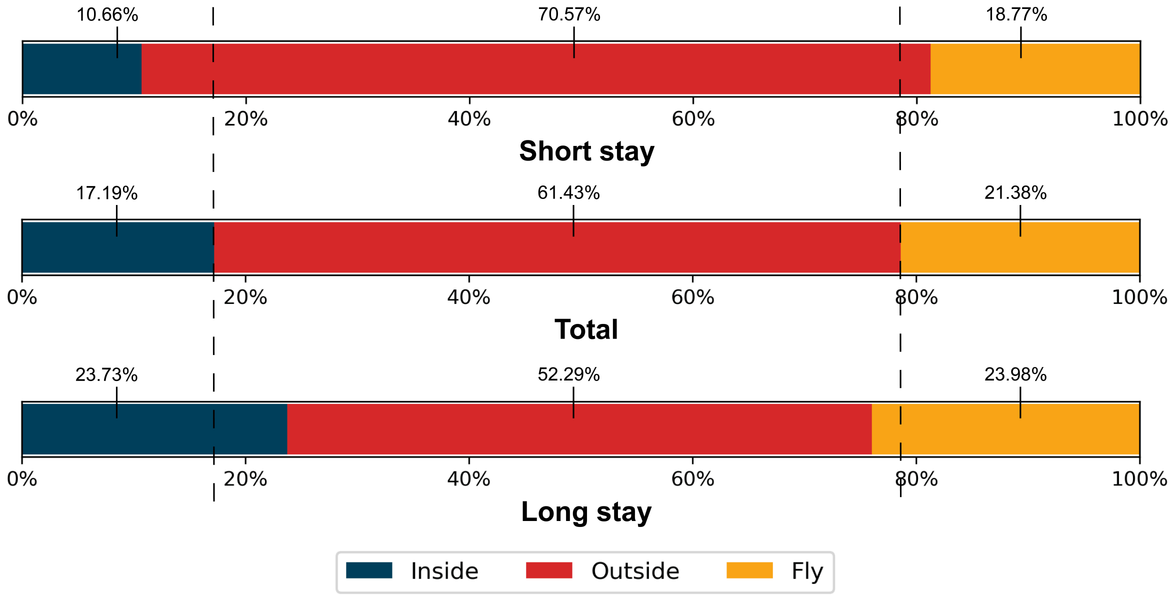

Figure 6.3: Choices for types of parking made for different lengths of stay

Table 6.5: Chi-square test short versus long stay

Characteristic	p-value	Chi-square value
Short vs Long	0	134.33

6.5.2. Influence of socio-demographics on parking choices

In this part, the influence of different socio-demographics on the parking choice is tested. For this, the aggregated groups described before will be used.

When comparing the different groups within these categories, gender, education level, and work situation did not give significantly different results. For genders, this means men and women indeed do not make different decisions in bike parking when the variables considered in this research are considered, as the sample distribution of the sample is comparable to the entire population. But according to the literature, men and women are expected to respond differently (Majumdar and Mitra, 2015, Rietveld and Daniel, 2004). However, this is mostly due to the feeling of safety according to the literature. This factor is not included in this research, which could be the reason there is no difference in behaviour between men and women. For the education level and work situation, it is not possible to draw a generalisable conclusion based on the current sample and if the outcome is different from the literature this could also be due to the distribution of the sample. Where the group making certain choices might be under or overrepresented.

For the education level, the group that followed a lower education is largely missing, so only middle and high education could be compared to each other. The parking choice of these groups is not significantly different from each other. But since the distribution of this variable is significantly different from the entire Dutch population, no generalisable conclusions can be drawn from the dataset in this research.

For the work situation, it is also difficult to draw conclusions. The group of full-time workers and students is large enough to do statistical tests. However, they also make up a large part of the entire dataset. Therefore, the results of the entire dataset are heavily influenced by these two groups and these not giving significant results could be due to the lack of spread in the data, instead of them actually not influencing the choices. This should also be considered when analysing the further results.

Next, a Chi-square test is performed for the socio-demographic age. Figure 6.4 shows the difference in parking choice for the younger and older group. The results of the Chi-square test as shown in Table 6.6 indicate the effect of age is significant when comparing the older group to the young group. It is therefore advised to include the variable age in the development of the model.

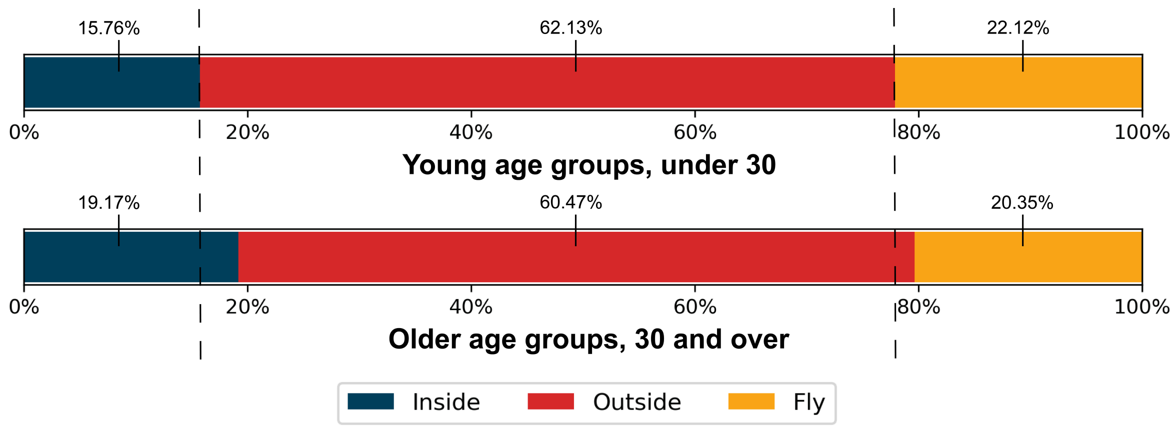

Figure 6.4: Choices for types of parking made by different age groups

Table 6.6: Chi-square test for age

Characteristic	p-value	Chi-square value
Young vs Old	0	6.83

Now, the parking choices of a person owning a cheap bike are compared to the parking choices of people owning an expensive bike. The choice of parking is shown in Figure 6.5. This shows people owning an expensive bike are more likely to choose inside parking over outside parking. The percentage of people choosing fly parking is, however, comparable to the people owning a cheap bike. The people choosing fly parking might not be influenced enough by the price of their bike to change their behaviour.

The results of the Chi-square test are shown in Table 6.7. These findings do not yet provide a conclusive answer regarding the impact of a person's bike price on their parking behaviour. When comparing the behaviour of a person owning a cheap bike versus an expensive one, the p-value is not significant for a confidence interval of 95%, however, it would be for a confidence interval of 90%. Therefore, the price of a bicycle should be evaluated to determine its impact on parking preferences.

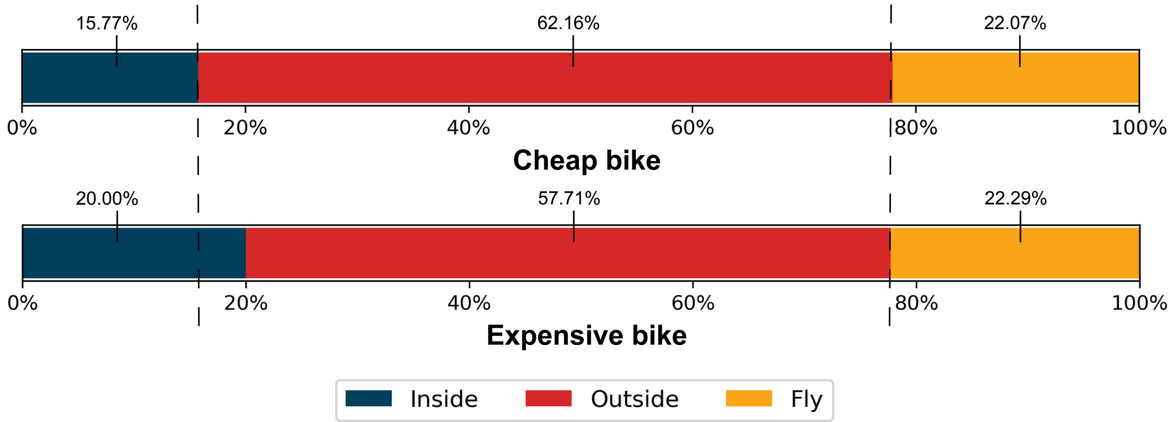

Figure 6.5: Choices for types of parking made for differently priced bikes

Table 6.7: Chi-square test for the price of a person's bike

Characteristic	p-value	Chi-square value
Cheap or Expensive	0.07	5.30

For frequency of bike use, the results for the parking choice are significantly different for frequent users and infrequent users compared to the behaviour of others. As is shown by the results of the Chi-square test in Table 6.8. The difference in parking choice is shown in Figure 6.6. It indicates that the more frequently people use their bikes, the more likely they are to choose fly parking and are less likely to go for an inside parking spot.

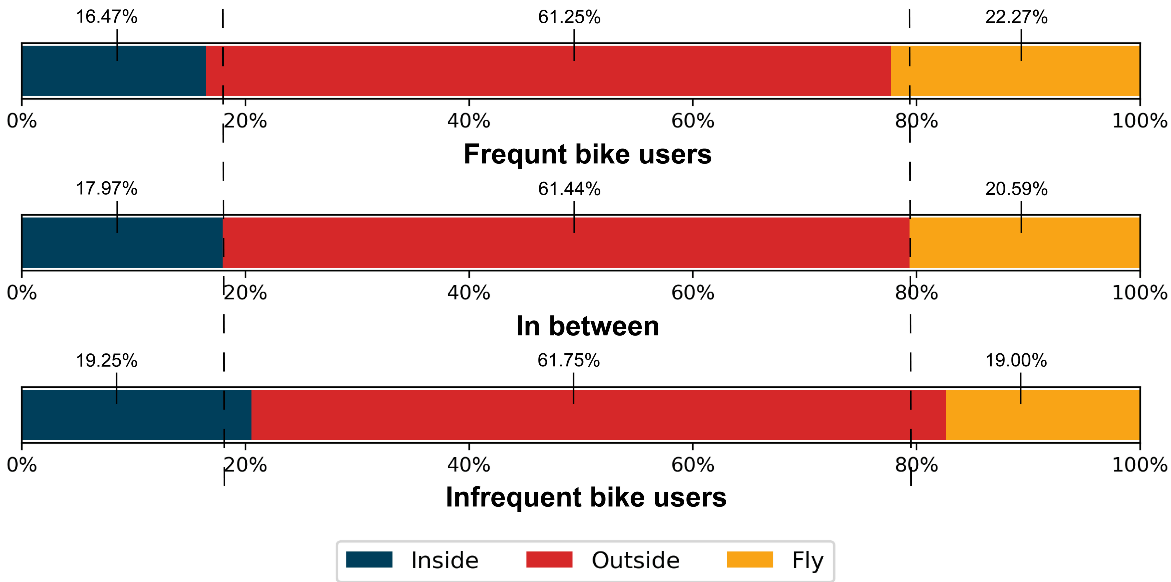

Figure 6.6: Choices for types of parking made for different frequencies of bike use

Table 6.8: Chi-square test for the frequency of bike use

Characteristic	p-value	Chi-square value
Infrequent vs rest of the sample	0.03	6.80
Between vs rest of the sample	0.89	0.24
Frequent vs rest of the sample	0.03	7.24

6.5.3. Influence of understanding of the signs on parking choices

Even though people received an explanation of the signs, it is explored if their initial understanding of the signs might still have influenced their parking choice. Since the literature indicated that if people are unfamiliar with a sign, this could also influence their reaction to it. To investigate this, separate groups were formed with people that understood all the signs correctly and people that understood none of them, as these are the groups for which the most difference in behaviour is expected. However, these groups did not present statistically different behaviour. So, this is not considered as a variable further in the research.

6.5.4. Influence of communication strategies on parking choices

It is a bit more difficult to compare the parking choices per communication strategy, as not all parking options are offered when negative education and neutral education are presented. Therefore, statistically significant differences might simply be due to the missing of one value, but still, they were compared to parking choice of the entire population to indicate their effect on parking choices. This is presented in Figure 6.7. In the end, the effect of socio-demographics on the effectiveness of the communication strategies should be investigated, but it is very difficult to do that through descriptive statistics, because of the limitation mentioned above. So, this will be done later on in the modelling step. In this part, it is analysed whether communication even has an effect on parking choice.

The neutral educative strategy seems to have an effect on the parking choice. It shows fewer people choose inside parking than in the total sample. This seems strange, but this might not be completely due to the communication and could also be affected by other attributes, like walking distance. For the hazardous strategy, fewer people choose fly parking. Both the number of people choosing inside parking and outside parking increases for this strategy. Lastly, there is the negative educative strategy, for this it seems more people choose for fly parking compared to the entire sample. But for this strategy, inside parking options are offered, and it is therefore hard to say if the communication truly causes this effect.

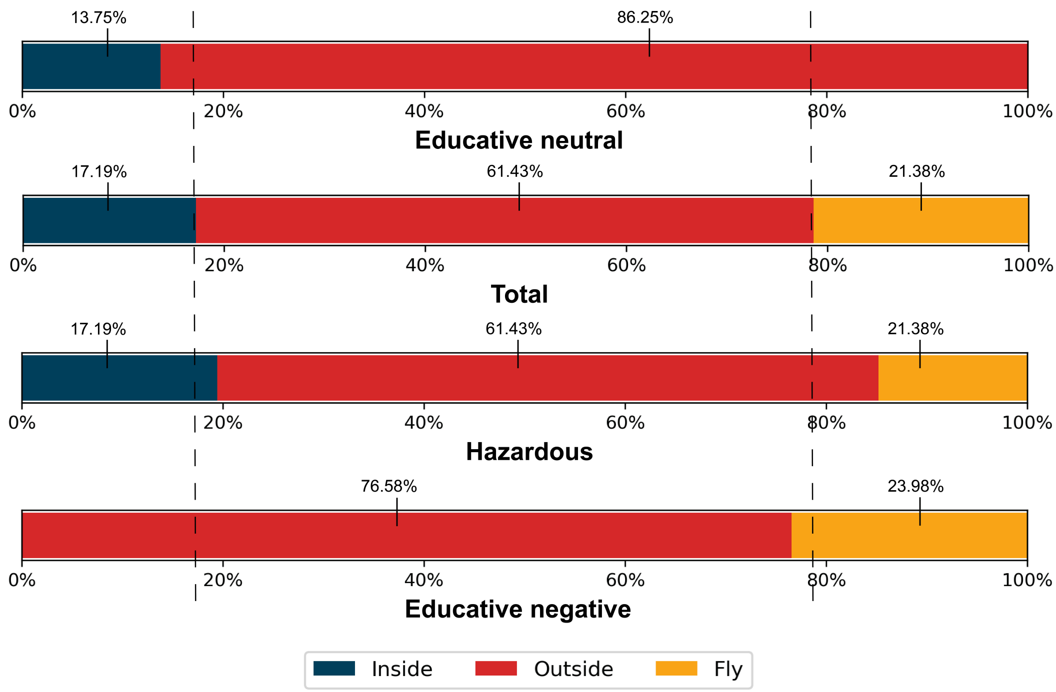

Figure 6.7: Parking choices based on the form of communication present

6.5.5. Influence of design of the images on parking choices

Two variables that the survey was not designed for, but in the images, might be of important. Firstly, whether people park at a lamppost/pole or at a tree and whether the pole people should park might be directly underneath a sign stating it is forbidden to park there. These are both variables for fly parking options, multiple options for fly parking are offered in the images, and it should be tested whether these factors might make the specific option more or less attractive. This is done by comparing the number of people choosing that specific option to the number of responses that was to be expected.

For instance, in question 4, 124 people chose fly parking and there were 3 options for fly parking, of which one was directly under a sign indicating this form of parking is forbidden. This means that, if there is no difference in preference for a certain spot, one would expect a third of the people to choose each option. The results of all questions were tested in a Chi-square test, comparing the expected values, so for three options a third of the people choosing a fly parking option, to the actual number of people who chose each fly parking spot. The results are shown in Table 6.9.

Table 6.9: Chi-square test influence of the design of images

	p-value	Chi-square
Parking underneath a sign indicating it is forbidden	0.9951	0.2
Parking at a tree	0.19	6.01

Both p-values are larger than 0.05, which means they are not significantly different from the overall results. This means that these parking options are not preferred or disliked. However, the survey was not designed for these variables. There may be additional variables, currently not included, that are unintentionally varied throughout the images, like distance to the side walk, that influence the choice of a specific fly parking spot. These variables are not tested in this research.

6.6. Conclusion on descriptive statistics

Looking at the results for the Chi-square test, it is likely that the variable for a short and long stay should be added as alternative specific to the model. The descriptive statistics showed age, frequency of use, and price of a bike are the factors likely to influence people's choice of parking options, so these should be considered for the MNL model describing parking behaviour. Furthermore, communication seems to indeed influence parking choices. But the descriptive statistics do not yet show the effect of the communication strategies on different user groups. Their interaction with communication will be explored further in the next chapter, Chapter 7, on discrete choice modelling.

How to aggregate these groups for the discrete choice modelling was identified in this chapter. With a group of people under 30 and 30 or over in terms of age, a male and female group, a group of people owning a bike of €300,- or over, or a cheap one of under €300,-, with three groups for the frequency of use of 1-3 times a week or more for frequent users, an in-between group of people indicating to use their bike 1 time a week or less and infrequent users that use their bike 1 time a month or less, lastly, there is also a group of full-time workers and on with student as more distinctions could not be made.

- Age: The participants were divided into two age groups - individuals under 30 and those aged 30 or over.
- Gender: Participants were divided into male and female groups. The group that identified differently is too small.
- Price of a bike: Participants were categorized based on the value of their bike – either owning a bike priced at €300 or more, or owning a cheaper bike priced under €300.
- Frequency of bike use: Participants were classified into three groups based on the frequency of bike use – frequent users (using their bike 1–3 times a week or more), in-between users (using their bike once a week or less), and infrequent users (using their bike once a month or less).
- Work situation: Participants were divided into two groups based on their employment status – full-time workers and students. Further distinctions beyond these categories were not feasible.

7 Results of discrete choice modelling

In the previous chapter, an initial statistical analysis was conducted to identify important factors for the modelling. This chapter outlines the steps taken to develop multinomial and mixed logit models. The modelling process is illustrated in Figure 7.1.

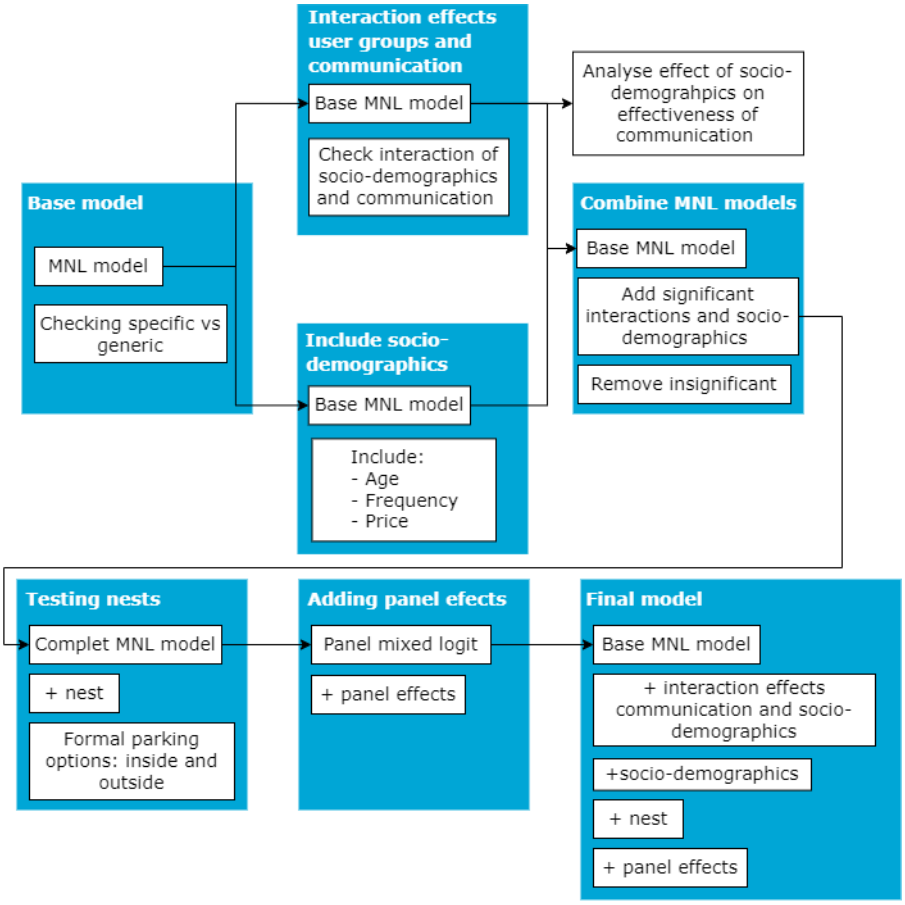

Figure 7.1: Schematic overview modelling steps

First, a basic MNL model that includes all variables the survey was designed for is developed in. Then it is determined whether to include the design parameters as generic or alternative-specific parameters to optimize the base model's performance. Next, two different models are created. The first model includes the interaction effects of communication and socio-demographics. This indicates which communication strategy might be more effective for certain user groups. The second model directly incorporated socio-demographic variables, these are combined to create a final model that used both direct effects and interaction effects to estimate parking choices based on the data.

Next, there is tested for a nest, it is tested whether the formal parking options are correlated and panel effects are added to develop a mixed logit (ML) model that best explains the results. This final model can be compared to the MNL model to see if the effect of the interactions became smaller or less significant. If this happens for a variable that is not well represented in the sample, the effect might be there in reality but is insignificant in the ML due to the poor spread of data.

The results of the MNL model with interactions and the differences between this model and the final ML model are analysed to answer the following two research questions:

6. What are the responses of different user groups to these communication strategies?
7. What communication strategies are effective for bicycle parking?

7.1. Basic MNL model

In this part, the steps of developing and analysing the basic MNL model are explained. In the design, it was assumed all parameters are included as generic. However, the results might indicate it would have been better to include some of them as alternative specific parameters. As the descriptive statistics already indicated for a short versus a longer stay.

First, the utility functions of the model are given where all variables are generic. Next, each variable is tested as alternative specific and the results of these models are presented. The best-performing hybrid models are created based on these results. The complete code used for the final MNL model can be found in Appendix E.

7.1.1. Utility functions

To estimate the models, utility functions are needed. The utility functions presented in Equation 7.1, Equation 7.2 and Equation 7.3 are created for the basic MNL model. These functions include all attributes identified in Chapter 5 on the survey design. Furthermore, the dummy coding of the variables is explained. As described in the methodology, most of the attributes need to be dummy coded. To estimate a dummy variable, the number of attribute levels minus one needs to be added as parameters in the utility functions to be able to estimate these dummies. The attribute level that is not included is the scenario to which the other levels of dummy variables are compared. The list of all dummy variables can be found in Section E.1.

