Parking Demand Management at Delft University of Technology

Master of Science Thesis
by
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TU Delft

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For the degree of Master of Science in Management of Technology at Delft University of Technology

By

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This thesis is dedicated to the memory of my father and grandfather.

Serafeim Gravanis
Delft, October 27, 2016

Executive Summary

The last decade the TU Delft underwent a tremendous growth. It is not only its growth but its increasing population as well. Thus, since the last years, new buildings and parking areas were built to host all its stakeholders. Due to this ongoing growth, and in an effort of the administration to establish its vision for a sustainable campus, its interest is focused to the parking stress that the TU Delft currently faces. More specifically, parking demand has been growing along with the increase of the university's population. Although the effects of Parking Demand Management (PDM) on people's behavior have already been the focus of many studies, its exact effects on the traveling and parking behavior on universities' commuters remain unclear. What is more, most of the studies consider alternatives such as on-street, off-street parking, whereas in the specific study alternative ways of transport that lead in parking demand reduction were chosen to be investigated.

The purpose of this study is to shed light in the effects of different Parking Demand Management strategies and apply them in the parking demand of the TU Delft. The framework that is developed in order to confront the increasing parking demand of the TU Delft includes two parts.

The first part focuses on the identification of the current parking supply and demand, followed by an estimation of the future parking demand. An observation in the parking areas of the TU Delft campus and forecasting techniques are employed to define the current and future parking supply. The results of the first part show that currently the parking demand of the TU Delft is inside the acceptable boundaries (86,5% of the total parking supply). However, according to the observations, the distribution of the volume of the parking demand differs from the distribution of the parking supply. Consequently, parking areas with less than 85% of occupancy and parking areas exceeding the parking supply are observed. Concerning the future parking demand, the results foreshadow a large increase in future. It is expected that in 2020 the demand for parking in the TU Delft campus will exceed the supply by 17,5%.

The second part, is dealing with the effects of the chosen Parking Demand Management (PDM) strategies in the commuters behavior. PDM is considered the application of different strategies and policies to reduce parking demand, or to redistribute it in space or time. To be able to identify the aforementioned effects on the commuters' behavior, a stated choice experiment is employed. As expected parking cost attribute has the highest effect on commuters' travelling and parking decisions. Furthermore, the calculation of the elasticities of all the attributes used in the stated choice experiment, confirms the hypothesis that the price incentivizes commuters in their travelling and parking choices. More specifically, every percentage increase of the parking price will result to approximately 1,5% of decrease in Drive Alone demand. As far as searching time is concerned, it is proved to be inelastic. Every percentage increase of searching time results to less than 0,5% decrease in the Drive Alone alternative, while every percentage increase of egress time results in 0,337% decrease of the same alternative.

In order to transfer the aforementioned theoretical approaches to practical results, simulations with the estimated model are realized. The results of the simulations prove that Carpooling is more preferable than Park & Ride with the initial policies. However, by reducing the cost of Park & Ride, in respect to Carpooling and by introducing minibus service to minimize its egress time their effects are managed to achieve a balance. More specifically, the model shows some remarkable reduction of parking demand due to carpooling and an increase of Park & Ride share at the same time. Finally, the simulations

that take place prove that with high parking fees a total annihilation of Drive Alone alternative is possible.

Finally, the two parts are combined to construct a complete plan of recommendations for the next five years. For this purpose, three scenarios based on the parking supply are developed. The first scenario considers the current parking supply to remain constant for the next five years. The second scenario implies the increase of the parking supply, while the third scenario considers the decrease of the number of parking spots in the campus. For all three scenarios parking fees are recommended and can be found in detail in Figure 22.

Sustainable mobility of the university can be achieved through the application of the aforementioned parking demand management strategies at the TU Delft campus. Nonetheless, an attempt to quantify the increase in sustainability through the estimation of the reduction of the CO_2 emissions is made. Briefly, for every 5% reduction of parking demand in the campus of the TU Delft, 145 tones of CO_2 per year will be avoided.

The successful implementation of the abovementioned framework can constitute a source of inspiration and consequently influence other institutions and organization to adopt a philosophy towards sustainable campuses. Therefore an attempt to generalize this case into other contexts is made. Not only universities' but also organizations such as airports, hospitals, and municipalities can benefit from the application of this framework. However, it is recommended that in different contexts, the coefficients of the model, as well as its attributes should be reconsidered and adapted according to the needs of the specific occasion.

Summary

During the last decade the TU Delft underwent a tremendous growth. It is not only its growth in terms of infrastructures but its increasing population as well. More specifically, the current population of the TU Delft is estimated to be 25546 people (TU Delft, Marketing & Communications, 2006). This increase in population in combination with the modern way of life and convenience led to a sharp increase of the parking demand in the campus the recent years. Due to this ongoing growth, and in an effort of the administration to establish its vision for a sustainable campus, its interest is focused to the parking stress that the TU Delft currently faces. More specifically, parking demand has been growing along with the increase of the university's population resulting nowadays to a parking occupancy rate of 86,5% during the peak hours. This sharp increase in the parking demand not only enhances the traffic congestion in the area of the campus but also results to an environmental stress due to CO_2 emissions. These facts show the urgency of defining the cause of the parking problem and the need for a structured approach to manage it.

In order to assist the administration's effort to manage the parking demand in a sustainable way, the research objective of the present thesis is to shed light on the effects of different Parking Demand Management (PDM) strategies and apply them in the parking demand of the TU Delft. PDM is considered the application of different strategies and policies to reduce parking demand, or to redistribute the aforementioned demand in space or time. The framework that was built in order to confront the increasing parking demand of the TU Delft includes two parts. The first part concerns the current and future parking demand and supply, while the second part deals with the effects that the PDM strategies have on the commuters of TU Delft. Finally, the results of the two parts are combined in order to construct a recommendation plan to manage the future parking demand in a sustainable way. (Figure i)

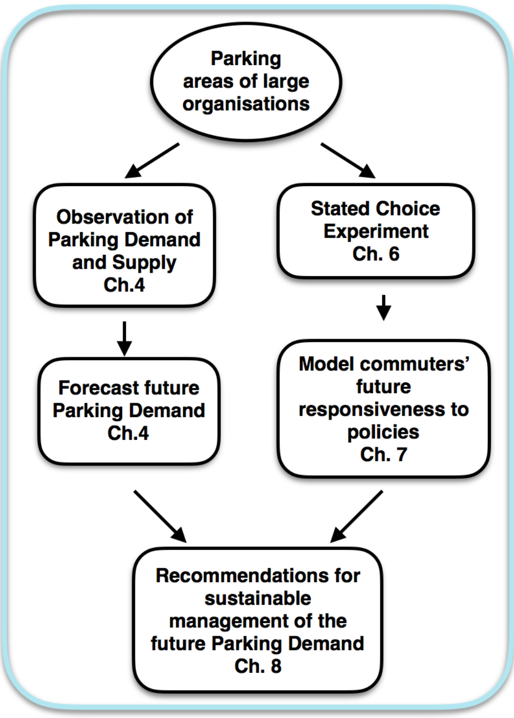

Figure i Representation of the Framework built for the purpose of this thesis.

The first part focuses on the identification of the current parking supply and demand, followed by an estimation of the future parking demand. An observation in the parking areas of the TU Delft campus and forecasting techniques are employed to define the current and future parking supply. The results of the first part show that currently the parking demand of the TU Delft is inside the acceptable boundaries (86,5% of the total parking supply). However, according to the observations, the distribution of the volume of the parking demand differs from the distribution of the parking supply. Consequently, parking areas with less than 85% of occupancy and parking areas exceeding the parking supply are observed. Concerning the future parking demand, the results foreshadow a large increase in future. It is expected that in 2020 the demand for parking in the TU Delft campus will exceed the supply by 17,5%.

The second part deals with the effects of the chosen PDM strategies in commuters' behavior. To be able to identify the aforementioned effects on the commuters' behavior, a stated choice experiment is employed. The combination of Carpooling and Park & Ride TDM strategies has not yet been discussed in the existing literature. Therefore, studying these two alternatives in combination to the status quo (Drive Alone) increases the scientific value of this research.

The experiment is conducted by the author in person in three large parking areas of the campus. More specifically, the survey is distributed in paper to randomly chosen commuters of the TU Delft during their arrival or departure from the parking areas. The methodology used to design the final survey (D-efficient design) requires the use of priors that are acquired from a pilot survey. Finally, 110 responses are gathered and distributed randomly into two groups; the estimation data set and the validation data set. These data sets are used to estimate and validate the coefficients of two models generated with the use of Multinomial Logit (MNL) and Mixed Multinomial Logit (MMNL) models. The model derived from the MMNL model application has higher adjusted rho-squared (0,272) compared to the model derived from then MNL model application (0,166). However, during the validation process, both of the models are found to have the same forecasting accuracy (56,7%).

Table i Estimated coefficients with the MNL and MMNL models (10000 draws, with panel effects).

Parameter	Multinomial Logit Model			Mixed Multinomial Logit Model		
	Value	t-test	p-val	Value	t-test	p-val
$\boldsymbol{\beta_1}$	**-1.97***	-5.92	0.00	**-3.42***	-5.33	0.00
$\boldsymbol{\beta_2}$	-0.199	-0.45	0.65	-0.482	-0.70	0.49
$\boldsymbol{\beta_{ExtraTraveltTime}}$	**-0.135***	-4.36	0.00	**-0.245***	-4.93	0.00
$\boldsymbol{\beta_{SearchingTime}}$	**-0.103***	-2.75	0.01	**-0.186***	-3.37	0.00
$\boldsymbol{\beta_{Egresstime}}$	**-0.0599***	-3.24	0.00	**-0.123***	-3.88	0.00
$\boldsymbol{\beta_{ParkingCost}}$	**-0.368***	-8.27	0.00	**-0.628***	-7.13	0.00
Sigma_$\boldsymbol{\beta_1}$	-	-	-	**2.19***	4.88	0.00
Sigma_$\boldsymbol{\beta_2}$	-	-	-	**2.56***	6.65	0.00
	Likelihood ratio test: 128.485 Adjusted rho-square : 0.166 Final log-likelihood: -287.313			Likelihood ratio test: **207.460** Adjusted rho-square: **0.272** Final log-likelihood: **-247.826**		
Number of observations	320			320		

***p<0,05**

The estimation and validation of the two models are followed by an analysis of their characteristics. The estimation of the model's coefficient revealed interesting aspects of the traveling and parking behavior of the TU Delft commuters. As expected parking cost attribute has the highest effect on commuters' travelling and parking decisions.

Furthermore, the calculation of the elasticities of all the attributes used in the stated choice experiment, confirms the hypothesis that the price incentivizes commuters in their travelling and parking choices. More specifically, every percentage increase of the parking price will result to approximately 1,5% of decrease in Drive Alone demand. As far as searching time is concerned, it is proved to be inelastic. Every percentage increase of searching time results to less than 0,5% decrease in the Drive Alone alternative, while every percentage increase of egress time results in 0,337% decrease of the same alternative.

Table ii Direct elasticities of the Drive Alone alternative for the three attributes (Parking Cost, Searching Time and Egress Time).

Attributes	Drive Alone direct elasticities
Parking Cost	-1,490
Searching Time	-0,432
Egress Time	-0,337

Furthermore, a relation between parking price and searching time is identified by the Value of Searching time; otherwise known as Willingness to Pay. TU Delft commuters are willing to pay €0,24 per minute decreased in searching time. Egress time affects also parking demand, nevertheless it has slighter impact than parking fees and searching time. Particularly, its estimated elasticities prove that it has a larger impact in Park & Ride than in Drive Alone alternative. Moreover, calculating the Value of Egress time for the TU Delft commuters, show that they are willing to pay €0,07 per minute egress time decreased less than per minute decreased searching time. Finally, regarding extra traveling time for its every percentage increase, Carpooling share decreases by 1%. However, its cross elasticities reveal that every percentage change in the extra traveling time affects reversely the shares of Drive Alone and Park & Ride (Table 25).

In order to transfer the aforementioned theoretical approaches to practical results, simulations of the estimated model are realized. The revealed behavior –current searching and egress time- of the respondents are used as the baseline to begin the simulations. During this process the application of different policies are simulated. A variety of price relations between the alternatives are investigated, while in all simulations a minibus service, which reduces the egress time for Park & Ride, is considered as well. The results of the simulations prove that Carpooling is more preferable to Park & Ride in the initial policy. However, by reducing the cost of Park & Ride, in respect to Carpooling and by introducing minibus service to minimize its egress time their effects are managed to achieve a balance. The model shows a remarkable reduction of parking demand due to carpooling and an increase in Park & Ride share at the same time. Finally, the simulations that took place prove that with high parking fees a total annihilation of Drive Alone alternative is possible.

Sustainable mobility of the university can be achieved through the application of the aforementioned parking demand management strategies at the TU Delft campus. Nonetheless, an attempt to quantify the increase in sustainability through the estimation of the reduction of the CO_2 emissions is made. For every 5% reduction of parking demand in the campus of the TU Delft, 145 tons of CO_2 per year will be avoided.

Finally, the two parts are combined to construct a complete plan of recommendations for the TU Delft. For this purpose, three scenarios based on the parking supply are developed. The first scenario considers the current parking supply to remain constant for the next five years. The second scenario implies the increase in the parking supply, while the third scenario considers the decrease in the number of parking spots in the campus. Figure ii, presents in detail the three scenarios.

