Influence of the Pilot Mobility Scheme on the intention to change modality

Bachelor thesis

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Preface

This Bachelor thesis is my last work to finish the Bachelor program of Civil Engineering at Delft University of Technology. I have learned a lot by doing research, writing the report, and giving a presentation. It was an enjoyable and challenging experience to do this thesis.

This thesis is about the *Pilot Mobility Scheme*, proposed by Dr. ir. D.C. Duives and Delft University of Technology. Hereby, I want to thank my supervisors Dr. ir. Y. Yuan, Dr. ir. D.C. Duives and Ir. R.P. Koster for their weekly evaluation, discussions and help during the Bachelor thesis. Also, I would like to thank my fellow students Luc Stappers and Rob Menken for their weekly reviews and feedback.

Jarco Vianen
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Summary

The Executive Board of the TU Delft created the *Mobility and Accessibility vision*, in which the aim is set to create a park-like healthy campus that is easily accessible for employees and students, and where they are keen to stay. This thesis focusses on the *Pilot Mobility Scheme* , which is part of the *Mobility and Accessibility vision.* The pilot can be used to find effective measures to decrease the use of cars to the TU Delft campus. In this pilot employees and students, who travel by car to the campus a certain number of days a week, are challenged to try alternatives of travelling and working. The total pilot exists of 4 block periods. The alternatives from which participants can choose are: ‘E-bike’, ‘OV-chipcard’, and ‘working at home’. Because there are not enough participants for the ‘OV-chipcard’ and ‘working and home’ group to obtain a reliable result, this thesis takes only the E-bike group into account. Moreover, only the first block period is used, which started on March 25, 2019 and ended on May 17, 2019.

The goal of this thesis is to create a conceptual model that represents the influence of the *Pilot Mobility Scheme* on the intention of people to change modality, based on the available data from the pilot. For this thesis, the following main question is formulated:

“To what extent does the Pilot Mobility Scheme influence the intention of participants to change their modality from car to E-bike?”

For the method to find an answer to this research question, three phases are distinguished: *literature review phase, processing phase* and *analysis phase.*

In the *literature review phase* a literature study is performed to find variables influencing mode choice. Based on the identified variables and Theory of Planned Behaviour, a conceptual framework is constructed (see figure 1).

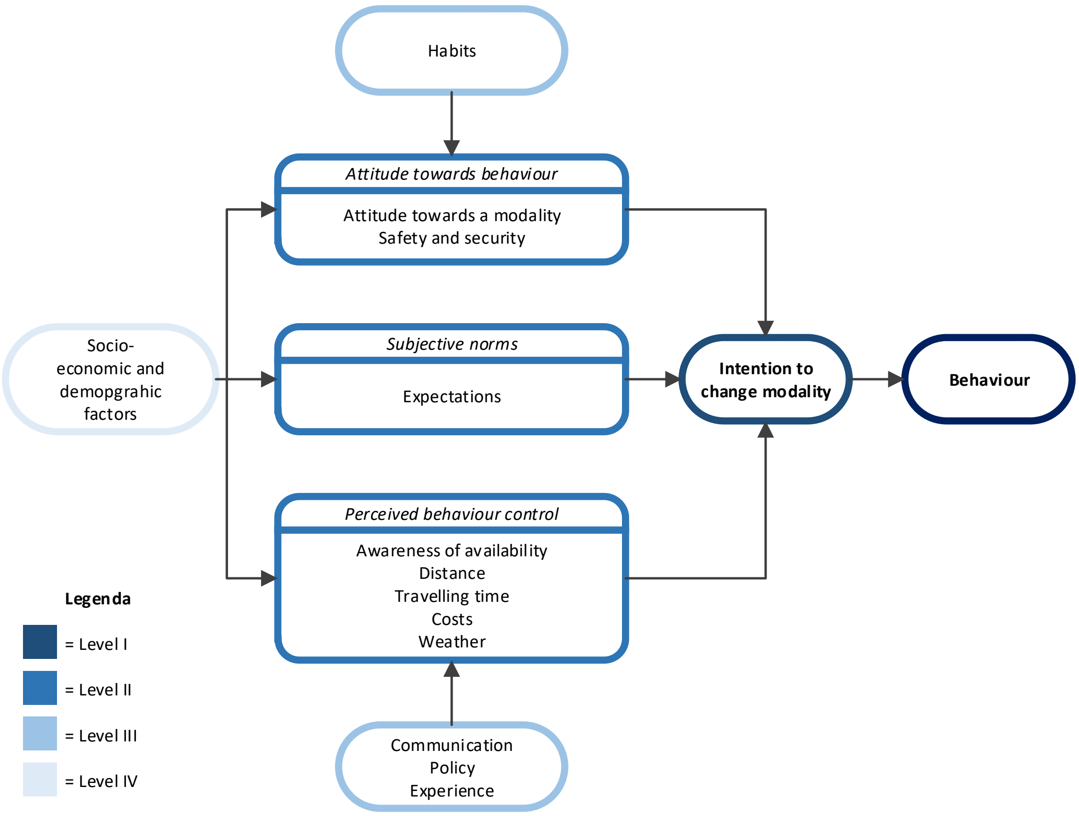

Figure 1: Conceptual framework influence of variables on intention to change modality

The conceptual framework is used in the next phase: the *processing phase*. Here, the data from three data-sources (*baseline measurement, pilot measurement, follow-up measurement*) are filtered and a data selection is made containing data for variables mentioned in the conceptual framework. Since the data selection does not contain information featuring all variables of the conceptual framework, a conceptual model (see figure 2) is created which can be used in the third phase: the *analysis phase*.

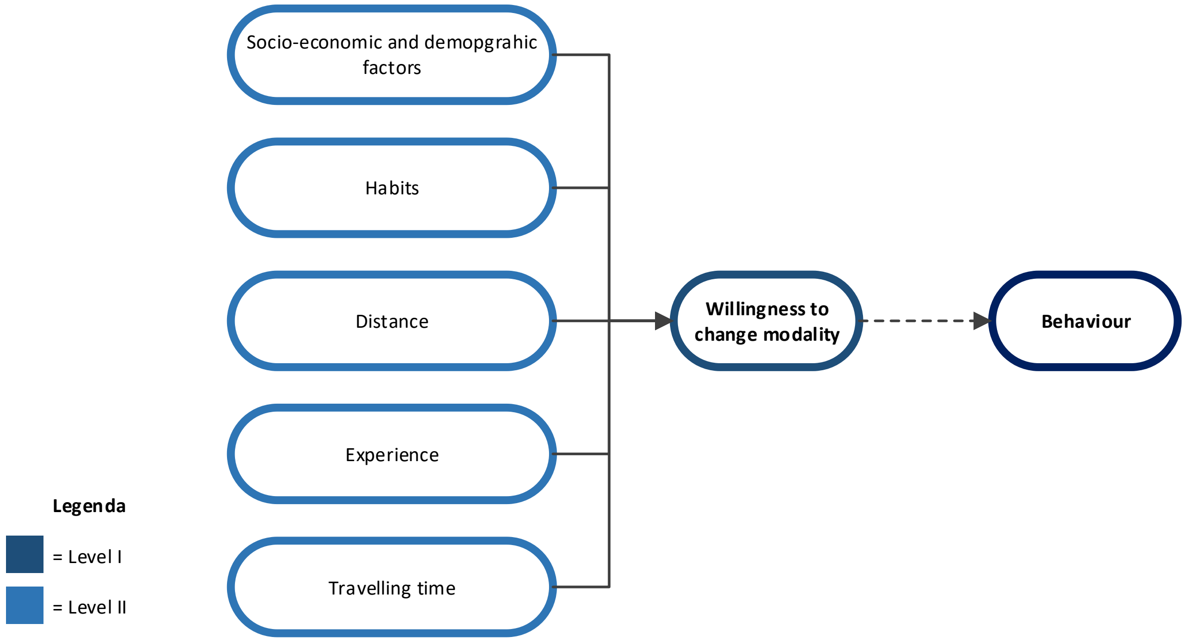

Figure 2: Conceptual model

In the conceptual model, hypothetical relationships are assumed. In the *analysis phase*, these hypothetical relationships are tested. Therefore, the Chi-Square test is used, which is a statistical analysis to test if there is a relationship between two variables. The results of the Chi-Square test are presented in table 1.

		p-value
1	Age	0,192
2	Gender	0,567
3	Status	0,408
4	Distance home – campus	0,197
5	Average travelling time home - campus	0,166
6	Relative car usage	0,429
7	Covered distance during pilot	0,338
8	Number of rides during pilot	0,713

Table 1: Chi-Square test between variables and intention to change modality.
*** Significant at 5%*

In table 1, it can be seen that based on the Chi-Square test and available data for this pilot no relationships can be found. Most likely, because only 4 out of 50 people do not have the intention to keep using the E-bike, no reliable statistical conclusion can be made for the *Intention to change modality* for this thesis. This means that the conceptual model (see figure 2) is not valid anymore. According to the *Theory of planned behaviour*, an intention could lead to behaviour. The actual behaviour after the pilot is not determined, however the use of the E-bike during the pilot is known, expressed in the *Covered distance by E-bike* and *Number of rides by E-bike* for this thesis. From table 2, it can be seen that the *Average travel time between home and campus* by car, are related to both the *Covered distance by E-bike* and *Number of rides by E-bike*. Also, it can be seen that the 'Habit', expressed in *Relative car usage*, is related to the *Number of rides by E-bike*.

		Covered distance	***Number of rides***
		p-value	**p-value**
1	Age	0,18	0,547
2	Gender	0,066	0,562
3	Status	0,509	0,644
4	Distance home – campus	0,432	0,675
5	Average travel time home - campus	0,001**	0,008**
6	Relative car usage	0,103	0,014**

Table 2: Chi-Square test between variables and use of the E-bike during the pilot.
***Significant at 5%*

It can be concluded that from the data of the *Pilot Mobility Scheme*, no valid statistical conclusion can be made for the *Intention to change modality*. This means that the conceptual model (see figure 2) is not valid for this thesis. However, the *Average travel time between home and campus* and *Relative car usage* have relationships with the use of the E-bike. These relationships imply that for people with a higher *Average travel time between home and campus* and higher *Relative car usage*, it could be more difficult to change from the car to the E-bike.

In future studies the relationships between the participants' experience during the pilot and their intention whether to keep using the E-bike or not after the pilot, should be investigated. Especially, the considerations not to keep using the E-bike should be taken into account. Extending the group size and pilot duration could lead to a more reliable result. With a bigger test group, a more valid statistical conclusion could be obtained about the negative group, assuming that in this case there are more people with the intention not to use the E-bike after the pilot. Extending the duration of the pilot to for example one year, could give a more representative result. During a year, the weather changes continuously, and it could be more difficult for people to keep their motivation than during eight weeks. Also the other tested modalities ('OV-chipcard' and 'working at home') could be used if there are enough participants. Additionally, variables that are left out from the conceptual model could be taken into consideration (e.g. weather, costs, attitude). This will lead to a more complete final conceptual model and reliable conclusion.

Finally, it should be mentioned that all conclusions, statements, and recommendations made are based on a group of only 50 participants. In reality, the change from car to other modalities applies for a much bigger group, not only on the TU Delft campus. This thesis could form a basis, which can be used in future studies.

1. Introduction

On a daily basis, 27.000 people travel to the TU Delft campus and this number will only increase in the next few years (TU Delft, n.d.). In the *Mobility and Accessibility vision* from July 2018, the Executive Board of TU Delft set itself the aim to create a park-like healthy campus that is easily accessible for employees, students and businesses alike, and where they are keen to stay. In this vision, three goals were set:

1) Fewer cars on the campus
2) A CO2-neutral campus by 2030
3) Dealing more smartly with space scarcity.

This thesis focusses on the *Pilot Mobility Scheme* , which is part of the *Mobility and Accessibility vision.* The pilot can be used to find effective measures to decrease the use of cars to the TU Delft campus. In this pilot, employees and students, who travel by car to the campus a certain number of days a week, are challenged to try alternatives of travelling and working (TU Delft, n.d.).

The pilot is split into 4 block periods. During each block period, which has a duration of eight weeks, a group of participants tries alternatives to cars. They can choose between three alternatives: an E-bike, an OV-chipcard and working at home. The OV-chipcard is a rechargeable 'transport ticket', which is used for the Dutch public transport. Each block period a participant is allowed to choose only one of these options, so during the pilot participants may not switch between alternatives. The participants are free to use their car or chosen alternative during the pilot. Participants have to complete a survey before and after the block period. During the pilot, the frequency of use of the alternatives is logged per participant. This thesis covers only the participants who used the E-bike in the first block, which started on Monday 25 March 2019 and ended on Friday 17 May 2019. For the first block, there is a total of 150 participants. The OV-chipcard group (18 participants) and working at home group (17 participants) are too small to obtain reliable results, so only the data of the E-bike group is used. For this thesis, all needed data is available for 50 E-bike users.

The goal of this thesis is to create a conceptual model that represents the influence of the *Pilot Mobility Scheme* on the intention of people to change modality, based on the available data from the pilot. Currently, numerous studies have been performed about factors that influence mode choice while little investigation has been performed regarding factors that influence people to change from one to another modality. To reach the goal, the following main question is formulated:

"To what extent does the Pilot Mobility Scheme influence the intention of participants to change their modality from car to E-bike?"

The research question is supported by the following sub-questions:

1) *"Which variables influence the mode choice of people and what theory can be used to model changes in mode choice?"*
2) *"What method can be used to determine whether there is a relationship between the intention to change modality and variables in the conceptual framework?"*
3) *"What are the relevant trends in data of the surveys and pilot featuring variables in the conceptual framework?"*
4) *"What are the relationships between the variables in the conceptual framework and intention to change modality?"*

In the following, these questions are answered one by one. First, in chapter 2 a literature study performed, resulting in a conceptual framework. Secondly, in chapter 3, the method of this thesis is described to obtain answers to the sub-questions. Next, in chapter 4 the data is processed to obtain a data selection. Based on the data selection an conceptual model can be constructed, which is used in chapter 5. In this chapter, a data analysis is performed to test the relationships in the conceptual model. Moreover, the results will be discussed. Finally, in chapter 6 the final conceptual model is presented and the main question is answered.

2. Literature review

The objective of this chapter is to construct a conceptual framework, representing the relations between variables and intention to change modality. The variables follow from a literature study. First, section 2.1 explains which studies are used to identify the variables. Section 2.2 focusses on the *Theory of planned behaviour* (Ajzen, 2005), which can be used to construct the conceptual framework. Next, in section 2.3 the variables are identified from a literature study. The more elaborated literature study can be found in *Appendix I: Literature study.* Finally, in section 2.4 the conceptual framework is constructed based on the variables from the literature study and *Theory of planned behaviour*.