The base scenario for the length of stay is short-term parking. The bases describing the parking space are outside parking and parking at street furniture, to which inside parking and parking in a rack are compared. The utility function will have three levels for communication added to it, as it has four attribute levels. The attribute level of no communication is taken as the base scenario, to which all other scenarios are compared.

$$\begin{aligned} U_{inside} = &ASC1 + \beta_{SorL} * SorL_1 + \beta_{IorO} * IorO_1 + \beta_{RorF} * RorF_1 + \beta_{WD} * WD_1 \\ &+ \beta_{Cneutral} * C_{neutral_1} \end{aligned} \quad (7.1)$$

$$\begin{aligned} U_{outside} = &ASC2 + \beta_{SorL} * SorL_2 + \beta_{IorO} * IorO_2 + \beta_{RorF} * RorF_2 + \beta_{WD} * WD_2 \\ &+ \beta_{Cneutral} * C_{neutral_2} \end{aligned} \quad (7.2)$$

$$\begin{aligned} U_{fly} = &\beta_{SorL} * SorL_3 + \beta_{IorO} * IorO_3 + \beta_{RorF} * RorF_3 + \beta_{WD} * WD_3 \\ &+ \beta_{Cnegative} * C_{negative_3} + \beta_{Chazardous} * C_{hazardous_3} \end{aligned} \quad (7.3)$$

Where:
ASC_i = alternative specific constant of i
U_i = the utility of alternative i
β_i = The parameter of the attributes
$SorL_i$ = variable for the length of stay, dummy coded for a short stay (0) and long stay (1)
$IorO_i$ = variable for the outside or inside parking, dummy coded for outside (0) and covered (1)
$RorF_i$ = variable for the parking in racks or against street furniture, dummy coded for street furniture (0) and racks (1)
WD_i = variable for the walking distance
$C_{strategy_i}$ = variable for communication, dummy coded for 4 attribute levels

7.1.2. Alternative specific or generic parameters

Each parameter will be tested as alternative-specific. It is checked whether the results of this new model improves and if the parameters stay or become significant by making them alternative-specific. The performance of each of the models is shown in Table 7.1, the total results also showing the value of the betas and their significance is added to Figure E.2 in Appendix E.

The first parameter tested is the length of stay of a trip. The model including this parameter as alternative specific performs much better, so this variable is included as alternative specific moving forward. Next, the neutral communication strategy is made alternative specific. This gives a model with similar performance as the generic one, and the results are significant for both models. Therefore, it is chosen to keep this variable generic, as it is more likely this variable will stay significant when more variables are added to the model later on. The other communication strategies do not need to be tested as none is the base used to compare the dummies to, and hazardous and negative communication already only influence fly parking.

Making parking inside or outside alternative specific does not improve the model. Therefore, it is decided to take this variable out of the model completely. The evidence in the literature of this having an influence on parking choice was weak. Therefore, it is not an unlogical outcome that this result is insignificant. Next, parking at a rack or at street furniture was made specific. This model performed very similarly to the generic one, so this variable is kept generic.

Lastly, there is walking distance. The design was made with actual numbers for the walking distance, since this was needed to be able to create a design. However, due to the use of images, there is no longer an absolute distance for the walking distance in the fly parking scenarios. First, only the walking distance for fly parking was made alternative specific, and it is tested whether it is better to code this variable as a dummy with two levels: close by and further away, or keep the absolute number and test both the original 25 meters and a more realistic distance to represent the images of 10 meters. The best-performing model is an alternative-specific dummy variable for fly parking. Now also the walking distance for inside and outside parking is made alternative specific, this also improves the model.

So, the final base model contains alternative specific parameters for the length of stay and the walking distance. It contains generic variables for all types of communication and for parking at a rack or at street furniture. The variable describing the effect on the parking choice of parking inside or outside is removed from the model, as it was insignificant in both the generic and alternative specific models. The full Python code used is included in Appendix E

Table 7.1: Performance of MNL model generic versus alternative specific

	Likelihood ratio test	AIC	BIC	adjusted rho square
Generic	1439,3847	2993,5734	3048,2900	0,3310
Long specific	1515,8583	2979,0999	3039,8961	0,3343
Neutral specific	1515,8583	2981,0999	3047,9757	0,3338
Inside specific	1515,8583	2979,0999	3039,8961	0,3343
Rack specific	1515,8583	2987,0999	3047,9757	0,3334
WD generic WD_fly dummy	1529,0279	2967,9303	3034,8061	0,3368
WD specific WD_fly dummy	1536,8084	2960,1497	3027,0255	0,3385

The results of this basic model are shown in Table 7.2. The dummy coded betas are included under the name for which their dummy coding is 1, as this makes them easier to interpret. So β_{IorO} is included as β Inside, as this is the situation for which the value is included in the utility. These will be analysed to provide an indication of the effects of communication strategies and other attributes. The ASCs indicate not all aspects of people's choices are captured by the different variables introduced in the model. Apparently, the inside and outside parking have a positive unexplained utility compared to fly parking. Next, all levels of communication attributes exhibit a negative effect on the utility of parking options when compared to the absence of no communication. Hazardous and negative communication only affect fly parking, and as expected, both show a negative effect.

For neutral communication, the negative effect seems strange, as this would mean presenting no communication on the parking options works better than presenting neutral communication. This might be because the scenario of no communication is not included in the design for all options, since this was not possible for the design of the question. Therefore, the model might not be able to make a good comparison between these scenarios. The communication itself may not be having a negative impact, but it could be due to the distance shown on the sign, which people might deem too far.

Next, there are the other factors than communication that also influence the parking choice. Firstly, the choice of inside parking versus outside parking. This is a positive value, since it is dummy coded as one for inside parking, this indicates that an inside parking spot has a positive effect. Next, the effect of a long-term versus a short-term stay. The values indicate that for a long stay, people are less likely to choose inside parking, as well as fly parking, compared to the formal outside parking spot. For the inside parking, that is an unexpected result, as the descriptive statistics in Figure 6.3 also showed an increase in inside parking for a long stay.

Then there is the issue of parking against a rack, or street furniture or tree. This factor is quite big, indicating people prefer parking at a rack over parking at street furniture or a tree massively. Next, there is the walking distance compared to parking at a formal inside spot, people are slightly less likely to walk as far for a formal outside spot. However, people are willing to walk towards a fly parking spot that is a bit further away. Looking at the results for walking distance of outside parking and other research, it's likely that this preference for fly parking is only true for this small change in distance. It's unlikely that people will also prefer a fly parking spot much further away than suggested in this research. It should be noted that the magnitude of the betas for these walking distances is not comparable, as the outside parking is multiplied by the actual distance, whilst the beta for fly parking is based on a dummy.

Table 7.2: Final base model

	Likelihood ratio test	AIC	BIC	adjusted rho square
WD specific WDfly dummy	1536.8084	2960.1497	3027.0255	0.3385
	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC inside	1.03	0.12	8.50	0
ASC outside	1.00	0.09	10.96	0
β **hazardous comm**	-1.78	0.14	-12.70	0
β **negative comm**	-1.34	0.20	-6.56	5.21E-11
β **neutral comm**	-2.03	0.24	-8.31	0
β **Inside**	1.03	0.12	8.50	0
β **Long for inside**	-0.86	0.20	-4.41	1.01E-05
β **Long for fly**	-1.29	0.23	-5.66	1.54E-08
β **Rack**	2.03	0.13	15.90	0
β **WD for outside**	-0.20	0.003	-7.71	1.22E-14
β **WDfly far**	0.71	0.25	2.81	0.005

7.2. Interaction effects

The next model that is developed is the MNL model, where only interaction effects of communication with socio-demographics are added to the base model. First, it will be described how these variables were added to the model, first separately and later all combined, and how these models performed. Secondly, the results of these models are analysed to give a first indication of the effect of belonging to certain user groups on the responses to different communication strategies.

7.2.1. Adding interaction effects to the model seperately

Interaction terms are added to the model for different socio-demographics, combined with each of the communication strategies. All interactions for a single socio-demographic are added to the model one at a time. The following socio-demographics are tested: gender, age, frequency of bike use, the price of a bike, and certain work situations. These are all included as the groups described in the descriptive statistics. For the frequency of use, the frequent users are used as a basis for the other two groups. Women are the base for gender, older people are the base for age, and cheaper bikes are the base for price. Education level cannot be tested due to the small spread in the data. For work situations, only two groups are compared to the sample, as these are the only ones large enough: full-time workers and students/scholars. The interaction of these groups with communication is tested. However, it should be noted that these groups form a large part of the sample compared to the Dutch population, so their impact might not be completely comparable to their impact in reality.

Table 7.3: Significant variables for models with interaction effects of socio-demographics and communication

Model	Significant values
Gender generic	None and neutral
Price specific	Neutral outside, None fly
Frequency generic	Neutral infrequent users, hazardous infrequent users
Age specific	Neutral outside
Full-time	Hazardous
Student specific	Neutral inside, hazardous

All interaction terms are tested one by one as alternative-specific and generic. The interaction effects were first added to the basic MNL model separately to see their impact on the model performance and determine whether they should be added as alternative specific or generic. Because of the limited size of the sample, no further combinations of interaction effects, like for instance a combination of being young and an infrequent bike user, as a lot of these groups would become too small to give statistically significant results. In these models, only the interaction terms that were significant are included, which interaction terms were significant is indicated in Table 7.3. The complete results with the estimations of all betas can be found in Section E.3.

7.2.2. Results of MNL model of separate interactions

In Figure 7.2 the measures that indicate the performances of all models are visualised. They are compared to each other, the results of each performance indicator are scaled relative to the performance of the other models of that indicator. The performance of a model combining all interactions is also included in this image, what this model looks like is discussed in Figure 7.2.2. Most performance indicators, except for the BIC, perform better for the models with interactions than without. This indicates that adding the interaction terms is likely to help to explain the results better.

Now the effect of the socio-demographics on the communication strategies is discussed. Starting with negative educative communication. As can be seen in column two of Table 7.3 there is no interaction effect included for the negative educative strategy because none of these interactions were significant. So, this communication strategy will not be more or less effective for different user groups. For the other communication strategies, the socio-demographics do appear to have an effect on their effectiveness. The values shown present the effect of the interaction on the parking choices, not the direct effect of the communication itself.

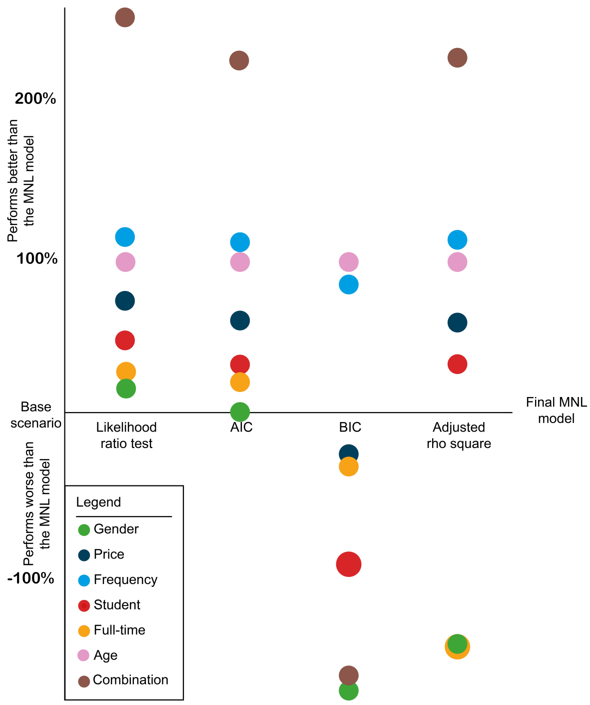

Figure 7.2: Performance of interaction effect models

No communication

No communication was used as the base to estimate the other communication levels, so the value itself is 0. However, people's gender and the price of a person's bike appear to have an effect on the effectiveness of this communication, or rather lack of communication.

The no communication strategy was only present for outside parking near the destination and fly parking. Since no communicating was used as the base to estimate the dummy, there is no separate value for the effect of no communication for the outside parking choices and fly parking. In Figure 7.3 the results are visualised. It shows that according to these interaction terms, being a male makes it less likely people choose outside parking or fly parking when no communication was presented. The interaction effect of gender does not seem strong. In the later models, when more variables are added, it should be checked whether this result is still significant.

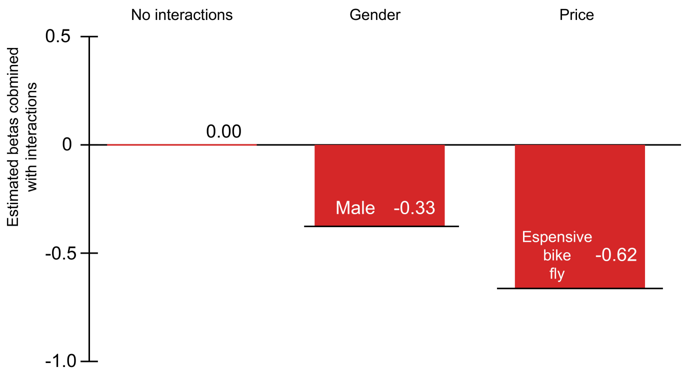

Figure 7.3: Effect of socio-demographics on no communication for outside and fly parking per added interaction

The other interaction effect that is significant for no communication is the one with people owning an expensive bike and using fly parking This variable indicates people with an expensive bike are less likely to choose fly parking.

Educative neutral communication

Neutral educative communication is present for the parking options inside and outside at a rack. The overall effect is negative, which was indicated to be strange. However, the effect of the interactions can still be compared to the effectiveness of the neutral educative strategy in the model where no interactions were present. The interactions gender and frequency of use were included as generic interactions for both inside and outside, as these models performed better and gave significant values. The interaction of price of a person's bike, people's age, and being a student or scholar with communication were added as alternative specific. The results are shown in Figure 7.4.

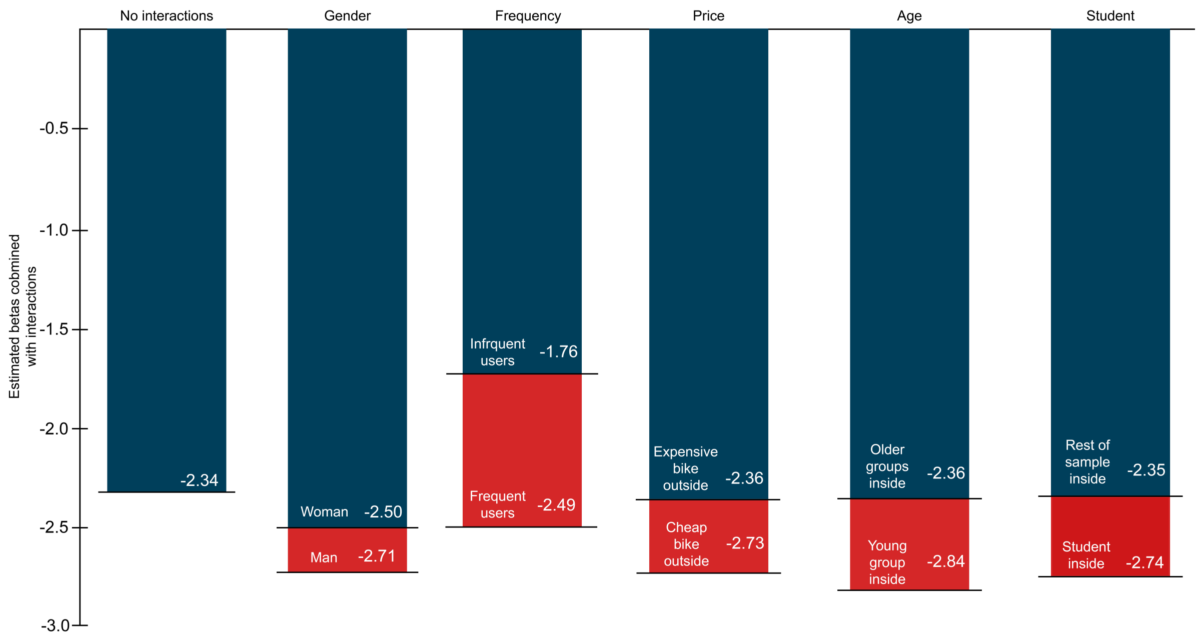

Figure 7.4: Effect of socio-demographics on neutral communication for inside and outside parking per added interaction

Starting with the effect of gender, the effect of this interaction is minimal. According to the results, men are less likely than women to choose the parking options inside or outside parking when they are indicated to them. Now for the interaction of frequency of use and the neutral educative strategy, according to the model, infrequent users are more likely to use the indicated parking spots than frequent bicycle users.

The following interaction effect that was added is the price of a person's bike. This interaction effect was only significant for outside parking. The effect of people owning an expensive bike is small compared to the original model. People that own a cheap bike appear to follow the instructions of the neutral strategy that direct them to an outside parking spot much less. The value for inside parking for this interaction with neutral educative strategy and the price of a person's bike is insignificant. So, apparently this strategy is not more or less effective to promote inside parking to people with a differently priced bike.

Then there is the interaction with age. This interaction effect is only significant for inside parking. The young group appears to be less likely to listen to the communication through the neutral strategy for inside parking. The value for the interaction of outside parking and age is insignificant, indicating that choosing for an outside parking spot, when it is indicated, is not affected by a person's age.

Lastly, there are students and scholars, which are most of the time also young people. Again, only the effect on inside parking was significant, the effect of the neutral educative strategy on students is even lower than for young people. This might be because students are not only young but also own a cheap bike and are frequent users most of the time, which all make the neutral strategy less effective, as shown by previous interaction effects. This might mean the interaction of being a student and this communication strategy also tries to explain part of these other interactions, since they are now added to separate models. Furthermore, the sample contains many students and scholars, compared to the national average, therefore the effect of being student or scholar might not become completely clear from this dataset. The model for the interaction with students and scholars performs badly, and this might be due to one of the reasons mentioned. When models are combined, it should be checked if the interaction with being a student is still significant for this dataset.

Hazardous communication

The hazardous strategy is only added to the fly parking option in the model. Therefore, the values for these variables indicate the disutility of the fly parking option when hazardous communication is presented.

These results, as shown in Figure 7.5, indicate frequent bike users are less likely to choose fly parking when hazardous communication is presented than infrequent bicycle users.

The group of full-time workers is slightly more likely to use the fly parking option compared to the rest of the sample, even though hazardous communication was presented to them. But, the rest of the sample consists of students and scholars for a large part. The same is true when looking at the results the other way around. Here, the results of the entire sample are probably heavily influenced by full-time workers. Still, the results show students and scholars are way less likely to choose fly parking when hazardous communication is presented. These results are now significant for the current sample, but this might mainly be due to the difference in behaviour between these two groups. It is not possible to know what types of behaviour groups in other work situations would show. However, it can be concluded that this communication strategy is very effective for students and scholars.

It is interesting that the age and price of a person's bike apparently do not have an effect on the effectiveness of the hazardous strategy. One might expect, again, that young people are more

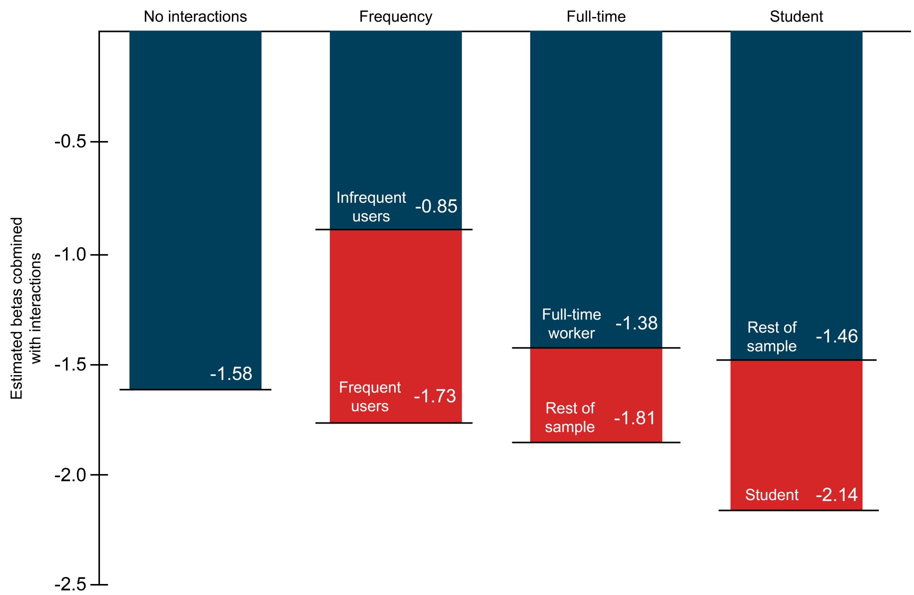

Figure 7.5: Effect of socio-demographics on hazardous communication for fly parking per added interaction

reckless, but maybe this effect is counteracted by their dependence on a bicycle. It could also be expected that people owning a cheap bike are less careful with their bike, but apparently this is not the case when they are presented with hazardous communication.

Combination of all interaction effects

In the final interaction model, all interaction effects were combined. Adding multiple variables might help explain the results even better, in terms of their effect on the effectiveness of the different communication strategies. As shown in Figure 7.2, the BIC only improves for the interaction between communication and the frequency of use, and a person's age. This indicates that these are strong interaction effects, which have an effect on the effectiveness of communication for different parking choices. For the adjusted rho square, the value for gender and working full-time decrease in performance. This means that adding the interaction of gender and of working full-time with the communication strategies does not really improve the model.

Furthermore, some effects become insignificant in this combined model, namely gender and the two interaction effects on the work situation. Adding the interaction effect for gender and communication gave the worst-performing model, so this one is removed first. The values for the work situation of students or scholars are still insignificant, so these are also removed from the model. This gives a model that performs well and includes only significant values. The results of this model, including the estimation of all betas, are presented in Table 7.4. The utility functions of this model are indicated in Equation 7.4, Equation 7.5 and Equation 7.6. Where the new interaction terms are indicated in red. The entire syntax for this model is presented in the appendix in Section E.3.

$$U_{\text{inside}} = ASC1 + \beta_{SorL_1} \cdot SorL_1 + \beta_{IorO} \cdot IorO_1 + \beta_{RorF} \cdot RorF_1 + \beta_{Cneutral} \cdot C_{\text{neutral}_1}$$
$$+\beta_{Cneutral\_infrequent} \cdot C_{\text{neutral}_1} \cdot \text{infrequent} \quad (7.4)$$
$$+\beta_{Cneutral\_young\_inside} \cdot C_{\text{neutral}_1} \cdot \text{young}$$

$$U_{\text{outside}} = ASC2 + \beta_{RorF} \cdot RorF_2 + \beta_{IorO} \cdot IorO_2 + \beta_{WD_2} \cdot WD_2 + \beta_{Cneutral} \cdot C_{\text{neutral}_2}$$
$$+\beta_{Cneutral\_infrequent} \cdot C_{\text{neutral}_2} \cdot \text{infrequent} \quad (7.5)$$
$$+\beta_{Cneutral\_expensive\_outside} \cdot C_{\text{neutral}_2} \cdot \text{expensive}$$

$$U_{\text{fly}} = \beta_{SorL_3} \cdot SorL_3 + \beta_{RorF} \cdot RorF_3 + \beta_{WD_{\text{fly}}} \cdot WD_3$$
$$+ \beta_{Cnegative} \cdot C_{\text{negative}_3} + \beta_{Chazardous} \cdot C_{\text{hazardous}_3}$$
$$+\beta_{Cnone\_expensive\_fly} \cdot C_{\text{none}_3} \cdot \text{expensive} \quad (7.6)$$
$$+\beta_{Chazardous\_infrequent} \cdot C_{\text{hazardous}_3} \cdot \text{infequent}$$
$$+\beta_{Chazardous\_fulltime} \cdot C_{\text{hazardous}_3} \cdot \text{fulltime}$$

The results of this model are shown in Table 7.4. The interaction effects of being a student or scholar and gender became insignificant in these combined models. For gender, the spread in the data is representative for the entire population, and therefore it is assumed that this parameter becoming insignificant is probably due to gender indeed not having an influence on the effectiveness of a communication strategy.