Figure ii Recommended scenarios

The successful implementation of the abovementioned framework can constitute a source of inspiration and consequently influence other institutions and organization to adopt a philosophy towards sustainable campuses. Therefore an attempt to generalize this case into other contexts is made. Not only universities' but also organizations such as airports, hospitals, and municipalities can benefit from the application of this framework. However, it is recommended that in different contexts, the coefficients of the model, as well as its attributes should be reconsidered and adapted according to the needs of the specific occasion.

The realization of this research led undoubtedly in a scientific contribution. This contribution concerns a framework, which combines a specific area's current and future parking demand with the effects that the different parking demand management measures have on commuters' traveling and parking behavior. Two alternative travelling and parking options ('Carpool' and 'Park & Ride') are studied at the same time in comparison to the status quo 'Drive Alone'. The results of this study show that commuters have a clear preference in 'Carpool' option than 'Park & Ride' and this is due to a combination of lower searching and egress time of the first than the latter. What is more, introducing parking fees is found to be the most effective way to stimulate commuters to choose the alternative options. Furthermore, during an analysis of the sample in segments, students express higher preference to alternative travelling and parking than employees, with the visitors to be the least influenced by the measures. Unfortunately, the lack of large number of responses available, leads to smaller rho-squares when analyzing separately the different segments of the population.

What is more, the models that are considered in this thesis are based on rational decision-making theories. Thus, attitudes that influence commuters' behavior are neglected.

Interaction effects between the variables are also neglected as usually in transport studies. The chosen method of conducting the experiment –in person at the parking areas- leads to a narrow choice of alternatives and attributes. Three alternatives are available in the experiment while, in reality, commuters have a great variety of means of transport. Finally, including more attributes would have increased the number of choice sets and consequently the length of the survey. In order to keep the survey short important attributes such as the traveling costs, traveling time and safety of parking are neglected.

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Chapter 1 Introduction

1.1 Background

Over the last decades, humanity has faced significant advancement in technology and sciences. As a result of these advancements, technology has been integrated completely in our lives. One of the technological breakthroughs that dramatically changed the way we perceive transportation is the automobile (Mayrand-Fiset, 2013). The concept of the automobile was introduced in the late 18th century and has now become one of the most dominant innovations (Berger, 2001). This argument is also supported by the 'Motorization Rate' [1], which has been following a constantly upward trend (Eurostat, 2016). Nowadays, the vast majority of people, nowadays, cannot conceive their lives without a car. It is beyond doubt that cars have taken deep root in our communities. However, it was not until recently, realized that the extensive car usage has some negative effects.

The excessive car usage combined with urbanization and the modern lifestyle has negative consequences for the environment as well as the mobility. To begin with, exhaust emissions of passenger cars amount to 12% of the total CO_2 emissions in Europe (Eurostat, 2015). Despite efforts by the European Union to decrease those emissions, it remains a considerably important contribution to the Greenhouse effect. Moreover, the impact of the unnecessary use of vehicles on mobility is easily conceivable due to its visible consequences. For instance, traffic congestion, which has been massively characterized as 'scourge', is considered to be one of the main factors negatively affecting an area's mobility and standards of life (Thomson & Bull, 2015). Finally, as a result of the aforementioned excessive use of cars, another problem makes its appearance; the increase of parking demand. The high motorization rate, and consequently, the use of cars brought in the surface the lack of parking spaces in frequented places (Eboli, Mazzulla, & Salandria, 2013).

The problems that are generated from the lack of sufficient parking supply are more noticeable in highly populated or visited areas (Barata, Cruz, & Ferreira, 2010). Campuses of universities are considered such areas. Very often, commuters in universities (i.e. students, staff and visitors) are struggling to find a parking spot. The reason behind this lies in the combination of high demand for parking in rush hours and the existing low supply. What is more, university campuses face a complicated problem since the combination of vehicular travel modes, bicycle paths and pedestrian walkways frequently create conflicts. As a result, the transport planning and parking management in university campuses need a special treatment. This is also the case for the campus of the TU Delft.

The above-mentioned points show the urgency of defining the cause of the parking problem and the need for a structured approach towards its solution. The main goal of this thesis is to give a closer insight into the issue through analyzing the parking problem of TU Delft and provide sustainable solutions.

1.2 Research Objectives and Research Questions

One of the main targets of this research is to shed light in the effects of different Parking Demand Management strategies and apply them in the parking demand of the TU Delft. In other words, studying the mobility of the campus and more specifically Parking Demand will assist in evaluating the existing and the future campus' situation. Concluding, the

[1] Cars per 1000 inhabitants

research objective can be formulated as a combination of the previous. Thus, *the primary goal of this research is to model adequately the current parking behavior of the TU Delft commuters and examine the impact of Parking Demand on their behavior when applying different strategies. Additionally, this analysis will assist to forecast the future parking demand, in a way that can be used for the evaluation of campus' Parking Demand.*

Based on the conducted Literature Review (Chapter 3) the following research question and sub-questions (a, b, c, d, e) were concluded:

"What are the effects of different parking management strategies on Parking Demand at the TU Delft?"

a. What is the current parking demand and supply and how will they evolve in the next five years?

b. Which parking management strategies and variables are relevant for managing the parking demand of the TU Delft campus and should be included in the model?

c. What are the effects of the different parking strategies on Parking Demand?

d. What recommendations can we make to manage Parking Demand and improve the campus' sustainability, regarding its commuters' parking behavior?

e. What are the implications of this study for parking management in other settings?

1.3 Added Value of the Thesis

In this section both the scientific contribution of the present study and the practical problem are discussed.

1.3.1 Scientific Contribution

The scientific aspect of the research problem is closely related to the aforementioned notions of Sustainability and Mobility (Transportation Demand Management). On one hand, sustainability in campuses, which is considered to be a broad concept, involves essential dimensions such as ecological, cultural, economic, social and transportation (Alshuwaikhat & Abubakar, 2007). However, the campus greening methods that are proposed in the literature of Sustainability focus more on environmental issues of the parking than dealing with the parking problem itself. On the other hand, the literature on Mobility Management, which is another popular topic among the scientists, mostly focuses in Transportation Demand Management (Aoun, Abou-Zeid, Kaysi, & Myntti, 2013; Barata, Cruz, & Ferreira, 2010; Lemos, Balassiano, Santos, & Portugal, 2006; Riggs, 2014) and Parking Management (Joshi, Khan, & Motiwalla, 2012; Litman, 2003; Shang, Lin, & Huang, 2007). In other words, Mobility Management focuses on solving the parking problem and usually overlooks possible criteria of sustainability. Concluding, it can be argued that the interrelation between the two concepts comprises an unexplored area. This unexplored area constitutes the scientific problem, which has occurred from the lack of knowledge in the specific field.

Furthermore, moving towards a sustainable environment, introduces multiple policies that can be implemented, especially in mobility related projects. Given the different interests and strategies it is difficult to identify the effects of Parking Demand Management strategies on the commuters' behavior. At this point, the lack of in depth study of these effects highlights the need for further examination and evaluation of the gap.

Additionally, although numerous studies discussing alternatives that can reduce parking demand are identified; none of them considers the alternatives of Carpooling and Park & Ride in combination with the status quo, Drive Alone.

Finally, most of the studies focus on the methods that can contribute in reducing parking demand and they neglect its percentage decrease that is needed. The same applies also to the future parking demand, which is usually considered constant. In other words, the current and the future occupancy levels of the studied parking area remain undefined in the majority of the literature.

Concluding, the problem statement can be defined and divided in four parts.

1. Absence of a framework that considers Sustainability and Mobility Management (Parking Demand Management). In other words, how sustainability is affected when applying different Parking Demand strategies.

2. There are relatively few studies that discuss the effects of the Parking Demand Management strategies on commuters' behavior, especially in urban areas such as universities' campus.

3. Lack of consistency in modeling the parking behavior of commuters in areas such as university's campuses and specifically when considering their future preferences regarding the three options: Driving alone, Carpooling, Park & Ride.

4. Lack of connection of the actual parking occupancy level to model commuters' parking behavior.

1.3.2 Practical Problem

Recently TU Delft's sustainability has been under the microscope the recent years. It is not only its growth as a knowledge spillover but also increasing numbers in students, employees and visitors as well (Mulder, 2014). Thus, since the last years, TU Delft underwent a tremendous construction activity. New buildings and parking areas were built to host all the aforementioned stakeholders (TU Delft M&C, 2009). However, the Administration of the University wants to transform the campus into a more sustainable and 'green' environment (TU Delft Webredactie Communication , 2015).

In order to succeed in its target, the Administration investigates the possible solutions and their alternatives towards a more sustainable campus. One of the most important aspects of the campus' sustainability is the aesthetics of the surrounding area. However, in order to improve the surrounding area in more green space, tradeoffs should be made. In this research one of the main tradeoffs, which is closely related to the campus parking demand, is examined. Transferring the majority of the parking lots, which are located in the central area of the campus to sustainable parking buildings in the 'outskirts', will eventually affect the campus' mobility.

TU Delft campus has more than twenty parking areas dispersed in different locations, usually near the respective faculties. Additionally, a high number of on-street parking spaces on the roadsides is provided as well. However, increasing the sustainability of the campus prerequisite the expansion of the green places. For this reason, the Administration examines the replacement of a part of the parking spaces with green. In order to be able to achieve the greening of the campus, Parking Demand should be decreased. What is more, a scenario of substituting the abolished parking spaces with one or two large main parking buildings is also considered by the Administration of the university (Aandestegge, 2015).

1.4 Thesis Outline of the Thesis

In this chapter, the Research Objectives and Questions, the Added Value and the Uniqueness of this thesis were presented. In the following chapter the methodology that is followed in order to approach the Research Problem is described. Chapter 3 provides a review of the literature on the defined Research Objective. Chapter 4, constitutes an effort to identify the current and future Parking Demand of the TU Delft campus and discusses the results of the observation. In Chapter 5, an argumentation concerning the suitability of the chosen alternatives and variables of the experiment is given. The following section, Chapter 6, introduce the Stated Choice Experiment that was conducted. The theory of the SC experiments and the process of designing and conducting the experiment are discussed. Later, in Chapter 7, the results of the aforementioned experiment and their analysis are presented and discussed. This thesis concludes with the conclusions and recommendations based on the previous chapters.

Chapter 2 Research Methodology

2.1 Introduction

In this chapter the research methodology of this thesis is described. In the first subsection, the framework, which was constructed in order to answer the research sub-questions is explained. More specifically, a more extended literature review, an on-site observation, an application of forecasting techniques and an on-street Stated Preference Survey approach adequately the research objective and provide clear answers to the research questions. Afterwards, these research strategies are combined in a framework built for confronting the practical research problem. Finally, the method of collecting the data and sampling, as well as, the method used to analyze them, are discussed.

2.2 Research Strategies

This subsection explains the approach of the present thesis to answer the research question and its sub-questions. To identify the current Parking Supply and Demand (first part of sub-question a) an observation is realized in the parking areas of the TU Delft. Additionally, forecasting techniques are employed to predict the future Parking Demand, which consist the second part of the sub-question a. Concerning the second (b) sub-question, a literature study is employed in order to identify the Parking Demand Management strategies and variables that are relevant for the TU Delft campus. In case that PDM strategies are implemented in the TU Delft, the results of the Stated Choice Experiment, can model the future behavior of the commuters (sub-question c). Combining the results of sub-questions a and c, recommendations to decrease future Parking Demand in a sustainable way will be given (sub-question d). Finally, an overall reflection of the findings will result in an attempt to generalize the recommendations for other contexts (sub-question e). Figure 1, presents the framework used to approach the research sub-questions

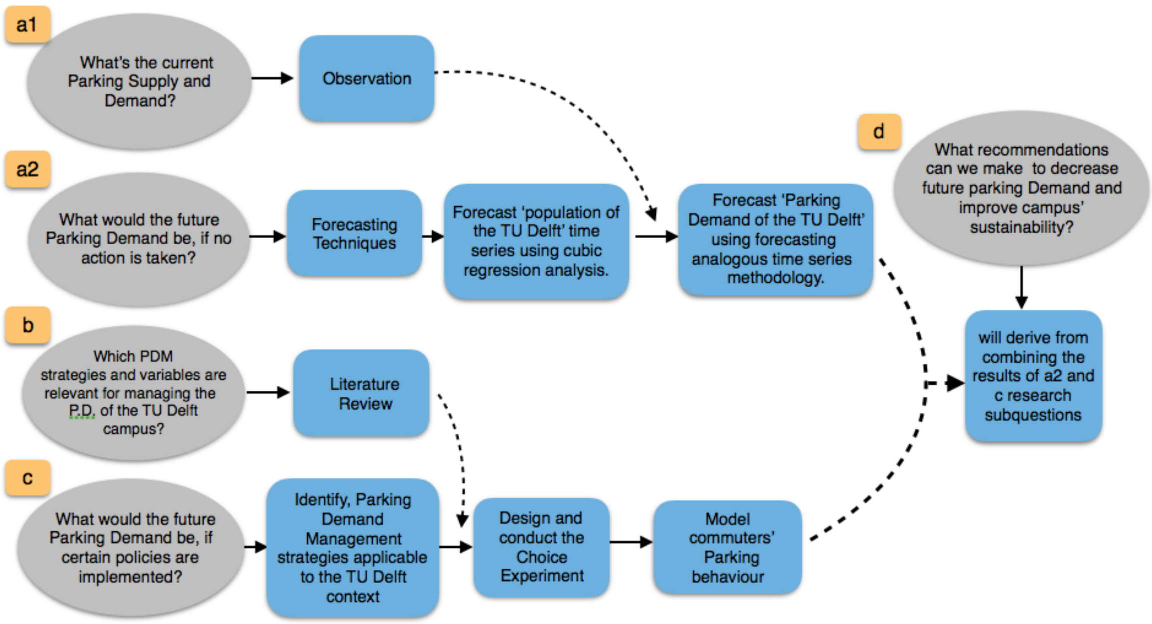


Figure 1 Framework to approach the research sub-questions.