2.1 Studies for variable identification

For the conceptual framework, variables have to be determined which could influence the intention of people to change from a modality that they used to use, to a new modality. However, little research has been done into factors that could influence a change in modality (*Google Scholar* and *Web of Science* were used to seek relevant studies with the following searching terms: "Change in mode choice", "Change in travelling modality", "Change in travelling behaviour"). Only three studies have been found: Brög et al. (2002), (Kenyon & Lyons, 2003), and Becker & Carmi (2019). Thus, also variables that influence mode choice are identified in order to set up the framework. Numerous studies have been done about mode choice, so a selection of studies is provided by my supervisor (all studies characterised by 'variables' and 'mode choice'). From this selection the following studies are used: Buehler (2010), Heinen et al. (2012), Schneider (2013), Motoaki & Daziano (2014), and Liu et al. (2014). Studies from the selection that are not used for the variable identification are:

- Hamre & Buehler (2014): this study focusses on the relationship between commuter benefits and mode choice. The main aspect in this study is the influence of free car-parking on the effectiveness of the commuter benefits. In the *Pilot Mobility Scheme*, the focus lies on the change to alternative travel modes based on a pilot, and not the effectivity of parking fees. Therefore, this study is not used in the literature study.
- Sun et al. (2017): this study lies its main focus on the spread of developments (e.g. population density, road density, commuting distances) and policy-making (built environment characteristics at the job or residential location). These aspects are also part of the study from Buehler (2010), so the study from Sun et al. (2017) is not used further for the identification of the variables.
- Duc-Nghiem et al. (2018): this study focusses on the facility choice of cyclists, which is useful for developers, planners and designers considering new developments for bike facilities. The mode choice aspect is not really part of this study. Therefore, also this study is not used in section 2.3 for the variable identification.
- Montini et al. (2017): this study focusses on the use of GPS data for the estimation of a mode and route choice model. Besides the GPS data, parameters and sociodemographic characteristics are added to the model. These characteristics are also mentioned by Buehler (2010). Moreover, the aspects why people choose a certain travel mode are not clearly visible in the study from Montini et al. (2017). Thus, this study is not used in section 2.3.

2.2. Theory of planned behaviour

According to a study from Ajzen (2005) , the behaviour of individuals can be explained in terms of a limited number of concepts. He developed the *Theory of planned behaviour* (see figure 3), which traces the causes of behaviour through a series of intervening levels. These levels are also shown in figure 3. From behaviour to beliefs (right to left), each level in the theory provides a more comprehensive account to the factors determining behaviour. At the first level (I), behaviour is assumed to be determined by an intention and behavioural control. At the next level (II), an intention is determined by the attitude towards behaviour, subjective norms, and perceived behaviour control. The last term, perceived behaviour control, explains an individual's belief about the consequences of performing the behaviour, and the presence of factors that could hinder or facilitate performance of the behaviour. At the third level (III), the behaviour is explained by an individual's behavioural, normative, and control beliefs.

Additionally, multiple variables may be related or influence the individual's beliefs (e.g. gender, age, education, nationality, intelligence etc.). These background factors can be divided into three main categories: personal, social, and informational categories. However, whether behavioural, normative, or control beliefs are influenced by background factors is an empirical question. That's why these relations are indicated with dotted lines. The background factors form the fourth level (IV).

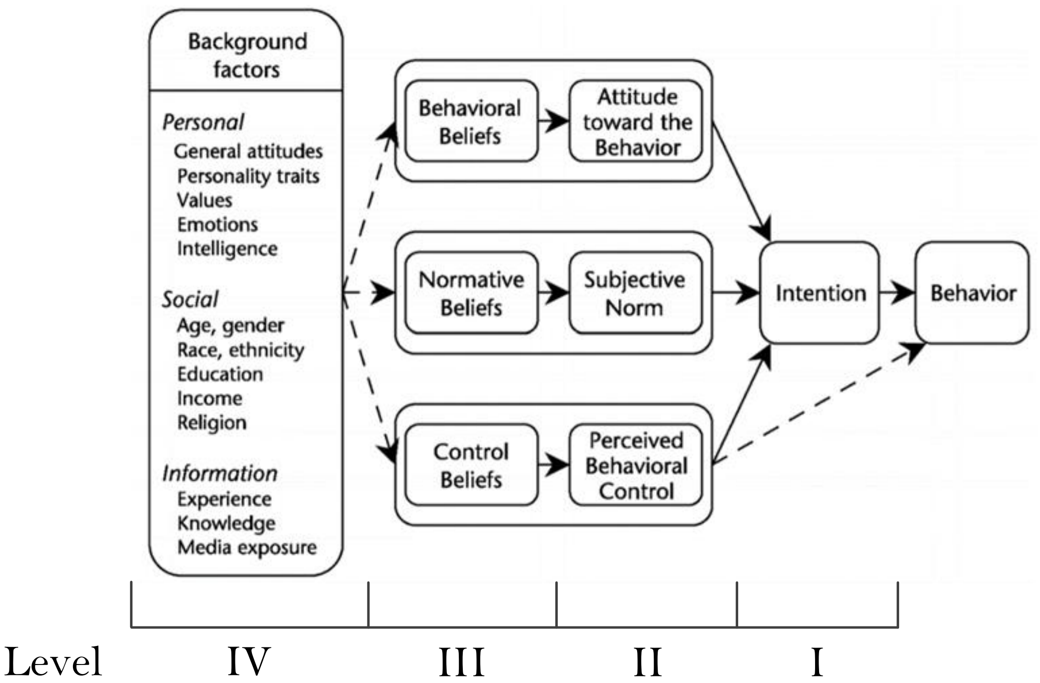

Figure 3: Role of background factors in the theory of planned behaviour (Ajzen, 2005)

For this study, the *Theory of planned behaviour* is relevant, because the goal is to construct a framework that represents the relationships between variables from the literature study and the intention of the participants to change their modality. The *Theory of planned behaviour* is also represented by a framework, which consists of a series of intervening levels and variables, leading to an intention. Eventually, the actual behaviour is determined by the intention, as described by Ajzen (2005).

2.3 Variables influencing mode choice

In this section, the variables are identified for the conceptual framework. The main thing that all studies used in this section have in common, is that they investigate the role of factors or variables on mode choice or a change in modality. For each study, the investigated variables are mentioned, and a link is made with the *Theory of planned behaviour*.

Buehler (2010) investigated the dissimilarities between travelling behaviour in Germany and the USA. He concluded that there are four categories of variables that influence differences in mode choice:

1) *Socio-economic and demographic factors:* this category contains many factors that are related to the background information of individuals, like age, gender, household composition, income, car ownership, etc.
2) *Spatial development patterns:* this category is about the density and spread of developments. These factors are closely related to trip distances and the availability of infrastructure (e.g. for cyclists, pedestrians, car drivers and public transport services).
3) *Transport and land-use policies:* governments and institutions influence the costs and availability of travel modes. Also, they could promote certain modalities and make them more attractive (e.g. by reducing the costs or upgrading the infrastructure).
4) *National cultures or individual preferences:* the culture in which people live influences their lifestyle and way of thinking. Differences between cultures could lead to differences in mode choice.

The identified categories that influence differences in mode choice are relevant. It is important to keep in mind that this thesis focusses on E-bike users who are all related to the TU Delft, while the study from Buehler (2010) focusses on modalities in general and people from different countries. First of all, the *Socio-economic and demographic factors* can be linked directly to level IV in the *Theory of planned behaviour*. Secondly, the *Spatial development patterns* can be linked to the '*perceived behaviour control'*. For this thesis, the *Spatial development patterns* are expressed in trip distance and travelling time. These factors could hinder the performance of the behaviour. For the *Transport and land-use policies* category, it should be noticed that every participant lives in the same country, so they are not influenced by different governments. However, there could be dissimilarities between the different municipalities in which the participants live. These policies could influence the factors in the '*perceived behaviour control'*.

Also lifestyles and individual preferences could differ between individuals. These two factors determine how people think about their own, and other people's mode choice. This was also investigated by Heinen et al. (2012), who researched the extent to which work-related factors affect the individual's decision to be a commuter cyclist. Their conclusion was that cycling was not only determined by 'hard' factors, such as the available infrastructure and socio-demographic factors, but also by the attitudes and expectations of the cyclist themselves and the people around them. For instance, when individuals are encouraged their colleagues and employer, and they are positive about bicycle commuting, they are more likely to use the bike. Here, a clear separation should be made between the attitude of an individual, and the expectations other have from that individual. The attitude of an individual can be linked to the '*attitude toward the behaviour*', while the expectations from others could be linked to the '*subjective norm'*.

Schneider (2013) also did a research to mode choice behaviour, and proposed the "*Theory of Routine Mode Choice Decisions"* to describe how people choose transportation modes for routine travel purposes. According to this theory, the mode choice decisions process contains five steps (see figure 4).

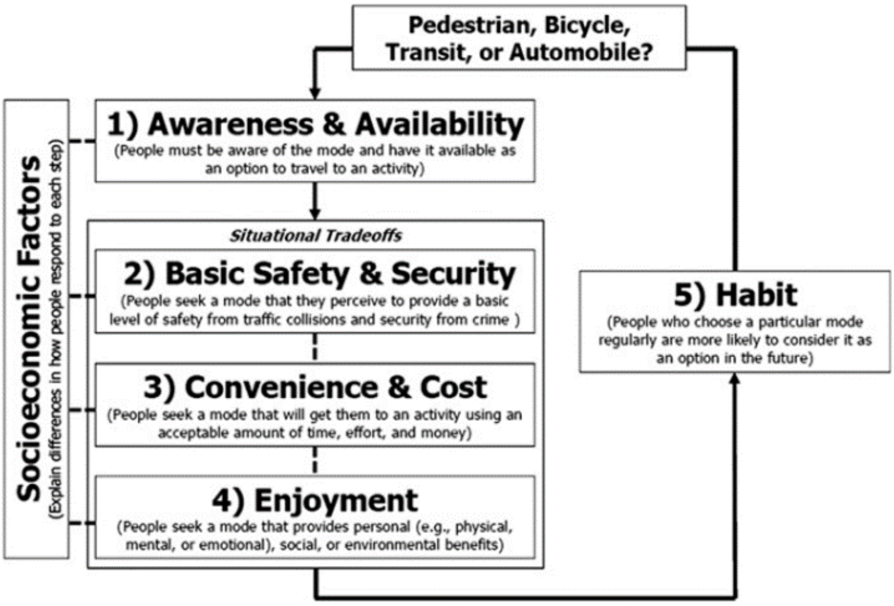

Figure 4: Theory of Routine Mode Choice Decisions, (Schneider, 2013)

The steps are clarified as follows:

1) Awareness and availability: this means that people must be aware of a travel mode and have the mode available as an option to travel. The awareness and availability of travel modes could facilitate the performance of behaviour, and therefore this factor can be linked to the '*perceived behaviour control*'.
2) Basic safety & security: people have the intention to seek for travel modes that they perceive to have a basic level of safety from traffic collisions and security from crime. In this case, it is assumed that the safety and security of a mode could influence the attitude of people towards a travel mode. Therefore, this factor is linked to the '*attitude toward the behaviour*'.
3) Convenience & cost: this means that people seek for travel modes that require less time, effort and costs. Cost and time could be factors to hinder the performance of behaviour, and therefore, these aspects are linked to the '*perceived behaviour control*'.
4) Enjoyment: people seek for travel modes that provides them with personal physical, mental or emotional benefits; helps them to achieve social status; or makes them feel good about benefiting the society or environment. These factors are assumed to shape the attitude of people towards a travel mode.
5) Habit: when people have chosen a particular travel mode regularly, they are more likely to use this option in the future. Habits cannot be directly interpreted as an attitude, however they could influence the attitudes of individuals. Therefore, the 'Habit' is related to the '*attitude toward the behaviour*'.

Socio-economic characteristics such as age, gender, household size etc., determine how individuals continue through the steps. These characteristics are also mentioned in the study from Buehler (2010).

Motoaki & Daziano (2014) showed that skills and experience have effect on cycling decisions. For their study, they took a few factors into account: weather conditions, cycling time, slope, cycling facilities, and traffic volume. They concluded that cyclists with more skills and experience are less affected by adverse weather conditions, slope inclination and heavy traffic. Moreover, more cycling facilities (e.g. dedicated cycling lanes, parking spaces, specialized traffic signs and signals) result in a higher share of cycling by not only individuals with higher skill and experience, but also by individuals who have less biking skills. The presence of these facilities is influenced by policies, as mentioned by Buehler (2010). The study from Motoaki & Daziano (2014) is relevant for this thesis, because during the pilot, the participants gain experience in cycling with an E-bike. As stated by Motoaki & Daziano, the experience could influence the participants' cycling decisions. As cyclists gain more experience, factors like 'distance' or 'weather' could become less relevant in their decision of mode choice. Therefore the 'experience' could influence the '*perceived behaviour control*'.

Also Liu et al. (2014) investigated the influence of weather, but in their case on Swedish people's travel behaviour. Results show that the weather impact on motorized and non-motorized vehicles differs in different seasons and regions. For the period studied in this thesis, there is no real difference in seasons, and the participants' residents are not spread through the whole country. However, the weather factor could influence people's mode choice. Subsequently, the experience influences in turn the mode choice of people in different weather conditions, as stated by Motoaki & Daziano (2014). The weather-factor could be seen as a hinderance or driver to use the E-bike, and is therefore linked to the '*perceived behaviour control*'.

As mentioned in section 2.1, little research has been done into factors that could influence a change in modality. The three found studies related to a change in mode choice are discussed below.

First of all, the communication towards individuals is an important variable, according to a study from Brög et al. (2002). They investigated that a change in travel mode depends on the way how information is brought to an individual. Information has to be "brought" to the customer instead of expecting him / her to get it from the provider. You have to make people think about the modalities they use to travel, which has proven to be highly successful in achieving shifts in mode from the car. The second variable highly depends on the aforementioned communication variable: the people's awareness of the available modalities (Kenyon & Lyons, 2003). Information about alternative modes has to be provided so people to make them aware of viable mode alternatives to travel. The communication-aspect does not influence mode choice directly, but it could make people more aware of the availability of travel modes. Therefore, the 'communication' is assumed to influence the '*perceived behaviour control*'.

Lastly, the costs could be a factor to change mode choice. Becker & Carmi (2019) investigated the role of parking fees in travel mode choice. They concluded that adding a parking free increased the tendency of people to leave the car at home. Besides costs, adding a parking also results in the time factor to be a significant factor. The time and cost factors were also mentioned in the study from Schneider (2013).

2.4 Conceptual framework

In this section, the conceptual framework is constructed based on the identified variables from the literature study in section 2.3, and *Theory of planned behaviour*.