Table 7.4: MNL model combinations of all significant interaction effects

	Likelihood ratio test	**AIC**	**BIC**	**adjusted rho squre**
Combined interactions	1585.7349	2923.2233	3026.5770	0.3468
	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC inside	0,69	0,11	6,51	0,00
ASC outside	1,40	0,09	15,75	0,00
β **hazardous comm**	-2,13	0,19	-11,46	0,00
β **hazardous x FT**	0,41	0,18	2,33	0,02
β **hazardous x infrequent**	0,84	0,28	3,01	0,00
β **negative comm**	-1,05	0,21	-5,10	0,00
β **neutral comm**	-2,50	0,24	-10,37	0,00
β **neutral x expensive on outside**	-0,31	0,13	-2,37	0,02
β **neutral x infrequent**	0,72	0,17	4,27	0,00
β **neutral x young on inside**	-0,37	0,14	-2,61	0,01
β **none x expensive on fly**	-0,49	0,19	-2,60	0,01
β **Inside**	0,69	0,11	6,51	0,00
β **Long inside**	-2,71	0,29	-9,24	0,00
β **Long fly**	-2,05	0,30	-6,96	0,00
β **Rack**	2,09	0,15	13,87	0,00
β **WD outside**	-0,02	0,00	-8,14	0,00
β **WDfly far**	0,59	0,22	2,61	0,01

But for the group of students and scholars, this might be slightly different. As indicated, this could also be caused by the lack of spread in the data of different work situations. Figure 7.6 shows the difference in the values for the betas for communication when interaction effect were added separately and were combined. For most of these values, there is a small spread.

For the beta hazardous, the combined model is however quite different from the model where the interaction with students was included. These values are indicated in Table 7.5.

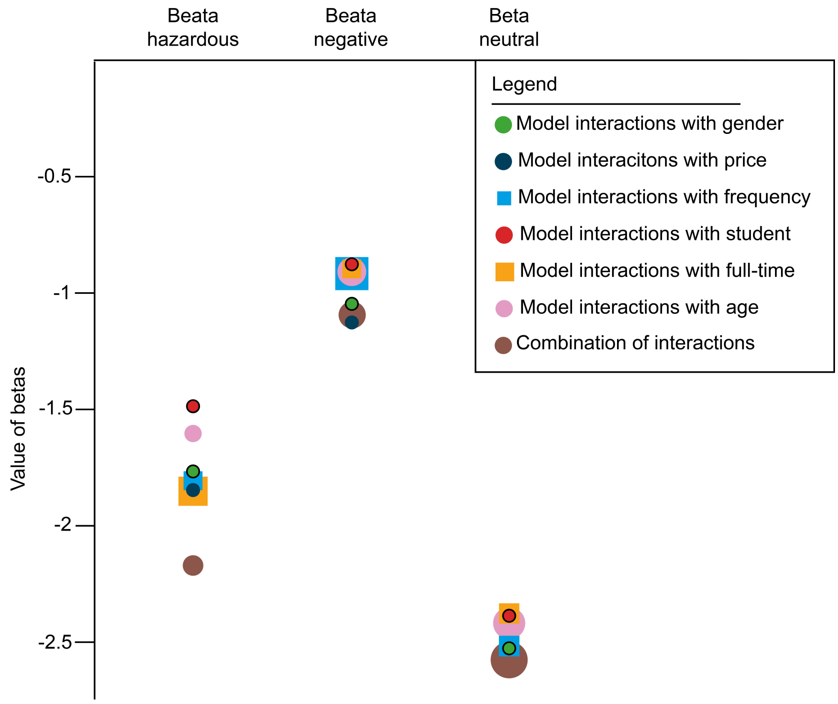

Figure 7.6: Values of betas of the different communication strategies for the interaction models

Table 7.5: Overview value hazardous and interaction hazardous and student

	Only interaction with students/scholars	Combined model
Hazardous	-1.46	-2.13
Hazardous x student	-0.68	

The interaction with hazardous and being a student/scholar is insignificant in the combined model, but for the models where this interaction was added, the value of the beta of hazardous is much less negative than the beta of hazardous communication in the final combined model. The large group of students and scholars now included in the sample, without the extra explanation of the interaction variable, therefore probably makes the entire beta hazardous more negative than in the model with the interaction with hazardous communication and student. So, it is indeed very likely that this effect is actually there but is not significant in the model due to the data.

The values of all betas and what they indicate will be discussed again later, in Section 7.6.2, when also the direct effect of socio-demographics are added to the model and an ML model is produced. The best performing model produced is then explained, as this should explain the parking behaviour best. What can be noted is there are no major changes, like sign changes or factors included in the base model becoming insignificant.

7.3. Adding socio-demographics to the base model

From the base model also another model is developed, this model includes the socio- demographics directly as these also potentially influence people's parking behaviour. This was also shown in the chapter Chapter 6 on descriptive statistics. The results for the parking choice changed significantly for age, the price of a person's bike, and the frequency of use, so these will all be added to the model. First, their individual effect on the performance of the model is investigated and next, they will be combined in an attempt to find the best model describing parking choices. This model can be combined with the model including the interaction effects in the next step, to eventually find the best working MNL model.

Table 7.6: MNL model combination of socio-demographics

	Likelihood ratio test	AIC	BIC	adjusted rho square
Combining interaction effects and socio-demographics	1562.9556	2940.0025	2025.1172	0.3430
	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC inside	0.677	0.102	6.647	0.000
ASC outside	1.462	0.090	16.285	0.000
β **expensive on outside**	-0.242	0.117	-2.064	0.039
β **infrequent on fly**	-0.412	0.142	-2.912	0.004
β **hazardous comm**	-1.587	0.131	-12.132	0.000
β **negative comm**	-0.855	0.191	-4.473	0.000
β **neutral comm**	-2.372	0.232	-10.242	0.000
β **Inside**	0.677	0.102	6.647	0.000
β **Long inside**	-2.586	0.290	-8.913	0.000
β **Long fly**	-2.118	0.293	-7.221	0.000
β **Rack**	2.139	0.146	14.643	0.000
β **WD outside**	-0.024	0.003	-8.310	0.000
β **WDfly far**	0.650	0.225	2.892	0.004
β **young on inside**	-0.436	0.138	-3.160	0.002

Start with adding age. The best performing model that also gives significant values for the betas is when this effect of age is only included for inside parking. The beta is negative, which indicates young people have a slight disutility for inside parking spots. Next, the price of a person's bike was included.The best performing model with significant outcomes for the betas is when it is applied as an alternative specific parameter. Lastly, frequency of use is added. Looking at what model gives the best performance whilst also giving significant outcomes, the best model is an alternative specific model, since the generic model does perform better, but does not give significant results.

Now these models with socio-demographics are combined to see if this gives a well performing model with significant estimates for the betas. This model gives an insignificant value for the expensive bikes at fly parking and inside parking, so these are removed from the model. This gives a better performing model with all betas significant. The estimates of this model are shown in Table 7.6. The results of the separately added socio-demographics are included in Figure E.4. The syntax of the final model combining all socio-demographics is included in Section E.4.

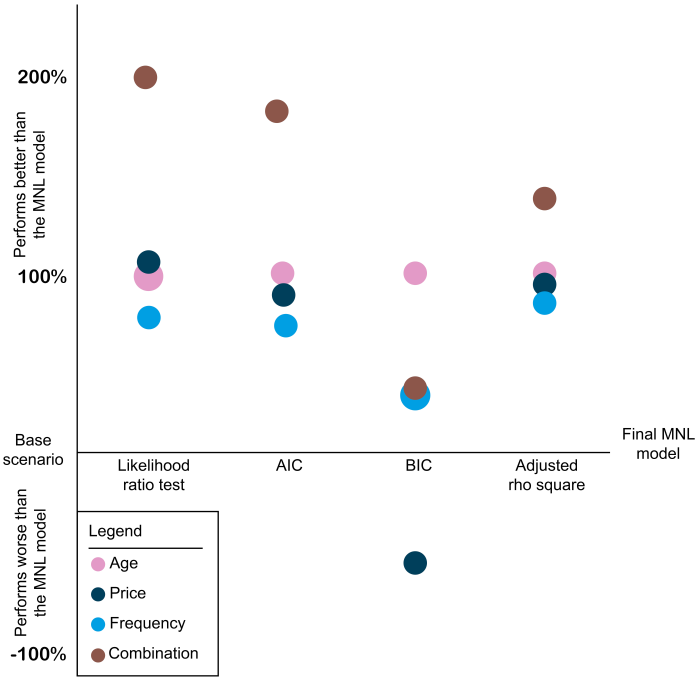

Figure 7.7: Performance of models with socio-demographics

The performance of the different models is visualised in Figure 7.7. This model combining the different socio-demographics performs better than the base model. There are, however, only a few effects of socio-demographics on parking behaviour significant. So, apparently very few of the socio-demographics included in this research impact the parking choice for cyclists.

7.4. Combining interaction effects and socio-demographics

The final models of the interaction effects and socio-demographics are combined. This results in a model where the values for the betas on the frequency of use and price of a bike are insignificant, so those are removed. This results in a model with only significant values. The AIC and BIC of this model are slightly worse than these values from the separate models for interactions and socio-demographics. The adjusted rho-square of this model performs better than for only the socio-demographics, and slightly worse than for the interactions. Still, the model combining all information is chosen as the model to add a nest and panel variables. As they only perform slightly worse, but they do provide additional information on the parking choices as more significant parameters are estimated. The utility functions of this combined model are shown in Equation 7.7, Equation 7.8, and Equation 7.9, where the included socio-demographic is added in dark blue. The entire syntax of the model is included in Section E.5. The results of the best performing MNL model is shown in Table 7.7, below.

$$U_{\text{inside}} = ASC1 + \beta_{SorL_1} \cdot SorL_1 + \beta_{IorO} \cdot IorO_1 + \beta_{RorF} \cdot RorF_1 + \beta_{Cneutral} \cdot C_{\text{neutral}_1}$$
$$+\beta_{Cneutral\_infrequent} \cdot C_{\text{neutral}_1} \cdot \text{infrequent} \quad (7.7)$$
$$+\beta_{Cneutral\_young\_inside} \cdot C_{\text{neutral}_1} \cdot \text{young} + \beta_{\text{young}_1} \cdot \text{young}$$

$$U_{\text{outside}} = ASC2 + \beta_{IorO} \cdot IorO_2 + \beta_{RorF} \cdot RorF_2 + \beta_{WD_2} \cdot WD_2 + \beta_{Cneutral} \cdot C_{\text{neutral}_2}$$
$$+\beta_{Cneutral\_infrequent} \cdot C_{\text{neutral}_2} \cdot \text{infrequent} \quad (7.8)$$
$$+\beta_{Cneutral\_expensive\_outside} \cdot C_{\text{neutral}_2} \cdot \text{expensive}$$

$$U_{\text{fly}} = \beta_{SorL_3} \cdot SorL_3 + \beta_{RorF} \cdot RorF_3 + \beta_{WD_{\text{fly}}} \cdot WD_3$$
$$+ \beta_{Cnegative} \cdot C_{\text{negative}_3} + \beta_{Chazardous} \cdot C_{\text{hazardous}_3}$$
$$+\beta_{Cnone\_expensive\_fly} \cdot C_{\text{none}_3} \cdot \text{expensive} \quad (7.9)$$
$$+\beta_{Chazardous\_infrequent} \cdot C_{\text{hazardous}_3} \cdot \text{infrequent}$$
$$+\beta_{Chazardous\_fulltime} \cdot C_{\text{hazardous}_3} \cdot \text{fulltime}$$

Table 7.7: MNL model combination of socio-demographics and interactions

	Likelihood ratio test	AIC	BIC	Adjusted rho square
Combining interaction effects and socio-demographics	1585.7349	2925.2232	3034.6564	0.3463
	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC Inside	0,69	0,11	6,51	7,6E-11
ASC Outside	1,40	0,09	15,75	0,0E+00
β hazardous comm	-2,13	0,19	-11,46	0,0E+00
β hazardous x FT	0,41	0,18	2,33	2,0E-02
β hazardous x infrequent	0,84	0,28	3,01	2,7E-03
β negative comm	-1,05	0,21	-5,10	3,4E-07
β neutral comm	-2,50	0,24	-10,37	0,0E+00
β neutral x expensive on outside	-0,31	0,13	-2,37	1,8E-02
β neutral x infrequent	0,72	0,17	4,27	1,9E-05
β neutral x young on inside	-0,18	0,07	-2,61	9,0E-03
β none x expensive on fly	-0,49	0,19	-2,60	9,3E-03
β Inside	0,69	0,11	6,51	7,6E-11
β Long inside	-2,71	0,29	-9,24	0,0E+00
β Long fly	-2,05	0,30	-6,96	3,5E-12
β Rack	2,09	0,15	13,87	0,0E+00
β WD outside	-0,02	0,00	-8,14	4,4E-16
β WDfly far	0,59	0,22	2,61	9,1E-03
β young on inside	-0,18	0,07	-2,61	9,0E-03

7.5. Mixed logit model

First, a model is developed, where a nest is tested for. Next, panel effects are added to the model. These steps are described first. Then the results of the entire model are described. Lastly, the mixed logit model is compared to the MNL models including interactions to see if there are mayor differences between the two.

7.5.1. Testing for a nest

Now, the presence of a nested structure is tested for. The inside and outside parking share similar characteristics, as they are both formal parking options. Formal parking might therefore share a similar average utility or disutility. This is tested using a nested logit model. The result for mu are shown in Table 7.8. The t-statistic from the sample t-test is 0.01, with an α of 0.05, for which the confidence interval is 1.96 it is determined mu is not significantly different from 1. As the t-statistics falls within the confidence interval. This means the inside and outside parking do not need to be included as a nested structure.

Table 7.8: Results for mu

	Value
mu	1.47
s	0.27
t	0.001
Z	+/-1.96

7.5.2. Panel effects

Since the mu for the nested structure is insignificant, only panel effects are added to the mixed logit model. When panel effects are added to the model, the interaction of hazardous communication and full-time workers becomes significant. So for the current data set this should be removed from the model. The utility functions for the ML model are shown in Equation 7.11, Equation 7.10, and Equation 7.12. The full syntax for the final ML model is included in Table E.6. Table 7.9 below shows the performance of the panel model compared to the MNL model, including socio-demographics and interactions. All performance indicators improved for the panel model and the value of sigma is 1.39 with a significance level that approximates 0.

Table 7.9: Performance of panel model

	Likelihood ratio test	AIC	BIC	adjusted rho square
Final MNL model	1585.7349	2921.2233	3018.4972	0.3472
Panel	1806.3644	2702.5937	2763.7039	0.3961

$$\begin{aligned} U_{inside} = {} & ASC1 + \beta_{SorL_1} * SorL_1 + \beta_{IorO} * IorO_1 + \beta_{RorF} * RorF_1 + \beta_{Cneutral} * C_{neutral_1} \\ & + \beta_{Cneutral\_infrequent} * C_{neutral_1} * infrequent \\ & + \beta_{Cneutral\_young\_inside} * C_{neutral_1} * young + \beta_{young_1} * young + Sigma \end{aligned} \tag{7.10}$$

$$U_{outside} = ASC2 + \beta_{IorO} * IorO_2 + \beta_{RorF} * RorF_2 + \beta_{WD_2} * WD_2 + \beta_{Cneutral} * C_{neutral_2} + \beta_{Cneutral\_infrequent} * C_{neutral_2} * infrequent + \beta_{Cneutral\_expensive\_outside} * C_{neutral_2} * expensive + Sigma \quad (7.11)$$

$$U_{fly} = \beta_{SorL_3} * SorL_3 + \beta_{RorF} * RorF_3 + \beta_{WD_{fly}} * WD_3 + \beta_{Cnegative} * C_{negative_3} + \beta_{Chazardous} * C_{hazardous_3} + \beta_{Cnone\_expensive\_fly} * C_{none_3} * expensive + \beta_{Chazardous\_infrequent} * C_{hazardous_3} * infrequent \quad (7.12)$$

7.6. Interpretation of ML model

The ML with panel effects improved on all performance parameters and is currently the best performing model. However, the ML model has the disadvantage of needing a better dataset than the MNL model. To see if this has an effect on the results, the ML model is first compared to the best performing MNL model. Afterwards, the results of the overall best model are discussed in Section 7.6.2.

7.6.1. Comparing the ML model to the MNL model with interactions

In Figure 7.8 the results of the ML and final MNL model are shown in on graph to be able to compare them. The effects in the ML model are all slightly more extreme. This is probably due to the introduction of sigma, which explains heterogeneity in choices of a single person. In the ML model, one interaction variable became insignificant, which was the one of being a full-time worker. Since the data on the work situation is not well dispersed, it is very likely this interaction effect became insignificant in the ML model because of the data available on it.

The effects of other interactions on the model are similar for most communication strategies. The fact that the interaction effects stayed significant and have a similar effect on the ML model as the MNL model indicates that the effect of the interaction effects of communication and socio-demographics is indeed strong. So, it can be concluded that belonging to a certain user group with specific socio-demographic characteristics influences the effect a communication strategy has. Unfortunately, the dataset in this research is not large enough to investigate the combination of different socio-demographics creating more specific groups that might present even more extreme behaviour.

Since the ML model is deemed the best performing model, the results of this model are discussed in the next section.

7.6.2. ML model results

The results, for the best-performing model, the panel model including the significant interaction effects and socio-demographics, are shown in Table 7.10.

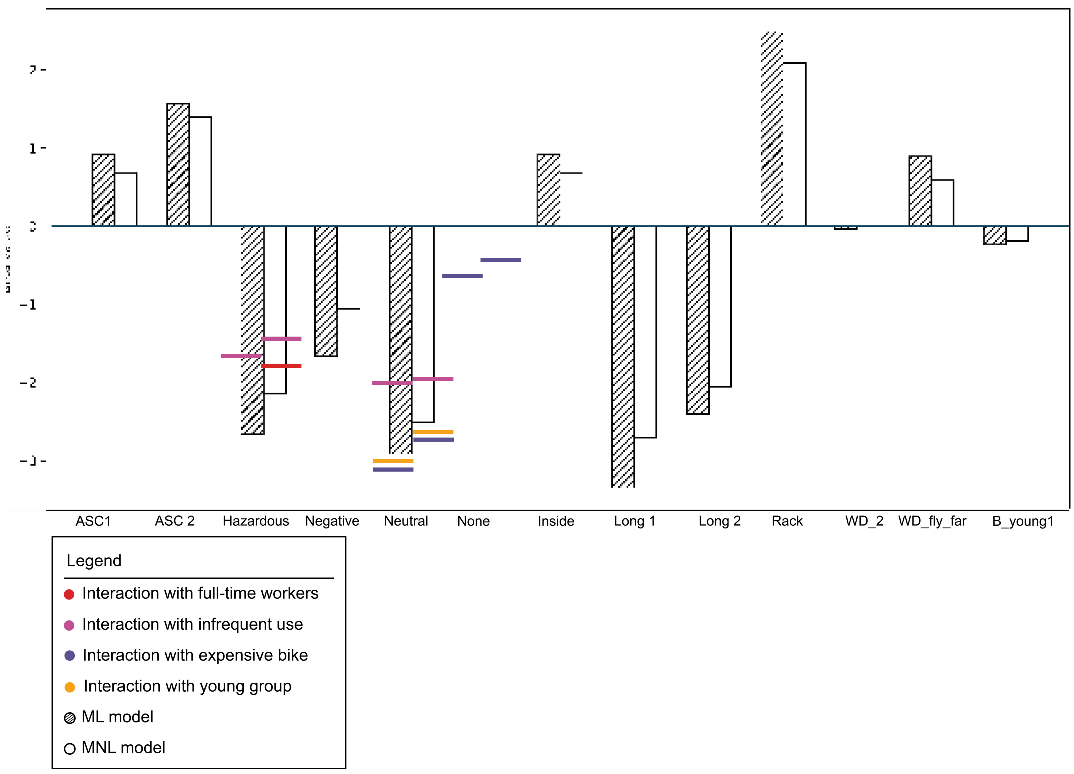

Figure 7.8: Compare results ML and MNL model with interactions

All attribute levels of communication still have a negative impact on the utility of the parking options in the ML model. Therefore, it can be concluded that people are less likely to utilize fly parking when it is communicated as prohibited. The effect of hazardous communication is almost twice as large as the effect of negative educative communication. However, the effect of hazardous communication is much lower for infrequent bicycle users.

Table 7.10: Final ML model with panel effects

	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC inside	0,92	0,11	8,05	0,00
ASC outsie	1,57	0,10	15,67	0,00
β hazardous comm	-2,66	0,20	-13,52	0,00
β hazardous x infrequent	1,09	0,33	3,32	0,00
β negative comm	-1,66	0,22	-7,55	0,00
β neutral comm	-2,91	0,24	-11,95	0,00
β neutral x expensive on outside	-0,38	0,17	-2,21	0,03
β neutral x infrequent	1,00	0,31	3,19	0,00
β neutral x young on inside	-0,24	0,10	-2,33	0,02
β none x expensive on fly	-0,74	0,22	-3,36	0,00
β Inside	0,92	0,11	8,05	0,00
β Long inside	-3,34	0,29	-11,53	0,00
β Long fly	-2,40	0,26	-9,24	0,00
β Rack	2,49	0,14	17,42	0,00
β WD outside	-0,03	0,00	-10,23	0,00
β WDfly far	0,89	0,22	4,08	0,00
β young on inside	-0,24	0,10	-2,33	0,02
Sigma_panel	-1,39	0,12	-12,04	0,00

The effect of neutral communication also stayed negative, which was not expected. The impact is even greater than for the hazardous strategy. What can be concluded is that the neutral educative strategy is influenced by many socio-demographics. Since it is more negative for certain user groups than for others. This means it is likely the effectiveness of this communication strategy depends on the user group, but more research is needed to identify if this effect is still there when the strategy has a more logical effect overall. Lastly, there is the base scenario of no communication. When no communication is presented, people with an expensive bike are less likely to choose fly parking.

There were also other factors, such as the length of stay, parking at a rack or street furniture, and the walking distance, which remained similar in effect to the most basic first model, although the numbers changed slightly. The last beta is for the effect being young has on the parking choice. This factor influences the inside parking choice, and it says young people are slightly less likely to use the inside parking. Lastly, the ASCs are still significant, indicating part of the variation in the choices cannot yet be explained by the variables included in the model variables.

Choice probability of fly parking

To address the central research question regarding the varying impacts of communication strategies, the aim is to identify the most effective approaches to reduce fly parking. According to the model, the negative educative and hazardous communication strategies help reduce fly parking. It is now analysed how much these communication strategies contribute to the reduction of fly parking. The probability of individuals choosing fly parking for various communication strategies is determined. This is done for each scenario, so varying all attributes. The results for each separate scenario are included in Section E.7.