In the following subsections a quick overview of the above-mentioned methods is presented. An in depth explanation of the methods is given before applying them in each chapter.

2.2.1 Literature Review as a method of research

To begin with, the literature review not only provides sufficient information regarding the involved concepts, but also assists the effort to enrich the existed literature framework. Moreover, the literature review contributes in the research with information of already published Study Cases for similar cases and even supports and increases the validity of our assumptions. For instance, Case studies that describe similar attempts of managing the parking demand, are considered for the TU Delft case as well. However, in order to have adequate information to proceed with modeling parking behavior, a variety of data is needed.

2.2.2 Observation of the Parking Occupation

An on-site observation is employed in order to create a better perception of the parking occupation for the case of the TU Delft campus. The purpose of this observation is not only to identify the current parking demand, but also the Parking Supply. A similar observation at the TU Delft was realized in 2014 from Spark B.V., a transportation-consulting firm (Spark B.V., 2014). In this way, a comparison between the previous and the current Parking Demand is made. Finally, the data gathered from this process assists the estimation of the future Parking Demand.

2.2.3 Forecasting Techniques

Another aim of this thesis is to predict the future Parking Demand, given the fact that no change will take place in the Parking policy of the university. Since not enough data were available to explain how the Parking Demand has been evolved through the years the analogous time series “Population of TU Delft” is used. Two different methods are employed in order to forecast the Parking Demand for the next five years. First, a cubic regression analysis is used to forecast the future population of the university and then, through a method of forecasting analogous time series an attempt to predict the future Parking Demand is made.

2.2.4 Stated Choice Experiment

The Stated Preference Survey provides an insight of the vehicle users’ preferences in hypothetical situations. Conducting a survey next to the on-site observation not only provides with the data needed to proceed with the modeling part, but also contributes in making the model more robust. Stated Preference Surveys give to the surveyor the ability to capture the tendency of the consumers –in this case the vehicle users- in hypothetical situations. A disadvantage of this type of survey is that captures the preferences and not the reality. In other words, in real situation the participants can act differently than they have stated during the survey. Moreover, the participants are usually reluctant to provide personal information and for this reason, it is chosen to preserve the anonymity of participants (Kroes & Sheldon, 1988).

2.3 Framework for confronting the Practical Problem

Concluding all the abovementioned research strategies in order to confront the increasing parking demand of the TU Delft the following Framework is developed. The framework that is constructed includes two parts (Figure 2). The first part concerns the current and future parking demand and supply, while the second part deals with the effects that the PDM strategies have on the commuters of the TU Delft. Finally, the results of the two parts are combined in order to construct a recommendation plan to manage the future parking demand in a sustainable way. This framework constitutes the base of this thesis and its generalization can result in a useful PDM tool.

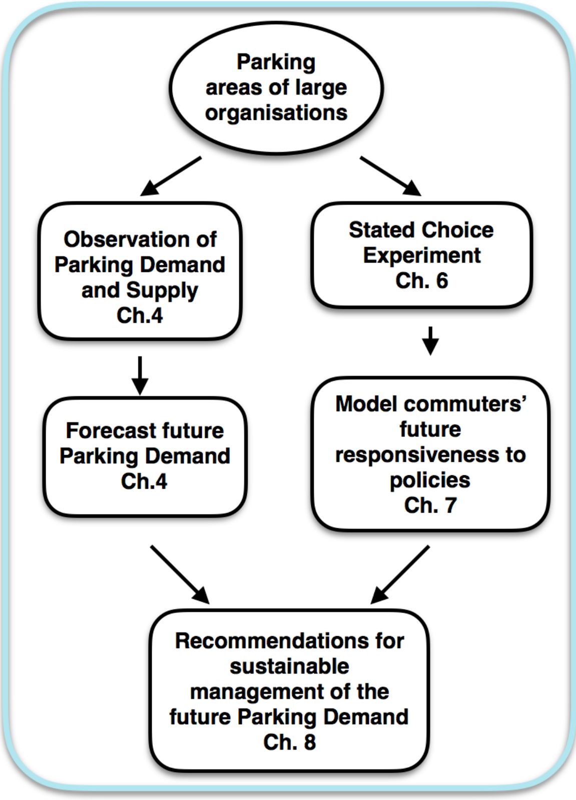


Figure 2 Framework for confronting the Parking Demand problem of the TU Delft

2.4 Data acquisition methods

A core ingredient of every research is the data that need to be acquired. An on-site observation provides with the occupation of each parking section in the university. In this way, the peak of the parking demand and its distribution during the day are identified. The result of this observation provides a clear insight of the current parking behavior of the car commuters and assists in the investigation of the future demand. Moreover, past Parking Demand data for each parking area was found in a report of a transportation-consulting firm, Spark B.V. (Spark B.V., 2014). What is more, in order to forecast the future Parking Demand, data is extracted from the annual 'TU Delft Highlights' and 'Facts & Figures' for the period 2004-2015 published by the Communication Department of the TU Delft (TU Delft, department Communication, 2015) (TU Delft, department of Marketing & Communication, 2014). Finally, data for the Stated Choice Experiment is gathered through an on-street survey. The surveys were distributed in paper and the respondents' answers were transferred to a Microsoft Excel file, before the analysis takes place.

2.5 Sampling Approach

As it was mentioned previously, the survey is one of the core ingredients of this research process. Conducting a survey on street provides with the data needed to model the commuters' behavior. An on street survey is chosen due to the fact that the research focuses on commuters who use the parking facilities of the university. An online survey was not possible to be distributed through the network of the university. Nevertheless, this approach would have failed to include visitors' behavior and preferences. What is more, to reassure that the measurements are representative, the survey was conducted in different parking facilities so that the preferences of all commuters are incorporated. The initial plan was to keep the proportion of the participants to the number of parking spaces in each parking facility constant. However, this plan was later found to be inefficient and three parking with largest supply were chosen to conduct the experiment.

2.6 Data Analysis Approach

The analysis of the data gathered from the on-site observation and the Stated Preference Survey, takes place in Microsoft Excel and Biogeme software respectively (Bierlaire, 2003). More specifically, regression analysis of the future Parking Demand is realized in Microsoft Excel environment, while a Discrete Choice Analysis in Biogeme is employed to generate the model. Discrete choice models are usually based on the utility-maximization of the respondents. In other words, the respondents reveal their preference by choosing the alternative, which maximizes their own utility (MacDonald, Anderson, & Verma, 2012). According to literature, the most commonly used model to analyze the data is the Multinomial Logit (MNL) model (Kropko, 2008). Furthermore, Mixed Multinomial Logit (MMNL) model is used to analyze the data as well. The two models and their results will be thoroughly explained in Chapter 6 and 7 respectively.

2.7 Conclusion

Concluding all the aforementioned, this chapter provided the core strategies and research methodologies to answer adequately the research questions. More specifically, four research methodologies, Literature Review, Observation, Forecasting Techniques and Stated Choice Experiment, were discussed. Concerning the data collection methods, four methods were used. Collection of the data needed was first realized through the observation of the parking areas and through an old parking occupation report of the TU Delft (Spark B.V., 2014). What is more, TU Delft reports were used to collect data regarding the population of the university and, finally, a Stated Choice Experiment was conducted via an on-street survey, useful to model the parking behavior of TU Delft commuters in hypothetical situations. Sampling approach was explained and the reasoning for choosing a street survey was given. Furthermore, the tools that were used and the approach to analyze the data were introduced. Finally, a Methodology Map, which presents every step of the present thesis, was constructed. Literature Review constituted the starting concept of all the branches of the Methodology. Actions, such as the 'evaluation of the alternatives and factors for the case of the TU Delft campus', 'Empirical Observation' and parts of the Choice Experiment are presented in grey rectangles, while results such as 'Attributes and levels', 'Parking occupation' and 'Final data' in ellipses. The Methodology Map, which is presented in Figure 3, will be recalled in every step of this thesis.

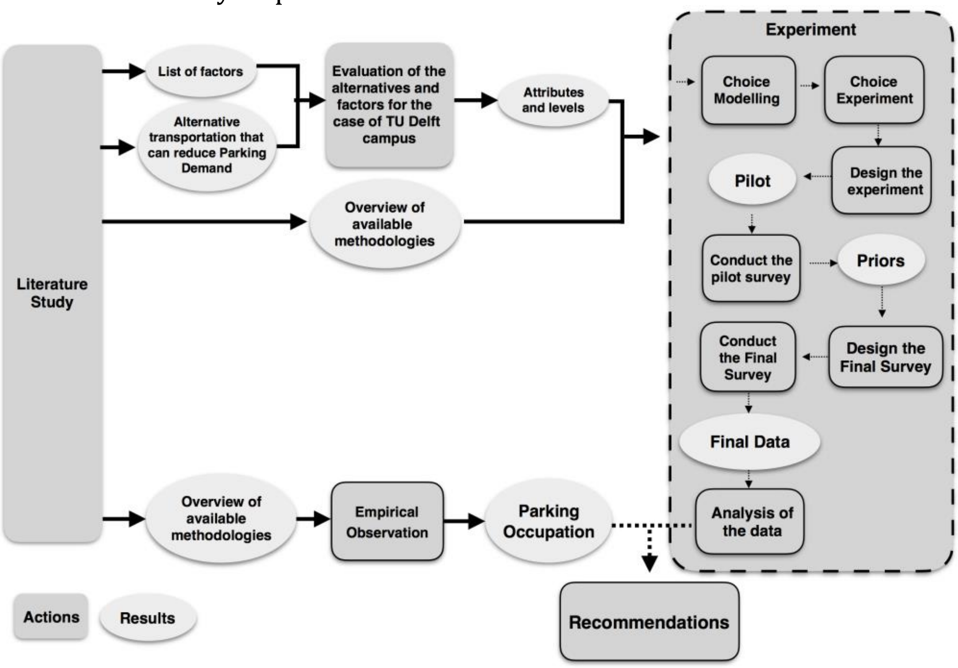


Figure 3 Methodology Map

Chapter 3 Literature Review: Parking Demand Management & Sustainability in Universities

3.1 Introduction

In this chapter the methodology used to identify the relevant literature as well as a synopsis of the useful concepts to approach the problem's solution are presented. The first step to gain information about the presented practical problem involved the investigation in Scopus and Google Scholar databases. Keywords, such as '*parking demand*', '*campus mobility*' and '*campus sustainability*' are used in the beginning of the research. While extending the research according to the references of studies presenting similar cases, Journals related to Transport discipline are proved to be of great assistance. Grey literature is also reviewed in an effort to gain broader knowledge for the studied subject.

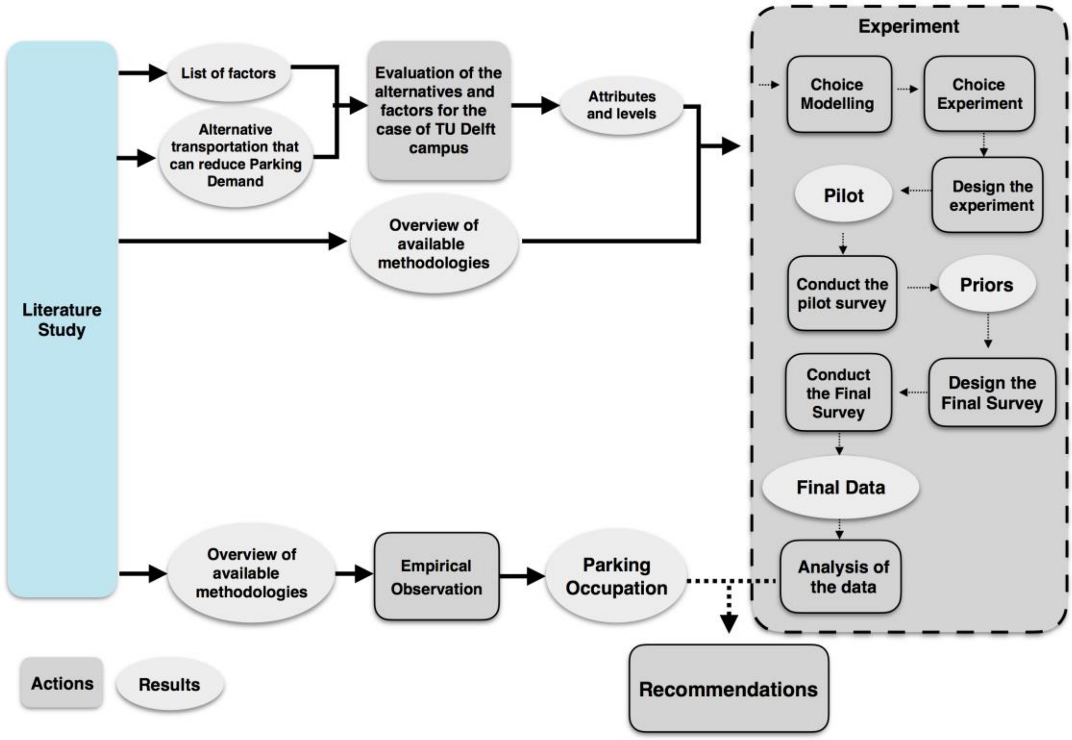


Figure 4 Methodology Map-Literature Review.