For this thesis, the actual behaviour is not determined, because this would mean an extra survey has to be held a certain time period after the pilot. However, the intention is determined in the follow-up measurement (second survey held just after the end of the pilot). In the framework, the *Intention to change modality* is defined as "*the intention of participants to change their modality from car to E-bike".* Like the *Theory of planned behaviour*, also for the conceptual framework different levels are used to show the progress of each level leading to a more comprehensive account to the factors determining behaviour.

The entire conceptual framework for this study is presented in figure 5.

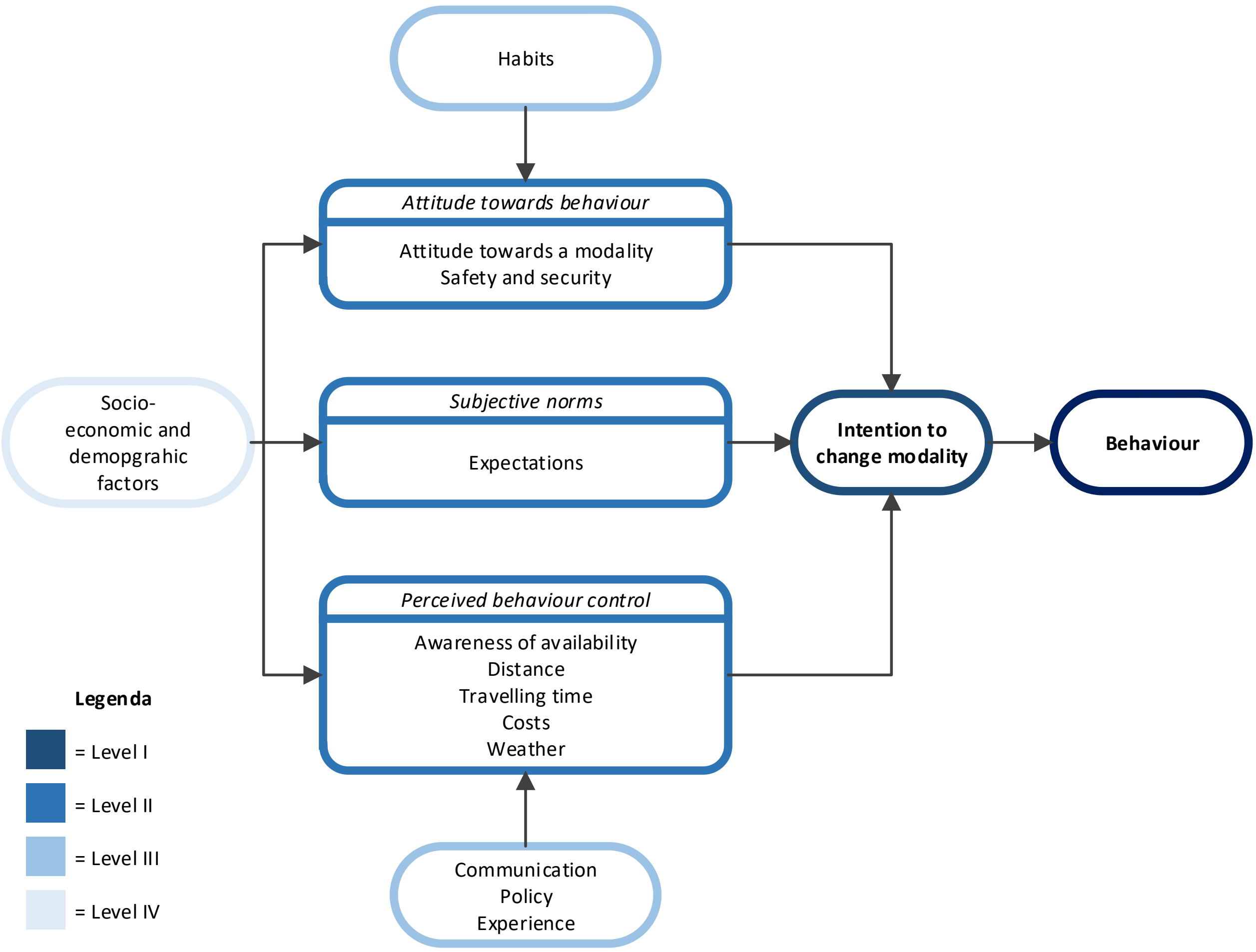

Figure 5: Conceptual framework influence of variables on intention to change modality

In this case the intention is the first level, which is defined as the intention to change modality in figure 5. At the second level, the identified variables are classified in the *attitude towards behaviour, subjective norms, and perceived behaviour control* groups according to the *Theory of planned behaviour*:

1) *Attitude towards behaviour*: the attitude towards a modality and the feeling of safety and security an individual has for a certain modality.
2) *Subjective norms*: the expectations of an individual and the people around him / her of mode choice.
3) *Perceived behaviour control*: the awareness of alternative modalities, distance from starting point to destination, travelling time, costs and weather.

The three groups mentioned above are also related to each other.

In the *Theory of planned behaviour*, the third level consists of the beliefs people have, however for this thesis these cannot be determined. Therefore a simplification is applied for the conceptual framework, which will be part of the discussion (see chapter *6. Discussion*). In this case, some variables are added that influence the *attitude towards behaviour* and *perceived behaviour control* group. These variables will form the third level in the conceptual model:

- Individuals' habits influence the attitude they have to a certain mode.
- Experience (e.g. *Pilot Mobility Scheme*) influences the awareness of viable mode alternatives and beliefs about the weather factor.
- Communication towards consumers about alternative modalities influences the awareness of viable mode alternatives.
- Policies from governments or institutions (e.g. TU Delft) influence the costs and awareness of availability of certain modalities.

Lastly, in the conceptual framework the fourth level contains the socio-economic and demographic factors. In the *Theory of planned behaviour* , these factors are related to the beliefs at the third level. However, due to the simplification, the factors are related to the three groups at the second level.

3. Methodology

This chapter contains the research methodology which is used to answer the research questions. The methodology is divided in three phases: *literature review phase, processing phase* and *analysis phase.* Figure 6 presents a schematic overview of the methodology.

3.1. Literature review phase

With the literature study performed in the *2. Literature review* chapter, an answer is obtained to the first sub-question:

"Which variables influence the mode choice of people and what theory can be used to model changes in mode choice?"

Based on the variables from literature study and *Theory of planned behaviour* (Ajzen, 2005), a conceptual framework is constructed (see figure 5). This conceptual framework will be used in the *processing phase* (see figure 6).

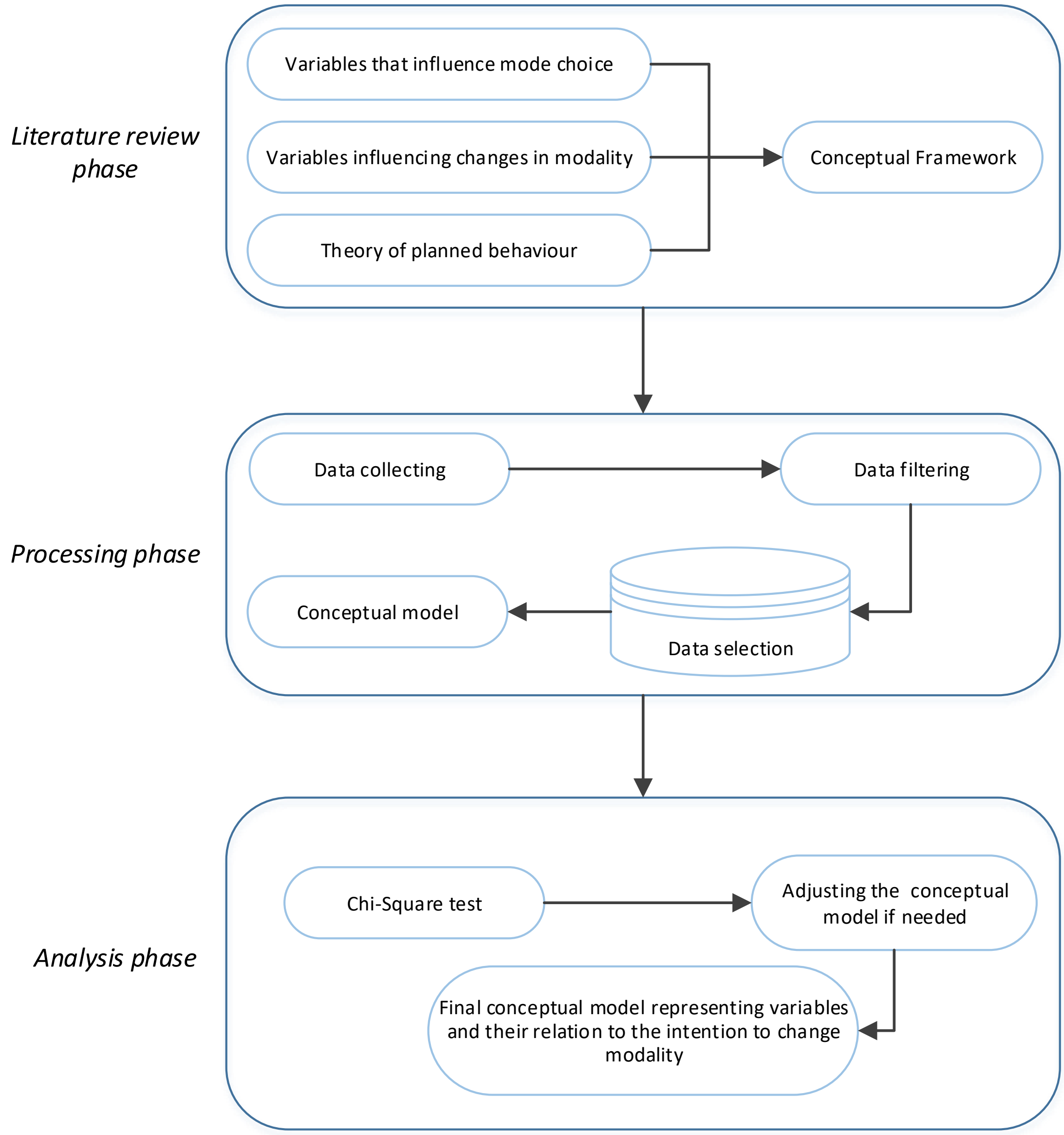

Figure 6: Scheme with the three phases of the methodology

3.2. Processing phase

In this second phase, data is collected from three data-sources (explained below) and processed to eventually obtain a data selection with data for the variables in the conceptual framework (see figure 3). The data-sources are obtained from the *Pilot Mobility Scheme*. The three data-sources are:

1) **Baseline measurement**: this data-source follows from the first survey held before the start of the pilot in the form of an Excel-file. It includes information of the background of the participants; for example: gender age, place of residence etc.; and also of the modality use before the start of the pilot. The participants predominantly used the car to go to the campus, but also different mode could have been used. The exact questions that have been asked in this survey are shown in *Appendix II*.
2) **Pilot measurement:** this data-source includes measurements from the pilot itself. It consists of an interactive tool and Excel-file, which contain the frequency of use of the E-bikes for each participant. For the E-bikes also the specific covered routes and distances are available. In the first block, only 17 people choose the 'working at home' alternative, and 18 people used the OV-chipcard, so for this thesis these groups is too small to obtain a reliable result. Therefore, only the data of the E-bike group is analysed.
3) **Follow-up measurement**: this data-source follows from the second survey held after the pilot in the form of an Excel-file. It includes the attitude of the participants towards the used modalities and intentions of the participants about using the alternatives in the future. Additionally, extra questions about the participants' characteristics, which are needed but were not asked in the first survey, are included.

These three data-sources contain information to give an answer to the following sub-question:

"What are the relevant trends in data of the surveys and pilot featuring variables in the conceptual framework?"

Data-source 1 provides background information of the participants. From this data-source question 2, 3, 5, 7 and 10 are used (see Appendix II). From data-source 2, the use of the E-bikes is obtained. Data-source 3 includes information about the willingness and intentions of the participants to change the car for another modality in the future. From this data-source, question 21 is used (see Appendix III).

The three data-sources from this pilot do not contain data for all variables mentioned in the conceptual framework. Therefore, only with the variables for which data is available, a conceptual model has to be constructed. Obviously, variables that are left out from the conceptual model are discussed in chapter *6. Discussion*. Moreover, not all information from the data-sources is relevant for this study. From the data-sources, a data selection has to be made containing only data for the variables which are mentioned in the conceptual framework.

There could be variables that influence the intention to change modality, but are not present in the conceptual framework. This is not in the scope of this thesis, and is a discussion point (see chapter *6. Discussion*).

3.3. Analysis phase

The third phase is the analysis phase, in which the data selection obtained in phase two is used. In this section, an answer is given to the second sub-question:

"What method can be used to determine whether there is a relationship between the intention to change modality and variables in the conceptual framework?"

To test the conceptual model, the significant relationships between the variables and intention to change modality have to be determined with a data analysis. In this case, a statistical analysis is used to test the relationships between the variables in the conceptual model: the Chi-Square test.

Chi-Square test

From the Chi-Square test, the variables that influence the intention to change modality can be identified. The null hypothesis of the Chi-Square test is that there is no relationship between two variables, in this case the variables are independent. A conclusion to the hypothesis has to be made with 95% confidence. When the p-value is less than 0.05, the hypothesis is rejected and this means that there is a statistical relationship between variables. Thus, the two variables are dependent (Statistics Solutions, n.d.).

To perform the analysis, the program SPSS is used. SPSS is a software platform from IBM that is used for advanced statistical analysis, machine-learning algorithms, text analysis etc. (IBM, n.d.). In SPSS, the Chi-Square statistic provides the p-values, which can be subsequently examined to the value 0.05.

Once the significant relations between variables and intention to change modality are determined, an answer can be given to the last sub-question:

"What are the relationships between the variables in the conceptual framework and intention to change modality?"

With the relations following from the data analysis, the conceptual model could be adjusted and / or supplemented if needed. The result is a final conceptual model which represents the variables and their relation to the intention to change modality based on the available data from the *Pilot Mobility Scheme* (see figure 6).

4. Data processing

In the processing phase, first an overview is made of the collected data to see the results from the surveys and pilot. Secondly, from the collected data, the relevant information is filtered. This is done based on the conceptual framework constructed in section 2.4. After having filtered the data, a data selection is obtained with only data for the variables from the conceptual framework. Based on the variables for which data is present in the data selection, an conceptual model is set up. This framework is used in chapter *5. Data analysis*.

4.1. Data collecting

Baseline measurement

In the first survey held before the pilot, background factors of the participants are identified. Examples for this are the age, gender, status and postal code of the participants. Also the number of days a certain modality is used, and the total number of days the participants travel to the campus, are logged. Moreover, the modes participants use to travel between home and campus and to or from the station, and the motives they have for this are obtained.

Pilot measurement

As mentioned in chapter *3. Methodology*, from the data of the pilot itself only the E-bike data can be used for this pilot. The *Pilot measurement* consists of two data-sources: an interactive tool (Microsoft Power BI) and Excel-sheet.