To get an insight into the effectiveness of the strategies, the average outcome over all situations per communication type is determined. This is shown in Table 7.11 below. Based on these results, it can be concluded that the deployment of hazardous and negative educative strategies results in a significant reduction in the choice probability of fly parking, according to the model. Only a small group will still prefer fly parking.

Table 7.11: Change in choice probabilities when communication strategies are introduced compared to no communication

	Short	Long
Percentage of people choosing fly parking no communication	0.41	0.54
Percentage of people choosing fly parking hazardous communication	0.07	0.10
Percentage of people choosing fly parking educative negative communication	0.10	0.14

7.7. Validation

The final MNL and ML models are validated in this section. First, it is tested whether the model provides generalizable and reliable outcomes. The dataset was used to obtain 5 random samples with 80% of the size of the entire sample Next, the estimates of the beta values estimated based on all subsets are presented in Figure 7.9 and Figure 7.10.

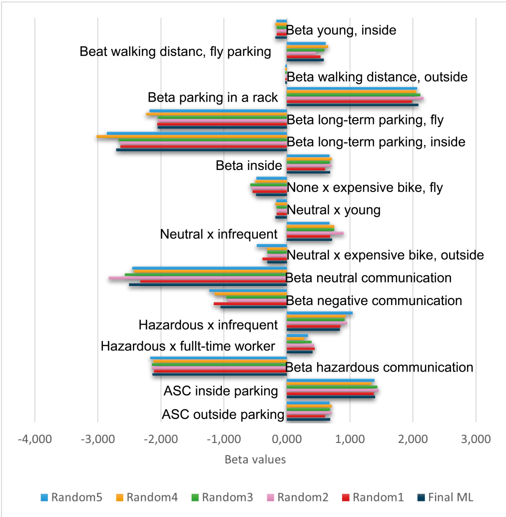

Figure 7.9: Beta values from MNL model compared to values based on 80% of the dataset

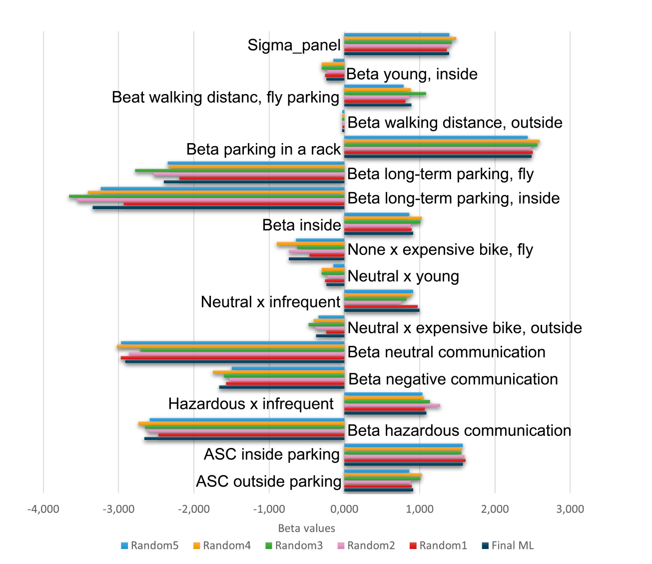

Figure 7.10: Beta values from ML model compared to values based on 80% of the dataset

To determine whether the values significantly differ, a t-test is performed, comparing each of the beta values of the random sample to the beta value found in the entire dataset. The critical value is 1.96 with α= 0.05. None of these values differed significantly from the beta values from the entire dataset. It indicates that the model provides accurate estimates of beta values. The tables with all the values for the betas of the models and the results from the t-test are provided in Section E.8.

The adjusted rho squares of the MNL and ML model are 0.3463 and 0.3443 respectively. These values are not extremely high, indicating certain important variables that could help explain the data better are not yet included in the model. However, since this is a study exploring a field in which not a lot of previous estimation and information on influencing factors is available, and combined with the other step in the validation, the model is deemed to give accurate estimates for most of the beta values, currently included.

7.8. Sensitivity analysis

The ML model, which is the best-performing model and gives good betas according to the validation. So, this model is selected for conducting the sensitivity analysis. Different scenarios to research need to be developed. The utility functions consist of many attributes, however not all of them can be changed. For instance, inside parking will always be inside and fly parking will never be provided at a rack. The research investigates how fly parking could be reduced through fly parking. Therefore, the focus of the sensitivity analysis is on the hazardous and negative educative communication strategies. The neutral educational strategy is not further investigated due to unexpected results, which are unlikely to yield practical and generalisable outcomes.

The attributes that can be varied for the hazardous and negative strategy include a short or long-term stay, age, the price of a person's bike, being a frequent or infrequent bike user, walking distance for outside parking, and walking distance for fly parking. Most of these variables are dummy coded, which implies that their impact is either present or absent. So, the choice probability of fly parking for different scenarios, including or excluding these dummy coded attributes, needs to be determined to say something about the sensitivity to these variables. The results of these choice probabilities for all scenarios are included in Section E.9.

In this section, the attributes to which people appear sensitive are discussed. The results indicate that individuals are highly sensitive to the walking distance from outside parking to their destination and whether they are searching for a parking spot for short or long-term parking. Additionally, age, the slightly greater distance to fly parking and the frequency of use are the most influential attributes. So, these are all discussed below.

7.8.1. Sensitivity to walking distance outside parking

The utility functions include one continuous variable: the walking distance for outside parking, referred to as WD2 in this section. Previous research has shown that walking distance has a significant impact on parking choice, and this analysis confirms that people are very sensitive to this attribute.

Interestingly, this sensitivity is particularly strong for long-term parking. Figure 7.11 shows an individual who is most and least likely to choose fly parking when hazardous communication is included. This is done to show the effect is there throughout all scenarios. Based on the tables in Section E.9 an individual least likely and most likely to choose fly parking were selected. The least likely to choose fly parking represents an old, frequent user with fly parking located right next to, so close to, their destination. The most likely to choose fly parking depicts a young, infrequent user with fly parking slightly further away. The graph demonstrates that the further the walking distance to the outside parking spot is, the more sensitive individuals are to the walking distance when seeking long-term parking. As the probability to choose fly parking shows exponential growth.

The same effect is there for the negative strategy, this can be seen in Table E.40 and Table E.41. Apparently, even if communication is presented prohibiting fly parking, if the walking distance becomes too long, people are no longer sensitive to the distinction between short-term and long-term parking and are willing to accept the risk associated with fly parking even for long-term parking.

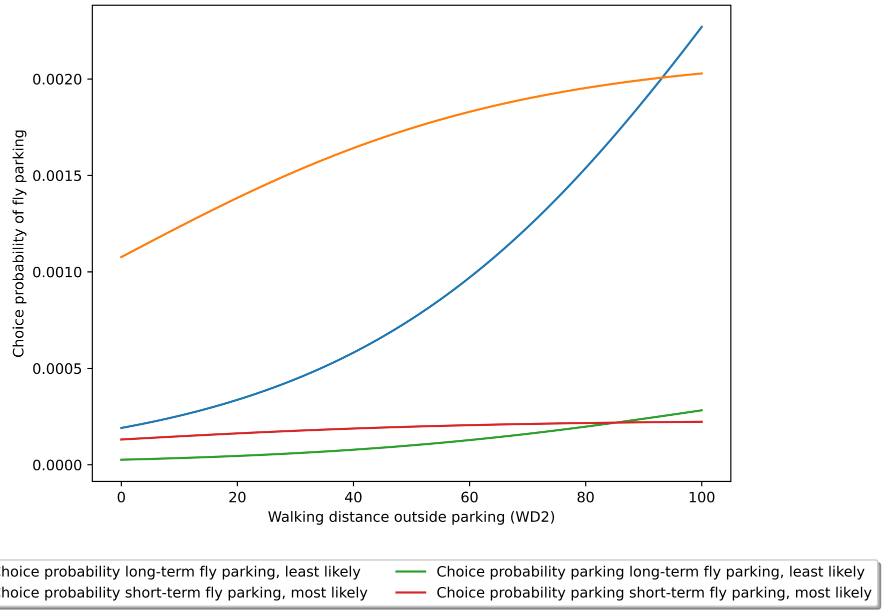

Figure 7.11: Effect of walking distance to outside parking of choice probability of fly parking

7.8.2. Sensitivity to age

Based on Table E.42 and Table E.41, Figure 7.12 and Figure 7.13 were created. These graphs show young people are more sensitive to communication strategies for long-term parking. Young people are more likely than older individuals to choose fly parking across all situations. However, the probability of choosing fly parking between young and older individuals diminishes for long-term parking. The probability of young people choosing fly parking drops. This indicates that young people are more sensitive to these strategies for long-term parking, and perceive the risk in this situation to be relatively higher.

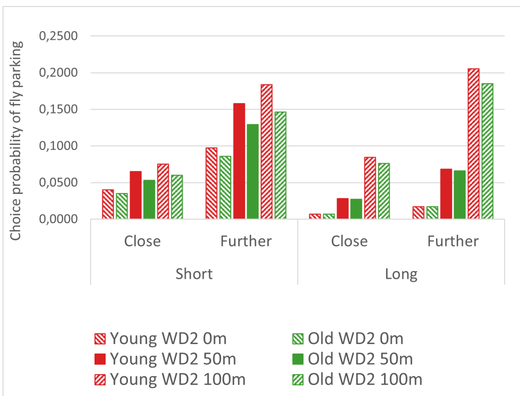

Figure 7.12: Choice probabilities of fly parking for the negative strategy comparing young and old people

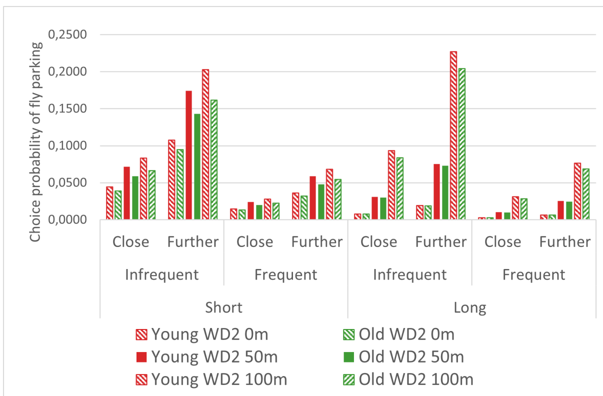

Figure 7.13: Choice probabilities of fly parking for the hazardous strategy comparing young and old people

7.8.3. Sensitivity to walking distance of fly parking

The next intriguing aspect is the effect of placing the fly parking spot slightly further away. This makes the fly parking spots more attractive. As discussed, this effect is likely limited to a short distance. However, Table E.37 and Table E.38 indicate that people exhibit high sensitivity to this attribute. This is visualised in Figure 7.14 and Figure 7.15. The data used for this graph is the same as for Figure 7.12 and Figure 7.13, but has been rearranged to be able to more easily identify the effect on the choice probability. Having a parking spot slightly further from their destination makes individuals around 2.4 times more likely to choose fly parking in all scenarios. Currently, there is no clear explanation for this difference in behaviour in Chapter 9 a possible explanation is given and more research into this will be proposed.

Figure 7.14: Choice probabilities of fly parking for the negative strategy comparing a walking distance of fly parking being close or slightly further away

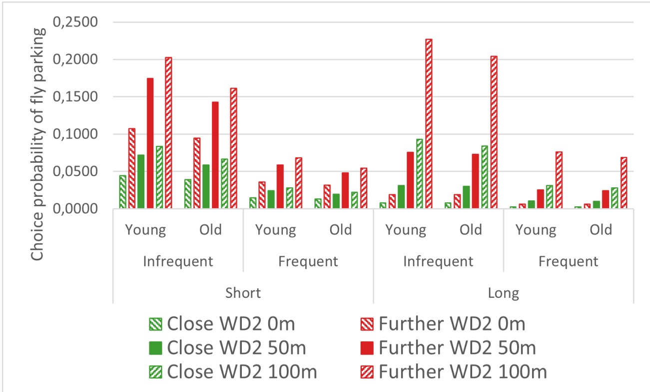

Figure 7.15: Choice probabilities of fly parking for the hazardous strategy comparing a walking distance of fly parking being close or slightly further away

7.8.4. Sensitivity to the frequency of bike use

The frequency of bike use only has an effect on the situation including the hazardous communication strategy. The negative strategy is not sensitive to this factor according to the model. The results for the probability of people choosing fly parking are included in Table E.43 and visualised in Figure 7.16. The results indicate that infrequent bike users are less sensitive to the hazardous strategy and are more almost three times more likely to choose fly parking when hazardous communication is introduced, compared to frequent users. Although the absolute number of people choosing fly parking is small when hazardous communication is included, infrequent bicycle users are almost three times more likely to choose fly parking than frequent users when hazardous communication is introduced.

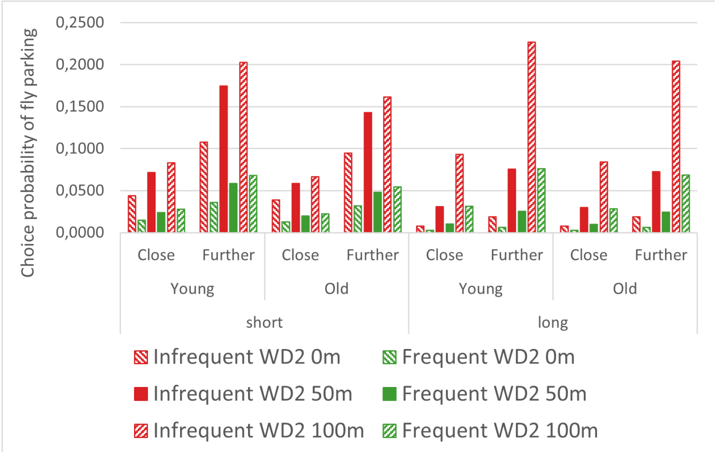

Figure 7.16: Choice probabilities of fly parking for the hazardous strategy comparing frequent and infrequent users

7.8.5. Conclusion on sensitivity analysis

The sensitivity analysis reveals that certain user groups are more or less sensitive to specific attributes, resulting in different probabilities of choosing fly parking. However, it should be noted that the overall impact of communication strategies remains the primary factor determining effectiveness, as shown in Table 7.11. Despite minor improvements that can be achieved by focusing on different user groups. The percentage of people likely to choose fly parking when hazardous or negative educative communication is introduced is minimal. Emphasizing the importance of these communication strategies in reducing fly parking for the entire population.

8 Conclusion

This thesis aimed to identify the effects of different communication strategies on distinct user groups, with the goal of changing their bicycle parking behaviour from fly parking to using formal parking places. Sub-questions were formulated to provide answers leading to the main research question. In this chapter, first, an answer to these sub-questions will be provided to finally answer the main research question.

8.1. Communication strategies and design of traffic signs

This research focuses on communication strategies provided through traffic signs along the route. In the literature, an answer was provided to the sub-question, *what communication strategies could be used for bicycle parking?* The strategies identified were: persuasive, educative, hazardous or threatening and normative communication. These strategies need to be translated to traffic signs to present them in the survey. This was only deemed possible for educative, hazardous and educative communication and traffic signs were designed for these strategies. Lastly, there is also the base scenario of no communication being provided. The design of the traffic signs needs to meet specific criteria, primarily familiarity and understandability. Therefore, the signs were based on existing traffic signs as much as possible. Moreover, people's understanding of the signs is tested to provide insight if this influences people's behaviour, and afterwards an explanation of each sign was presented. The research showed people understood the signs well, and not understanding the signs at first did not affect their behaviour significantly.

8.2. Identified characteristics

The literature also revealed communication is not the only factor that influences parking behaviour. Answering the following sub-question, *what factors are known to influence parking behaviour?* Three groups of characteristics were identified, ones that describe the bike parking, the trip, and people's own characteristics. Not all the factors found in the literature could be included in this research, as this would mean too many trade-offs need to be researched. Therefore, a selection was made of factors that were deemed important or were already included due to the parking places that should be offered according to the scope.

For the bike parking characteristics, this means the following were identified: parking inside or outside, at a rack or at street furniture, and the walking distance. For the trip characteristics, currently, only the length of stay was included. Personal characteristics that were included are gender, age, work situation, education level, price of a person's bike and their frequency of use of a bike.

8.3. Stated preference method

To provide insights into the choices individuals make when selecting a bike parking spot, their trade-offs need to be identified. It was therefore asked *which method should be used to investigate people's choices when presented with communication about bike parking?* An online stated preference survey was identified as the most suitable method to collect data within the constraints of a master's thesis. To achieve a realistic representation of reality without overloading participants with information and making the survey too long or repetitive, images were chosen to present the choice situations. A single clip is used to test how effective the traffic signs are as a way to communicate.

The collected data was processed using descriptive statistics and discrete choice modelling. Descriptive statistics provided initial insights into the effects of communication on parking behaviour and helped assess the sample composition. Discrete choice modelling was employed to identify the effects of all included variables on behaviour.

8.4. Responses of user groups to communication

These outcomes of the models are used to identify *what the responses of different user groups to the communication strategies are?* To provide an answer to this, the interactions of communication strategies with the socio-demographics are examined.

Regarding the negative educational strategy, there is no significant interaction with socio-demographics. According to the current data, the negative educational strategy effectiveness is lower overall relative to the hazardous strategy, but the negative educational strategy is not more or less effective for a certain user group. Therefore, this communication method could be used to reach a wide audience.

The neutral educative strategy performs the least effectively, since it has a negative effect, where a positive one was expected. Implying that the information provided creates a greater disutility for the formal parking spots, making the choice probability of people choosing fly parking higher. It could, however, be that this is more due to the distance indicated on the sign, rather than the communication strategy itself. It is also possible that the model cannot accurately assess the influence of the neutral strategy compared to the baseline level of no communication. This does not mean that the neutral communication strategy is completely ineffective. Further research is required. However, the interaction effects between this type of communication and socio-demographics are evident. Indicating, it is likely that this communication strategy becomes more or less effective when used on different user groups.

One of these interactions is with the frequency of bicycle use. Infrequent users are more likely to use the indicated parking spots than frequent bicycle users. Infrequent bicycle users may be less knowledgeable about bike parking in general. For educative communication to be effective, the information presented should be new to the people receiving it (van Erp, 2007). The information on bicycle parking might feel newer to infrequent users than to frequent users, which could be the reason infrequent users are more willing to follow instructions on bicycle parking.

People who own a cheap bike follow the instructions of the neutral strategy, which directs them to an outside parking spot much less than the rest of the sample. In those cases, they often choose fly parking over a designated outside parking spot. An explanation for this is that people with a cheap bike are probably less careful with it (Larsen, 2017, der Spek and Scheltema, 2015, Heinen and Buehler, 2019).

Next, there is the interaction effect of the neutral educative strategy and being young on inside parking. The model indicated young people are less likely to listen to communication through the neutral strategy for inside parking. According to the data, young people are likely to prefer fly parking over inside parking. This was also shown in Figure 6.4. Young people are often described as more reckless, in literature, than older people, so they probably do not mind the risk of parking their bikes in fly parking spots as much (Kaplan et al., 2018).

However, the results for the hazardous and negative strategies showed that young people are more sensitive to these strategies for long-term parking compared to short-term parking. Indicating, they assess the risk of illegally using fly parking for long-term parking to be higher. Where older people asses this risk way more similarly for both short and long-term parking.

Throughout the models, the interaction with an expensive bike was significant for no communication. The model suggests that people with an expensive bike are less likely to use fly parking than other people when they do not receive communication on fly parking. This seems logical because they might want to park their bikes in a safer spot, and do not want to run the risk of losing it (Larsen, 2017, der Spek and Scheltema, 2015). When no communication is offered, people with an expensive bike do however not prefer an inside parking spot over an outside spot.

According to the model, when frequent users are presented with hazardous communication, they are less likely to choose fly parking. Frequent bike users might be very dependent on their bike as a mode of transportation and might therefore be more careful and do not want to risk their bike being towed away. Another explanation is that frequent bicycle users are more likely to have experienced a situation where their bike was indeed taken away when they wrongly parked it. People are more likely to obey the rules when they feel the chances of getting caught are higher (Klepper and Nagin, 1989). Therefore, they might assess the risk of their bike being towed away as higher. These might be reasons why this strategy is more effective for frequent bike users, as long as their bikes indeed get towed away once in a while.

The effect of being a student or a full-time worker on the communication strategy does not become completely clear in this research. Since the values on the work situation were not significant in the combined ML model. However, in the separate models and MNL model, their interaction effects were significant. ML models need better datasets to estimate results correctly (Train, 2009). The lack of significant results in the combined models may be attributed to a lack of distribution in the data.

When considering long-term parking strategies, people become increasingly sensitive to the walking distance, and will choose fly parking more often for a walking distance of 100m. This indicates that people are becoming increasingly likely to choose fly parking for a longer walking distance, and that the assumption that people are willing to walk as far as a 100m for a formal parking spot for long-term parking is not a valid one.

Although all the interactions between communication strategies and socio-demographics described in the previous section were significant, the ones researched using the sensitivity analysis indicated that the communication strategies themselves have the most impact on the parking choice. This choice is only marginally influenced by these interactions, compared to the effect of the strategies.

8.5. Most effective communication strategies for bike parking

The last sub-question to answer is: *what communication strategies are effective for bicycle parking?* When the neutral educative strategy, which gives unexpected negative results that cannot be explained, is left out, the model shows that hazardous communication is the most effective way of communication, except for the group of infrequent bicycle users. The negative educative strategy is also an effective way of discouraging fly parking, and the advantage of the negative communication strategy seems to be that its effectiveness is not influenced by a person's characteristics. What should be noted is that reducing the percentage of people using fly parking is achieved for the most part by communication strategies in general. The hazardous and negative strategy reduces the likelihood of people choosing fly parking to a small value. Therefore, belonging to a certain user group only marginally influences the absolute number of people choosing fly parking.

The performance of people in the question following the clip where they are asked to identify indicates that traffic signs are likely not the best syntax for communication for cyclists, especially if they are not instructed specifically to look out for them. Therefore, in reality, if people are not made aware of the traffic sings beforehand, they will probably not notice them and people will not follow their instructions. So, a better syntax or combination of syntaxes is needed to have effective communication.

8.6. Best communication strategy for distinct user groups

Based on all these sub-questions, an answer to the main research question can be provided. This main question is: *What along-route communication strategies motivate distinct user groups most to change their bicycle parking behaviour from choosing fly-parking to parking at designated bicycle parking places?*

Overall, it can be concluded that belonging to a certain user group with specific socio-demographic characteristics indeed influences the effectiveness of some along-route communication strategies. In this research, only the negative educative strategy is not influenced by socio-demographics. But the effectiveness of the strategies itself is much larger than the effect of these interactions. Therefore, the effectiveness of the strategy itself is most important and the best strategy to reduce fly parking is the hazardous strategy. Unfortunately, the dataset in this research is not large enough to investigate the combination of different socio-demographics, which might make the effect stronger, so this conclusion can only be drawn for the individual socio-demographics.

9 Discussion and recommendations

The aim of this chapter is to discuss the findings of the research presented in the previous chapters and provide recommendations for future research and practical implications. First, the discussion of the limitations of the research is presented in Section 9.1 and secondly, the recommendations are given in Section 9.2.