To begin with, the literature that is related with the scientific problem and the research identified objectives. At first, a description of the **general parking problem** is provided and is followed by its consequences and the necessity of confronting them from two different perspectives; **Mobility** and **Sustainability** concepts. Afterwards, the research of the literature is focused on parking issues within campus of universities, which consists also the essential concern of this thesis. Terms such as "**campus mobility**" and "**campus greening**" are introduced and the reasoning behind the identification of the research gap is presented. A wide variety of papers discussing Parking Demand management are identified. After studying them in depth the following conclusion is extracted; none of them focuses adequately on the sustainability factors. On the other hand, the literature concerning sustainability in campuses refers to the importance of Green Transportation but overlooks the strategies of achieving it. Finally, an overview of different cases in universities is presented and a discussion for the case of TU Delft follows.

3.2 Parking Problem

One of the main issues to be confronted in the portfolio of Transport Demand Management and Sustainable Mobility is the existing parking problem. The so-called parking problem has become a central subject of study and discussion among the part of the scientific community specializing in traffic management and urban transportation planning (Barata, Cruz, & Ferreira, 2010; Davis, Pijanowski, Robinson, & Engel, 2010; Marsden, 2006; Shoup, 2006). Undoubtedly, finding a parking spot in the city center has become extremely difficult and costs money as well as time. Searching for a parking space not only affects but also aggravates the environmental consequences and the traffic congestion (Barata, Cruz, & Ferreira, 2010).

In order to better understand the parking problem, it is necessary to provide some background information on how the problem occurred. There are two explanations for the emergence of the parking problem. According to the first, the increase of the number of vehicles combined with urbanization creates an unprecedented parking demand, especially in urban areas (Mehta, V., & Juremalani, 2015). Others, however, such as Mulley and Ison (2014) argue that the parking problem appeared due to the fact that facilities for movement (e.g. highways and streets) have been developed to a much greater extent than facilities for parking.

Before explaining the consequences of the parking problem, it is useful to provide information on how the different kinds of parking are classified. To begin with, the introduction of different policies resulted in the two main classifications; 'Public Parking' and 'Private Parking'. 'Public Parking' refers to parking areas that are available for the public, while the latter serves users for private purposes (Weterings, 2013). What is more, several types of parking facilities are identified in the existing literature, and finally are categorized into two: on-street and off-street. The first constitute designated spaces located on the road, while the off-street parking lots are located off the road and can be divided into two subcategories; Surface parking and Structured or Underground Parking. According to Mulley and Ison (2014), parking spaces can be characterized as public on-street, public off-street, office parking, public non-residential and residential parking. However, the lack of consistency in decision-making regarding the Parking Management strategies creates a confusion, which aggregates the parking problem and its consequences.

These consequences can be separated into direct and indirect ones. The direct consequences refer to the impact that derives straight from the problem while the indirect go beyond the obvious impact of the problem. Regarding the direct consequences, parking issues not only increase the traffic congestion in a city, but also hamper emergency vehicles and provoke accidents. For instance, firefighting trucks face difficulties accessing fire hydrants due to the parked cars. What is more, according to Mulley & Ison (2014) illegally parked cars is the cause of 10% of the accidents that happen in urban cities. Finally, one of the most important negative effects of the parking problem is considered its impact on the Land use. More specifically, the high demand for parking has created major concerns due to the significant spatial imprint of the parked vehicles. It is a fact that this imprint has followed an exponentially growth the recent years, especially in urban areas (Rodrigue, 2013). In Figure 5, land requirements per parking space for the different parking types are presented.

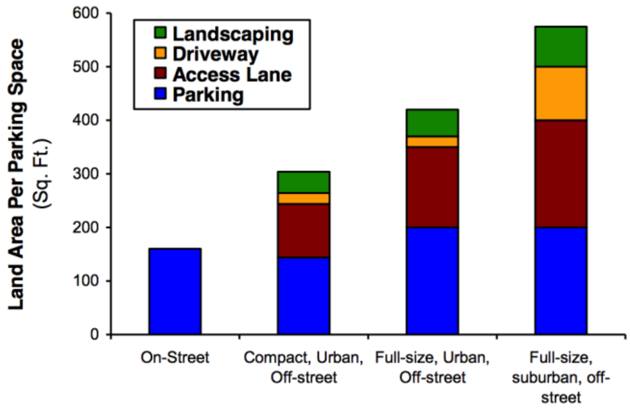


Figure 5 Land required per parking space for different parking types (Litman, 2006, p. 11).

Besides the direct consequences of the parking problem, indirect consequences are also observed in urban areas. To begin with, the parking problem enhances air pollution from CO_2 exhausting fumes and contributes to noise pollution in large cities (Shakir & Mohammed, 2013). It can be characterized as a 'vicious circle', due to the fact that cruising for parking enhances traffic congestion, requires more fuel and increases the emissions. Consequently, traffic congestion is increased and the extra emissions from unnecessary car usage aggravate the Greenhouse Effect. Finally, another indirect result of the high demand for parking space and the lack of parking management is related to the cost of the land used for parking facilities. The high demand of land, especially in urban areas, increases the costs of creating additional parking supply. Moreover, according to Figure 6, it can be noticed that the construction, operating and maintenance costs cannot be considered negligible. All the aforementioned costs are usually incorporated in -national and municipality- tax rates or in house rent (Litman, 2016).

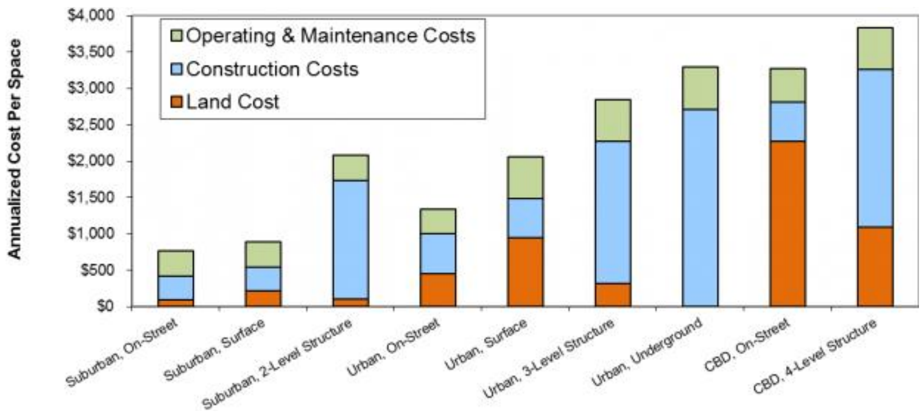


Figure 6 Annualized costs per parking space (Litman, 2016, p. 11).

Concluding, the aforementioned direct and indirect consequences of the high parking demand dictate the urgent confrontation of the issue for two reasons. When attempting to cope with the direct consequences in an area, its mobility will also be improved. As a result, accidents and traffic congestion due to parked cars will be avoided. On the other hand, coping with the indirect consequences will increase both environmental and economic sustainability. Reducing the car usage and traffic, will result in the reduction of the Greenhouse emissions and land can be used prudently in future. Moreover, unspecified financial burdens for parking facilities can be avoided.

3.3 Mobility and Sustainability in Universities

In the previous section the necessity of coping with the parking problem -from Mobility and Sustainability point of view- is stressed. However, these concepts still remain broad enough for the purpose of this report. In an attempt to narrow down the context of the aforementioned concepts, urban areas are chosen as the point of focus. This choice is due to two reasons. First, in urban areas parking problem is considered to be more intense and second, due to the fact that the campus of the TU Delft is located in an urban area. What is more, even Transportation Mobility refers to a wide variety of factors (e.g. means of transport, routes of transport, parking demand) and Sustainability considers different pillars (e.g. environment, economy, society) the focusing –and common- point is the environmental impact (campus' sustainability) of campus' *Parking Demand.*

While the research area becomes more specific in the area of the university's campus the notion of 'campus mobility' is introduced. 'Campus mobility' represents the accessibility of the campus from the neighboring regions and the convenience of movement inside its boundaries (Lemos, Balassiano, Santos, & Portugal, 2006).

Some of the most common methods to achieve sustainable mobility within a campus are the alternative ways of transport. First, increasing and improving the reachability and the facilities of the transport perspectives, as well as committing collaborations with public transport companies. Expansion of the public transport network can work as a booster, and influence positively the commuters towards using them. Second, introducing or increasing the existing parking fees is proved to be efficient method to reduce the parking demand and consequently the emissions of CO_2 and traffic congestions. Therefore, students and employees in universities are encouraged to walk or cycle to their destination. Moreover, the introduction of Parking Permits in the universities' policies can be interpreted in two ways. On the one hand, may lead to decrease of Parking Demand by forbidding specific commuters (e.g. students) to park in the campus. On the other hand, cannot work as an incentive to dissuade commuters holding the permit to travel by car (Nelson/Nygaard consulting associates, 2011). Furthermore, Park & Ride is a lately introduced strategy used to avoid traffic stress in urban areas. The commuter is given the alternative to park his vehicle in a remote area and then use a transit or walk to his destination (Nelson/Nygaard consulting associates, 2011). In order to allure the commuter to choose this alternative less expensive parking fees are introduced. Finally, recent initiatives of shared trips such as, carpooling and sharing parking fees enhance the sustainability of campus transportation. (Lemos, Balassiano, Santos, & Portugal, 2006; Rasool & Mukherjee, 2014)

Regarding the indirect consequences, sustainability has been under intensive study from scientists and academics, thus its application could not be missing from academia. The first time that sustainability was referenced within the academic community was in 1972, known as Stockholm Declaration (UNESCO, 1972). Since then, a 'snowball effect" of different similar declarations had started all over the world (i.e. Talloires Declaration, Halifax Declaration, Swansea Declaration) (UNESCO, 1990; UNESCO, 1991; UNESCO, 1993). During this initiative, the concept of 'campus greening' was introduced. Its main goal was to achieve the promotion of sustainable activities within the academic community (United Nations Environment Programme, 2014). Consequently, the frame under which a university would be considered as sustainable was formed.

During this critical period of maturation, scientists attempted to approach the definition and identified the need for sustainability in universities. The common ground of these approaches is defined as the awareness of the environmental responsibility and promotion of minimization of the negative environmental, societal and economic effect of activities in the educational institutions (Cole, 2003; Piper, 2002; Velazquez, Munguia, Platt, & Taddei, 2006). Moreover, the need for 'campus greening' is emphasized in many articles (Barnes & Jerman, 2002; Bernheim, 2003; Corcoran, Calder, & Clugston, 2002; Cortese, 2005; Viebahn, 2002). It can be argued that the environmental impact of activities and operations that take place in universities are overlooked. However, studies prove that both the waste generation and the consumption of water, electricity and hydrocarbon are of significant importance and comparable to complex buildings (i.e. hospitals, mega hotels) (Alshuwaikhat & Abubakar, 2007). Thus, universities, nowadays, are expected to follow the same standards as the industry regarding the environmental criteria issued by the Environmental Protection Agency (Savely, Carson, & Delclos, 2007).

3.4 Sustainable Mobility and Parking in Universities' cases

One of the core problems that the TU Delft faces is related to the intensive use of vehicles is the parking problem. TU Delft case is not unique, since the parking problem can be considered universal and is met in other universities as well. Therefore, it is essential for this study to review and analyze the efforts of other universities to solve their parking shortage problem and sustainability issues. In this attempt, cases of other universities based on the two main concepts –Mobility and Sustainability- were identified and reviewed. Their synopsis is presented in Table 35 of Appendix A.

The majority of the papers discussing sustainability refer to initiatives in university campuses to achieve energy and water efficiency, enhance recycling and manage the waste generated from the universities' activities. However, transportation and commuting are also considered to be among the factors that can affect sustainability of a campus. Velazquez, Munguia, Platt and Taddei (2006) emphasize the importance of greening the transportation activities in the campus. What is more, Filho, Shiel, Paço and Brandhil (2015) also highlight the importance of implementing alternative transportation strategies. Green Transportation remains a core concept in the effort towards a sustainable campus (Koester, Eflin, & Vann, 2006) and Darus et al. (2009) discuss the reduction of the CO_2 emissions when universities' commuters switch to alternative ways of transport. One the other hand, expanding the green spaces and the diversity of the campus vegetation will enhance the sustainability from environmental aspect (Koester, Eflin, & Vann, 2006). All the above-mentioned, stress the importance of focusing on Green Transportation. Nevertheless, the methodology and strategies to achieve it in practical are not discussed in depth.