In the interactive tool, the following can be seen:

- A density map which represents the number of locks / unlocks for a specific E-bike, and for all E-bikes. In the obtained data-source, the locks and unlocks can be distinguished, so the start and end of a certain journey are known.
- The total number of rides for all bikes per day, per week and during the whole pilot. In total 4818 rides have been made during the pilot.
- The number of rides per day, per week and during the whole pilot for a specific E-bike. Each E-bike has a unique number, which is linked to the person who used the E-bike.

Data is not derived from the figures and histograms that are shown in the interactive tool. The tool is only used to link each E-bike with a specific participant.

The Excel-sheet is used as the data-source for the *Pilot measurement*, in which the following things can be seen:

- Points in time when an E-bike is locked or unlocked. An unlock is expressed in ‘time_start’, and a lock is expressed as ‘time_end’. As the captions suggest, an unlock is assumed the start of a ride, and a lock is assumed the end of a ride.
- Covered distance between the start and end of a ride.

Table 3 presents an example how the Excel-sheet for a certain participant could look like.

person_uuid:	"xxxxxxxxxxxxxxxxxxxxxx"			
time_start	**time_end**	**latitude**	**longitude**	**distance**
29-5-2019 09:16	29-5-2019 09:56	x	x	4290
29-5-2019 16:23	29-5-2019 16:53	x	x	4310
30-5-2019 09:08	30-5-2019 09:36	x	x	4300
30-5-2019 16:39	30-5-2019 17:06	x	x	4307

Table 3: Example of an Excel-sheet of the Pilot measurement

In the Excel-sheet, something remarkable can be noticed. A percentage of the rides have a duration of one or a few days. These so-called 'unreliable rides' suggest that people do not always lock their bike after a ride, for example when they arrive at home. For most participants, the percentage of unreliable rides is negligible considering their total number of rides. However, for 9 participants this percentage exceeds 10%, which could give a distorted picture of the number of rides. On the other hand, excluding all unreliable rides (and distances) would lead to an even more distorted picture of reality.

It is still investigated what is the best way to specify the unreliable rides, e.g. by using the GPS data. However, for this thesis this is not taken into account. It is known that an unreliable ride exists of at least one ride. Therefore, the unreliable rides are counted as 1 ride so the minimum of total number of rides is used for the *data analysis*.

Follow-up measurement

The first block period finished on May 17, and after this block the second survey was held. This survey mainly focusses on the attitude of the participants towards modalities after the pilot. Also, the participants' experience during the pilot of a chosen modality is asked. Moreover, the survey includes the intention of the participants to use their chosen alternative instead of the car in the future. This last aspect is important for this thesis, because the goal is to construct a model representing the variables and their relationship to the intention to change modality. Of course, for thesis only the E-bike group is used. In figure 7, the distribution of the participants' intention to use the E-bike to go to the campus in the future, is presented. It can be seen, that in total 50 people have given an answer to the question about their intention to keep using the E-bike in the future. That is why for thesis all needed data is available for only 50 E-bike users, as mentioned in chapter *1. Introduction*.

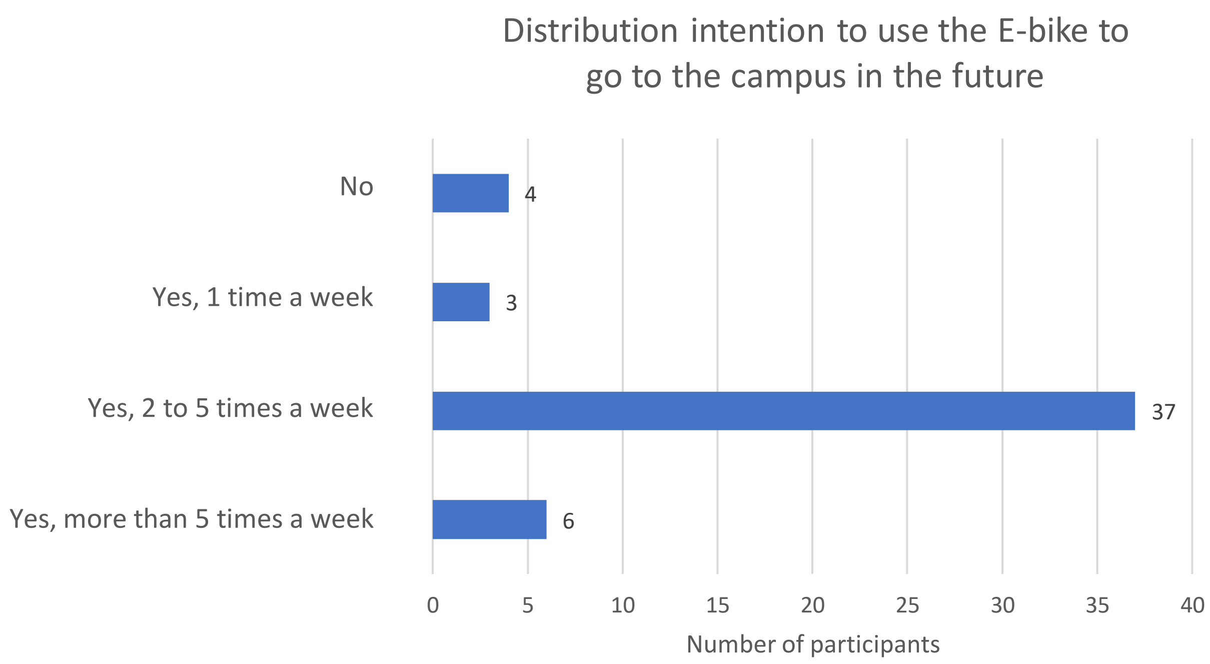

Figure 7: Distribution of intention to use the E-bike to go to the campus in the future

4.2. Data filtering

Based on the conceptual framework and the data that is provided, the relevant information can be filtered out of the data-sources.

First of all, the *baseline-measurement* provides some socio-economic and demographic factors: gender, age, the number of students and employees and the postal code. With the postal codes, the distances between home and work can be determined for each participant by using *Google Maps*. Additionally, by using *Google Maps*, the average travelling time by car between home and the campus can be measured. In order to do this, the arrival time is set on Tuesday 09:00 AM, because it is assumed that most trips are at Tuesdays and Thursdays, and Tuesday morning gives an indication of the relative average travel delay. Moreover, at 09:00 AM most of the participants have to be on the campus. To determine the distances and travelling times, the parking area which lies northwest to the Green Village is used as destination at the campus (see figure 8). This is done because the majority of the participants parks their car at this place.

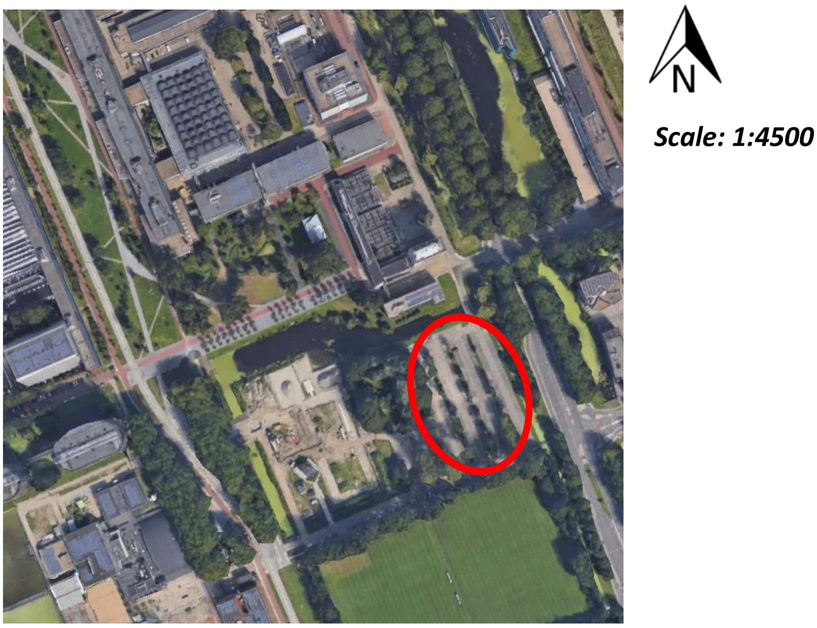

Figure 8: Location at the campus for time / distance measurements

Secondly, from the *baseline measurement* the participants' habits considering mode usage can be identified. For the data analysis, the number of days the participants travel to the campus by car is divided by the numbers of days they actually go to the campus.

Also, the *pilot measurement* gives information about the participants' experience of the pilot itself. This experience or 'reveal' represents the use of the E-bike during the pilot. For this thesis, the use of the E-bike during the pilot is expressed in the number of rides and covered distances. Which of these two factors shows the best correlation in this case is determined in chapter *5. Data analysis.*

Finally, from the *follow-up measurement* the intention of the E-bike group to change modality can be derived. This data is essential to test the conceptual model in chapter *5. Data analysis*.

4.3. Data selection

To do the data analysis in SPSS, the obtained data-sources cannot be exported in their original form. As mentioned before, the original data-sources contain data which is not relevant for this study. Therefore, a data selection is made in the form of a new Excel-file, which can be exported to SPSS, and is usable for the data analysis. This file contains data for variables that are in the conceptual framework, and available from the data-sources.

The data selection file contains data of each participant of the E-bike group for the following variables:

- Socio-economic and demographic factors:
  - Gender
  - Age
  - Status
- Distance from home to the campus by car [km]
- Average travelling time from home to the campus by car [min]
- Habit: the relative car usage, presented in the number of days the participant travels to the campus by car , divided by the total number of days the participant travels to the campus.
- Experience / Reveal:
  - Total covered distance during the pilot by E-bike [km]
  - Total numbers of rides during the pilot by E-bike
- Intention to change modality

Table 4 gives an example how the data selection Excel-file looks like for each participant.

Age	Gender	Av. Time home – campus [min]	Dist. Home-campus [km]	#Rides	Covered distance [km]	Intention	Status	Relative car usage
23	Male	8	2,6	6	10	No	Student	0,8

Table 4: Example of data selection Excel-file

4.4. Conceptual model

As mentioned in the methodology, only with the group of variables for which data is available, a conceptual model is constructed. This group of variables follows from the data selection. Figure 9 shows the conceptual framework constructed in section *3.1 Literature review*, however in this case the variables that cannot be determined or quantified from the data selection, are coloured light-grey. These variables are excluded from the conceptual model and discussed in chapter *6. Discussion*.

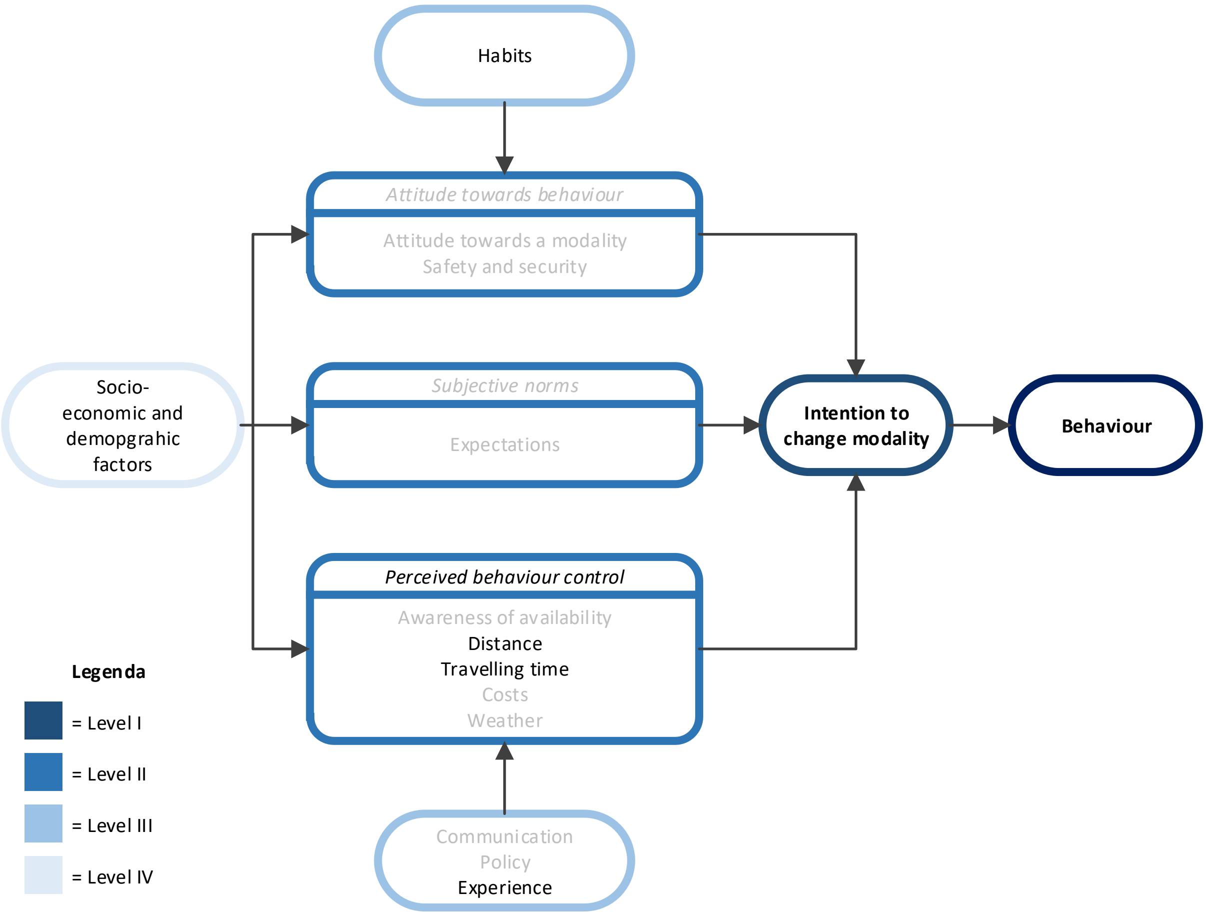

Figure 9: Conceptual framework with the variables excluded from the conceptual model coloured light-grey

Based on the variables that are coloured in black in figure 9, the conceptual model is constructed in figure 10. To make the framework usable for the data analysis, a simplification is done by decreasing the number of levels from four to two in the conceptual model (see figure 10). It can be seen that the relationship between the intention and actual behaviour is shown with a dotted line, because the behaviour cannot be determined for this pilot.