9.1. Discussion

This discussion section will cover several topics, including the limitations of the survey method, the effect of context on people's choices, and the results of the data analysis.

Stated preference survey method

The stated preference survey method has its limitations. Respondents may provide answers that they think are expected from them, so they select the formal parking options over fly parking more often than they will do in real life (Train, 2009). Another limitation of the stated preference survey method is that participants do not actually experience the real-life consequences of their choices. For example, in this research, respondents did not face the actual risk of losing their bikes, fearing this less than they would in reality (Molin, 2018). Thus, there may be discrepancies between the hypothetical choices made by respondents in the survey and their actual behaviour. With people indicating they choose a formal option more often than they will in reality.

Survey design

The survey design played a crucial role in collecting the data for this study. Therefore, the design of this survey has influenced the results gathered from it. While many attributes of bike parking that could influence behaviour were included in this study, it was not possible to include all of them in the survey. One attribute that was not accounted for was the perceived safety of the parking spot. This is an essential factor, as people have different perceptions of safety and might choose different parking spots because of it (Molin and Maat, 2014, Celis and Bolling, 2001). According to current literature, if formal parking options are perceived as safer than fly parking, it will likely influence women to choose the formal option more often. Future research should investigate the impact of perceived safety on parking choices to gain a more comprehensive understanding of the factors that influence bike parking behaviour.

Another limitation of the survey design was the inability of respondents to answer if they were unsure or in doubt about a certain choice situation. This limitation may have resulted in a loss of valuable data, as respondents may have been forced to pick a single answer.

Next, an extra iteration of the design of the choice situation with priors from the pilot could have been included in the survey design. This was deemed impractical due to constraints in time and recruiting participants for this study. Finally, the way the choice situations needed to be presented also introduced some challenges. As discussed before, some walking distance scenarios could not be included in the current design and presenting people with at least some information on the inside and outside parking spots was needed for most scenarios.

Context in situations

People were presented with the context that their trip was either for a short or a long stay, but no other context was provided to them. Some of these could, however, also influence parking behaviour. Some of them are discussed here. Firstly, no trip purpose was indicated to participants in this research. The literature did not indicate this could influence the effectiveness of communication. The absence of trip purpose or time of day in the choice situations provided to participants may however have affected their decision-making process. These factors could have a significant impact on bike parking behaviour. Moreover, some respondents even indicated in their open answers that being in a hurry would change their parking decisions.

Another potential limitation is that the survey placed participants in unfamiliar situations, requiring them to decide on where to park their bikes in a new environment. This could differ from the situation in real life, where people may be familiar with the area and have a regular spot to park. This means the regulations would interfere with their daily routine much more, and this could influence the effectiveness of the communication strategies(Goldenbeld and Wisman, 2004).

Finally, while the survey assumed that respondents paid attention to the traffic signs in the choice situations, it is possible that some participants may have missed them or not found them important. If this was the case, they could have based solely on other factors. It was impossible to include all factors influencing parking behaviour in this research, and some might have been included in the images unintentionally. So, it is possible that other aspects of the choice situation, have induced a person's decision instead of the communication. The model might try to explain these influences through the communication parameters, which would be inaccurate.

Representation of respondents

In this research, it is important to consider the representation of the respondents, as it can impact the validity and generalizability of the findings. The voluntary nature of participation may have contributed to a more engaged and motivated sample to provide detailed and accurate responses. But it is also possible that self-selection bias could have influenced the sample. This effect can be seen in the distribution of the sample compared to the entire Dutch population, where only the distribution in gender was comparable.

The under and over-representation of certain groups may limit the generalizability of the findings of this research. Especially in the groups of education and work situations, certain groups are underrepresented in the sample. This means that the sample does not include enough individuals from a particular work situation range or education level to draw meaningful conclusions about that group. Additionally, the sample size for the groups was too small to make a combination of socio-demographics and create more specific groups, since the sample would become too small to give statistically significant results.

The sample size and variation were not always sufficient to estimate the ML model. For instance, a full-time work situation was found to give significant interaction effects MNL, but the accuracy of these results is uncertain due to the limited data on the other work situations included in the total sample.

Analysis

The analysis of the data in this study revealed limitations. One limitation was the lack of a situation with no communication for inside and outside parking, making it difficult to assess the effect of that communication strategy compared to neutral educative communication. Because the questions were designed using images, a certain distance towards these parking options was always required when neutral educative communication was used. Therefore, the negative impact of this parameter may not be due to the type of communication, but rather to the distance displayed.

The images introduced some extra variables the survey was not designed for. Two of these were easily identifiable, like offering fly parking in different ways, at a tree, or directly under a sign. These were not statistically different from the rest of the sample according to the current results. However, the design of the images was not optimized to take into consideration all variables that make fly parking options more or less attractive.

Furthermore, the current analysis yielded unexpected results for the neutral educative strategy. Since it indicates, informing people formal parking spaces are there discourages the use of them. In this research, it is not examined what the cause of these outcomes is, as no data was collected for this phenomenon. But it could, as mentioned, be due to the distances displayed on the traffic signs.

What should also be kept in mind is that the ASCs are also still significant. Indicating there is an effect that promotes inside and outside parking, compared to fly parking, that was not identified in this model. Identifying this

9.2. Recommendations

The recommendations will give practical implications and address the gaps in the research in terms of method, the data needed and other variables that need to be researched still.

9.2.1. Practice

The recommendations for practice are discussed in this section. This research suggests hazardous communication is the most effective approach to move people away from fly parking. However, it is also indicated that infrequent bicycle users are less responsive to this strategy. To reach a broad audience, the negative educative strategy is recommended, as the effectiveness of this strategy is not influenced by socio-demographics according to the current research.

What should be noted is that this research does not indicate traffic signs are the best syntax to convey these messages. Especially, if they are introduced without prior announcement or attention, as has been done in this survey, it was shown many people do not pay attention to them.

The assumption of the municipality of Delft people are willing to walk a 100m towards a formal parking spot is challenged by the current research. Even in situations where communication indicating that fly parking is prohibited was presented, the number of people who are likely to choose fly parking increased exponentially. So, to reduce fly parking, this distance should be decreased in the strategy for long-term parking. Because the choice probability for fly parking for long-term parking is increasing exponentially, it would already be beneficial to reduce this distance by only 10 meters.

9.2.2. Future research

The study utilized a stated preference survey method with images to examine the influence of communication strategies on bicycle parking choice behaviour. Despite the stated preference survey's ability to gather data on multiple factors simultaneously, many aspects of bicycle parking and the effect of communication on it remain unknown and future research is needed. In this section, some recommendations for future research are presented.

More variables to be researched

To gain a more comprehensive understanding of bike parking behaviour, further research could investigate the importance of various attributes in greater detail. One such attribute is the effect of communication using syntaxes besides traffic signs. While the current study focused only on traffic signs, future research should consider exploring the impact of other syntaxes and comparing their effectiveness. When looking into a different communication syntax, it would be especially interesting to select one for which a normative strategy can also be developed and tested. This was not possible to test this in the current research. The combination of different approaches should also be researched, like combining persuasive communication before a trip, which has already proven to be effective and the traffic signs during.

Another variable that was not considered in the current study is the attractiveness of a specific bike parking spot for fly parking. The only factor that was included is the distance of a fly parking spot from a destination. The probability of individuals opting for fly parking at locations situated slightly further from a person's intended destination has been found to be higher. Currently, there is no explanation for this. People might feel uncomfortable parking right in front of their destination when they are aware this is prohibited. But future research into the attractiveness of fly parking spots is needed to draw a conclusion.

This research should also include other factors possibly making a fly parking spot more attractive. For instance, if the parking spot is at a tree versus a pole. The current study did not show a significant difference, but the survey was also not designed to research this. It could also be tested if availability or crowdedness have an effect on this preference. In this research, this was only indirectly included for the fly parking.

The influence of situational factors on parking behaviour should also be researched in future studies. Factors such as a trip's purpose and time constraints should be included. Moreover, the lack of familiarity with parking locations could also have influenced participants' choices and behaviour, so future studies should consider incorporating familiarity with the situation into the experimental design.

For the neutral educative strategy, it is currently unclear why, according to the model results, it discourages people to use formal parking spots. A possibility is that the walking distance presented on the signs are the cause of this response by people. The walking distances included in this research could have been too high, or being confronted by a specific distance could have discouraged people. Future research should provide information where this disutility for communication on formal parking spots comes from. It should be tested to see if shorter walking distances being displayed on the signs, or not displaying them at all, influences people's response to this communication strategy. Furthermore, it is currently common in traffic to indicate how far a person has to travel by using a distance. However, it could also be interesting to see if people's responses are different when a time is indicated instead of a distance.

Finally, the study's literature review revealed that there are still some gaps in understanding the perceived safety of bicycle parking. Therefore, it was not included as a factor in this research. Future research should further investigate this variable and distinguish its different aspects and effect on parking behaviour, so it can better be incorporated in the future.

In the current research, the ASCs are still significant. Incorporating and further researching the factors mentioned in this section could help to reduce the ASCs and make them insignificant, indicating all behaviour is captured by the attributes of the model. Including these other values should also increase the value of the adjusted rho square, indicating that the model better fits the data.

Data

In case a research method is deployed where a lot of data is gathered, such as in a stated preference survey, a larger and more representative sample size is needed to draw generalizable conclusions and create more specific user groups from the data. It is recommended to obtain a better dataset that is more dispersed for factors such as education level and work situation. This may provide more insight into how to target a specific group. To create more distinct user groups, where multiple socio-demographics are combined to create one group, a larger sample size is needed. Otherwise, these groups are not large enough to get statistically significant results.

This study estimated results, which could be used as better priors to design more relevant choice situations in future research, improving the model's estimation and explanatory power. So, future research could explore ways to optimize survey design to capture more accurate data.

Research method

An SP survey is a powerful tool, as it makes it possible to gather quite some data on many factors at once. However, the survey had some limitations. The first one is how the information was provided through the images. These might have caused the neutral strategy's peculiar outcome, by always having to indicate the distance on the sign. Future research should consider testing shorter walking distances. Other research methods should also be considered in future research. Such as real-life experiments. The real-life experiment could be employed to validate the stated preference survey's outcomes. Particularly, the effect of no communication compared to the neutral educative strategy could probably be better tested in a real-life experiment. People can be asked to consider any spot and are free to move to search for one. Such an experiment could also provide a solution to the drawback of a stated preference survey of people not providing their actual choices.

Future research should also consider allowing participants to answer if they are in doubt about different parking spots, as this could provide more insight into the trade-offs people make. A qualitative approach may be more appropriate for exploring these complexities, since it may not facilitate quantitative analysis.

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A Pilot Survey

A.1. Creating partial choice sets list

The Python code that was used to create a csv file containing all possible combinations of communicaiton strategies and parking alternatives in such a way that each combinations of two parking alternatives that is possible exist whilst the third one contains the extremely high value 999999 for the walking distance is presented below.The Python code used is presented on the next page.

In [1]:
```python
import itertools
import pandas as pd
import numpy as np
```

In [2]:
```python
#Long trip: 0, Short trip: 1
SorL = [0,1]

#Outside: 0, Inside: 1
IorO = [0,1]

#Street furniture 0, Rack: 1
RorF = [0,1]

#walking distances in meter and high value
WD_in = [50,100,200,999999]
WD_out= [0,50,150,999999]
WD_fly = [0,25,999999]

#Communication options
#Minimal communication: 0, Educative netural: 1, Educative negative: 2,
Hazardous: 3
C = [0,1,2,3]
```

In [3]:
```python
#Creating lists
list_inside = list(itertools.product(SorL, IorO, RorF, WD_in,C))
list_outside = list(itertools.product(SorL, IorO, RorF, WD_out,C))
list_fly = list(itertools.product(SorL, IorO, RorF, WD_fly,C))
```

In [4]:
```python
#Create dataframe inclduing all combinations
total_list = list(itertools.product(list_inside,list_outside,list_fly))
total1 = pd.DataFrame(total_list)

inside = pd.DataFrame(total1[0].tolist())
inside.rename(columns = {0:'inside.SorL',1:'inside.IorO',2:'inside.RorF'
,3:'inside.WDin',4:'inside.c'}, inplace = True)

outside = pd.DataFrame(total1[1].tolist())
outside.rename(columns = {0:'outside.SorL',1:'outside.IorO',2:'outside.R
orF',3:'outside.WDout',4:'outside.c'}, inplace = True)

fly = pd.DataFrame(total1[2].tolist())
fly.rename(columns = {0:'fly.SorL',1:'fly.IorO',2:'fly.RorF',3:'fly.WDfl
y',4:'fly.c'}, inplace = True)
```

In [5]:
```python
#Give correct names to columns for Ngene
total2 = pd.concat([inside,outside,fly], axis=1)
total2['design'] = 1
total2['cset'] = total2.index
total2 = total2[['design', 'cset','inside.SorL','inside.IorO','inside.Ro
rF','inside.WDin','inside.c',
                            'outside.SorL','outside.IorO','outside.RorF',
'outside.WDout','outside.c',
                            'fly.SorL','fly.IorO','fly.RorF','fly.WDfly',
'fly.c']]

#print(len(total2))
```

In [6]:

```
#Drop not existing combinations
#Walking distance, drop short walking distance for long trips
#and long walking distance for short trips
in4 = total2[(total2['inside.SorL'] == 0) & (total2['inside.WDin'] == 50
)].index
total2.drop(in4,inplace = True)

in5 = total2[(total2['inside.SorL'] == 1) & (total2['inside.WDin'] == 20
0)].index
total2.drop(in5,inplace = True)

in6 = total2[(total2['outside.SorL'] == 0) & (total2['outside.WDout'] ==
 0)].index
total2.drop(in6,inplace = True)

in7 = total2[(total2['outside.SorL'] == 1) & (total2['outside.WDout'] ==
 150)].index
total2.drop(in7,inplace = True)


#Drop choice sets of communication techniques that don't match
in1 = total2[(total2['inside.c'] == 0) & (total2['outside.c'] == 0) & (t
otal2['fly.WDfly'] == 999999)].index
total2.drop(in1,inplace = True)

in2 = total2[(total2['inside.c'] == 0) & (total2['outside.c'] == 1) & (t
otal2['fly.WDfly'] == 999999)].index
total2.drop(in2,inplace = True)

in3 = total2[(total2['inside.c'] == 1) & (total2['outside.c'] == 0) & (t
otal2['fly.WDfly'] == 999999)].index
total2.drop(in3,inplace = True)


#Drop communication that does not exist for a certain type of parking
in23 = total2[(total2['inside.c']==0)].index
total2.drop(in23, inplace = True)

in8 = total2[(total2['inside.c']==2)].index
total2.drop(in8, inplace = True)

in9 = total2[(total2['inside.c']==3)].index
total2.drop(in9, inplace = True)

in10 = total2[(total2['outside.c']==2)].index
total2.drop(in10, inplace = True)

in11 = total2[(total2['outside.c']==3)].index
total2.drop(in11, inplace = True)

in12 = total2[(total2['fly.c']==1)].index
total2.drop(in12, inplace = True)

#Drop double 9999
in13 = total2[(total2['inside.WDin'] == 999999) & (total2['outside.WDout
'] == 999999)].index
total2.drop(in13,inplace = True)

in14 = total2[(total2['inside.WDin'] == 999999) & (total2['fly.WDfly'] =
= 999999)].index
```

```
total2.drop(in14,inplace = True)

in15 = total2[(total2['outside.WDout'] == 999999) & (total2['fly.WDfly']
 == 999999)].index
total2.drop(in15,inplace = True)

#Drop the no 9999 lines
in16 = total2[(total2['inside.WDin'] != 999999) & (total2['outside.WDout
'] != 999999) & (total2['fly.WDfly'] != 999999) ].index
total2.drop(in16,inplace = True)


#Drop parking alternatives that do not exist
in17 = total2[(total2['inside.IorO'] == 0)].index
total2.drop(in17,inplace = True)

in18 = total2[(total2['inside.RorF'] == 0)].index
total2.drop(in18,inplace = True)

in19 = total2[(total2['outside.IorO'] == 1)].index
total2.drop(in19,inplace = True)

in20 = total2[(total2['outside.RorF'] == 0)].index
total2.drop(in20,inplace = True)

in21 = total2[(total2['fly.IorO'] == 1)].index
total2.drop(in21,inplace = True)

in22 = total2[(total2['fly.RorF'] == 1)].index
total2.drop(in22,inplace = True)
```

In [7]:

```
#Create final csv
total2.to_csv(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Python\\incomp
lete.csv', index = False)
```

A.2. Experimental design

In this part the Ngene syntax used to create the survey is presented. First, the code is opened by the word design. In the first line the alternatives are introduced: covered parking (called inside here), outside parking and fly parking. In the next line the number of rows is specified this indicates how many choice situations Ngene needs to create. The following line indicates that the Modified Federov algorithm needs to be used and where the list with so-called candidates, in other words, the partial choice sets can be found. Lastly, the type of design, which is an MNL d-efficient design, is indicated.

For communication, all levels are kept in the design. The combinations that are not possible are not included in the candidate set of the partial choice sets and will therefore not be included in the design.

Now the model needs to be specified this is done using a utility function for each alternative. For the dummy coded attributes, the meaning of the numbers is as follows. The priors were matched to the correct attribute levels.

- short: 1 = short trip, 0 = long trip
- in: 1 = inside, 0 = outside
- racks: 1 = parking in racks, 0 = parking at street furniture
- comm: 3 = hazardous communication, 2 = negative educative communication, 1 = neutral educative communication, 0 = minimal communication

Lastly on the first line for the alternative inside the following is included: (6,6). This is the constraint which is added to get 6 questions for the short-term parking scenario and 6 questions for the long-term.

```
Design
;alts = inside, outside, fly
;rows = 12
;alg = mfederov(candidates = H:\My Documents \Afstuderen \partialchoicesets.csv)
;eff = (mnl,d)

;model:
U(inside) = short.dummy[0] * SorL[1,0](6,6) +
             in.dummy[0.001] * IorO [1,0] +
            racks.dummy[0.001] * RorF[1,0] +
            walkingdistance[-0.001]* WDin[50, 100, 150, 999999] +
            comm.dummy[-0.001 | -0.001 | 0.001] * C[3, 2, 1, 0] /

U(outside) = short.dummy[0] * SorL[1,0] +
              in.dummy[0.001] * IorO [1,0] +
             racks.dummy[0.001] * RorF[1,0] +
             walkingdistance[-0.001]* WDout[0, 50, 100, 999999] +
             comm.dummy[-0.001 | -0.001 | 0.001] * C[3, 2, 1, 0] /

U(fly) = short.dummy[0] * SorL[1,0] +
         in.dummy[0.001] * IorO [1,0] +
         racks.dummy[0.001] * RorF[1,0] +
         walkingdistance[-0.001]* WDfly[0, 25, 999999] +
         comm.dummy[-0.001 | -0.001 | 0.001] * C[3, 2, 1, 0] /
```

B Final design

The final design of the full survey in English is included below.

Survey on bicycle parking behaviour

Research Rolien Holster

* Vereist

Introduction

Welcome

Dear participant,

You are invited to participate in this questionnaire which is part of my graduation research at the TU Delft. In my project, I am researching bicycle parking behaviour in city centres. More than a quarter of all trips in the Netherlands are made by bicycle. However, there is still little known about the choices people make when parking their bicycles in the city center. Gaining more knowledge about this can contribute to reducing the nuisance of parked bicycles.

The questionnaire consists of three parts. In part 1, you will be shown a video and asked a few questions about what you saw. Then, you will be presented with 12 hypothetical situations in which you are asked to choose between different parking options. In the final part, you will be asked about a number of personal characteristics,. Your participation is anonymous, your answers will be treated confidentially. Your participation is voluntary and you can stop at any time.

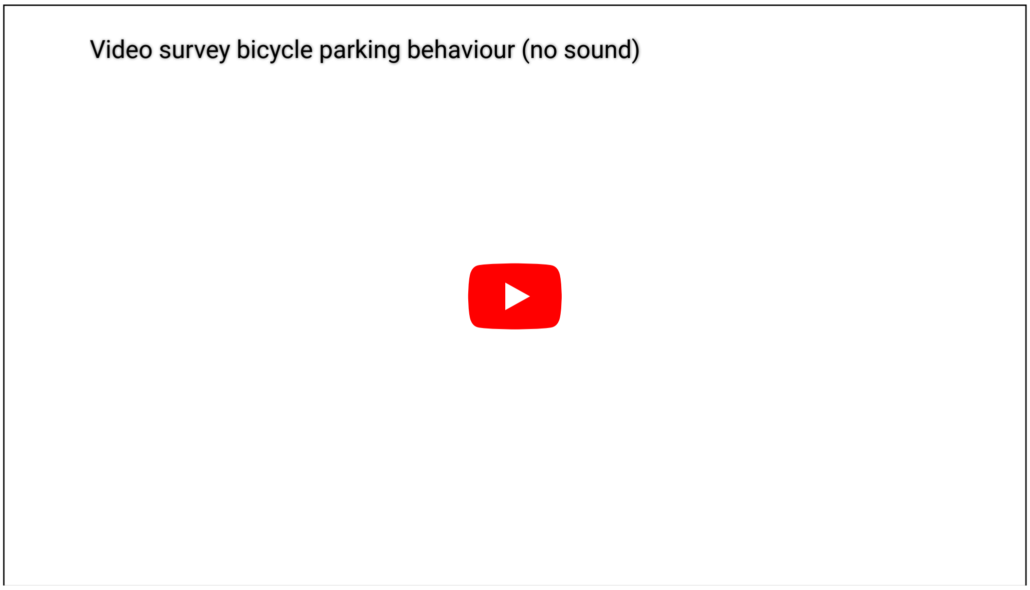
By participating in this questionnaire, you agree to the conditions mentioned above and give permission for the data you have entered to be used for this research and to be archived in a TU Delft database, so they can be used for future research and education.

Filling out the questionnaire will take about 10 minutes.
Thank you for your participation!

Rolien Holster
For questions, you can contact me at: r.s.holster@student.tudelft.nl

Video

You are on your way to the city center by bike and are looking for a place to park your bike. Watch the following video carefully.
If you are filling out the survey on a mobile device, it will open the YouTube app if you click on the link instead of the red play button, if it does you can return to the survey after watching the clip.



Questions on the video

1

Which traffic signs have you seen pass by? Multiple answers may be correct. *

- [ ] 1

- [ ] 2

- [ ] 3

- [ ] 4

- [ ] 5

- [ ] 6

- [ ] I didn't see any signs

Interpretation traffic signs

In The Netherlands, the traffic sign you see here means it is forbidden to park there. Some questions will now be asked on different traffic signs and sub-signs that have been designed by me for this research.