Studying the Mobility in campuses through different case studies in universities, the importance of Transportation Demand Management is identified. The most important strategies of the TDM are Information and Marketing, managing the Transport system, efficient use of the land and improving the Road Infrastructure (Lemos, Balassiano, Santos, & Portugal, 2006). According to the problem definition and the research objective, from all four strategies, managing the Transport system of the TU Delft campus is the focusing point. Eventually, reducing the use of car results in reducing the parking demand as well. Balsas (2003) argues that using TDM strategies, a modal shift from vehicles to bicycle and walking can be achieved. Therefore, managing the transportation system of a campus can be done in a way that will have positive results from the sustainability perspective. This can be achieved through the introduction of a variety of mobility policies such as car-sharing, carpooling, mass transit, use of alternative fuels and Park & Ride (Balsas, 2003; Banister & Stead, 2004; dell'Olio, Bordagaray, Barredaa, & Ibeasa, 2014). Moreover, Rasool and Mukherjee (2014) discuss ways to reduce the motorized vehicles in the campus by introducing parking fees or relocating the parking areas in its periphery. Concluding, the most important for this assignment TDM strategy, is the one that focuses on decreasing the intensive use of the car.

In a case study of Eindhoven University of Technology, Waerden, Borgers and Timmermans (2006) investigate the attributes and behavior of the car users through an on-street questionnaire. The results of this survey give an insight of the commuters' preferences regarding future parking measures (parking fee introduction and restricted access to non-university car drivers) (Van der Waerden, Borgers, & Timmermans, 2006). Similarly, in the case of Beijing University of Aeronautics and Astronautics, Shang, Lin and Huang (2007) use an observation method to analyze the occupancy rate and conclude to a model that describes the vehicle users' behavior. Tembhurkar and Khobragade (2015) move one-step further the modeling the commuters' parking behavior by developing a model, which assists in forecasting the future parking demand. Taking as granted, the increase of TU Delft's population the recent years, modeling the current parking behavior is not sufficient and forecasting techniques should be implemented to build an efficient model for future use.

In the case of Minnesota State University, Filipovitch and Boamah (2016) attempt through a series of parking occupancy survey to model the parking behavior and identify the optimum parking price level. One of the underlying risks when applying such parking policies is to fail to achieve a balance between the supply and demand of parking. In other words, there is always the possibility when increasing the price level that the decrease in demand will be high enough not to cover the maintenance costs (Filipovitch & Boamah, 2016). Within this research for the case of the TU Delft, this risk is taken in consideration, even though, with the current policy, parking in the campus area is free of charge and the university is burdened with the maintenance costs.

Finally, one of the goals of modeling the parking behavior of the TU Delft is by introducing TDM strategies to reduce the parking demand and develop a sustainable campus. In a similar case in the University of Coimbra, in an effort to reduce the parking demand in the campus, the reduction of the Greenhouse gas emissions is calculated using 6 different scenarios (Ferreira, Freire, Cruz, & Barata, 2012). What is more, another sustainable solution is examined in Clemson University campus by relocating the parking spaces from the central area to the periphery (Fries, Dunning, & Chowdhury, 2009). The same solution is also examined by the Administration of the TU Delft and can result in actions such as improving the aesthetics of the campus, extension of green spaces and reforestation of the campus as proposed in similar cases (Filho, Shiel, Paço, & Brandli, 2015; Koester, Eflin, & Vann, 2006; Rasool & Mukherjee, 2014).

3.5 Conclusion

After having reviewed all the aforementioned cases, the following conclusions were made. First, scientific reports –with exception of some- discard the current parking demand and supply and focus only on the identification of the commuters' behavior (first part of research sub-question a). Second, even researchers have attempted to build models that forecast the future parking demand; they discard the possible increase of the population, which commutes to a specific area. For instance, the population of the TU Delft has been increased since the last years and consequently the commuters who travel by car. Therefore, this important aspect, the increasing number of commuters, should be taken into consideration (second part of research sub-question a). Third, it was observed that each case was uniquely confronted. Thus, in order to identify the effect of the PDM strategies on parking demand of the TU Delft (research sub-question c) the relevant PDM strategies and their variables should be identified (research sub-question b). Furthermore, the practical problem of the parking demand of the TU Delft can be sustainably confronted by combining the findings of the overall sub-questions (research sub-question d). Finally, a framework that comprises the aforementioned tasks will not only assist for the purpose of this study but also when applying it on other settings (research sub-question e).

Chapter 4 Observation of the Parking Occupation in the TU Delft campus

4.1 Introduction

Observing the parking occupation of an area constitutes the most critical part of Transportation reports. Usually, occupation data are collected by firms that specialize in traffic data. In the present study, an attempt to collect data in a traditional way is done. In the following chapter, the methodology used to realize the observation and its results are discussed (Figure 7). Finally, an attempt to forecast the Parking Demand for the next five years is made.

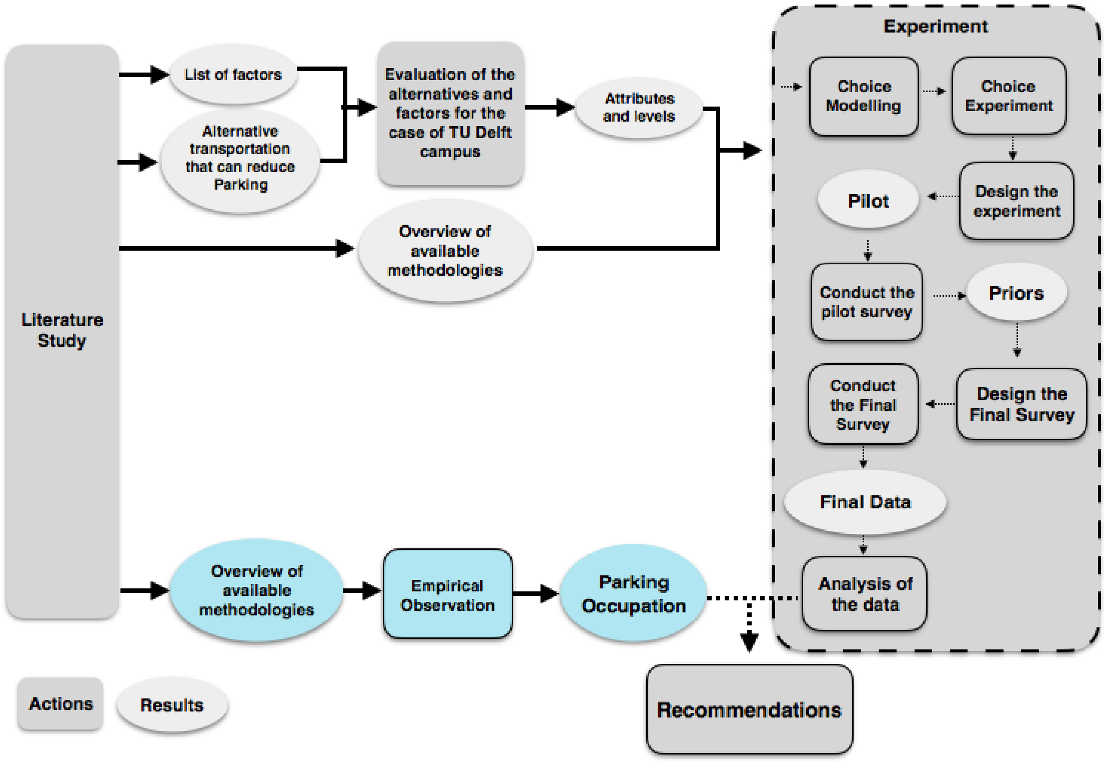


Figure 7 Methodology Map-Empirical Observation

4.2 Set up

There is a wide variety of methods to acquire the occupation of parking areas. According to the existing literature there are two ways to gather the data. On one hand, data can be gathered through a parking sensor (AlGhwiri, 2014), which creates the most accurate model. Nevertheless, the high cost of the sensors and the fact that the campus parking spaces are open (without an entrance/exit) and dispersed in different locations constitute their application difficult. On the other hand, on field observation can be used in order to identify commuters' behavior in absolute numbers (Riggs, 2014).

The on field observations took place during the busiest days of the week, targeting to capture the maximum Parking Demand in the campus. According to the report of Spark consultants, the busiest days in terms of car usage are Tuesdays and Thursdays (Jager & Hove, 2014). Thus, the observations were decided to take place on these days (17th, 19th, 23rd, 26th of May) for specific timeslots (9:00-11:00, 11:00-13:00, 13:00-15:00, 15:00-17:00, 18:30-19:30, 23:00-00:00).

In order to have a better perception of the available parking supply, the campus of the TU Delft has been investigated and all the available parking areas were identified. While conducting this investigation, the available parking lots –otherwise known as parking supply- were counted. Each full round of a campus observation took approximately three hours, thus, observing all the parking areas in six different timeslots per day seemed impossible. Therefore, the parking areas were divided into two groups in a way that conducting six observations during a day would become feasible. The weather during the observation consisted of low temperatures (13-14 °C) with small chances of rain.

During the measurements, properly parked vehicles, illegally parked vehicles and obstacles such as containers and trailers were considered as parked vehicles. Worth mentioning is the fact that in some cases (e.g. 07. Voorterrein v/m Deltares) constructions took place, resulting in reduced available parking spaces.

4.3 Observation's Results

The observations, which took place in four different days, prove that there is actual parking shortage in specific parking areas. The results and their graphical representation can be seen in Appendix B. On the one hand, parking areas such as the parking lot of Aula/Library (03. Parkeerterrein Aula/Library) and the eastside of Architecture faculty (34. Bouwkunde Oostzijde) are found to be overloaded than the 'legal' supply. In Table 1 the observed number of cars during the day is presented, while Figure 8 shows the excess in Parking Demand for the two parking areas.

Table 1 Parking Occupation in the parking lot of Aula/Library and the eastside of Architecture faculty.

Parking Place	Date	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
Parkeerterrein Aula/Library	19/05/2016	296	243	**306**	**339**	275	57	24
	23/05/2016	296	241	**312**	**314**	273	59	19
Bouwkunde Oostzijde	17/05/2016	176	134	**212**	**253**	**195**	95	65
	26/05/2016	176	113	**187**	**196**	**194**	97	68

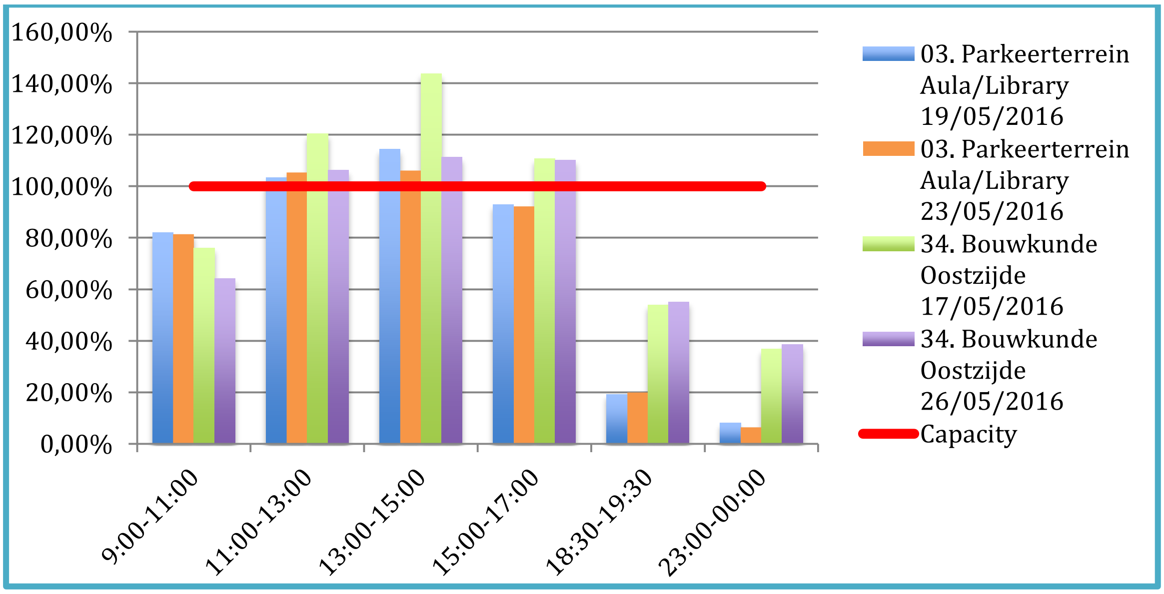


Figure 8 Percentage representation of the Parking Occupation in the parking lot of Aula/Library and the eastside of Architecture faculty.

On the other hand, parking areas such as Sports & Culture and Korvezeestraat can be characterized as less popular, since their maximum capacity is never met. Table 2, presents the number of cars parked, while Figure 9 the excess in Parking Supply in the two parking areas.

Table 2 Parking Occupation in the parking lot of Sports & Culture and Korvezeestraat.