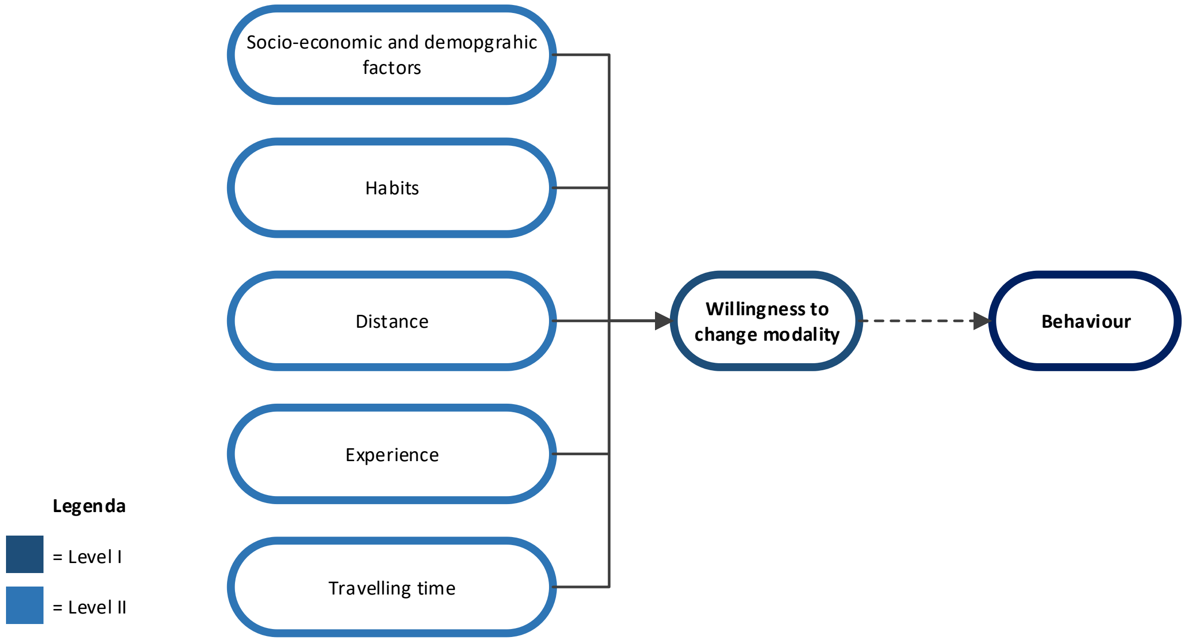

Figure 10: Conceptual model

5. Data analysis

This chapter combines the data analysis and discussion of the results from the analysis. The data analysis is used to test the conceptual model from section *4.4 Conceptual model*, based on the data selection from section *4.3 Data selection*. First, in section 5.1 a Chi-Square test is performed to check whether there is a relationship or not between each variable and intention to change modality. Also, in section 5.2 the relationships between variables and the use of the E-bike during the pilot are tested with a Chi-Square test. In both sections, the results of the Chi-Square test are discussed.

5.1. Chi-Square test intention to change modality

In SPSS, first the 'Scale' variables are grouped into 'Ordinal' variables. This can be done as follows: '*Transform*' → '*Recode into Different Variables'* → '*Old and New Values'*. Here, the different sub-groups can be defined as numbers to choose by yourself. Next, a label has to be assigned to each number, so the sub-group categories become visible by clicking on '*Value Labels*'. This step is essential because 'Scale' variables exist of individual data points, which cannot be used for the Chi-Square test. By grouping the individual data of a variable into sub-groups, the variable is made 'Ordinal'. The number of sub-groups is chosen five or six, depending on the available data, so a clear distribution can be obtained. The following variables are converted from 'Scale' to 'Ordinal':

- Age
- Distance from home to the campus by car [km]
- Average travel time from home to the campus by car [min]
- Relative car usage: the number of days the participant travels to the campus by car , divided by the total number of days the participant travels to the campus.
- Total covered distance during the pilot by E-bike [km]
- Total numbers of rides during the pilot by E-bike

Subsequently, 'Ordinal' variables can be combined with 'Nominal' variables in the Chi-Square test. The following variables are 'Nominal':

- Gender
- Status

Also, the intention to change modality is 'Nominal' in SPSS. Before performing the Chi-Square test, first stacked bar plots are made (see Appendix IV) between each variable from the conceptual model, and the intention to change modality. These stacked plots show the sub-groups for the 'Ordinal' variables, and give an overview of the data. The plots are not discussed further in the report, so they are not included in this section.

It should be noticed that not all eight variables that are used for the Chi-Square test are completely independent. In this thesis, for each variable the data is used which is provided by the pilot. In the data analysis, all variables are treated as unique variables.

Now the Chi-Square test is performed with SPSS to test the relationship between each variable and the intention to change modality (see table 5). For the alpha, a value of α = 0,05 is taken. This means that there is a relationship if the p-value < 0,05.

		p-value
1	Age	0,192
2	Gender	0,567
3	Status	0,408
4	Distance home – campus	0,197
5	Average travel time home - campus	0,166
6	Relative car usage	0,429
7	Covered distance during pilot	0,338
8	Number of rides during pilot	0,713

Table 5: Chi-Square test between variables and intention to change modality.
*** Significant at 5%.*

From table 5, it can be seen that according to the Chi-Square test and available data there are no p-values lower than α = 0,05. Moreover, there are no p-values which lie very close to 0,05. The variable from which the p-value lies closest to α = 0,05 is 5. However, the p-value of 0,166 is more than three times larger than the required value α = 0,05. For the rest of the variables, the p-values are much higher than α = 0,05; variable 8 has the highest p-value of 0,713.

Thus, based on the Chi-Square test and available data, no relationships between the variables from the conceptual model and intention to change modality, can be found. This means that the conceptual model is not valid anymore. Now, the question is why there are no relationships, despite the fact that the conceptual model is constructed based on previous studies.

In figure 7 it can be seen that 46 out of 50 participants have the intention to keep using the E-bike in the future. This means that the outcome of the question about the participants' intention is very positive. From those 46 participants, 37 participants are suggesting to use the E-bike 2 to 5 times a week. This could be a factor why no relations are found with the Chi-Square test: the vast majority has chosen the option 'Yes, 2 to 5 times a week'. Moreover, only 4 out of 50 people do not have the intentions to keep using the E-bike. So, for this thesis no valid statistical conclusion can be made for the *Intention to change modality*. This means that for both positive (intention to keep using the E-bike) and negative (no intention to keep using the E-bike) groups no clear profile can be made. The fact that so many participants are positive about the E-bike could due to the fact that they had a biased opinion about E-bikes before the pilot. Maybe some of the participants already had the intention to buy an E-bike, and the pilot could have been an opportunity for them to try out an E-bike.

5.2. Chi-Square test use of the E-bike during the pilot

The actual behaviour after the pilot is unknown, however the behaviour during the pilot is known, expressed in *Covered distance by E-bike* and *Number of rides by E-bike*. For this thesis, these two variables represent the use of the E-bike during the pilot, as mentioned in section 4.2. Of course, the question about the participants' intention to keep using the E-bike has been asked after the participants have used the E-bike. For both *Covered distance by E-bike* and *Number of rides by E-bike*, a Chi-Square test is performed with the remaining six variables. Also for this test the 'Scale' variables are grouped into 'Ordinal' variables, as explained in section 5.1. The results are presented in table 6. Again, for the alpha a value of $\alpha = 0{,}05$ is taken. This means that there is a relationship if the p-value < 0,05.

		Covered distance	***Number of rides***
		p-value	**p-value**
1	Age	0,18	0,547
2	Gender	0,066	0,562
3	Status	0,509	0,644
4	Distance home – campus	0,432	0,675
5	Average travel time home - campus	0,001**	0,008**
6	Relative car usage	0,103	0,014**

Table 6: Chi-Square test between variables and use of the E-bike during the pilot.
***Significant at 5%*

From table 6, it can be seen that according to the Chi-Square test three relationships can be found. First, the *Average travel time between home and campus* has relationships with both *Covered distance by E-bike* and *Number of rides by E-bike* (p-values of 0,001 and 0,008 below the $\alpha = 0{,}05$). With the *Covered distance by E-bike*, a positive relationship can be identified based on the cross table in *Appendix V*. This means that a higher travelling by car time leads to a predominantly higher covered distance with the E-bike during the pilot. At first sight, this seems logical: a higher travelling time usually means that the participants live further away from the campus, so per ride this means a relatively higher covered distance. With the *Number of rides by E-bike*, a negative relationship can be identified based on the cross table in *Appendix V*. This means that a higher travelling by car time leads to a lower number of rides with the E-bike during the pilot. As mentioned, a higher travelling time usually means that the participants live further away from the campus. In this case, this leads to a lower number of rides in the pilot.

In the *Average travel time between home and campus*, also the traffic jams are taken into account. This means that a participant who lives in a high density area (with relatively more traffic jams than in a low density area) could have a relatively higher *Average travel time between home and campus*, while having a relatively lower distance between home and campus. So, a higher *Average travel time between home and campus* does not always result in a higher distance between home and campus. It could happen that the travel time between home and campus by E-bike is the same or even lower than the *Average travel time between home and campus* by car, due to the traffic jams. This could declare why there is no relationship between the *Distance between home and campus*, and *Covered distance by E-bike* and/or *Number of rides by E-bike*. However, no clear statement can be made for this according to the available data.

According to the Chi-Square test and data from the pilot, the use of the E-bike is not influenced by the distance people live from the campus, but the density of the place where they live. Of course, in reality the *Distance between home and campus* could influence E-bike use: at a certain distance, the E-bike is not beneficial anymore.

Further, the *Relative car usage* has a relationship with the *Number of rides by E-bike* (p-value of 0,014 below the $\alpha = 0{,}05$). Here, a negative relationship can be identified based on the cross table in *Appendix V*. This means that higher relative use of the car (before the pilot) leads to a lower number of rides with the E-bike during the pilot. Apparently, the habits of the participants play a role in the use of the E-bike. The more the participants used the car to go to the campus before the pilot, the less rides they made during the pilot.

So, both the *Relative car usage* and *Average travel time between home and campus* by car, have a negative relationship with the *Number of rides by E-bike* the participants have made during the pilot. This could mean that there is a correlation between the travelling time and number of days people use the car to go to the campus. To research whether there is a correlation or not, the Pearson Correlation Coefficient is determined by using SPSS. This gives a Pearson Correlation Coefficient of 0,214 and a corresponding p-value of 0,136. Thus, in this case the *Relative car usage* and *Average travel time between home and campus* variables are not correlated.

Finally, it can be seen that for *Gender* and *Covered distance by E-bike*, the p-value of 0,066 lies close to $\alpha = 0{,}05$ According to the Chi-Square test, there is no relationship between *Gender* and *Covered distance by E-bike*. However, because the p-value is close to $\alpha = 0{,}05$, also for these variables a cross table is added in *Appendix V*. Buehler (2010) stated that females make shorter trips then males. From the cross table in *Appendix V*, it can be seen that males indeed tend to make longer trips then females. However, because in this thesis no relationship can be found, no valid statement can be made. The absence of a relationship could be due to the group composition and data from the pilot.

6. Discussion

In chapter *5. Data analysis*, the results from the Chi-Square tests are discussed. Besides the results from the data analysis, there are more relevant aspects that have to be discussed. The first part focusses on the construction of the conceptual framework. In the second part, issues regarding the construction of the conceptual model are discussed. Finally, the link between this thesis and the reality is discussed.

First of all, it could be that there are variables influencing a change in modality, but they are not identified in the literature study. This could lead to an incomplete conceptual framework. For this thesis only the variables that are identified in the literature study, and from which data is available, are considered. An example of a variable that is not included in the conceptual framework is 'maintenance' or 'mechanical problems' (Motoaki & Daziano, 2014). Other variables could follow from studies which have not been taken into account for this thesis. Secondly, for the construction of the conceptual framework, a simplification if performed regarding the *beliefs*. In the *Theory of Planned Behaviour* (see figure 3), it can be seen that the beliefs from level III influence the variables in level II. However, for this thesis the participants' *beliefs* cannot be determined from the data-sources. This is why a simplification is performed to the *Theory of Planned Behaviour*, to construct the conceptual framework. The *beliefs* – level, level III, is replaced by variables that influence the variables in level II (see figure 5). These level III variables do not represent beliefs, but are separate aspects that influence the variables in level II. For a more complete conceptual framework, also the *beliefs* should be taken into account in future studies.

The conceptual framework is based on the literature study. However, this framework could not be used directly for the data analysis. Therefore, a conceptual model is constructed based on the available data from the data-sources. With this data, some variables in the conceptual framework cannot be determined or quantified for this pilot, and are therefore excluded from the conceptual model. The following variables are excluded:

- The participants' attitude towards behaviour: in the chapter *2. Literature review*, it is stated that someone's attitude to a certain travel mode is determined by lifestyle, preferences, governments, institutions and also companies. In the baseline measurement, questions have been asked about the participants' motivations to travel by car instead of using a bike or OV-chipcard. However, the attitude they have towards certain modes and why they have that attitude cannot be derived from the data-sources, so explicit data is not available. As mentioned in section 5.1, it could be that the participants already had a positive attitude towards E-bikes before the pilot. This could explain why the vast majority is so positive about E-bikes after the pilot.
- Expectations others have of an individual about mode choice: Heinen et al. (2012) concluded that mode choice is influenced by expectations other have of an individual. For this thesis, this variable cannot be determined, because the surveys contain only questions about the individual participants.
- Communication towards participants: how the distribution of information about the pilot has led to the group of participants exactly, is not included in the data-sources. Around the campus, some promotion signs can be found. However, the communication towards individuals is not quantifiable for this thesis.

- Policy: as stated in chapter *2. Literature review*, the costs and availability of travel modes are influenced by governments and institutions. In this case, every participant lives in the same country, so they are not influenced by different governments. Also, all participants are influenced by the same policy from the TU Delft, so for this aspect no distinction can be made between the participants. There could be a difference in car usage between the participants due to in the influence of the municipalities' policies, however this is not determined for this pilot.
- Awareness of viable alternatives of the participants: this variable is mentioned in two studies in chapter *2. Literature review* from Schneider (2013) and Kenyon & Lyons (2003). Kenyon and Lyons (2003) concluded that someone's awareness of a travel mode highly depends on the communication by an institution, company, or government towards that person. As mentioned above, the communication variable cannot be quantified for this thesis, which also holds for the awareness.
- Weather: to include the weather in the data analysis, it must be known what the exact weather conditions are for a certain moment during the pilot. This can be derived from meteorological data. Next, weather has to be quantified for the whole pilot per participant, but this is excluded from this thesis.
- Costs: all participants are influenced by the same policy from the TU Delft: they can try an alternative mode for free during the block period, so no distinction can be made for this aspect. Additionally, factors like policies that could influence dissimilarities in costs to use a car are not determined in the pilot.