2

What does the following traffic sign mean according to you?
Multiple answers may be correct. *

- [ ] You are not allowed to park your bike at a tree here
- [ ] You are not allowed to park your bike here at all
- [ ] You are not allowed to park your bike at street furniture here
- [ ] You are not allowed to park your bike at a lamppost/pole here

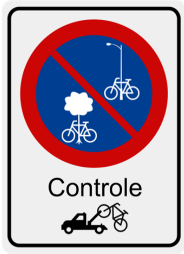
3

What does the following combination of traffic sign and sub-sign mean according to you? *

- ◯ You are not allowed to park in this area
- ◯ You are not allowed to park where this sign is placed only

4

What does the following combination of traffic sign and sub-sign mean according to you? *



- ◯ Illegally parked bikes are being checked for and if you are wrongly parked, your bike will be towed away
- ◯ Illegally parked bikes are being checked for and if you are wrongly parked, you will receive a fine

5

What does the following combination of traffic sign and sub-sign mean according to you? *

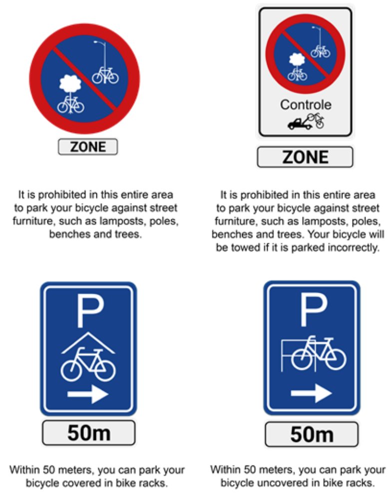
- ◯ Within 50 meters to the right you can park your bike covered in bike racks
- ◯ Within 50 meters to the right you can park your bike uncovered in bike racks

6

What does the following combination of traffic sign and sub-sign mean according to you? *

- ◯ Within 50 meters to the right you can park your bike covered in bike racks
- ◯ Within 50 meters to the right you can park your bike uncovered in bike racks

Explanation of signs as intended in this research



Example

You will be presented with 12 situations in which you are asked to indicate which of the presented parking options has your preference.
In the first 6 situations, you must park your bike for a **maximum of half an hour** in the city.
Then there are 6 situations where you must park your bike for **at least two hours** in the city.

All parking options are **free** and there is **always sufficient space available**.

The **orange boxes** indicate the different **parking options**.
The **yellow box** indicates your **destination**.
The questions are multiple choice, so choose the letter that corresponds to the orange box that you choose for each question.

An example question is now being presented first:

In each question, you will see a photo like the one below.
You are asked to select the location where you would park your bike.

In this question, A means that you choose this bike rack, B means that you choose a parking spot within 100m and C means you will park against the pole. In this example you don't need to fill in an answer

7

Select the location where you would park your bike:Vraag *

- ○ A
- ○ B
- ○ C

Choice situations part 1: **short visit**

This is the part on the choice situations.
In the first 6 situations, you need to park your bike in the city for a **maximum of half an hour**.

7

Select the location where you would park your bike:
*

- ◯ A
- ◯ B
- ◯ C

8

Select the location where you would park your bike: *

- ◯ A
- ◯ B

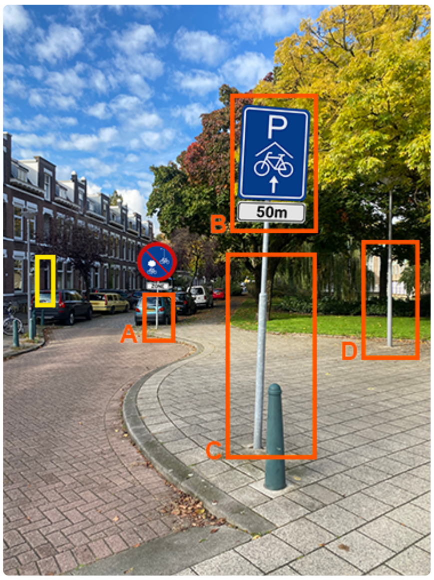
9

Select the location where you would park your bike: *

- A
- B

10

Select the location where you would park your bike: *



- A
- B
- C
- D

11

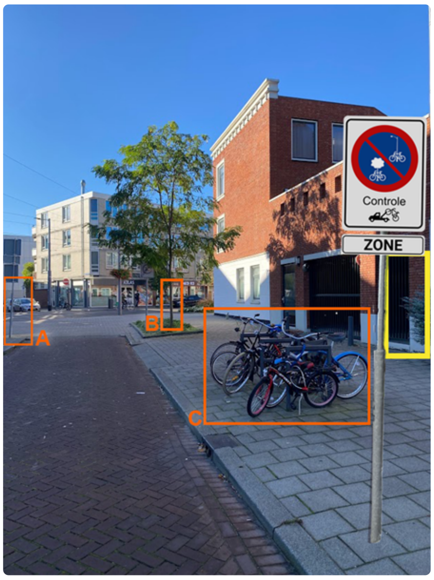
Select the location where you would park your bike: *

◯ A

◯ B

12

Select the location where you would park your bike: *



◯ A

◯ B

◯ C

Choice situations part 2: **long visit**

In the next 6 situations, you need to park your bike in the city for **at least two hours**.

13

Select the location where you would park your bike: *

- A
- B
- C
- D

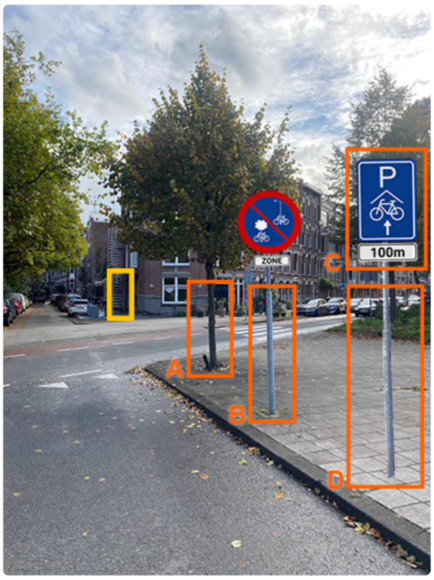
14

Select the location where you would park your bike: *

- A
- B

15

Select the location where you would park your bike: *



- A
- B
- C
- D

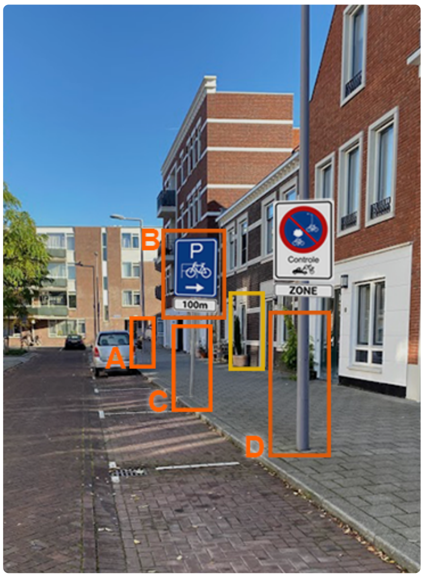
16

Select the location where you would park your bike: *

- A
- B
- C
- D

17

Select the location where you would park your bike: *



- A
- B
- C
- D

18

Select the location where you would park your bike: *

- A
- B
- C

Personal characteristics

19

With which gender do you identify? *

- ◯ Woman
- ◯ Man
- ◯ I would rather not say
- ◯ Andere

20

To what age group do you belong *

- ◯ 20 years or younger
- ◯ 20 to 30 years
- ◯ 30 to 40 years
- ◯ 40 to 65 years
- ◯ 65 to 80 years
- ◯ 80 years or older

21

What is the highest educational level you have achieved a diploma for? *

- ◯ No education completed
- ◯ Primary education
- ◯ Secondary education
- ◯ Bachelors degree
- ◯ Master degree
- ◯ PhD or more
- ◯ I would rather not say
- ◯ Andere

22

Which of the following best describes your current work situation? *

- Full time employment
- Parttime employment
- Unemployed
- Freelancer
- Student/Scholar
- Pensioner
- I would rather not say
- Andere

23

How often do you go to the city center by bike? *

- 4 times a week or more
- 1-3 times a week
- 1 time a week or less
- 1 time a month or less
- Never
- I would rather not say

24

What is the value of the bike you use for these trips to the city? *

- My bike could break down at any moment and needs to be replaced any moment now
- My bike is cheap and/or second hand (€300 or less)
- My bike is solid and quite new (€300-€1500)
- My bike is expensive (€1500 or more)
- My bike is irreplaceable, it has emotional value to me
- It is a rented bike, some form of shared mobility
- I would rather not say
- Andere

25

Do you have any other comments?

C Approval of HREC

Date 10-Feb-2023
Contact person Dr. Cath Cotton, Policy Advisor Academic Integrity
E-mail c.m.cotton@tudelft.nl

TU Delft Delft University of Technology

Human Research Ethics Committee
TU Delft
(http://hrec.tudelft.nl/)
Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft
Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Master thesis: Communication strategies to encourage the use of bicycle parkings
Applicant: Holster, Rolien

Dear Rolien Holster,

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

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:

- In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
- Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor.
- Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
- Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research!

Sincerely,

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

D Descriptive statistics

In Table 6.2 below the parking choices of groups with different socio-demographic characteristics are presented. These choices were compared to the parking choices of the entire sample using a chi-sqaure test to indicate whether the results were significantly different. Indicated in green are the results that are significantly different, the p-values are smaller than 0.05. These are factors that should definitely be included in the MNL model to check their effect. The chi-square value indicates how large the influence is on the choice is likely to be.

Table D.1: Chi-square test for length of stay, socio-demographics and communication

	Count	Parking choice			Chi-square test		
		Inside	Outside	Fly	Compared to	p-value	Chi-square value
Total sample	269	17.19	61.43	21.38			
Length of stay							
Short	269	10.66	70.57	18.77	Population	0	48.11
Long	269	23.73	52.92	23.98	Population	0	42.40
					Short compared to long	0	134.33
Age							
Young 0-30	156	15.76	62.13	22.12	Population	0.40	1.86
Older group 30 and over	113	19.17	60.47	20.35	Population	0.26	2.72
					Young compared to old	0.03	6.83
Gender							
Woman	135	17.93	61.47	20.59	Population	0.34	2.17
Man	131	16.34	61.44	22.20	Population	0.97	0.07
					Man compared to woman	0.97	0.06
Price of bike							
Cheap	148	15.77	62.16	22.07	Population	0.93	0.15
Expensive	104	20	57.71	22.29	Population	0.76	0.56
					Cheap compared to expensive	0.07	5.30
Frequency of use							
Infrequent use	46	20.58	62.07	17.35	Population	0.53	1.27
Frequent use	220	16.48	61.25	22.27	Population	0.97	0.06
					Infrequent compared to frequent	0.007	10.22
Work situation							
Fulltime	137	17.09	60.22	22.69	Population	0.57	1.13
Student/scholar	28	15.71	63.94	20.35	Population	0.48	1.47
Education							
Low and medium	104	18.43	61.78	19.79	Population	0.39	1.88
High	152	16.23	61.29	22.48	Population	0.52	1.30
					Low and medium compared to high	0.1	4.62
Understanding of signs							
all good and two correct	76	16,94	61,98	21,08	Population	0,9103	0,19
all wrong	56	12,5	58,33	29,17	Population	0,609	0,99
Communication							
Hazardous	269	19.42	65.80	14.78	Population	0	22,93
Educative negative	269	0	76.58	23.42	Population	0,2665	1,23
Educative neutral	269	13.75	86.25	0	Population	0,0027	9

E Models

E.1. Dummy coding

In the tables below the dummy coding used in the models is introduced. In Table E.1 the dummies for all factors included in the base model are included. In the other table, Table E.2 the dummy coding used for the socio-demographics is shown.

Table E.1: Dummies base model

	Short or long			
Short	0			
Long	1			
	Inside or outside			
Inside	1			
Outside	0			
	Rack or street furniture			
Rack	1			
Street furniture	0			
	WD_fly_dummy			
Close	0			
Further away	1			
Communicaiton	C3_Hazardous	C1_Educative_neutral	C2_Educative_neutral	C3_Educative_negative
No communication	0	0	0	0
Hazardous	1	0	0	0
Educative neutral	0	1	1	0
Educative negative	0	0	0	1

Table E.2: Dummies socio-demographics

Gender	gender	
Female	1	
Male	0	
Price of the bike	price	
Cheap under €300	1	
Expensive over €300	0	
Frequency of use	freq	
Infrequent, 1 time a mont or less	1	
Frequent, 1 time a week or more	0	
Age	age_young	
Young, under 30	1	
Over 30	0	
Work situation	fulltime	student
Fulltime	1	0
Student/scholor	0	1

E.2. Base MNL model

Syntax final MNL model

```
#Read data
df = pd.read_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\data_base_model.xlsx')

database = db.Database('data_base_model',df)

# Allows to use the names of the variable as Python variable
globals().update(database.variables)

#Betas
B_SorL1 = Beta('B_Long1', 0, -1000, 1000, 0) #of 1 op het laatst om hem vast te zetten
B_SorL3 = Beta('B_Long3', 0, -1000, 1000, 0)
B_Inside = Beta('B_Inside', 0, -1000, 1000, 0)
B_RorF = Beta('B_Rack', 0, -1000, 1000, 0)
B_WD2 = Beta('B_WD_2', 0, -1000, 1000, 0)
B_WDfly_far = Beta('B_WDfly_far', 0, -1000, 1000, 0)
B_C_neutral = Beta('B_C_neutral', 0, -1000, 1000, 0)
B_C_negative = Beta('B_C_negative', 0, -1000, 1000, 0)
B_C_hazardous = Beta('B_C_hazardous', 0, -1000, 1000, 0)

# [Utilities]
Inside =  B_SorL1 * Long1 + B_Inside' * Inside1 + B_RorF * Rack1 + B_C_neutral *
C1_Educative_neutral
Outside = B_Inside' * Inside2 + B_RorF * Rack2 + B_WD2 * WD2 + B_C_neutral *
C2_Educative_neutral
Fly = B_SorL3 * Long3 + B_Inside' * Inside3 + B_RorF * Rack3 + B_WDfly_far * WD3 +
B_C_negative * C3_Educative_negative + B_C_hazardous * C3_Hazardous

# [Choice set and availibity]
V = {1:Inside, 2:Outside, 3:Fly}
av = {1: available1, 2: available2, 3: available3}

#[Model] MNL
logprob = models.loglogit(V, av, choice)

# Create a biogeme object
naming = bio.BIOGEME(database,logprob)

# Give a name
naming.modelName = 'Biogeme_basis_MNL_ChatGPT_final_base.py'

# Estimate parameters
results = naming.estimate()

# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
print(pandasResults)
pandasResults.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Results\\final.xlsx')

# Get the correlation matrix between the parameters
pandasCorrelations = results.getCorrelationResults()
#print(pandasCorrelations)

# Get other general statistics
pandasGeneralStat = results.getGeneralStatistics()
print(pandasGeneralStat)
```

Results base MNL model

Table E.3: Results generic model

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Short or long alternative specific	1439,3847	2993,5734	3048,2900	0,3310
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_inside	0,269073	0,055268	4,868558	1,12E-06
ASC_outside	1,238581	0,082617	14,99193	0
B_C_hazardous	-1,76507	0,127809	-13,8102	0
B_C_negative	-1,44654	0,164678	-8,78408	0
B_C_neutral	-1,98464	0,221714	-8,95135	0
B_Inside	0,717529	0,055268	12,98283	0
B_Long	-2E-16	5,3E-17	-3,837	0,000125
B_Rack	1,507655	0,121075	12,45224	0
B_WD	-0,01041	0,000881	-11,8157	0

Table E.4: Results short or long alternative specific model

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Short or long alternative specific	1515,8583	2979,0999	3039,8961	0,3343
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,607094	0,074965	8,098408	6,66E-16
ASC2	1,091471	0,084461	12,92283	0
B_C_hazardous	-1,67572	0,127837	-13,1083	0
B_C_negative	-1,10622	0,188774	-5,86001	4,63E-09
B_C_neutral	-2,22882	0,220237	-10,1201	0
B_Inside	0,607094	0,074965	8,098408	6,66E-16
B_Long1	-0,66946	0,194761	-3,43735	0,000587
B_Long3	-0,61014	0,162155	-3,76266	0,000168
B_Rack	1,698565	0,119087	14,26322	0
B_WD	-0,01104	0,001031	-10,7104	0

Table E.5: Results neutral alternative specific model

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Neutral alternative specific	1515,8583	2981,0999	3047,9757	0,3338
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC2	1,49654457	0,111898836	13,37408528	0
B_C_hazardous	-1,675496724	0,127832847	-13,10693425	0
B_C_negative	-1,10601634	0,188770135	-5,859064212	4,65483E-09
B_C_neutral_inside	-0,203164789	0,046114456	-4,405663824	1,0546E-05
B_C_neutral_outside	-2,228555747	0,220223015	-10,11954062	0
B_Inside	-0,203164789	0,046114456	-4,405663824	1,0546E-05
B_Long1	-0,669302216	0,194758315	-3,43657838	0,000589112
B_Long3	-0,610140198	0,162154151	-3,762717101	0,000168077
B_Rack	1,293379781	0,083929954	15,41022873	0
B_WD	-0,01103865	0,001030638	-10,71050273	0

Table E.6: Results inside or outside alternative specific model

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Inside or outside alternative specific	1515,8583	2979,0999	3039,8961	0,3343
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,607093947	0,074964599	8,098408482	6,66134E-16
ASC2	1,091471234	0,084460693	12,92283065	0
B_C_hazardous	-1,675724643	0,127836956	-13,10829587	0
B_C_negative	-1,10621739	0,188773925	-5,860011598	4,62835E-09
B_C_neutral	-2,228822126	0,220237489	-10,12008509	0
B_Inside1	0,607093947	0,074964599	8,098408482	6,66134E-16
B_Long1	-0,669460569	0,194760861	-3,437346528	0,000587444
B_Long3	-0,610136249	0,162155398	-3,76266382	0,000168113
B_Rack	1,698565181	0,119087064	14,26322153	0
B_WD	-0,011038725	0,001030658	-10,71036736	0

Table E.7: Results rack or street furniture alternative specific model

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Rcak alternative specific	1515,8583	2979,0999	3039,8961	0,3343
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,970906	0,082996	11,6982	0
ASC2	1,395011	0,09619	14,50264	0
B_C_hazardous	-1,67574	0,127838	-13,1084	0
B_C_negative	-1,10621	0,188773	-5,86	4,63E-09
B_C_neutral	-2,2288	0,220236	-10,1201	0
B_Inside	0,970906	0,082996	11,6982	0
B_Long1	-0,66943	0,194761	-3,43719	0,000588
B_Long3	-0,6101	0,162155	-3,76247	0,000168
B_Rack1	0,970906	0,082996	11,6982	0
B_Rack2	1,395011	0,09619	14,50264	0
B_WD	-0,01104	0,001031	-10,7103	0

Table E.8: WD_fly dummy and WD alternative specific

	Likelihood ratio test	AIC	BIC	adjusted rho squre
WD generic WDfly dummy	1529,0279	2967,9303	3034,8061	0,3368
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	1,029217	0,121116	8,497781	0
ASC2	0,996551	0,090893	10,96395	0
B_C_hazardous	-1,78113	0,140199	-12,7043	0
B_C_negative	-1,33706	0,203673	-6,56473	5,21E-11
B_C_neutral	-2,02777	0,244137	-8,30588	0
B_Inside	1,029217	0,121116	8,497781	0
B_Long1	-0,86332	0,195551	-4,41479	1,01E-05
B_Long3	-1,28801	0,227687	-5,65694	1,54E-08
B_Rack	2,025767	0,127384	15,90282	0
B_WD_2	-0,01974	0,002559	-7,71378	1,22E-14
B_WDfly_far	0,708987	0,252221	2,810976	0,004939

E.3. MNL model with interaction effects

Syntax for the final interaction model

```
#Read data
df = pd.read_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\data_base_model.xlsx')
database = db.Database('data_base_model',df)
# Allows to use the names of the variable as Python variable
globals().update(database.variables)

#Betas
ASC1 = Beta('ASC1', 0, -1000, 1000, 0)
ASC2 = Beta('ASC2', 0, -1000, 1000, 0)
B_Long1 = Beta('B_Long1', 0, -1000, 1000, 0)
B_Long3 = Beta('B_Long3', 0, -1000, 1000, 0)
B_Inside = Beta('B_Inside', 0, -1000, 1000, 0)
B_Rack = Beta('B_Rack', 0, -1000, 1000, 0)
B_WD2 = Beta('B_WD_2', 0, -1000, 1000, 0)
B_WDfly_far = Beta('B_WDfly_far', 0, -1000, 1000, 0)
B_C_neutral = Beta('B_C_neutral', 0, -1000, 1000, 0)
B_C_negative = Beta('B_C_negative', 0, -1000, 1000, 0)
B_C_hazardous = Beta('B_C_hazardous', 0, -1000, 1000, 0)

#[interactions] price
B_C_neutral_expensive_o = Beta('B_C_neutral_expensive_o', 0, -1000, 1000, 0)
B_C_none_expensive_f = Beta('B_C_none_expensive_f', 0, -1000, 1000, 0)

#frequency
B_C_neutral_infreq = Beta('B_C_neutral_infreq', 0, -1000, 1000, 0)
B_C_hazardous_infreq = Beta('B_C_hazardous_infreq', 0, -1000, 1000, 0)

#age
B_C_neutral_young_i = Beta('B_C_neutral_young_i', 0, -1000, 1000, 0)

#fulltime
B_C_hazardous_FT_f = Beta('B_C_hazardous_FT_f', 0, -1000, 1000, 0)

# [Utilities]
Inside = ASC1 + B_Long1 * Long1  + B_Inside' * Inside1 + B_Rack * Rack1 + B_C_neutral * C1_Educative_neutral +
B_C_neutral_infreq * C1_Educative_neutral * infrequent + B_C_neutral_young_i * C1_Educative_neutral * age_young
Outside = ASC2 + B_Inside' * Inside2 + B_Rack * Rack2 + B_WD2 * WD2 +  B_C_neutral * C2_Educative_neutral +
B_C_neutral_expensive_o * C2_Educative_neutral * price + B_C_neutral_infreq * C2_Educative_neutral * infrequent
Fly = B_Long3 * Long3 + B_Inside' * Inside3 + B_Rack * Rack3 + B_WDfly_far * WD3 + B_C_negative *
C3_Educative_negative + B_C_hazardous * C3_Hazardous + B_C_none_expensive_f * C3_None * price +
B_C_hazardous_infreq * C3_Hazardous * infrequent + B_C_hazardous_FT_f * C3_Hazardous * fulltime

# [Choice set and availibity]
V = {1:Inside, 2:Outside, 3:Fly}
av = {1: available1, 2: available2, 3: available3}

#[Model] MNL
logprob = models.loglogit(V, av, choice)
# Create a biogeme object
naming = bio.BIOGEME(database,logprob)

# Give a name
naming.modelName = 'Biogeme_basis_MNL_ChatGPT_combi_ASC.py'

# Estimate parameters
results = naming.estimate()
# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
print(pandasResults)
pandasResults.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Results\\interactions_combi_ASC.xlsx')

# Get the correlation matrix between the parameters
pandasCorrelations = results.getCorrelationResults()

# Get other general statistics
pandasGeneralStat = results.getGeneralStatistics()
```