Parking Place	Date	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
Sports & Culture	19/05/2016	324	193	270	290	293	56	16
	23/05/2016	324	182	268	264	114	43	12
Korvezeestraat	17/05/2016	158	91	101	138	117	73	70
	26/05/2016	158	88	107	115	111	67	72

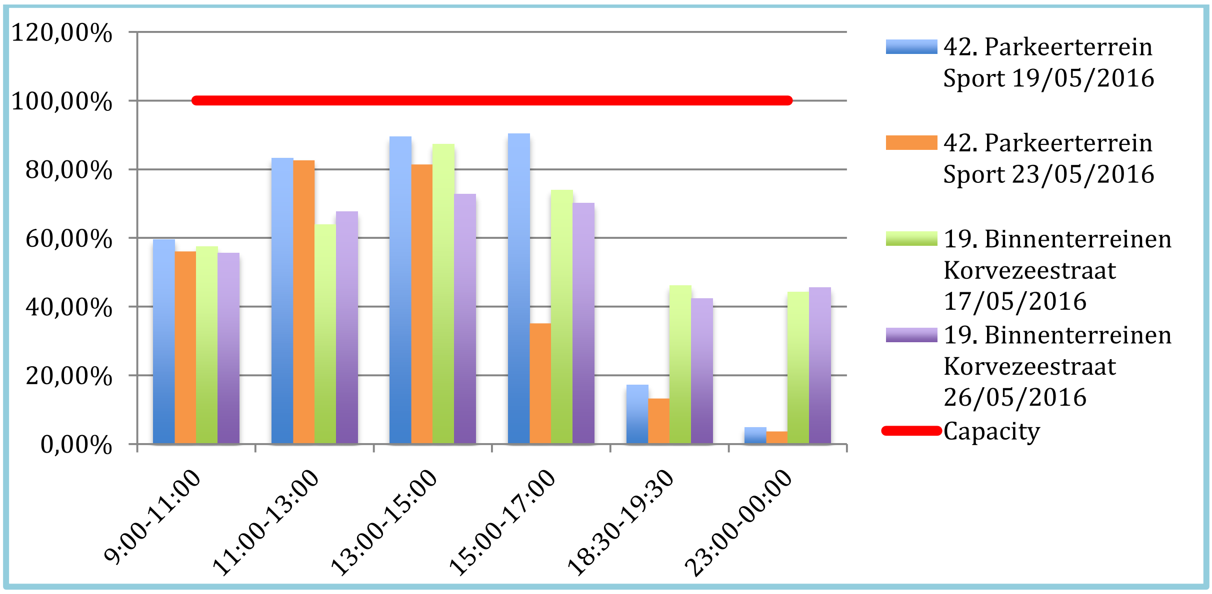


Figure 9 Percentage representation of the Parking Occupation in the parking lot of Sports and Korvezeestraat.

In Figure 10 the map of the TU Delft campus and the respective numbered parking areas can be seen. The parking areas that are stressed from a parking demand perspective are depicted in red color. More specifically, during peak hours, 38% of the parking areas are oversupplied. Furthermore, 68% of the parking areas exceeds the optimum occupation limit (85%), while only 32% of the parking areas are undersupplied.

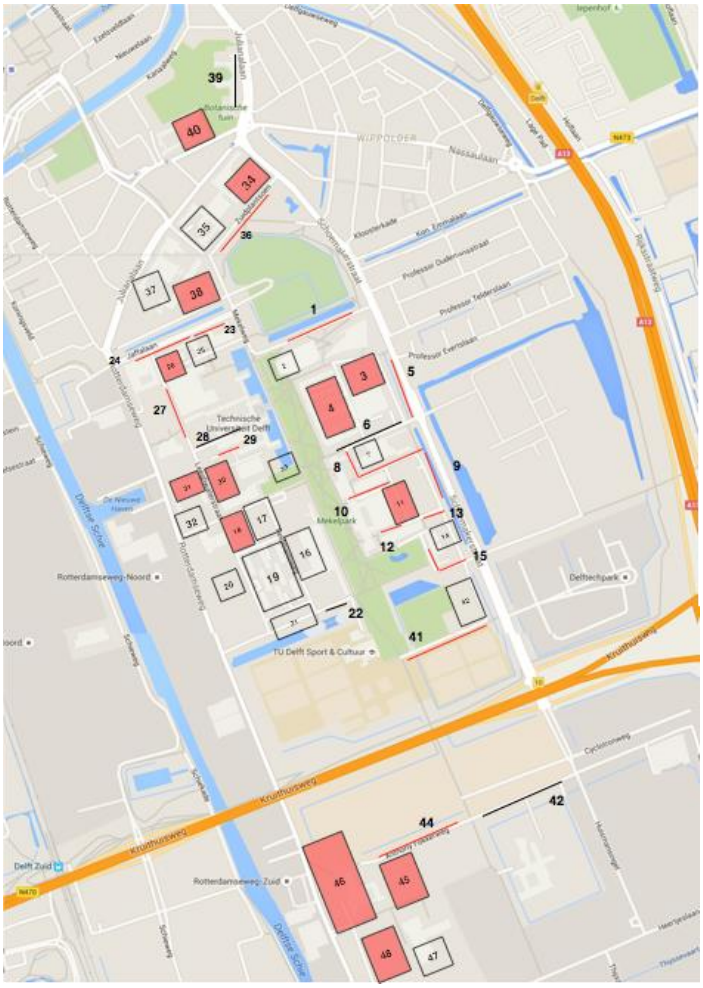


Figure 10 Map of the TU Delft campus. Source: (Google maps, 2016) Redesigned by the author.

4.4 Future Parking Occupation

As aforementioned, one of the aims of this research is to forecast the future parking demand. For this purpose, forecasting methods are employed. More specifically, cubic regression analysis and 'forecast by analogy' methods are used to forecast the future Parking Demand. Even thought there exist a wide variety of forecasting methods, the specific methods are chosen due to the availability of data that describe the size of prediction. The methodologies, as well as the mathematical description of the methods used, are described, followed by the results received after their application.

4.4.1 Forecast analogous time series

This method assumes that two different phenomena have the same behavior through time and they can be described by the same model or mathematical equation. In other words, when two subjects are related to each other, it is feasible to forecast the behavior of the one if their relation and the future behavior of the second are known. (Duncan, Gorr, & Szczypula, 2001)

4.4.2 Polynomial Regression analysis

Polynomial regression in statistics is considered a type regression, in which the relation between the independent variable (X) and the dependent variable (Y) is described with the use of a polynomial function (Bethea, Duran, & Boullion, 1995). The target of regression analysis is to model the expected value of Y in terms of the value of X. In general, the expected value of the dependent variable Y can be model as a n^{th} degree polynomial, which is described from Equation 1.

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + . . . + a_n x^n + \varepsilon \quad (1)$$

Equation 1 General form of polynomial regression model.

4.4.3 Set up

The lack of an available time series that describes the behavior of the Parking Demand in the past, leeds to an indirect method to forecast its future values. Practically, 'forecast by analogy' can be useful, in forecasting the future Parking Demand by forecasting another related time series first. It is known that Parking Demand is related to the population of the close area and consequently its commuters (Stienstra, 2014). Therefore, estimating the increase of the TU Delft population in the future can be sufficient to provide the future Parking Demand through analogy. In simple words, the cubic regression is used to forecast the future population of the TU Delft and then, through analogy the future Parking Demand is derived.

Prerequisite of applying the regression forecasting method is to gather the related data of the time series of the population of Students and Employees of the TU Delft though the time. The data are acquired from the annual report 'Facts & Figures' published by the TU Delft (TU Delft, department Communication, 2015). In Figure 11 and 12 the two time-series, their forecasts and their polynomial equations are presented.

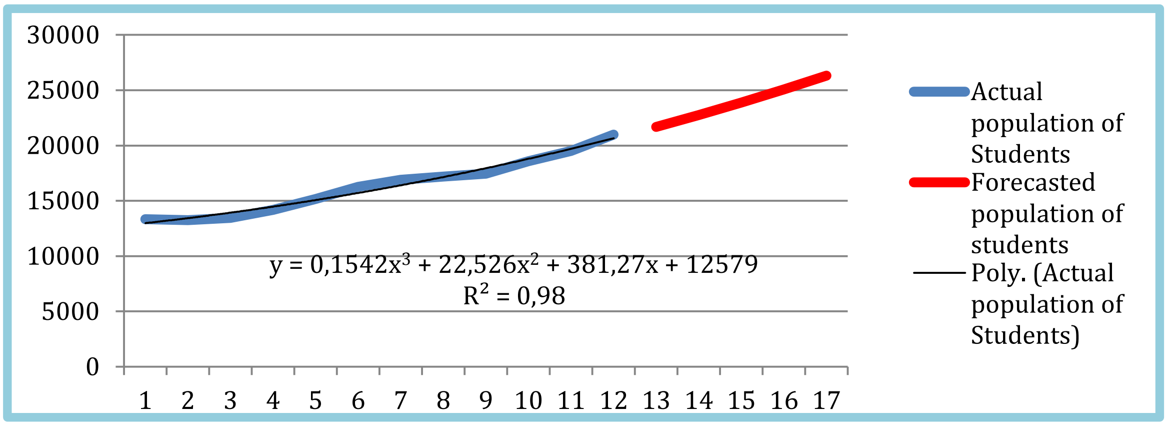


Figure 11 Forecasts of the students' population for the next five years.

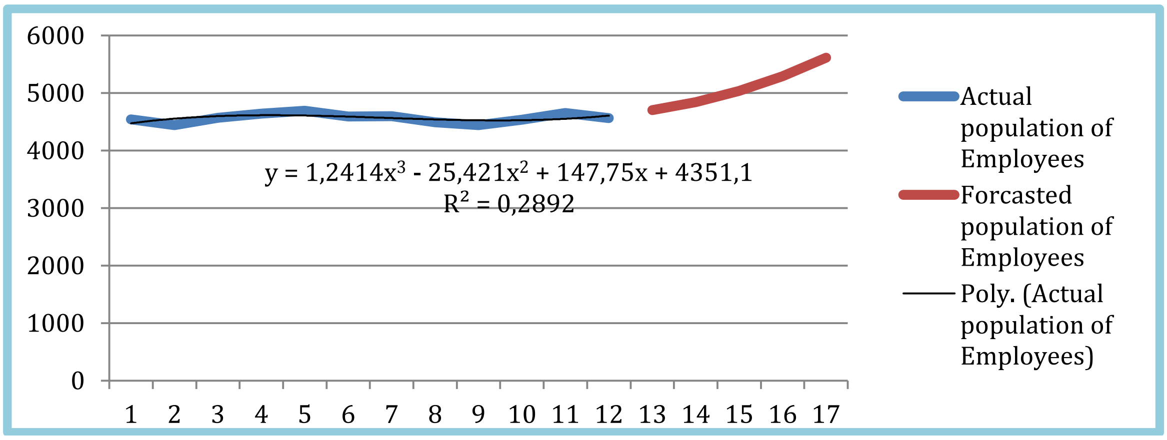


Figure 12 Forecasts of the employees' population for the next five years.

Concluding, the population of the TU Delft is expected to increase to 31942 in the following 5 years. Consequently, if there is not any action taken regarding the Parking Policy of the campus, the Parking Demand will increase accordingly. In Table 3 the forecasting of the two analogous time series –total population of the TU Delft and Parking Demand- is presented. The percentage of the employees who commute by car is assumed 32% according to Maat and Heinen (2010) report, while the same ratio concerning students is respectively assumed 10%.

Table 3 Forecasts of the Parking Demand using the forecasts of the TU Delft population.

Academic Year	TU Delft population*	Parking Demand	P.D. increase from current level (%)
2015-16	25546	3263	-
2016-17	*26384*	3673	12,57
2017-18	*27598*	3825	17,22
2018-19	*28924*	4001	22,62
2019-20	*30369*	4201	28,75
2020-21	*31943*	4430	35,76

***as TU Delft population the sum of Students and Employees was considered**

According to the forecasts, Parking Demand is expected to rise up to 4430, which is 660 parking spaces more than the current Parking Supply (3770 parking spaces) estimated from the observation that took place.

4.5 Conclusion

In this chapter the process of the parking occupancy and its analysis were discussed. Observing the parking occupancy in the campus of the TU Delft constitutes a core concept that is useful for the final recommendation of this thesis. Knowing the current Parking Supply and Demand assists in the identification of the appropriate policies that should be applied in the future. To conclude, the Parking Supply (3770 parking spaces) can be considered sufficient for the current demand (3263 parking spaces). According to literature the ratio of Parking Demand to Supply during peak hours should range around 85% (Shoup, 2006). For the case of the TU Delft campus this ratio during peak hours is estimated to be 86,5%, which –according to literature- is an acceptable level. However, according to the observations, the distribution of the volume of the parking demand differs from the distribution of the parking supply. Consequently, parking areas with less than 85% of occupancy and parking areas exceeding the parking supply are observed. Finally, regarding the future parking demand, the forecasting realized in section 5.4 (117,5% parking demand in 2020) dictates the immediate of solution of the future parking shortage. Therefore, if the aggregate issue of the increasing parking demand is considered, its recommended reduction is presented in Table 4.

Table 4 Ratio of Parking Demand to Parking Supply and Recommended reduction for the next five years.

Academic Year	$\frac{\textit{Parking Demand}}{\textit{Parking Supply}}$	Recommended reduction
2015-16	86,5%	1,50%
2016-17	97,42%	12,42%
2017-18	101,45%	16,45%
2018-19	106,12%	21,12%
2019-20	111,43%	26,43%
2020-21	117,50%	32,50%

Chapter 5 Parking Demand Management and relevant variables for the TU Delft context

5.1 Introduction

This chapter constitutes an attempt to identify the existing parking demand strategies and analyze their relevance with the TU Delft context. What is more, the relevant for the model variables are discussed. The choice of the appropriate variables -otherwise known, as attributes- as well their relevant levels are explained. Through the process that is depicted in Figure 13 with blue color, an answer to the second research sub question *('Which parking management strategies and variables are relevant for managing the parking demand of the TU Delft campus and should be included in the model?')* is provided.