Based on the variables for which data is available from this pilot, several results are obtained. These results are already discussed in the previous chapter, but also a link have to be made with the reality. The absence of relationships between the variables from the conceptual model and *Intention to change modality* could be due to the fact that after the pilot, the vast majority of the participants has the intention to keep using the E-bike in the future. According to the *Theory of planned behaviour*, intentions could lead to behaviour. For this pilot, it is uncertain how valuable the intention of the participants after the pilot actually is. Of course, the purchase of an E-bike is a relatively big investment. If the participants buy an E-bike after the pilot, the actual behaviour should be determined a few months after the pilot. Even then it is not known if the participants will keep using the E-bike consistently in the future. This implies that the intention of people is not equal to their actual behaviour. Due to a limited time range, the actual behaviour in the future cannot be determined for this thesis. Therefore, in the conceptual model the relation between the intention and behaviour is represented with a dotted line.

7. Conclusion and recommendations

The goal of this thesis is to create a conceptual model representing the relationships between variables and intention to change modality. The final conceptual model is shown in figure 11.

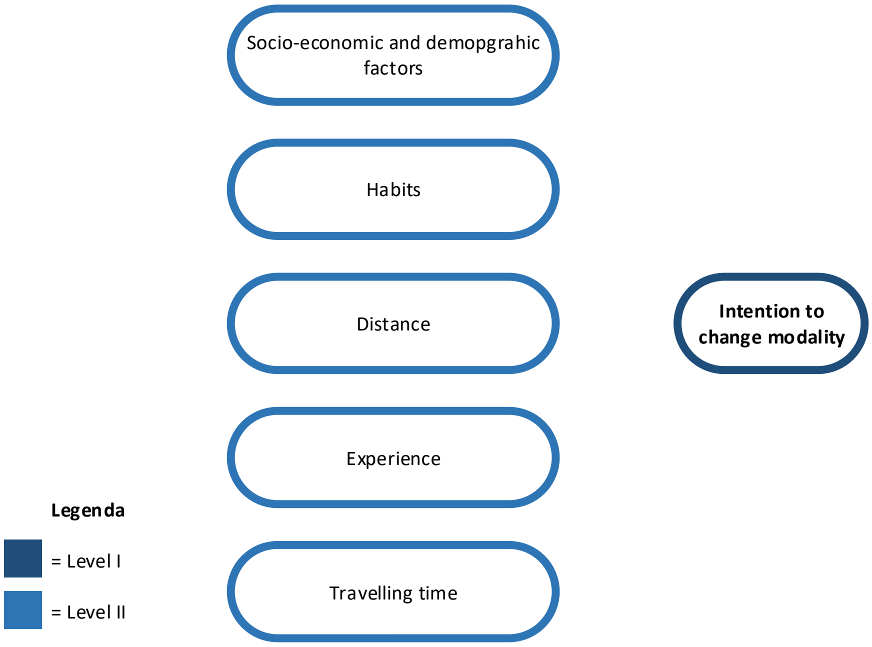

Figure 11: Final conceptual model representing the relationships between variables and the intention to change modality

Based on the available data and data analysis, no relationships between the variables from the conceptual model and intention to change modality, can be found (see figure 11). However, because only 4 out of 50 people do not have the intentions to keep using the E-bike, no valid statistical conclusion can be made for the *Intention to change modality* for this thesis. As mentioned, the behaviour after the pilot is not determined, however the use of the E-bike during the pilot is known, expressed in the *Covered distance by E-bike* and *Number of rides by E-bike*. From the data analysis it can be concluded that the *Average travel time between home and campus* by car, is related to both *Covered distance by E-bike* and *Number of rides by E-bike*. This means that the place where people live influences the E-bike use. Also the 'Habit', expressed as *Relative car usage*, influences the *Number of rides by E-bike*. As stated by Schneider (2013), mode choice is influenced by the 'Habit'. People whose relative car usage was higher before the pilot, were less likely to use the E-bike during the pilot.

It can be concluded that from the data of the *Pilot Mobility Scheme*, no valid statistical conclusion can be made for the *Intention to change modality*. However, the *Average travel time between home and campus* and *Number of rides by E-bike* have relationships with the use of the E-bike. These relationships imply that for people with a higher *Average travel time between home and campus* and higher *Relative car usage*, it could be more difficult to change from the car to the E-bike.

In future studies the relationships between the participants' experience during the pilot and their intention whether to keep using the E-bike or not after the pilot, should be investigated. Especially, the considerations not to keep using the E-bike should be taken into account. For this thesis, the vast majority was positive about the E-bike, while only a small group is negative. This could have led to the absence of relationships between the variables and intention to change modality.

Moreover, a bigger group of participants should be used, which will lead to a more reliable result. With a bigger test group, a more valid statistical conclusion could be obtained about the negative group, assuming that in this case there are more people with the intention not to use the E-bike after the pilot. Furthermore, the duration of the pilot could be extended to get a more reliable result. This thesis only includes the E-bike participants of the first block period (eight weeks). Extending the duration to for example one year, could give a more representative result. During a year, it could be more difficult for people to keep their motivation than during eight weeks. Also the weather could differ a lot during the year. Of course, for the research to the total *Pilot Mobility Scheme*, all participants of the 4 block periods can be taken into account. By extending the group size and pilot duration, relationships could be found between the variables from the conceptual model and *Intention to change modality*. Also the other tested modalities ('OV-chipcard' and 'working at home') could be used if there are enough participants.

Adapting question 21 from the follow-up measurement (see Appendix III) could also contribute to a more reliable result. The sub-answer 'Yes, 2 to 5 times a week' could be split up. In figure 7, it can be seen that 37 out of 50 participants answered 'Yes, 2 to 5 times a week', which could have led to no relationships based on the Chi-Square test.

Also the variables that are left out from the conceptual model could be taken into consideration. To test those variables, the current measurements should be extended. For example, the following variables could be tested and added to the conceptual model in future studies:

- Weather: the exact times when a ride is made are available from the pilot measurement. Also, the data of the weather for a certain time can be obtained from the internet. Then, the weather data should be processed into a file which is usable for data analysis. An option is to determine whether it rained or not during each ride. This could lead to a percentage of rides with rain per participant.
- Costs: no real difference can be made for the E-bike costs between the participants. Therefore, the costs of the car for an average week could be determined. For every participant, it is known where they live and how often they travel to the campus by car. The fixed costs (e.g. insurance, tax, depreciation) should be added to complete the total price tag.
- Attitude: in future studies more questions could be asked to find out what the attitude is of the participants towards the travel modes. Asking the same question before and after the pilot about the mode they use(d) could also lead to a change in attitude. An example of a multiple choice question which could be added is: "*What is your opinion about E-bikes*".

Adding more variables to the conceptual model could lead to a more complete final conceptual model and reliable conclusion.

Finally, it should be mentioned that all conclusions, statements, and recommendations made are based on a group of only 50 participants. In reality, the change from car to other modalities applies for a much bigger group, not only on the TU Delft campus. This thesis could form a basis, which can be used in future studies.

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Appendix I: Literature study

According to a study to dissimilarities between travelling behaviour in Germany and the USA, variables that influence mode choice are: (1) socio-economic and demographic factors, (2) spatial development patterns, (3) transport and land-use policies, as well as (4) national cultures or individual preferences (Buehler, 2010).

1) *Socio-economic and demographic factors*
   Internationally, income and automobile ownership are the primary determinants for explaining differences in mode choice according to most analyses. However, for industrialized countries – where most households own a car and most growth of travel is for discretionary trips – socio -economic variables may be less important determinants for mode choice. In wealthy countries, demographic variables like household composition and life cycle, gender and age may be more relevant for travelling behaviour.

2) *Spatial development patterns*
   The density and spread of developments are also determinants of mode choice. When there is a low density and big spread of developments, walking and cycling are less attractive modalities. Often, this is influenced by the long trip distances and a lack of pedestrian and cycling infrastructure. On the other side, higher densities with a mix of land-use lead to more opportunities for walking and cycling, due to the shorter trip distances. Also, travelling by car in dense areas is less attractive due to traffic congestion, less parking supply and higher parking costs. Additionally, in areas with higher densities the provision of public transport is economical.
   In general, spatial development patterns are less relevant for the variability in mode choice than the socio-economic and demographic patterns.

3) *Transport and land-use policies*
   Transport policies from governments at all levels influence the mode choice. Higher operating costs for automobiles (such as gasoline and sale taxes, automobile registration fees, tolls and parking costs) and slower car travel speeds make travelling by car less attractive. Also, governments have influence on the infrastructure supply and land-use. More road infrastructure supply make travelling by car faster and more convenient, while higher densities and a greater mix of land-use make trips by foot, bike and public transport more viable. Finally, policies that promote walking, cycling and public transport could have an influence on the mode choice.

4) *National cultures or individual preferences*
   The theory of "ecosocialization", developed by Gleesen & Low (2001), is an indicator for cultural changes towards more sustainability and sustainable modes of transport in society. Cultural differences also could influence the lifestyle of people, resulting in differences in travelling behaviour.

Heinen et al. (2012) have investigated the extent to which work-related factors affect the individual's decision to be a commuter cyclist. They concluded that cycling was not only determined by 'hard' factors, such as the available infrastructure and socio-demographic factors, but also by the attitudes and expectations of the cyclist themselves and the people around them. Employees who are more positive about bicycle commuting are more likely to cycle to work. Moreover, when employers offer facilities at work like a bicycle storage inside and changing facilities, employees are more encouraged to use the cycle.

On the other hand, employees who are expected by their colleagues to use the car, are less likely to commute by cycle. The presence of facilities for other transport modes and an increase in the commute distance also reduces the change of an individual using the bicycle. Furthermore, when people have to transport goods , they are less likely to take the bicycle. Finally, providing a public transport pass or free car to employees has a negative effect on bicycle use. Travel compensation schemes could encourage individuals to use the bicycle and public transport, which are considered sustainable modes of transport.

According to a study from Motoaki & Daziano (2014), weather conditions, cycling time, slope, cycling facilities, and traffic volume, have effect on cycling decisions. They also showed that cyclists can be divided into two segments based on cycling skills and experience. Cyclists with more skills and experience are less affected by adverse weather conditions, slope inclination and heavy traffic. Moreover, more cycling facilities (e.g. dedicated cycling lanes, parking spaces, specialized traffic signs and signals) result in a higher share of cycling by not only individuals with higher skill and experience, but also by individuals who have less biking skills. Bike lanes also neutralize factors that discourage people from using a bike (rain, snow, slope, heavy traffic).

Also Liu et al. (2014) investigated the influence of weather, but in their case on Swedish people's travel behaviour. The weather data included the mean of daily temperature, p of rain precipitation and road surface condition. Results show that the weather impact on motorized and non-motorized vehicles differs in different seasons and regions. The findings highlight the importance to incorporate individual and regional unique anticipation and adaptations behaviours within policy design and infrastructure management.

Schneider (2013) also did a research to mode choice behaviour, and proposed the “*Theory of Routine Mode Choice Decisions”* to describe how people choose transportation modes for routine travel purposes. According to this theory, the mode choice decisions process contains five steps.

The steps are clarified as follows:

1) Awareness and availability: this means that people must be aware of a travel mode and have the mode available as an option to travel. The relation between awareness and mode choice has been emphasized in different studies.
2) Basic safety & security: people have the intention to seek for travel modes that they perceive to have a basic level of safety from traffic collisions and security from crime.
3) Convenience & cost: this means that people seek for travel modes that require less time, effort and costs.
4) Enjoyment: people seek for travel modes that provides them with personal physical, mental or emotional benefits; helps them to achieve social status; or makes them feel good about benefiting the society or environment.
5) Habit: when people have chosen a particular travel mode regularly, they are more likely to use this option in the future.

Socio-economic characteristics such as age, gender, household size etc., determine how individuals continue through the steps. The theory combines the travel behaviour field and psychology field. The travel behaviour field focusses on time, costs, socio-economic factors, perceptions of the local environment, and attitudes towards travel modes, while the psychological field focusses on the thought process, including intentions and habits. Finally, the theory emphasizes that a comprehensive approach is needed to shift routine automobile travel to other travel modes and increase sustainable transportation. Focussing just on a single step, such as improving the safety for pedestrians and cyclists, without increasing the awareness of walking and cycling, decreasing distances or encouraging community support may do little to reduce the use of the car.

According to a study from Brög et al. (2002), a change in travel mode depends on the way how information is brought to an individual. This study describes the concept of Individualised Marketing (IndiMark®), a so-called "soft policy", developed by Socialdata. The concept is based on a targeted, personalized, customized market approach which empowers people to change their modality. Information has to be "brought" to the customer instead of expecting him / her to get it from the provider. Using these "soft policies" make people think about the modalities they use to travel, and it has proven to be highly successful in achieving shifts in mode from the car.

A second variable that could influence a change in modality is the people's awareness of the available modalities (Kenyon & Lyons, 2003). As stated in the study from Brög et al. (2002), communication plays a big role in influencing people to change modality. Information about alternative modes has to be consulted so people to make them aware of viable mode alternatives to travel. The results from the study of Kenyon & Lyons (2003) suggest that the "presentation of a number of modal options for a journey in response to a single enquiry could challenge previous perceptions of the utility of non-car modes, overcoming habitual and psychological barriers to consideration of alternative modes."

Thirdly, the costs could be a factor to change mode choice. Becker & Carmi (2019) investigated the role of parking fees in travel mode choice. Their results show that "adding a parking free not only increased the tendency to leave the car at home, it also influenced the relative weight given to the considerations that determine to leave the car at home." More specifically, this means that previously significant considerations as pro-environmental attitudes and social discomfort on leaving the car at home became non-significant, and previously insignificant considerations as time and costs became significand predictors. Thus, they concluded that parking fees are an effective measure to change travel mode.

Appendix II: Questions baseline measurement

Pilot Mobility Scheme TU Delft

* 1. Name:

* 2. Gender:
Female
Male

* 3. Age:

* 4. TU Delft e-mail address:

* 5. Postal code residence:

* 6. Residence:

* 7. I am a/an:
Employee
Student

* 8. If you are an employee: How many hours do you work a week based on your contract?

* 9. Which TU building is most important for you to study / work?

* 10. How many days a week do you travel to the TU Delft campus on average?
1
2
3
4
5
6
7

* 11. Are you working days/times flexible?
Yes
No

* 12. How many days a week do you use the following mode to travel to the campus on average? Choose the travel mode you use the most.
Number of days on foot
Number of days bicycle
Number of days E-bike
Number of days scooter
Number of days motor
Number of days auto (driver)
Number of days auto (passanger)
Number of days train
Number of days bus/tram
Number of days other,

* 13. If you travel (partly) by public transport, how you do travel from you home to the station?
On foot
Bicycle
E-bike
Scooter
Motor
Car (driver)
Car (passanger)
Other
n/a

* 14. If you travel (partly) with the public transport, how you do travel from the station to the campus?
On foot
Bicycle
E-bike
Scooter
Motor
Car (driver)
Car (passanger)
Other
n/a

* 15. Do you travel between different buildings or locations during an average working day?
Yes
No

* 16. If so, between which buildings?