Results for the models with interactions

Generic

Table E.9: MNL model interaction effects gender

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Gender generic	1540.8379	2958.1203	3031.0758	0.3390
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,671076	0,101843	6,589298	4,42E-11
ASC2	1,475024	0,082658	17,84499	0
B_C_hazardous	-1,73825	0,163029	-10,6622	0
B_C_negative	-1,01977	0,213361	-4,77955	1,76E-06
B_C_neutral	-2,49863	0,262364	-9,52355	0
B_C_neutral_gender	-0,22329	0,120008	-1,86058	0,062803
B_C_none_gender	-0,33143	0,201136	-1,64779	0,099396
B_Inside	0,671076	0,101843	6,589298	4,42E-11
B_Long1	-2,66591	0,294513	-9,05193	0
B_Long3	-2,04835	0,296193	-6,9156	4,66E-12
B_Rack	2,1461	0,148726	14,42984	0
B_WD_2	-0,02382	0,002949	-8,07641	6,66E-16
B_WDfly_far	0,603073	0,226817	2,658857	0,007841

Table E.10: MNL model interaction effects frequency

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Frequency generic	1559.1701	2974.7881	3020.8231	0.3426
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,607117	0,094585	6,418737	1,37E-10
ASC2	1,480715	0,081962	18,06588	0
B_C_hazardous	-1,72525	0,138998	-12,412	0
B_C_hazardous_infreq	0,882921	0,277889	3,177239	0,001487
B_C_negative	-0,87221	0,191842	-4,54648	5,45E-06
B_C_neutral	-2,49445	0,234293	-10,6467	0
B_C_neutral_infreq	0,735163	0,166267	4,421569	9,8E-06
B_Inside	0,607117	0,094585	6,418737	1,37E-10
B_Long1	-2,55782	0,290669	-8,79978	0
B_Long3	-2,08963	0,293852	-7,11118	1,15E-12
B_Rack	2,087832	0,143139	14,58607	0
B_WD_2	-0,02427	0,002936	-8,26649	2,22E-16
B_WDfly_far	0,642721	0,224422	2,863899	0,004185

Alternative specific

Table E.11: MNL model interaction effects price

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Price specific	1551.4534	2949.5048	3028.5398	0.3409
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,604383	0,098205	6,1543	7,54E-10
ASC2	1,41709	0,087046	16,27985	0
B_C_hazardous	-1,81872	0,148853	-12,2182	0
B_C_negative	-1,09801	0,206386	-5,32019	1,04E-07
B_C_neutral	-2,36274	0,239186	-9,87825	0
B_C_neutral_expensive_o	-0,36813	0,128563	-2,86346	0,00419
B_C_none_expensive_f	-0,62033	0,181298	-3,42159	0,000623
B_Inside	0,604383	0,098205	6,1543	7,54E-10
B_Long1	-2,742	0,292495	-9,37453	0
B_Long3	-2,04482	0,294011	-6,95492	3,53E-12
B_Rack	2,021473	0,148122	13,64739	0
B_WD_2	-0,02377	0,002921	-8,13666	4,44E-16
B_WDfly_far	0,592218	0,223904	2,644963	0,00817

Table E.12: MNL model interaction effects age

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Age specific	1549.6995	2949.2587	3022.2141	0.3409
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,718233	0,101432	7,080946	1,43E-12
ASC2	1,422055	0,083932	16,94288	0
B_C_hazardous	-1,57849	0,13004	-12,1385	0
B_C_negative	-0,85152	0,190798	-4,46296	8,08E-06
B_C_neutral	-2,36149	0,231378	-10,2062	0
B_C_neutral_young_i	-0,48066	0,137431	-3,49747	0,00047
B_Inside	0,718233	0,101432	7,080946	1,43E-12
B_Long1	-2,57361	0,289925	-8,8768	0
B_Long3	-2,10828	0,292963	-7,19641	6,18E-13
B_Rack	2,140288	0,143684	14,89576	0
B_WD_2	-0,02438	0,002942	-8,28619	2,22E-16
B_WDfly_far	0,64894	0,224595	2,889382	0,00386

Table E.13: MNL model interaction effects full-time job

	Likelihood ratio test	AIC	BIC	adjusted rho squre
FT worker	1542.8735	2956.0847	3029.0401	0.3394
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,604461	0,093846	6,441009	1,19E-10
ASC2	1,472227	0,081607	18,04039	0
B_C_hazardous	-1,81301	0,164483	-11,0225	0
B_C_hazardous_FT	0,434973	0,175642	2,476478	0,013269
B_C_negative	-0,85967	0,191156	-4,49725	6,88E-06
B_C_neutral	-2,34333	0,231898	-10,105	0
B_Inside	0,604461	0,093846	6,441009	1,19E-10
B_Long1	-2,56344	0,290117	-8,83589	0
B_Long3	-2,09869	0,293449	-7,1518	8,56E-13
B_Rack	2,076688	0,141929	14,63187	0
B_WD_2	-0,02439	0,002939	-8,29818	0
B_WDfly_far	0,657602	0,224357	2,931057	0,003378

Table E.14: MNL model interaction effects student or scholar

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Student specific	1546.6681	2954.2901	3033.3251	0.3400
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,633592	0,095235	6,652963	2,87E-11
ASC2	1,459548	0,081875	17,82655	0
B_C_hazardous	-1,46027	0,135035	-10,814	0
B_C_hazardous_student	-0,67632	0,256721	-2,63444	0,008428
B_C_negative	-0,85421	0,190871	-4,4753	7,63E-06
B_C_neutral	-2,34689	0,232194	-10,1074	0
B_C_neutral_student_i	-0,39067	0,170316	-2,29381	0,021802
B_Inside	0,633592	0,095235	6,652963	2,87E-11
B_Long1	-2,56638	0,289435	-8,86686	0
B_Long3	-2,09672	0,2926	-7,16582	7,73E-13
B_Rack	2,093141	0,142343	14,70489	0
B_WD_2	-0,02434	0,002932	-8,30169	0
B_WDfly_far	0,652417	0,223541	2,918551	0,003517

E.4. MNL model with socio-demographics

Syntax of final model with socio-demographics

```
#Read data
df = pd.read_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\data_base_model.xlsx')
database = db.Database('data_base_model',df)

# Allows to use the names of the variable as Python variable
globals().update(database.variables)

#Betas
ASC1 = Beta('ASC1', 0, -1000, 1000, 0)
ASC2 = Beta('ASC2', 0, -1000, 1000, 0)
B_Long1 = Beta('B_Long1', 0, -1000, 1000, 0) #of 1 op het laatst om hem vast te zetten
B_Long3 = Beta('B_Long3', 0, -1000, 1000, 0)
B_Inside = Beta('B_Inside', 0, -1000, 1000, 0)B_Rack = Beta('B_Rack', 0, -1000, 1000, 0)
B_WD2 = Beta('B_WD_2', 0, -1000, 1000, 0)
B_WDfly_far = Beta('B_WDfly_far', 0, -1000, 1000, 0)
B_C_neutral = Beta('B_C_neutral', 0, -1000, 1000, 0)
B_C_negative = Beta('B_C_negative', 0, -1000, 1000, 0)
B_C_hazardous = Beta('B_C_hazardous', 0, -1000, 1000, 0)
B_young1 = Beta('B_young1', 0, -1000, 1000, 0)
B2_expensive = Beta('B2_expensive', 0, -1000, 1000, 0)
B3_infreq = Beta('B3_infreq', 0, -1000, 1000, 0)

# [Utilities]
Inside = ASC1 + B_Long1 * Long1  + B_Inside' * Inside1 +  B_Rack * Rack1 + B_C_neutral *
C1_Educative_neutral  + B_young1 * age_young
Outside = ASC2 + B_Inside' * Inside2 + B_Rack * Rack2 + B_WD2 * WD2 +  B_C_neutral *
C2_Educative_neutral + B2_expensive * price
Fly = B_Long3 * Long3 + B_Inside' * Inside3 + B_Rack * Rack3 + B_WDfly_far * WD3 + B_C_negative *
C3_Educative_negative + B_C_hazardous * C3_Hazardous + B3_infreq * infrequent

# [Choice set and availibity]
V = {1:Inside, 2:Outside, 3:Fly}
av = {1: available1, 2: available2, 3: available3}

#[Model] MNL
logprob = models.loglogit(V, av, choice)

# Create a biogeme object
naming = bio.BIOGEME(database,logprob)

# Give a name
naming.modelName = 'Biogeme_basis_MNL_ChatGPT_all_B3_price_ASC.py'

# Estimate parameters
results = naming.estimate()

# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
pandasResults.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Results\\socio-dem_combi_ASC.xlsx')

# Get the correlation matrix between the parameters
pandasCorrelations = results.getCorrelationResults()
pandasCorrelations.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\all_B3_price_ASC.xlsx')

# Get other general statistics
pandasGeneralStat = results.getGeneralStatistics()
```

Results MNL model socio-demographics

All work best when they are alternative-specific. Try adding all socio-demographics that were significantly different according to the chi-square test. So, age, price of a person's bike and frequency of use are introduced. Age and price of a person's bike are added as two groups, these were aggregated as smaller groups would mean the sample is too small. For frequency, three groups were added. For each socio-demographic, one level is the base level to which the other level(s) is/are compared. The results are shown in the tables below.

Table E.15: MNL model age add

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Age add	1549,7	2949,259	3022,214	0,341
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,718232	0,101432	7,080943	1,43E-12
ASC2	1,422056	0,083933	16,94285	0
B_C_hazardous	-1,57848	0,13004	-12,1385	0
B_C_negative	-0,85151	0,190798	-4,4629	8,09E-06
B_C_neutral	-2,36149	0,231379	-10,2062	0
B_Inside	0,718232	0,101432	7,080943	1,43E-12
B_Long1	-2,57361	0,289925	-8,87679	0
B_Long3	-2,10828	0,292963	-7,19641	6,18E-13
B_Rack	2,140289	0,143684	14,89576	0
B_WD_2	-0,02438	0,002942	-8,28618	2,22E-16
B_WDfly_far	0,648933	0,224594	2,889357	0,00386
B_young1	-0,48066	0,137431	-3,49747	0,00047

Table E.16: MNL model price add

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Price add	1550,46	2950,502	3029,537	0,3407
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,528512	0,096364	5,484513	4,15E-08
ASC2	1,558534	0,086992	17,91578	0
B2_expensive	-0,59628	0,164325	-3,62865	0,000285
B3_expensive	-0,39907	0,142645	-2,79764	0,005148
B_C_hazardous	-1,57614	0,129726	-12,1498	0
B_C_negative	-0,84768	0,190757	-4,44375	8,84E-06
B_C_neutral	-2,36619	0,232287	-10,1865	0
B_Inside	0,528512	0,096364	5,484513	4,15E-08
B_Long1	-2,57766	0,289938	-8,89038	0
B_Long3	-2,11336	0,292935	-7,21443	5,42E-13
B_Rack	2,087045	0,145741	14,32025	0
B_WD_2	-0,0244	0,00294	-8,29846	0
B_WDfly_far	0,646296	0,224328	2,88103	0,003964

Table E.17: MNL model frequency add

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Frequency add	1546,7	2952,258	3025,213	0,3402
	Value	**Rob. Std err**	**Rob. t-test**	**Rob. p-value**
ASC1	0,593110313	0,093867113	6,318616755	2,63915E-10
ASC2	1,445518588	0,082071018	17,61302137	0
B3_freq	-0,419544053	0,140550256	-2,985010938	0,002835682
B_C_hazardous	-1,583907349	0,130407509	-12,14582937	0
B_C_negative	-0,864218235	0,191162309	-4,520861027	6,15886E-06
B_C_neutral	-2,348905568	0,231745206	-10,13572454	0
B_Inside	0,593110313	0,093867113	6,318616755	2,63915E-10
B_Long1	-2,570488474	0,29019887	-8,857679143	0
B_Long3	-2,103406123	0,293601034	-7,164164552	7,82707E-13
B_Rack	2,038628901	0,142463238	14,30985937	0
B_WD_2	-0,024425997	0,002943094	-8,299429438	0
B_WDfly_far	0,660321126	0,224775262	2,937694838	0,003306623

E.5. MNL model with interactions and socio-demographics

Syntax model with interactions and socio-demographics

```
#Read data
df = pd.read_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\data_base_model.xlsx')
database = db.Database('data_base_model',df)
# Allows to use the names of the variable as Python variable
globals().update(database.variables)

#Betas
ASC1 = Beta('ASC1', 0, -1000, 1000, 0)
ASC2 = Beta('ASC2', 0, -1000, 1000, 0)
B_Long1 = Beta('B_Long1', 0, -1000, 1000, 0)
B_Long3 = Beta('B_Long3', 0, -1000, 1000, 0)
B_Inside = Beta('B_Inside', 0, -1000, 1000, 0)
B_Rack = Beta('B_Rack', 0, -1000, 1000, 0)
B_WD2 = Beta('B_WD_2', 0, -1000, 1000, 0)
B_WDfly_far = Beta('B_WDfly_far', 0, -1000, 1000, 0)
B_C_neutral = Beta('B_C_neutral', 0, -1000, 1000, 0)
B_C_negative = Beta('B_C_negative', 0, -1000, 1000, 0)
B_C_hazardous = Beta('B_C_hazardous', 0, -1000, 1000, 0)

#[interactions]
#price
B_C_neutral_expensive_o = Beta('B_C_neutral_expensive_o', 0, -1000, 1000, 0)
B_C_none_expensive_f = Beta('B_C_none_expensive_f', 0, -1000, 1000, 0)

#frequency
B_C_neutral_infreq = Beta('B_C_neutral_infreq', 0, -1000, 1000, 0)
B_C_hazardous_infreq = Beta('B_C_hazardous_infreq', 0, -1000, 1000, 0)

#age
B_C_neutral_young_i = Beta('B_C_neutral_young_i', 0, -1000, 1000, 0)

#fulltime
B_C_hazardous_FT_f = Beta('B_C_hazardous_FT_f', 0, -1000, 1000, 0)

#[Socio-demographics]
B1_young = Beta('B_young1', 0, -1000, 1000, 0)

# [Utilities]
Inside = ASC1 + B_Long1 * Long1 + B_Inside' * Inside1 + B_Rack * Rack1 + B_C_neutral * C1_Educative_neutral +
B_C_neutral_infreq * C1_Educative_neutral * infrequent + B_C_neutral_young_i * C1_Educative_neutral * age_young + B1_young
* age_young
Outside = ASC2 + B_Inside' * Inside2 +  B_Rack * Rack2 + B_WD2 * WD2 +  B_C_neutral * C2_Educative_neutral +
B_C_neutral_expensive_o * C2_Educative_neutral * price + B_C_neutral_infreq * C2_Educative_neutral * infrequent
Fly = B_Long3 * Long3 + B_Inside' * Inside3  + B_Rack * Rack3 + B_WDfly_far * WD3 + B_C_negative * C3_Educative_negative +
B_C_hazardous * C3_Hazardous + B_C_none_expensive_f * C3_None * price + B_C_hazardous_infreq * C3_Hazardous *
infrequent + B_C_hazardous_FT_f * C3_Hazardous * fulltime

# [Choice set and availibity]
V = {1:Inside, 2:Outside, 3:Fly}
av = {1: available1, 2: available2, 3: available3}

#[Model] MNL
logprob = models.loglogit(V, av, choice)

# Create a biogeme object
naming = bio.BIOGEME(database,logprob)

# Give a name
naming.modelName = 'Biogeme_basis_MNL_ChatGPT_interactions_socio_ASC.py'

# Estimate parameters
results = naming.estimate()
# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
pandasResults.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Results\\interactions_socio_ASC.xlsx')

# Get the correlation matrix between the parameters
pandasCorrelations = results.getCorrelationResults()

# Get other general statistics
pandasGeneralStat = results.getGeneralStatistics()
```

E.6. Mixed logit models

Nested

Table E.18: Final ML model with nest structure

	Likelihood ratio test	AIC	BIC	adjusted rho squre
Nested	1588.7904	2924.1678	3039.6805	0,3465
	Value	Rob. Std err	Rob. t-test	Rob. p-value
ASC1	0,742628	0,119155	6,232464	4,59E-10
ASC2	1,176969	0,16519	7,124934	1,04E-12
B_C_hazardous	-2,26071	0,217825	-10,3786	0
B_C_hazardous_FT_f	0,410032	0,177065	2,315717	0,020574
B_C_hazardous_infreq	0,815989	0,279166	2,922949	0,003467
B_C_negative	-1,31971	0,2932	-4,50105	6,76E-06
B_C_neutral	-2,03818	0,374191	-5,4469	5,13E-08
B_C_neutral_expensive_o	-0,31786	0,119766	-2,654	0,007954
B_C_neutral_infreq	0,691992	0,164162	4,215301	2,49E-05
B_C_neutral_young_i	-0,2069	0,066893	-3,09294	0,001982
B_C_none_expensive_f	-0,50918	0,18359	-2,77346	0,005546
B_Inside	0,742628	0,119155	6,232464	4,59E-10
B_Long1	-2,68898	0,251966	-10,672	0
B_Long3	-1,96759	0,262692	-7,49012	6,88E-14
B_Rack	1,919597	0,142904	13,43273	0
B_WD_2	-0,02511	0,003169	-7,92288	2,22E-15
B_WDfly_far	0,912385	0,372144	2,451699	0,014218
B_young1	-0,2069	0,066893	-3,09294	0,001982
MU	1,467622	0,467673	3,138134	0,0017

Panel

```
#Read data
df = pd.read_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\data_panel_model.xlsx')
database = db.Database('data_panel_model',df)

# Allows to use the names of the variable as Python variable
globals().update(database.variables)
database.panel("panel_id")

#Betas
ASC1 = Beta('ASC1', 0, -1000, 1000, 0)
ASC2 = Beta('ASC2', 0, -1000, 1000, 0)
B_Long1 = Beta('B_Long1', 0, -1000, 1000, 0)
B_Long3 = Beta('B_Long3', 0, -1000, 1000, 0)
B_Inside = Beta('B_Inside', 0, -1000, 1000, 0)
B_Rack = Beta('B_Rack', 0, -1000, 1000, 0)
B_WD2 = Beta('B_WD_2', 0, -1000, 1000, 0)
B_WDfly_far = Beta('B_WDfly_far', 0, -1000, 1000, 0)
B_C_neutral = Beta('B_C_neutral', 0, -1000, 1000, 0)
B_C_negative = Beta('B_C_negative', 0, -1000, 1000, 0)
B_C_hazardous = Beta('B_C_hazardous', 0, -1000, 1000, 0)

#[interactions]
#price
B_C_neutral_expensive_o = Beta('B_C_neutral_expensive_o', 0, -1000, 1000, 0)
B_C_none_expensive_f = Beta('B_C_none_expensive_f', 0, -1000, 1000, 0)

#frequency
B_C_neutral_infreq = Beta('B_C_neutral_infreq', 0, -1000, 1000, 0)
B_C_hazardous_infreq = Beta('B_C_hazardous_infreq', 0, -1000, 1000, 0)

#age
B_C_neutral_young_i = Beta('B_C_neutral_young_i', 0, -1000, 1000, 0)

#[Socio-demographics]
B1_young = Beta('B_young1', 0, -1000, 1000, 0)

#[panel]
Sigma_panel = Beta('Sigma_panel',0,-100,100,0)
Zero = Beta('Zero',0,-100,100,1)
Zero_sigma_panel = Zero + Sigma_panel * bioDraws('Zero_sigma_panel','NORMAL')

# [Utilities]
Inside = ASC1 + B_Long1 * Long1 + B_Inside' * Inside1 + B_Rack * Rack1 + B_C_neutral * C1_Educative_neutral +
B_C_neutral_infreq * C1_Educative_neutral * infrequent + B_C_neutral_young_i * C1_Educative_neutral * age_young + B1_young
* age_young + Zero_sigma_panel
Outside = ASC2 + B_Inside' * Inside2 + B_Rack * Rack2 + B_WD2 * WD2 +  B_C_neutral * C2_Educative_neutral +
B_C_neutral_expensive_o * C2_Educative_neutral * price + B_C_neutral_infreq * C2_Educative_neutral * infrequent +
Zero_sigma_panel
Fly = B_Long3 * Long3 + B_Inside' * Inside3 + B_Rack * Rack3 + B_WDfly_far * WD3 + B_C_negative * C3_Educative_negative +
B_C_hazardous * C3_Hazardous + B_C_none_expensive_f * C3_None * price + B_C_hazardous_infreq * C3_Hazardous *
infrequent

# [Choice set and availibity]
V = {1:Inside, 2:Outside, 3:Fly}
av = {1: available1, 2: available2, 3: available3}

# Define the contribution to the log likelihood function is slightly different for the panel effects
obsprob = models.logit(V,av,choice)
condprobIndiv = PanelLikelihoodTrajectory(obsprob)
logprob = log(MonteCarlo(condprobIndiv))

# Create the Biogeme
biogeme = bio.BIOGEME(database, logprob, numberOfDraws=10000)
biogeme.modelName = 'ML_panel_ASC'
# Estimate the parameters
results = biogeme.estimate()

# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
pandasResults.to_excel(r'C:\\Users\\Rolien\\Documents\\Afstuderen\\Results\\Panel_ASC.xlsx')
# Get the correlation matrix between the parameters
pandasCorrelations = results.getCorrelationResults()
# Get other general statistics
pandasGeneralStat = results.getGeneralStatistics()
```

E.7. Choice probabilities of parking

Table E.19: No communication short-term parking WD2 of 50m

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	81,77	81,73	85,21	84,77	81,77	81,38	85,08	84,74	81,77	81,58	85,08	84,92	81,63	81,23	85,08	84,74
% Outside	18,06	17,88	14,66	14,58	17,88	17,80	14,64	14,58	18,06	18,02	14,79	14,76	18,03	17,94	14,64	14,58
% Fly	0,16	0,40	0,13	0,65	0,34	0,83	0,28	0,68	0,16	0,40	0,13	0,32	0,34	0,82	0,28	0,68

Table E.20: No communication long-term parking WD2 of 100m

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	41,25	41,13	47,16	47,03	41,15	40,89	47,06	46,79	41,25	41,13	47,16	47,03	41,15	40,89	47,06	46,80
% Outside	58,54	58,36	52,65	52,50	58,40	58,03	52,54	52,23	58,54	58,36	52,65	52,50	58,40	58,03	52,54	52,24
% Fly	0,21	0,52	0,19	0,46	0,44	1,08	0,40	0,98	0,21	0,52	0,19	0,46	0,44	1,07	0,40	0,97

Table E.21: No communication short-term parking WD2 of 50m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	82,07	81,88	85,21	85,04	81,93	81,53	85,08	84,74	82,07	81,88	85,21	85,04	82,07	81,68	85,08	84,74
% Outside	17,77	17,73	14,66	14,63	17,74	17,65	14,64	14,58	17,77	17,73	14,66	14,63	17,59	17,51	14,64	14,58
% Fly	0,16	0,39	0,13	0,32	0,33	0,81	0,28	0,68	0,16	0,39	0,13	0,32	0,34	0,81	0,28	0,68

Table E.22: No communication long-term parking WD2 of 100m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	41,98	41,85	47,16	47,03	41,88	41,62	47,06	46,80	41,98	41,85	47,16	47,03	41,88	41,62	47,06	46,80
% Outside	57,81	57,64	52,65	52,50	57,68	57,32	52,54	52,24	57,81	57,64	52,65	52,50	57,68	57,32	52,54	52,24
% Fly	0,21	0,51	0,19	0,46	0,44	1,06	0,40	0,97	0,21	0,51	0,19	0,46	0,44	1,06	0,40	0,97