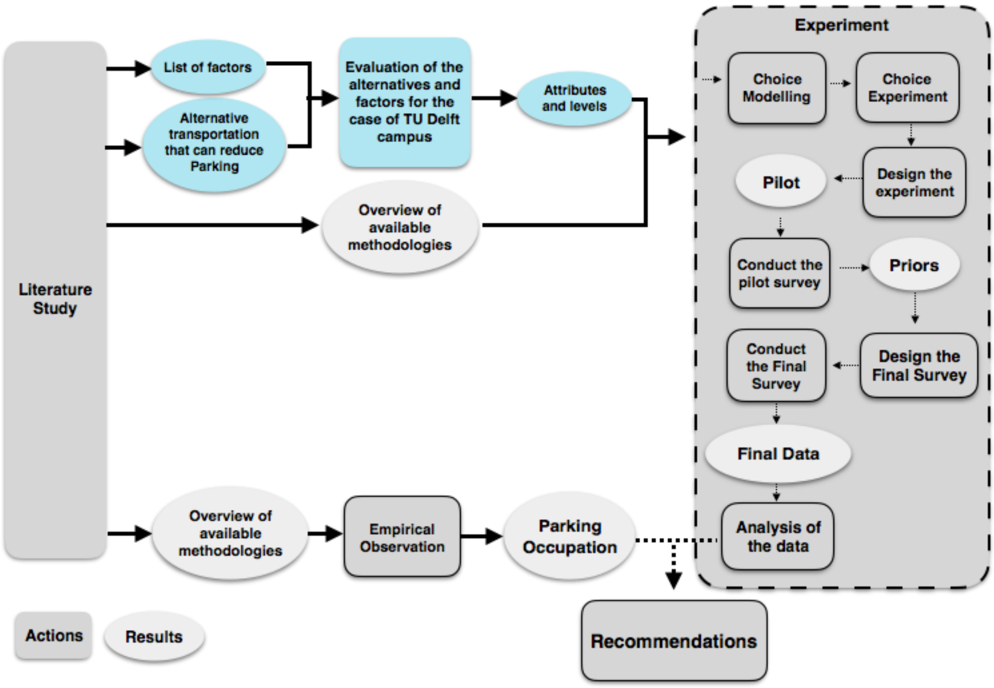


Figure 13 Methodology Map- Relevant Attributes and levels.

5.2 Parking Demand Strategies

In a previous chapter the importance of Travel Demand Management (TDM) has been stressed. In this section, an overview of the possible tools or policies to achieve an effective Parking Demand Management is given. An effective PDM strategy should combine restraints, as well as, incentives (push and pull measures). In Table 5, some of the measures that are analyzed are presented.

Table 5 (Despacio and Institute for Transportation and Development Policy (ITDP), 2013)

Push measures	Pull measures
Pricing policy	Improve public transportation
Parking Supply Management	Bicycle and pedestrian infrastructure
Parking Regulation	Park & Ride permits
Improve Enforcement and Control	Carpooling permits
	Vanpooling
	Improve User Information and Marketing
	Teleworking
	Financial Incentives (Parking cash-out)

Parking **pricing policy** is considered a sensitive topic, since it affects the most car commuters (Hess & Polak, 2004; Van der Waerden, Borgers, & Timmermans, 2006; Washbrook, Haider, & Jaccard, 2006; Weis, Vrtic, Widmer, & Axhausen, 2011). In general, the introduction or a change of a pricing mechanism should be realized after careful consideration and study. In fact, the optimum parking price should be defined from the desired level of parking demand, as well as, the existing supply. There exist a wide variety of theories and formulas in the literature that define the relation between the optimum parking demand and parking fee; the predominant sets the optimum parking fee, when parking demand ranges approximately in 85% of the total parking demand (Shoup, 2006). In Figure 14, the relation between parking demand and parking fee is presented, as well as the optimal parking demand according to Shoup (2006).

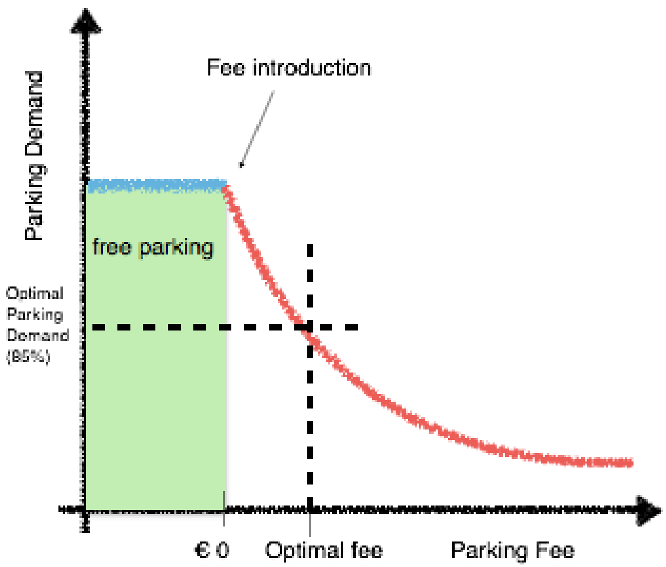


Figure 14 Relation between Parking Demand and Parking Fee (Shoup, 2006). Source: designed by the author.

Managing the supply of the parking is considered another important PDM tool, since it can affect both ways, negatively and positively, the total supply. On the one hand, due to sustainability reasons, the decision makers are willing to decrease the parking areas. On the other hand, there exist several ways to increase the parking capacity if necessary. By using angled instead of parallel on-street parking, reducing parking space size, using wasted space (corners, non-exploitable land, etc.) and removing abandoned non-operating cars, parking supply can be increased (Litman, Parking Management: Strategies, Evaluation and Planning, 2006).

Another related to Parking Demand TDM tool is linked to **parking regulation**. It is considered to be a method to control who, where and for how long each "type" of vehicle is allowed to park in a specific area. For instance, delivery and transit vehicles are distinguished from the regular; the same also applies for commuters with disabilities. Furthermore, special permits also can be given to employees, residents and carpoolers. Finally, time regulation is an important aspect as well; 10-30% of the parking supply should be intended for short-stay use. (Litman, 2006)

A type of remote parking, **Park & Ride**, is considered a sustainable way to manage Parking Demand. Parking in remote areas is usually free or appreciably inexpensive than those in busy locations. However, this option requires sufficient information regarding their availability in parking spaces and transit facilities to the close urban areas. (Litman, 2006)

Carpooling is considered to be a sustainable and economical way to travel, especially when is incentivized with less expensive and privileged parking permits. Two, or three commuters travel together and share travelling costs while searching time is reduced when special parking permits are available. In a larger scale, **vanpool** allows larger groups to share ride and experience respective to carpoolers' benefits. (Despacio and Institute for Transportation and Development Policy (ITDP), 2013)

Improving the **bicycle and pedestrian infrastructures** enhances the use of remote and sharing parking. Walkability and 'bikeability' is measured in terms of safety and distance to be travelled.

Concluding all the above-mentioned Parking Demand Management strategies, Table 36 (Appendix A) is reviewed again aiming to identify which of them are used in similar studies. The result of this process is summarized in Table 6.

Table 6 Parking Demand Management used in similar studies.

Parking Demand Incentive	Reference
Choice of parking	(Hilvert, Toledo, & Bekhor, 2012) (Axhausen & Polak, 1991) (Hess & Polak, 2004) (Teknomo & Hokao, 1997) (Karki, 2015) (Hess & Polak, 2009) (Golias, Yannis, & Harvatis, 2001)
Car-sharing	(Catalano, Casto, & Migliore, 2008)
Carpooling	(Catalano, Casto, & Migliore, 2008) (Washbrook, Haider, & Jaccard, 2006)
Public Transport	(Catalano, Casto, & Migliore, 2008)
Transit	(Washbrook, Haider, & Jaccard, 2006)
Park & Ride	(Bos & Molin, 2006) (Yang, Choudhury, Ben-Akiva, Silva, & Carvalho, 2009)
Shared Taxi	(Yang, Choudhury, Ben-Akiva, Silva, & Carvalho, 2009)
Express minibus	(Yang, Choudhury, Ben-Akiva, Silva, & Carvalho, 2009)

As it can be noticed, the majority of the literature is dealing with the choice of the parking (Axhausen & Polak, 1991; Golias, Yannis, & Harvatis, 2001; Hess & Polak, 2004; Hess & Polak, 2009; Hilvert, Toledo, & Bekhor, 2012; Karki, 2015; Balsas, 2003; Axhausen & Polak, 1991) while a few are dealing with alternative means of transport that reduce Parking Demand. Catalano et al. (2008) study Carsharing, Carpooling and Public Transport, while Washbrook et al. (2006) consider Carpooling and Transit as alternatives in their choice experiment.

The choice of the alternatives that are examined in the present research is made on the basis of the maximum decrease of Parking Demand for the context of the TU Delft and the characteristics of the choice experiment. Taking in account that the experiment takes place on the parking areas, a maximum of three alternatives (the basic alternative is Driving Alone) are considered as limit. What is more, since the focusing point is alternatives that include use of parking facilities, public transport, transit, and shared taxi are excluded. Even, express minibus from the Delft Station is considered public transport; the option of using a minibus to commute in the area of the university is examined as well. Carsharing, is not considered an alternative, which can reduce the Parking Demand at the TU Delft; regardless who owns the car, the result is one more parked car in the campus. Therefore, the final choices for the alternatives of the choice experiment are Carpooling and Park & Ride.

5.3 Selection of Variables

As far as the second part of the research question is concerned, an overview of the variables-attributes used in similar studies is given. Afterwards, an argumentation for the choice of the variables that are used in the choice experiment follows. During the literature review, many attributes are identified. A summary of the attributes mentioned in Table 36 (Appendix A) is presented in Table 7.

Table 7 Attributes found in literature

Revealed Preference Attributes	Stated Preference Attributes
Trip Origin	Parking duration
Destination and purpose	Parking type
Parking searching time	**Parking price**
Walking time to destination	**Searching/Waiting time**
Parking costs	**Walking/Egress time**
Parking duration	Time of travel
Trip frequency	Access time
Age	In vehicle travel time
Sex	Road charge
Number of cars owned	**Time spending picking up other carpoolers**
Member of family who travel every day	Bus travel time
Income	Waiting time
Mode of transport	Refund
Distance of the trip/travelling time	Safety of Parking
Household size	Fine for illegal Parking
Education level	
Transit pass	

As far as the revealed preferences attributes are concerned, only five of the abovementioned are chosen as the most suitable for the context of this research and due to survey's length constrains. Parking searching time, walking time to the final destination, parking costs, parking duration and trip frequency are included in the revealed preferences questions of the survey.

Regarding the Stated preference attributes the four most critical and often met in the literature are the parking price, searching time, walking /egress time and –since carpooling is an alternative- time spent to pick up other carpoolers.

5.4 Conclusion

Concluding all the aforementioned, the alternatives that may decrease the Parking Demand at the TU Delft campus and were chosen for the Stated Choice Experiment are the Carpooling and the Park & Ride strategies. These two were found the most suitable for the context of the TU Delft case, and including the dominant way of travelling "Drive Alone" will constitute the three main alternatives of the choice experiment. Finally, four relevant to the alternatives attributes were chosen for the Stated Preference part, as well as five attributes for the revealed preferences part. In Figure 15 a conceptual model of the chosen alternatives and attributes is presented.

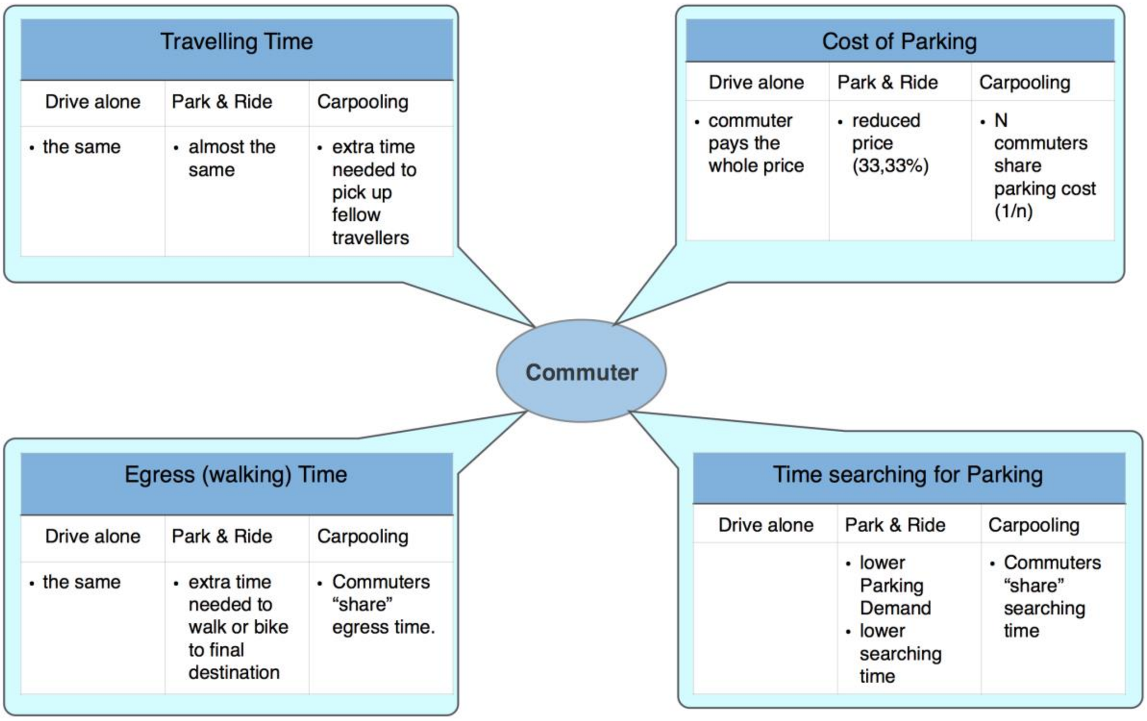


Figure 15 Conceptual model of the alternatives and attributes.