* 17. If so, how?:
On foot
Own bicycle
TU bicycle
Bicycle sharing (e.g. Mobike)
Else:

* 18. What is the reason you participate to this pilot? (more answers possible)
Traffic jams
Saving money
Saving time
Working or studying while travelling
To use social media in the public transport
To avoid parking problems
Arrive at the campus more relaxed
To contribute to a healthier environment
Out of curiosity
It is healthy
Else:

* 19. What is the reason your travelled between your home and the campus mostly by using the car instead of the bicycle? (more answers possible)
The distance between home and work is too big
Cycling costs more time compared to using the car
I can easily park my car at the campus
It is unpleasant to arrive at the campus sweating
I wear good clothes to the campus
Cycling does not fit my image
The change to get wet by the rain is too big
I have a physical impairment
I don't like cycling
There aren't enough parking spaces for your bike on the campus
There aren't enough showers at the campus
I have to carry too much luggage
I haven't got a proper bike
There is no good cycling route to the campus
I have no cycling buddy
It is unsafe to travel by bike
I have to carry my children
I have bad experiences cycling
I oftenly travel to others locations by car
Else:

* 20. What is the reason your travelled between your home and the campus mostly by using the car instead of the public transport? (more answers possible)
Travelling with the public transport costs more time
The connections aren't sufficient
I can easily park my car at the campus
Comfort
Public transport is expensive
Using public transport does not fit my image
I have to carry too much luggage
I have to drop off / pick up my children
Else:

* 21. Which travel alternative are you going to use? (more answers possible)
Free E-bike
Free OV-chipcard
Free E-bike & Free OV-chipcard
Free OV-chipcard with electrical scooter
Working at home

* 22. Would you also consider such a travel mode also without this pilot?
Yes
No

* 23. If you are using the free OV-chipcard with eletrical scooter: have you ever heard about it before the pilot?
Yes
No

* 24. Do you have any ideas to make the pilot more attractive? No

Yes: ….

* 25. How did you know about this pilot?
Via an information stand
Via posters or folders at the campus
Via signs at the campus
Someone told me about it
Via TU news
Else:

* 26. Do you have any ideas to promote the pilot?
No
Yes: …

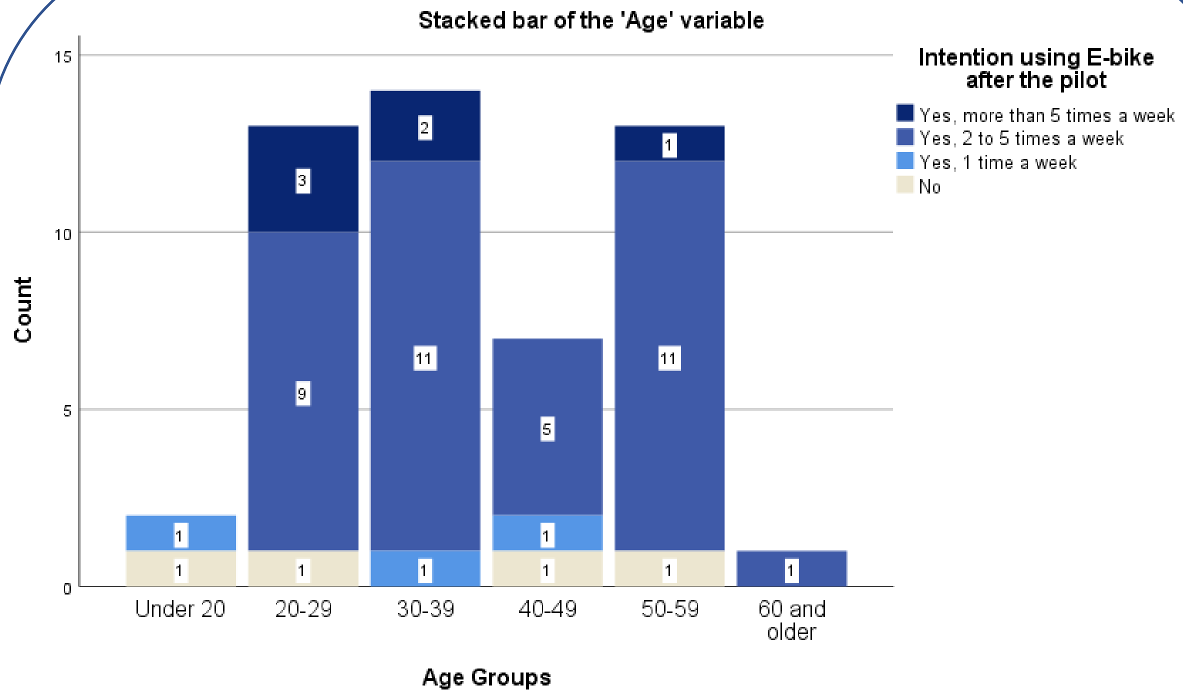
* 27. Do you have any other questions or suggestions?
No
Yes: …

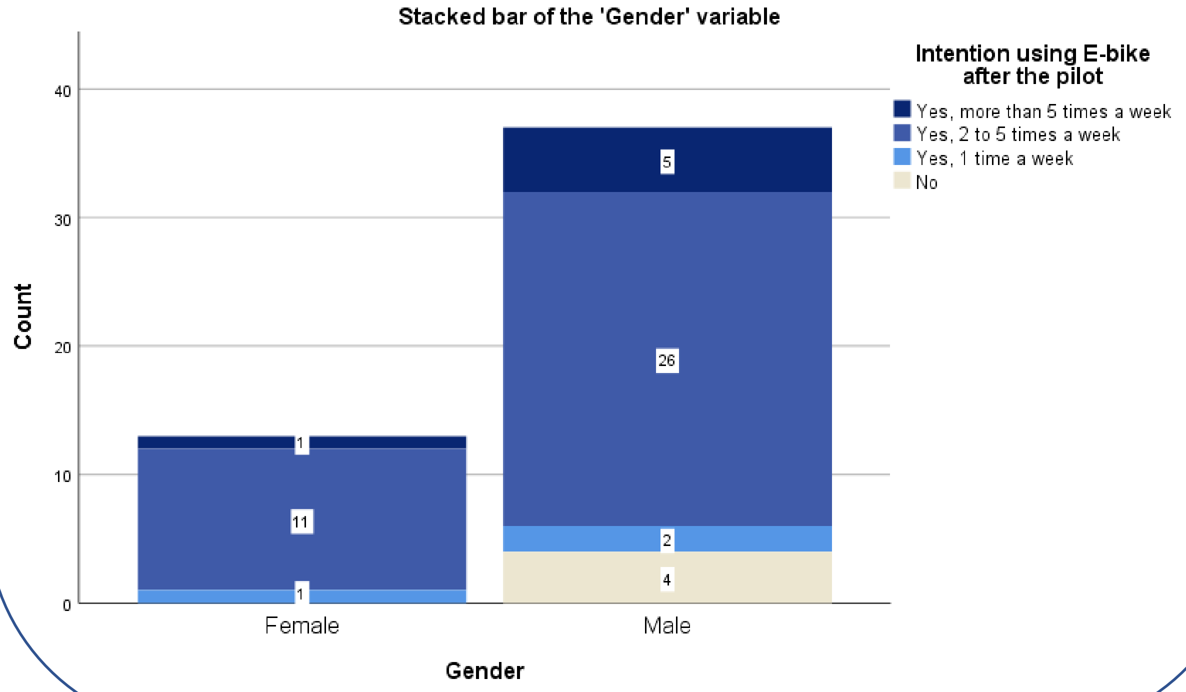
Appendix III: Used question follow-up measurement

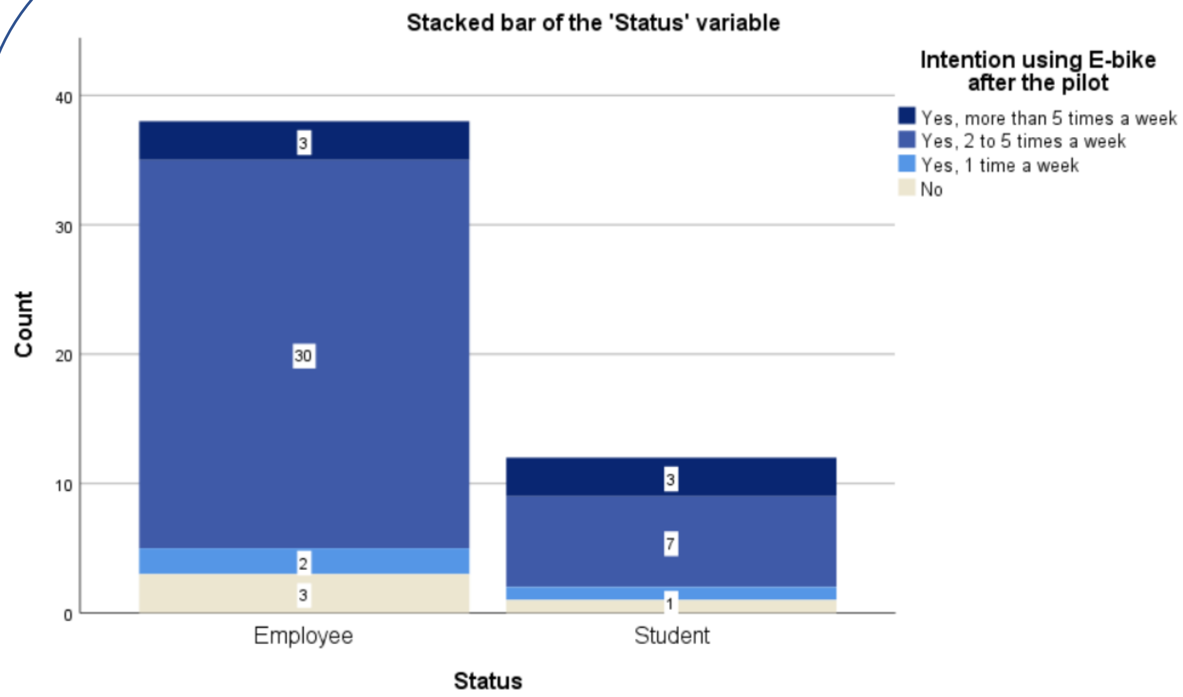
From the follow-up measurement, question 21 is used:

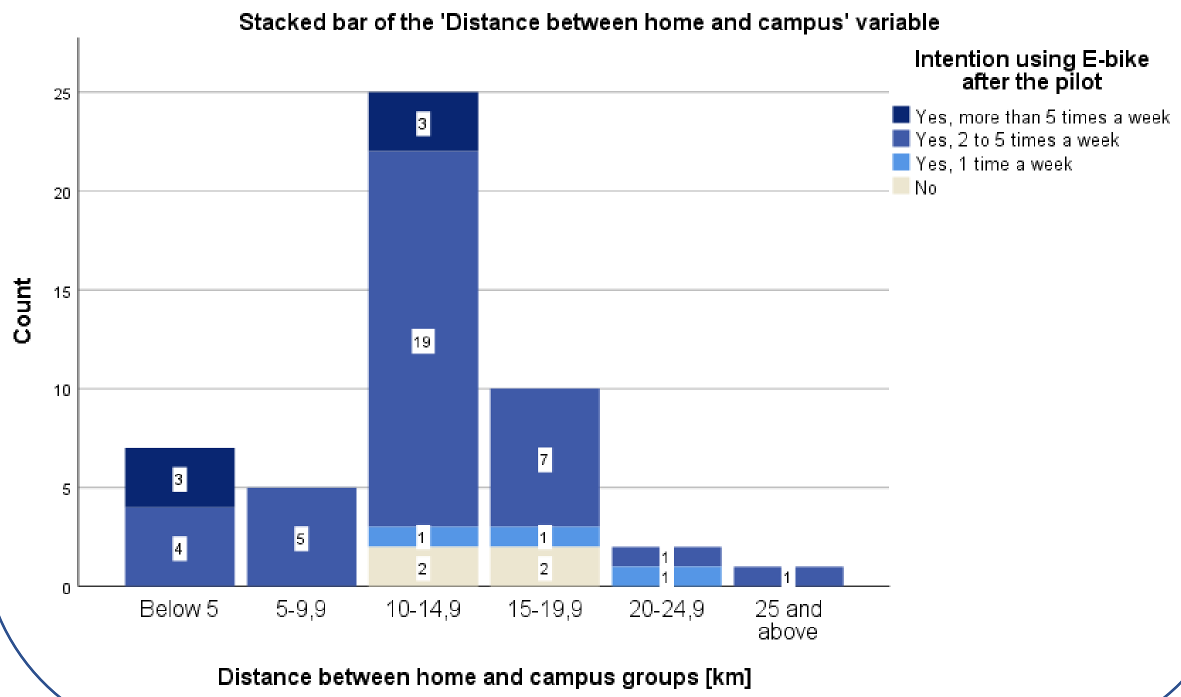
"Would you like to keep using the E-bike for your journey to the campus?"