Table E.23: Hazardous communication short-term parking WD2 of 50m

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	81,85	81,76	85,15	85,07	81,85	81,76	85,15	85,07	81,89	81,86	85,18	85,15	81,89	81,86	85,18	85,15
% Outside	18,08	18,06	14,80	14,78	18,08	18,06	14,80	14,78	18,09	18,08	14,80	14,80	18,09	18,08	14,80	14,80
% Fly	0,07	0,17	0,06	0,14	0,07	0,17	0,06	0,14	0,02	0,06	0,02	0,05	0,02	0,06	0,02	0,05

Table E.24: Hazardous communication long-term parking WD2 of 100m

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	41,30	41,24	47,21	47,16	41,30	41,24	47,21	47,16	41,33	41,31	47,24	47,22	41,33	41,31	47,24	47,24
% Outside	58,61	58,53	52,70	52,64	58,61	58,53	52,70	52,64	58,64	58,62	52,73	52,71	58,64	58,62	52,73	52,73
% Fly	0,09	0,23	0,08	0,20	0,09	0,23	0,08	0,20	0,03	0,08	0,03	0,07	0,03	0,08	0,03	0,03

Table E.25: Hazardous communication short-term parking WD2 of 50m reducing interaction with infrequent users

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	81,85	81,78	85,15	85,09	81,85	81,78	85,15	85,09	81,74	81,71	85,18	85,15	81,89	81,86	85,18	85,15
% Outside	18,08	18,07	14,80	14,79	18,08	18,07	14,80	14,79	18,24	18,23	14,80	14,80	18,09	18,08	14,80	14,80
% Fly	0,06	0,16	0,05	0,13	0,06	0,16	0,05	0,13	0,02	0,06	0,02	0,05	0,02	0,06	0,02	0,05

Table E.26: Hazardous communication long-term parking WD2 of 100m reducing interaction with infrequent users

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	41,30	41,25	47,22	47,17	41,30	41,25	47,22	47,17	41,33	41,31	47,24	47,22	41,33	41,31	47,24	47,22
% Outside	58,61	58,54	52,71	52,65	58,61	58,54	52,71	52,65	58,64	58,62	52,73	52,71	58,64	58,62	52,73	52,71
% Fly	0,08	0,20	0,08	0,18	0,08	0,20	0,08	0,18	0,03	0,08	0,03	0,07	0,03	0,08	0,03	0,07

Table E.27: Hazardous communication short-term parking WD2 of 50m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	82,14	82,06	85,15	85,07	82,14	82,06	85,15	85,07	82,18	82,15	85,18	85,15	82,18	82,15	85,18	85,15
% Outside	17,79	17,77	14,80	14,78	17,79	17,77	14,80	14,78	17,80	17,79	14,80	14,80	17,80	17,79	14,80	14,80
% Fly	0,07	0,17	0,06	0,14	0,07	0,17	0,06	0,14	0,02	0,06	0,02	0,05	0,02	0,06	0,02	0,05

Table E.28: Hazardous communication long-term parking WD2 of 100m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	42,03	41,97	47,21	47,16	42,03	41,97	47,21	47,16	42,05	42,04	47,24	47,22	42,05	42,04	47,24	47,22
% Outside	57,88	57,80	52,70	52,64	57,88	57,80	52,70	52,64	57,91	57,89	52,73	52,71	57,91	57,89	52,73	52,71
% Fly	0,09	0,22	0,08	0,20	0,09	0,22	0,08	0,20	0,03	0,07	0,03	0,07	0,03	0,07	0,03	0,07

Table E.29: Negative educative communication short-term parking WD2 of 50m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	82,15	82,07	85,15	85,09	82,15	82,07	85,15	85,09	82,15	82,07	85,15	85,09	82,15	82,07	85,15	85,09
% Outside	17,79	17,77	14,80	14,79	17,79	17,77	14,80	14,79	17,79	17,77	14,80	14,79	17,79	17,77	14,80	14,79
% Fly	0,06	0,16	0,05	0,13	0,06	0,16	0,05	0,13	0,06	0,16	0,05	0,13	0,06	0,16	0,05	0,13

Table E.30: Negative educative communication long-term parking WD2 of 100m reduced disutility of inside parking for young people

Frequency	Infrequent								Frequent							
Price	Expensive				Cheap				Expensive				Cheap			
Age	Young		Old		Young		Old		Young		Old		Young		Old	
WD fly	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further	Close	Further
% Inside	42,03	41,98	47,22	47,17	42,03	41,98	47,22	47,17	42,03	41,98	47,22	47,17	42,03	41,98	47,22	47,17
% Outside	57,88	57,82	52,71	52,65	57,88	57,82	52,71	52,65	57,88	57,82	52,71	52,65	57,88	57,82	52,71	52,65
% Fly	0,08	0,20	0,08	0,18	0,08	0,20	0,08	0,18	0,08	0,20	0,08	0,18	0,08	0,20	0,08	0,18

E.8. Validation

Table E.31: Beta values of random samples MNL model

	Final MNL		Random 1		Random 2		Random 3		Random 4		Random 5	
	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err
ASC1	0,688	0,106	0,606	0,117	0,712	0,121	0,683	0,121	0,712	0,118	0,680	0,118
ASC2	1,400	0,089	1,378	0,096	1,456	0,106	1,434	0,104	1,339	0,095	1,390	0,099
B_C_hazardous	-2,134	0,186	-2,110	0,209	-2,140	0,208	-2,142	0,210	-2,120	0,207	-2,170	0,206
B_C_hazardous_FT_f	0,410	0,176	0,445	0,195	0,432	0,201	0,393	0,199	0,277	0,193	0,334	0,196
B_C_hazardous_infreq	0,842	0,280	0,849	0,309	0,956	0,323	0,915	0,313	0,930	0,301	1,044	0,307
B_C_negative	-1,055	0,207	-1,159	0,230	-0,933	0,233	-0,964	0,231	-1,146	0,235	-1,232	0,233
B_C_neutral	-2,503	0,241	-2,329	0,263	-2,827	0,285	-2,570	0,279	-2,425	0,260	-2,452	0,267
B_C_neutral_expensive_o	-0,308	0,130	-0,387	0,144	-0,300	0,147	-0,308	0,145	-0,315	0,145	-0,477	0,145
B_C_neutral_infreq	0,718	0,168	0,689	0,188	0,900	0,194	0,749	0,187	0,752	0,183	0,675	0,189
B_C_neutral_young_i	-0,184	0,070	-0,163	0,079	-0,154	0,079	-0,163	0,079	-0,185	0,079	-0,170	0,078
B_C_none_expensive_f	-0,488	0,187	-0,545	0,207	-0,553	0,209	-0,581	0,210	-0,505	0,211	-0,484	0,206
B_Inside	0,688	0,106	0,606	0,117	0,712	0,121	0,683	0,121	0,712	0,118	0,680	0,118
B_Long1	-2,707	0,293	-2,642	0,325	-2,641	0,332	-2,672	0,333	-3,019	0,327	-2,854	0,329
B_Long3	-2,054	0,295	-2,056	0,329	-2,041	0,334	-2,047	0,332	-2,234	0,332	-2,178	0,332
B_Rack	2,089	0,151	1,984	0,163	2,168	0,177	2,117	0,177	2,051	0,165	2,070	0,168
B_WD_2	-0,024	0,003	-0,025	0,003	-0,022	0,003	-0,024	0,003	-0,026	0,003	-0,025	0,003
B_WDfly_far	0,586	0,225	0,536	0,247	0,460	0,256	0,597	0,254	0,659	0,248	0,617	0,250
B_young1	-0,184	0,070	-0,163	0,079	-0,154	0,079	-0,163	0,079	-0,185	0,079	-0,170	0,078

Table E.32: Results t-test MNL model compared to random samples

	Random 1	Random 2	Random 3	Random 4	Random 5
ASC1	-0,014	0,004	-0,001	0,004	-0,001
ASC2	-0,005	0,010	0,006	-0,013	-0,002
B_C_hazardous	0,002	-0,001	-0,001	0,001	-0,003
B_C_hazardous_FT_f	0,004	0,002	-0,002	-0,014	-0,008
B_C_hazardous_infreq	0,000	0,007	0,005	0,006	0,013
B_C_negative	-0,009	0,010	0,008	-0,008	-0,015
B_C_neutral	0,013	-0,022	-0,005	0,006	0,004
B_C_neutral_expensive_o	-0,011	0,001	0,000	-0,001	-0,023
B_C_neutral_infreq	-0,003	0,018	0,003	0,004	-0,004
B_C_neutral_young_i	0,005	0,008	0,005	0,000	0,004
B_C_none_expensive_f	-0,005	-0,006	-0,009	-0,002	0,000
B_Inside	-0,014	0,004	-0,001	0,004	-0,001
B_Long1	0,004	0,004	0,002	-0,019	-0,009
B_Long3	0,000	0,001	0,000	-0,011	-0,007
B_Rack	-0,013	0,009	0,003	-0,005	-0,002
B_WD_2	-0,005	0,014	0,002	-0,010	-0,008
B_WDfly_far	-0,004	-0,010	0,001	0,006	0,002
B_young1	-0,163	-0,154	-0,163	-0,185	-0,170

Table E.33: Beta values of random samples ML model

	Final ML		Random 1		Random 2		Random3		Random 4		Random 5	
	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err	Value	Rob. Std err
ASC1	0,916	0,114	0,894777	0,12351506	0,881477	0,13227644	1,011	0,131	1,031445	0,12541737	0,864042	0,12273568
ASC2	1,573	0,100	1,609497	0,11040828	1,597935	0,11865468	1,554	0,108	1,563133	0,11211545	1,572325	0,11172673
B_C_hazardous	-2,656	0,197	-2,47241	0,20590988	-2,61211	0,21675048	-2,649	0,218	-2,73631	0,22848341	-2,584296	0,22162463
B_C_hazardous_infreq	1,091	0,328	1,068357	0,33148447	1,271321	0,38053451	1,137	0,359	1,0549	0,37599415	1,038693	0,37873041
B_C_negative	-1,665	0,221	-1,57358	0,23037585	-1,52843	0,24042636	-1,600	0,254	-1,74749	0,24528304	-1,497027	0,24296356
B_C_neutral	-2,910	0,243	-2,9718	0,27546416	-2,86396	0,27286245	-2,710	0,259	-3,02459	0,27693466	-2,965251	0,27636424
B_C_neutral_expensive_o	-0,376	0,170	-0,24042	0,19509549	-0,38278	0,19567728	-0,474	0,188	-0,40667	0,18998461	-0,345109	0,17939073
B_C_neutral_infreq	0,998	0,313	0,972847	0,31025016	0,757301	0,34512523	0,825	0,356	0,892421	0,34242783	0,912985	0,35626395
B_C_neutral_young_i	-0,238	0,102	-0,25759	0,10978735	-0,23092	0,1175302	-0,300	0,113	-0,3	0,11281885	-0,147155	0,11169723
B_C_none_expensive_f	-0,738	0,220	-0,46447	0,23501881	-0,73902	0,25035271	-0,627	0,244	-0,89523	0,25140504	-0,644435	0,23664465
B_Inside	0,916	0,114	0,894777	0,12351506	0,881477	0,13227644	1,011	0,131	1,031445	0,12541737	0,864042	0,12273568
B_Long1	-3,344	0,290	-2,9299	0,31568013	-3,54709	0,33395347	-3,659	0,319	-3,40796	0,33344416	-3,237651	0,32321885
B_Long3	-2,399	0,260	-2,19286	0,28424126	-2,53341	0,28587838	-2,781	0,287	-2,32945	0,29604485	-2,346145	0,28550885
B_Rack	2,489	0,143	2,504275	0,15557374	2,479412	0,16407574	2,565	0,166	2,594579	0,15781592	2,436367	0,15523983
B_WD_2	-0,030	0,003	-0,02698	0,00317632	-0,03122	0,003285	-0,032	0,003	-0,02945	0,0033262	-0,028141	0,00316161
B_WDfly_far	0,890	0,218	0,809884	0,25512751	0,857955	0,25393358	1,086	0,236	0,881472	0,24931339	0,788612	0,24431475
B_young1	-0,238	0,102	-0,25759	0,10978735	-0,23092	0,1175302	-0,300	0,113	-0,3	0,11281885	-0,147155	0,11169723
Sigma_panel	1,3922	0,11564102	1,358914	0,13733941	1,403474	0,13190669	1,427653	0,12887138	1,487333	0,14108834	1,397001	0,12956367

Table E.34: Results t-test ML model compared to random samples

	Random1	Random2	Random3	Random4	Random5
ASC1	-0,002	-0,003	0,007	0,009	-0,004
ASC2	0,003	0,002	-0,002	-0,001	0,000
B_C_hazardous	0,009	0,002	0,000	-0,004	0,003
B_C_hazardous_infreq	-0,001	0,005	0,001	-0,001	-0,001
B_C_negative	0,004	0,006	0,003	-0,003	0,007
B_C_neutral	-0,002	0,002	0,008	-0,004	-0,002
B_C_neutral_expensive_o	0,007	0,000	-0,005	-0,002	0,002
B_C_neutral_infreq	-0,001	-0,007	-0,005	-0,003	-0,002
B_C_neutral_young_i	-0,002	0,001	-0,005	-0,005	0,008
B_C_none_expensive_f	0,012	0,000	0,005	-0,006	0,004
B_Inside	-0,002	-0,003	0,007	0,009	-0,004
B_Long1	0,013	-0,006	-0,010	-0,002	0,003
B_Long3	0,007	-0,005	-0,013	0,002	0,002
B_Rack	0,001	-0,001	0,005	0,007	-0,003
B_WD_2	0,009	-0,004	-0,008	0,001	0,005
B_WDfly_far	-0,003	-0,001	0,008	0,000	-0,004
B_young1	-0,002	0,001	-0,005	-0,005	0,008
Sigma_panel	-0,002	-0,009	0,001	-0,009	0,003

E.9. Sensitivity analysis

E.9.1. Walking distance

Table E.35: Choice probabilities of fly parking for hazardous communication comparing WD2

	Short							
	Infrequent				Frequent			
	Young		Old		Young		Old	
	Close	Further	Close	Further	Close	Further	Close	Further
WD 0m	0,0442	0,1076	0,038946	0,0948	0,0149	0,0362	0,0131	0,0319
WD 50m	0,0717	0,1744	0,0588	0,1430	0,0241	0,0586	0,0197	0,0481
Difference in choice probability 0 and 50m	1,621	1,620	1,509	1,508	1,621	1,621	1,509	1,509
WD 100m	0,0834	0,2028	0,0664	0,1615	0,0280	0,0682	0,0223	0,0543
Difference in choice probability 50 and 100m	1,163	1,163	1,130	1,130	1,163	1,163	1,130	1,130
	Long							
	Infrequent				Frequent			
	Young		Old		Young		Old	
	Close	Further	Close	Further	Close	Further	Close	Further
WD 0m	0,0078	0,0191	0,0078	0,0189	0,0026	0,0064	0,0026	0,00635
WD 50m	0,0310	0,0755	0,0299	0,0728	0,0104	0,0254	0,0100	0,0245
Difference in choice probability 0 and 50m	3,959	3,958	3,854	3,853	3,960	3,959	3,854	3,854
WD 100m	0,0933	0,2270	0,0840	0,2043	0,0314	0,0763	0,0282	0,0687
Difference in choice probability 50 and 100m	3,008	3,005	2,807	2,805	3,009	3,008	2,808	2,807

Table E.36: Choice probabilities of fly parking for negative communication comparing WD2

	Short				Long			
	Young		Old		Young		Old	
	Close	Further	Close	Further	Close	Further	Close	Further
WD 0m	0,0400	0,0974	0,0352	0,0858	0,0071	0,0173	0,0070	0,0171
WD 50m	0,0649	0,1578	0,0532	0,1294	0,0281	0,0683	0,0271	0,0659
Diffrenence 0 ad 50 m	1,6208	1,6203	1,5089	1,5085	3,9594	3,9582	3,8538	3,8527
WD 100m	0,0754	0,1835	0,0601	0,1462	0,0845	0,2054	0,0760	0,1849
Difference 50 and 100m	1,1629	1,1627	1,1297	1,1296	3,0083	3,0059	2,8072	2,8053

E.9.2. Walking distance of fly parking

Table E.37: Choice probabilities of fly parking for hazardous communication comparing WD fly parking

	Short				Long			
	Infrequent		Frequent		Infrequent		Frequent	
	Young	Old	Young	Old	Young	Old	Young	Old
Close WD2 0m	0,0442	0,0389	0,0149	0,0131	0,0078	0,0078	0,0026	0,0026
Further WD2 0m	0,1076	0,0948	0,0362	0,0319	0,0191	0,0189	0,0064	0,0063
Difference in choice probability	2,43	2,43	2,43	2,43	2,44	2,44	2,44	2,44
Close WD2 50m	0,0717	0,0588	0,0241	0,0197	0,0310	0,0299	0,0104	0,0100
Further WD2 50m	0,1744	0,1430	0,0586	0,0481	0,0755	0,0728	0,0254	0,0245
Difference in choice probability	2,43	2,43	2,43	2,43	2,43	2,43	2,43	2,43
Close WD2 100m	0,0834	0,0664	0,0280	0,0223	0,0933	0,0840	0,0314	0,0282
Further WD2 100m	0,2028	0,1615	0,0682	0,0543	0,2270	0,2043	0,0763	0,0687
Difference in choice probability	2,43	2,43	2,43	2,43	2,43	2,43	2,43	2,43

Table E.38: Choice probabilities of fly parking for negative communication comparing WD fly parking

	Short		Long	
	Young	Old	Young	Old
Close WD2 0m	0,0400	0,0352	0,0071	0,0070
Further WD2 0m	0,0974	0,0858	0,0173	0,0171
Difference in choice probability	2,43	2,43	2,44	2,44
Close WD2 50m	0,0649	0,0532	0,0281	0,0271
Further WD2 50m	0,1578	0,1294	0,0683	0,0659
Difference in choice probability	2,43	2,43	2,43	2,43
Close WD2 100m	0,0754	0,0601	0,0845	0,0760
Further WD2 100m	0,1835	0,1462	0,2054	0,1849
Difference in choice probability	2,43	2,43	2,43	2,43

E.9.3. Long or short term stay

Table E.39: Choice probabilities of fly parking for hazardous communication comparing short-term and long-term parking

	Infrequent				Frequent			
	Young		Old		Young		Old	
	Close	Further	Close	Further	Close	Further	Close	Further
WD2 0m short	0,0442	0,1076	0,038946	0,0948	0,0149	0,0362	0,0131	0,0319
WD2 0m long	0,0078	0,0191	0,0078	0,0189	0,0026	0,0064	0,0026	0,00635
Difference in choice probability	0.18	0.18	0.20	0.20	0.18	0.18	0.20	0.20
WD2 50m short	0,0717	0,1744	0,0588	0,1430	0,0241	0,0586	0,0197	0,0481
WD2 50m long	0,0310	0,0755	0,0299	0,0728	0,0104	0,0254	0,0100	0,0245
Difference in choice probability	0.43	0.43	0.51	0.51	0.43	0.43	0.51	0.51
WD2 100m short	0,0834	0,2028	0,0664	0,1615	0,0280	0,0682	0,0223	0,0543
WD2 100m long	0,0933	0,2270	0,0840	0,2043	0,0314	0,0763	0,0282	0,0687
Difference in choice probability	1.12	1.12	1.27	1.26	1.12	1.12	1.27	1.27

Table E.40: Choice probabilities of fly parking for negative communication comparing short-term and long-term parking

	Young		Old	
	Close	Further	Close	Further
WD2 0m short	0,0400	0,0974	0,0352	0,0858
WD2 0m long	0,0071	0,0173	0,0070	0,0171
Difference in choice probability	0.18	0.17	0.20	0.20
WD2 50m short	0,0649	0,1578	0,0532	0,1294
WD2 50m long	0,0281	0,0683	0,0271	0,0659
Difference in choice probability	0.43	0.43	0.51	0.51
WD2 100m short	0,0754	0,1835	0,0601	0,1462
WD2 100m long	0,0845	0,2054	0,0760	0,1849
Difference in choice probability	1.12	1.12	1.27	1.26

E.9.4. Age

Table E.41: Choice probabilities of fly parking for hazardous communication comparing young people to older people

	Short				Long			
	Infrquent		Frequent		Infrequtn		Frequent	
	Close	Further	Close	Further	Close	Further	Close	Further
Young WD2 0m	0,0442	0,1076	0,0149	0,0362	0,0078	0,0191	0,0026	0,0064
Old WD2 0m	0,038946	0,0948	0,0131	0,0319	0,0078	0,0189	0,0026	0,00635
Difference in choice probability	1.14	1.14	1.14	1.14	1.01	1.01	1.01	1.01
Young WD2 50m	0,0717	0,1744	0,0241	0,0586	0,0310	0,0755	0,0104	0,0254
Old WD2 50m	0,0588	0,1430	0,0197	0,0481	0,0299	0,0728	0,0100	0,0245
Difference in choice probability	1.22	1.22	1.22	1.22	1.04	1.04	1.04	1.04
Young WD2 100m	0,0834	0,2028	0,0280	0,0682	0,0933	0,2270	0,0314	0,0763
Old WD2 100m	0,0664	0,1615	0,0223	0,0543	0,0840	0,2043	0,0282	0,0687
Difference in choice probability	1.26	1.26	1.26	1.26	1.11	1.11	1.11	1.11

Table E.42: Choice probabilities of fly parking for negative communication comparing young people to older people

	Short		Long	
	Close	Further	Close	Further
Young WD2 0m	0,0400	0,0974	0,0071	0,0173
Old WD2 0m	0,0352	0,0858	0,0070	0,0171
Difference in choice probability	113,57	113,56	100,93	100,93
Young WD2 50m	0,0649	0,1578	0,0281	0,0683
Old WD2 50m	0,0532	0,1294	0,0271	0,0659
Difference in choice probability	121,99	121,97	103,70	103,70
Young WD2 100m	0,0754	0,1835	0,0845	0,2054
Old WD2 100m	0,0601	0,1462	0,0760	0,1849
Difference in choice probability	125,57	125,54	111,13	111,11

E.9.5. Frequency of bicycle use

Table E.43: Choice probabilities of fly parking for hazardous communication comparing infrequent and frequent users

	short				long			
	Young		Old		Young		Old	
	Close	Further	Close	Further	Close	Further	Close	Further
Infrequent WD2 0m	0,0442	0,1076	0,0389	0,0948	0,0078	0,0191	0,0078	0,0189
Frequent WD2 0m	0,0149	0,0362	0,0131	0,0319	0,0026	0,0064	0,0026	0,0063
Difference in choice probability	2,98	2,98	2,98	2,98	2,98	2,98	2,98	2,98
Infrequent WD2 50m	0,0717	0,1744	0,0588	0,1430	0,0310	0,0755	0,0299	0,0728
Frequent WD2 50m	0,0241	0,0586	0,0197	0,0481	0,0104	0,0254	0,0100	0,0245
Difference in choice probability	2,98	2,97	2,98	2,98	2,98	2,98	2,98	2,98
Infrequent WD2 100m	0,0834	0,2028	0,0664	0,1615	0,0933	0,2270	0,0840	0,2043
Frequent WD2 100m	0,0280	0,0682	0,0223	0,0543	0,0314	0,0763	0,0282	0,0687
Difference in choice probability	2,98	2,97	2,98	2,97	2,98	2,97	2,98	2,97