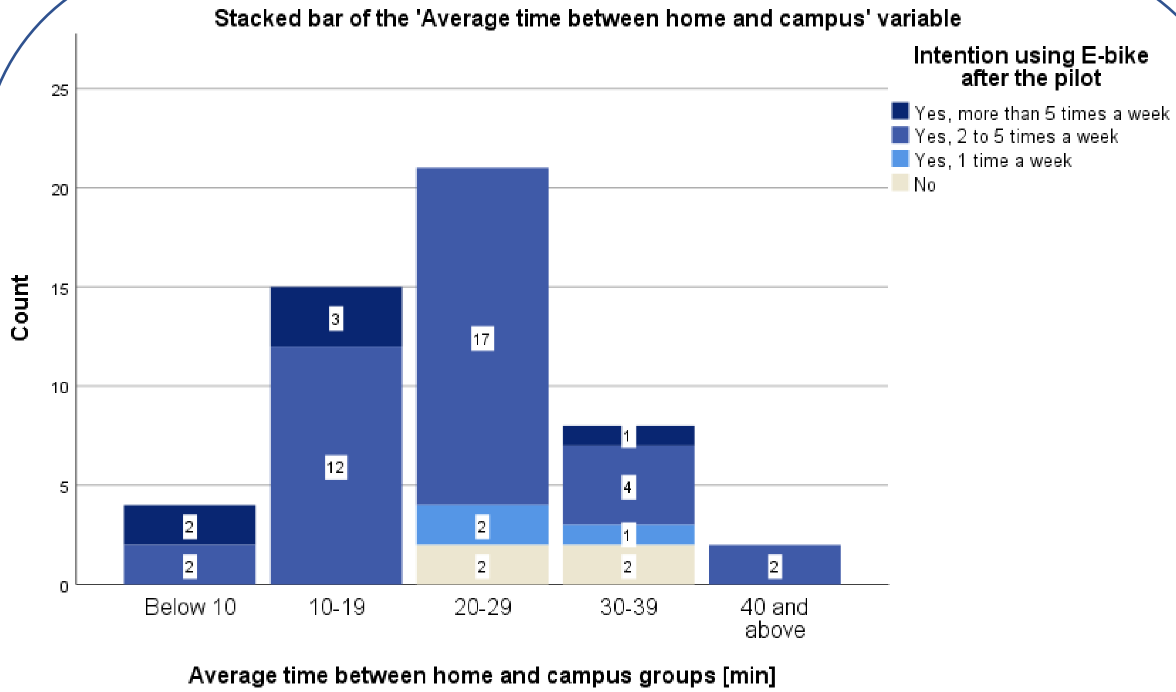
Appendix IV: Stacked bar plots

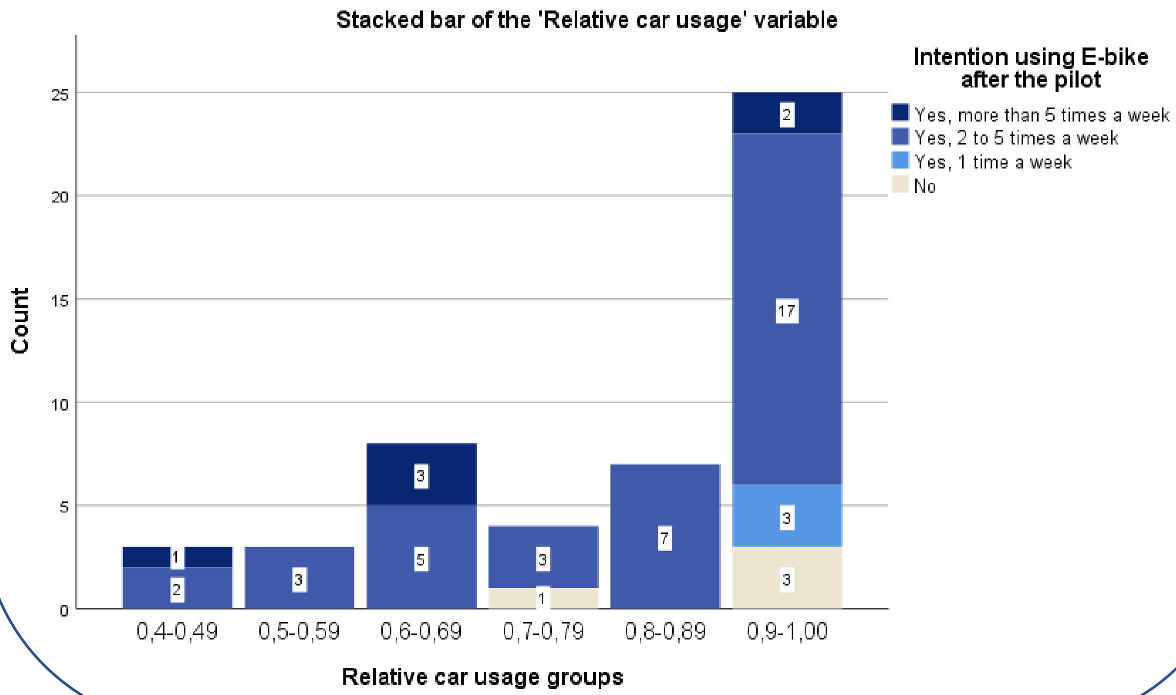


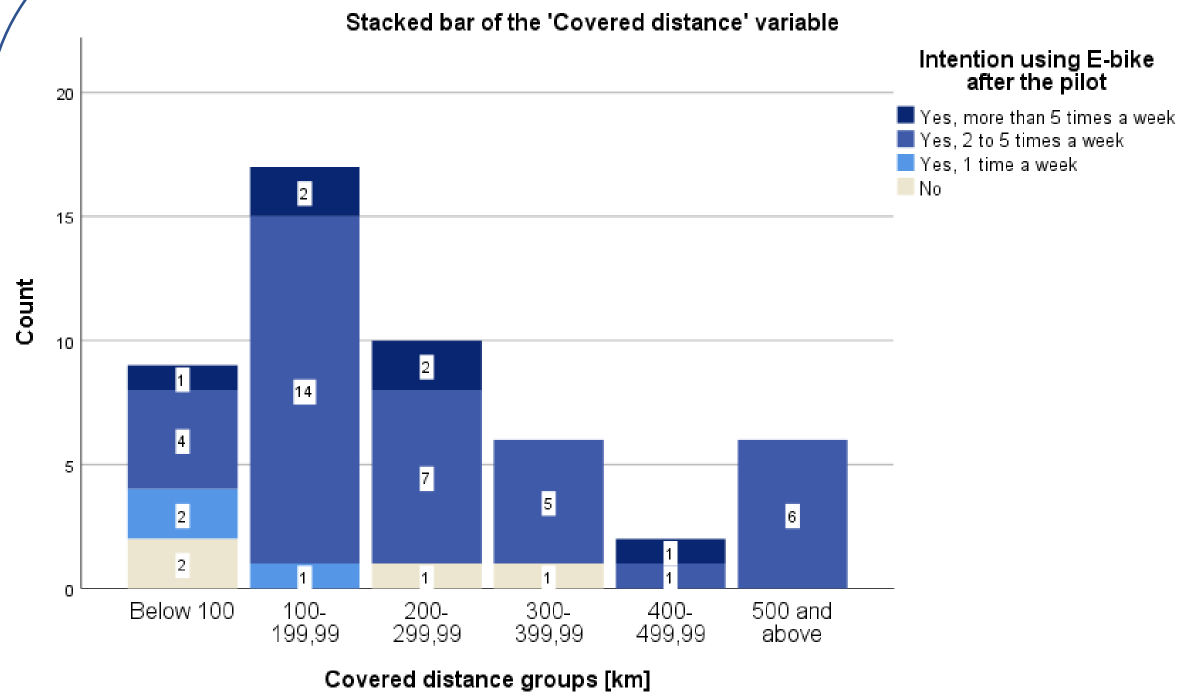


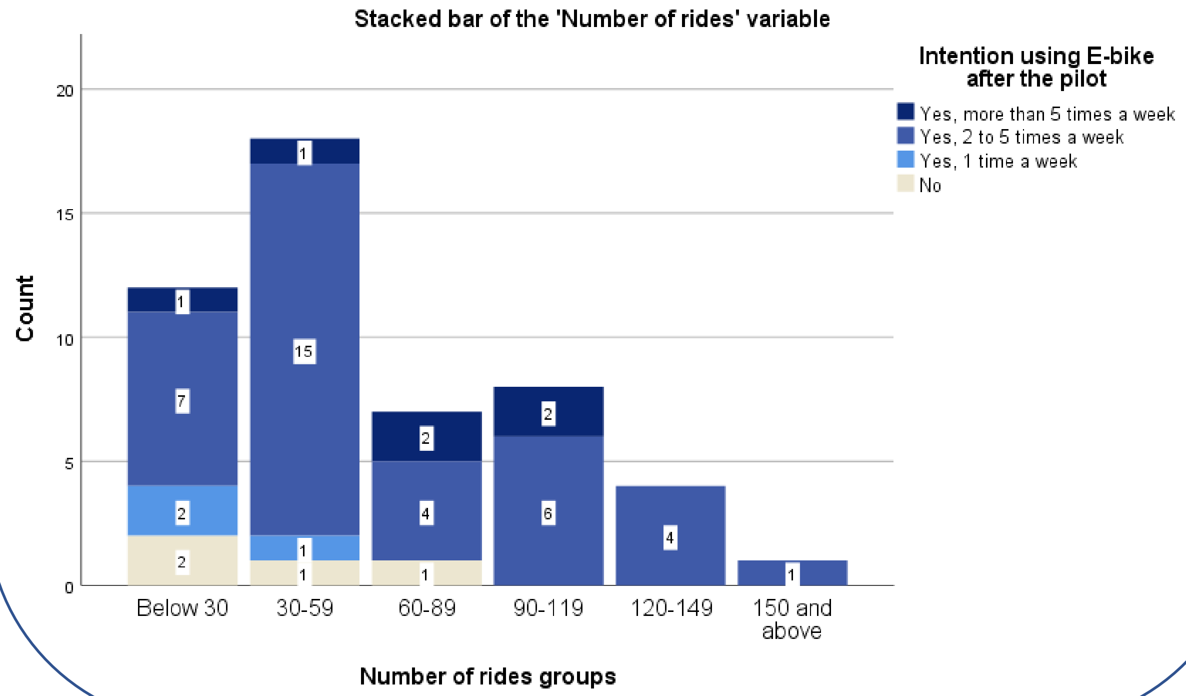

Stacked bar of the 'Status' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
10
20
30
40
3
30
2
3
3
7
1
Employee
Student
Status


Stacked bar of the 'Distance between home and campus' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
5
10
15
20
25
3
4
5
3
19
1
2
7
1
2
1
1
1
Below 5
5-9,9
10-14,9
15-19,9
20-24,9
25 and above
Distance between home and campus groups [km]


Stacked bar of the 'Average time between home and campus' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
5
10
15
20
25
2
2
3
12
17
2
2
1
4
1
2
2
Below 10
10-19
20-29
30-39
40 and above
Average time between home and campus groups [min]


Stacked bar of the 'Relative car usage' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
5
10
15
20
25
1
2
3
3
5
3
1
7
2
17
3
3
0,4-0,49
0,5-0,59
0,6-0,69
0,7-0,79
0,8-0,89
0,9-1,00
Relative car usage groups


Stacked bar of the 'Covered distance' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
5
10
15
20
Below 100
100-199,99
200-299,99
300-399,99
400-499,99
500 and above
Covered distance groups [km]


Stacked bar of the 'Number of rides' variable
Intention using E-bike after the pilot
Yes, more than 5 times a week
Yes, 2 to 5 times a week
Yes, 1 time a week
No
Count
0
5
10
15
20
Below 30
30-59
60-89
90-119
120-149
150 and above
Number of rides groups

Appendix V: Chi-Square test results of variable combinations with p-value < 0,05 and the 'Covered distance' – 'Gender' combination

Average time between home and campus Groups * Covered Distance Groups Crosstabulation

			Covered Distance Groups						
			Below 100	100-199,99	200-299,99	300-399,99	400-499,99	500 and above	Total
Average time between home and campus Groups	Below 10	Count	3	1	0	0	0	0	4
		Expected Count	,7	1,4	,8	,5	,2	,5	4,0
	10-19	Count	2	5	5	1	1	1	15
		Expected Count	2,7	5,1	3,0	1,8	,6	1,8	15,0
	20-29	Count	2	11	4	1	0	3	21
		Expected Count	3,8	7,1	4,2	2,5	,8	2,5	21,0
	30-39	Count	2	0	1	4	0	1	8
		Expected Count	1,4	2,7	1,6	1,0	,3	1,0	8,0
	40 and above	Count	0	0	0	0	1	1	2
		Expected Count	,4	,7	,4	,2	,1	,2	2,0
Total		Count	9	17	10	6	2	6	50
		Expected Count	9,0	17,0	10,0	6,0	2,0	6,0	50,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	44,290[a]	20	,001
Likelihood Ratio	35,875	20	,016
Linear-by-Linear Association	7,418	1	,006
N of Valid Cases	50		

a. 28 cells (93,3%) have expected count less than 5. The minimum expected count is ,08.

Average time between home and campus Groups * Number of rides groups Crosstabulation

			Number of rides Groups						Total
			Below 30	30-59	60-89	90-119	120-149	150 and above	
Average time between home and campus Groups	Below 10	Count	0	3	1	0	0	0	4
		Expected Count	1,0	1,4	,6	,6	,3	,1	4,0
	10-19	Count	2	5	2	3	3	0	15
		Expected Count	3,6	5,4	2,1	2,4	1,2	,3	15,0
	20-29	Count	7	8	2	3	1	0	21
		Expected Count	5,0	7,6	2,9	3,4	1,7	,4	21,0
	30-39	Count	3	2	2	1	0	0	8
		Expected Count	1,9	2,9	1,1	1,3	,6	,2	8,0
	40 and above	Count	0	0	0	1	0	1	2
		Expected Count	,5	,7	,3	,3	,2	,0	2,0
Total		Count	12	18	7	8	4	1	50
		Expected Count	12,0	18,0	7,0	8,0	4,0	1,0	50,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	38,307[a]	20	,008
Likelihood Ratio	23,091	20	,284
Linear-by-Linear Association	,047	1	,829
N of Valid Cases	50		

a. 27 cells (90,0%) have expected count less than 5. The minimum expected count is ,04.

Relative car usage * Number of rides Groups Crosstabulation

			Number of rides Groups						
			Below 30	30-59	60-89	90-119	120-149	150 and above	Total
Relative car usage	0,4-0,49	Count	0	0	1	0	2	0	3
		Expected Count	,7	1,1	,4	,5	,2	,1	3,0
	0,5-0,59	Count	1	0	2	0	0	0	3
		Expected Count	,7	1,1	,4	,5	,2	,1	3,0
	0,6-0,69	Count	1	2	1	2	1	1	8
		Expected Count	1,9	2,9	1,1	1,3	,6	,2	8,0
	0,7-0,79	Count	1	2	0	1	0	0	4
		Expected Count	1,0	1,4	,6	,6	,3	,1	4,0
	0,8-0,89	Count	0	3	0	3	1	0	7
		Expected Count	1,7	2,5	1,0	1,1	,6	,1	7,0
	0,9-1,00	Count	9	11	3	2	0	0	25
		Expected Count	6,0	9,0	3,5	4,0	2,0	,5	25,0
Total		Count	12	18	7	8	4	1	50
		Expected Count	12,0	18,0	7,0	8,0	4,0	1,0	50,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	42,991[a]	25	,014
Likelihood Ratio	38,890	25	,038
Linear-by-Linear Association	9,497	1	,002
N of Valid Cases	50		

a. 34 cells (94,4%) have expected count less than 5. The minimum expected count is ,06.

Gender * Covered Distance Groups Crosstabulation

			Covered Distance Groups						
			Below 100	100-199,99	200-299,99	300-399,99	400-499,99	500 and above	Total
Gender	Female	Count	4	3	2	2	2	0	13
		Expected Count	2,3	4,4	2,6	1,6	,5	1,6	13,0
	Male	Count	5	14	8	4	0	6	37
		Expected Count	6,7	12,6	7,4	4,4	1,5	4,4	37,0
Total		Count	9	17	10	6	2	6	50
		Expected Count	9,0	17,0	10,0	6,0	2,0	6,0	50,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10,363[a]	5	,066
Likelihood Ratio	11,450	5	,043
Linear-by-Linear Association	,429	1	,512
N of Valid Cases	50		

a. 9 cells (75,0%) have expected count less than 5. The minimum expected count is ,52.