Chapter 6 Designing the Stated Choice Experiment

6.1 Introduction

The present chapter focuses on the type of experimental research, which was employed to reach the primary goal of this thesis. Firstly, the advantages of using such research methods are explained and a theoretical background is given concerning the two different designs of Stated Choice Experiments. On the basis of the method, which was used to analyze the collected data, the two models, Multinomial Logit (MNL) and Mixed Multinomial Logit (MMNL) are presented. Finally, the steps that are followed to set up and conduct the pilot and the final survey are described. In Figure 16 a schematic representation of the methodology followed during the Experiment is presented.

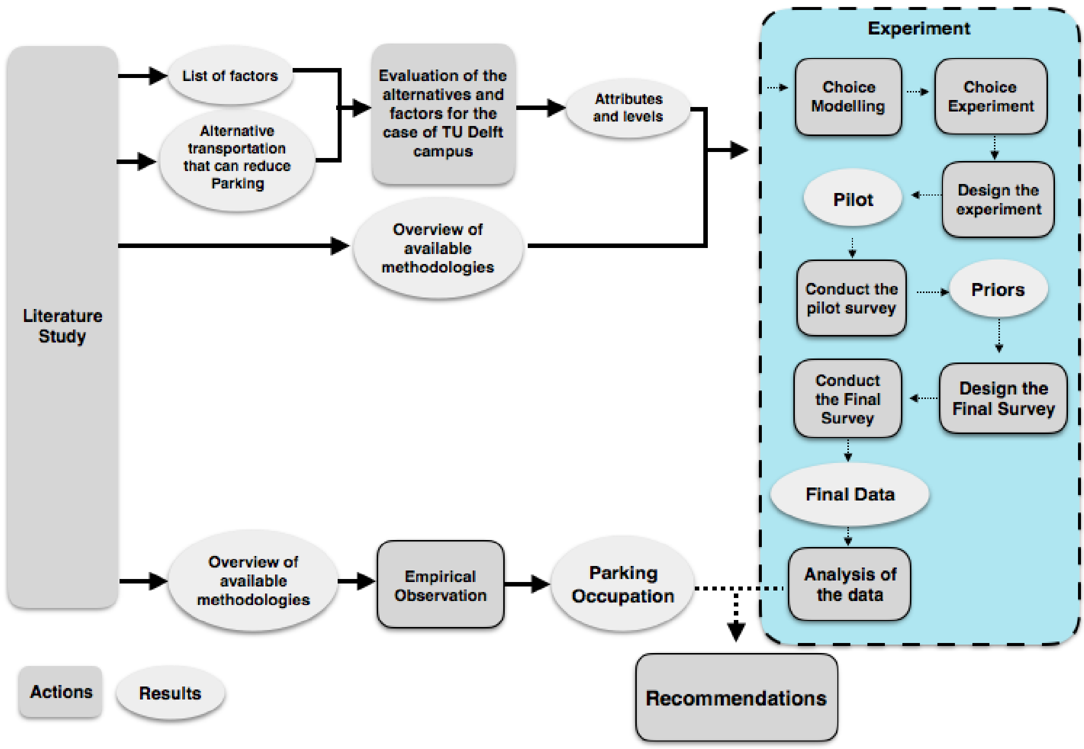


Figure 16 Methodology Map-Experiment.

6.2 Experimental Designs

In general, experimental research methods can be characterized as beneficial since the unconstrained control of the variables involved, assist the determination of the cause and effect (Odle & Mayer, 2009). What is more, the high level of control they provide in combination with the large volume of data collected and ability to analyze them in depth, increase the external and internal validity (Bordens & Abbott, 2002). For the sake of this study, two of the most prevalent types of experimental designs are used; the full factorial design and the fractional factorial design.

6.2.1 Full Factorial Design

The main characteristic of factorial designs is the fact that every level of the involved attributes is combined with all the levels of the remaining attributes. In other words, it is a complete enumeration of all possible combinations of the all the levels, which is often called "full factorial". The core advantage of these designs is that they result to truly independent attribute effects. However, the possible combinations of the attributes levels are increasing, while new attributes are introduced. The number of combinations is given by Equation 2.

$$S^f = \prod_{k=1}^{K} l_k \tag{2}$$

Equation 2 Formula to estimate the number of combinations of a full factorial design.

Accordingly, the full factorial design (4 attributes, 3 levels each) of this study is (3x3x3x3=) 81. This number of combinations creates difficulties during the survey process, since it is considered long survey for a single participant. As a result, full factorial designs are suitable mainly for experiments that include small number of attributes and level. Another, approach to limit the number of the questions to be asked is to create a subset of choices from the full factorial design. The design that derives from the process of limiting the choices of a full factorial design is called fractional factorial design and is discussed in the next subsection. (Louviere, Hensher, & Swait, 2000)

6.2.2 Fractional Factorial Design

As aforementioned, the approach to decrease the number of choice sets when designing an experiment results to a fractional factorial design. Fractional factorial designs reduce the number of combinations by selecting a specific subset, which can maintain the ability to provide efficient analysis of specific effects. Nevertheless, fractional factorial designs do not possess the statistical advantages of the full factorial designs due to the fact that they always lose statistical information. Theorists have developed a wide variety of methods to deal with the samples in order to minimize this loss of statistical information. Two of them, the orthogonal and the efficient design, are used to construct the pilot and the final survey respectively; thus, they are described in the following subsections. (Louviere, Hensher, & Swait, 2000)

6.2.2.1 Orthogonal Design

By the term orthogonal design the attribute level balance is implied. The popularity of the orthogonal designs lies behind two reasons. Firstly, construction of orthogonal designs is characterized as simple task, especially with the assistance of a software package. Secondly, the existence of orthogonality in a design guarantees the absence of multicollinearity and minimizes the variance of each estimated parameter. Finally, orthogonality is hard to be kept during the analysis phase of the data set, even if the design was orthogonal. For instance, in case of a blocked orthogonal design orthogonality might disappear if the blocks are not equally distributed. (ChoiceMetrics, 2014)

6.2.2.2 Efficient Design

In contradiction to orthogonal designs, the target of efficient design is not to minimize the correlation between the variables but to accurately estimate the parameters. In other words, efficient is called a design, which assists the researcher to estimate the critical parameters with the least achievable standard error (SE). The most critical part of this estimation is the AVC matrix, prerequisite of which to be calculated is the availability of the parameters' values. Nevertheless, since the Stated Choice experiments' purpose is to estimate these parameters, an approximate prior knowledge of them is needed. This prior knowledge can be derived from the relevant literature or from a pilot experiment. (ChoiceMetrics, 2014)

As aforementioned, AVC matrix is the key factor, which determines the efficiency of a design. Examining the whole matrix can be challenging and time consuming. For this reason, it is common to assess the design in respect to one specific value and strain to minimize its error. The most widely used error is the D-error, which generates the so-called D-efficient design. It is based on determinant of the AVC matrix and takes into account both variance and covariance. On the contrary A-error generates an A-efficient design, which is based on the trace of the AVC matrix. Its difference with the D-error is that it takes into consideration only the standard errors and disregards the covariates between the attributes. Finally, S-efficient designs are used when the study requires the minimization of a specific parameter's standard error in order to achieve its significance.

6.2.2.3 Orthogonal VS Efficient Designs

Taking into consideration the analysis of the available designs, an effort to give a comparison between them is made. On the one hand, orthogonal designs follow the traditional method, avoid multicollinearity between the parameters and generate sufficiently good results. However, a large number of participants is needed to achieve significance of the parameters. On the other hand, different efficient designs can be employed to approach different statistical targets. D-efficient design is used to increase the overall reliability, while S-efficient design increases the reliability of only one of the parameter. Finally, although the A-efficient design ignores the covariates between the parameters, it is proved to be useful when the minimization of the Standard Error is required. The aforementioned characteristics of each design are summarized in Table 8.

Table 8 Orthogonal VS Efficient Designs. (Molin, 2016)

Design	Based on…	Focus on…	Used when…
Orthogonal		Annihilating Multicollinearity and minimizing the variance of the parameters	Uncorrelated parameters is the target
D-efficient	Determinant of the AVC matrix	Variance and Covariance	Increasing the overall reliability is the target
A-efficient	Trace of the AVC matrix	Standard Error and ignores the covariates	Minimizing Standard Error is the target
S-efficient	Determinant of the AVC matrix	Minimizing Standard Error of the hardest to reach significance parameter	The reliability of the 'most difficult' parameter is needed to be increased

In the present research, a D-efficient design is used in the final Stated Choice Experiment, since an overall reliability of the parameters is the target. Nevertheless, D-efficient design required priors and this is overcome with the assistance of a pilot survey.

6.3 Discrete Choice Models

For the analysis of the collected data Discrete Choice Models are employed. In the following section two of the most popular discrete choice models are presented and their differences are outlined. Preceding the models' description, the concept of Utility specification is explained.

6.3.1 Utility

For analyzing the data gathered from the Stated Preference Survey a Discrete Choice Analysis will be used. Discrete choice models are usually based on the utility-maximization of the respondents. In other words, the respondents will reveal their preference by choosing the alternative, which maximizes their own utility (MacDonald, Anderson, & Verma, 2012).

Let U_{nsi} express the utility of alternative i, which is chosen by respondent n, in choice situation s. Utility U_{nsi} can be subdivided in three factors; the observed factor, V_{nsi} and two unobserved factors, n_{nsi}, and ε_{nsi}. The mathematical representation of the Utility can be found in Equation 3.

$$U_{nsi} = V_{nsi} + n_{nsi} + \varepsilon_{nsi} \quad (3)$$

Equation 3 Mathematical representation of Utility

The observed factor of utility, V_{nsi}, is considered to represent a linear relationship between the observed level of attribute, x, and its corresponding parameter, β.

6.3.1 Multinomial Logit Model

According to literature, the most commonly used model to analyze the data is the Multinomial Logit model (MNL) (Kropko, 2008). In the Multinomial Logit model, the utility can be represented according to Equation 4.

$$V_{nsi} = \sum_{k=1}^{k} \beta_{ik} * x_{nsik} \quad (4)$$

Equation 4 Mathematical representation of the utility in the MNL model.

If the marginal utilities are assumed to be fixed for a population and $n_{nsi} = 0$, then Equation 3 is transformed to Equation 5. Therefore, the probability (P_{nsi}) of the participant n to choose the alternative *i* in choice situation *s* is given by Equation 6.

$$U_{nsi} = V_{nsi} + \varepsilon_{nsi} \quad (5)$$

Equation 5 Utility function under the assumption that $n_{nsi} = 0$

$$P_{nsi} = \frac{\exp(V_{nsi})}{\sum_{m \in i_{ns}} \exp(V_{nsi})} \quad (6)$$

Equation 6 Probability of the participant n to choose the alternative i in choice situation s.

Since the Stated Preference Survey includes three alternative scenarios (Driving along, Carpooling, Park & Ride) it is described by three different utility functions ($U_{Drive\text{-}Alone}$, $U_{carpooling}$, $U_{Park\&Ride}$), whose parameters are defined during the analysis of the survey. Equations 7, 8 and 9, give the utility functions of the three alternatives.

$$U_{Drive\_alone} = \beta_{SearchingTime} * T_{searchingtime_{DA}} + \beta_{Egresstime} * T_{Egresstime_{DA}} + \beta_{ParkingCost} * C_{ParkingCost\_DA} \quad (7)$$

Equation 7 Utility function for the alternative Drive Alone.

$$U_{Park\&Ride} = \beta_1 + \beta_{Egresstime} * T_{Egresstime\_P\&R} + \beta_{ParkingCost} * C_{ParkingCost\_P\&R} \quad (8)$$

Equation 8 Utility function for the alternative Park & Ride.

$$U_{Carpooling} = \beta_2 + \beta_{ExtraTraveltTime} * T_{ExtraTravelTime_C} + \beta_{SearchingTime} * T_{searchingtime_C} + \beta_{Egresstime} * T_{Egresstime_C} + \beta_{ParkingCost} * C_{ParkingCost\_C} \quad (9)$$

Equation 9 Utility function for the alternative Carpooling.

Where,

$\beta_{ExtraTraveltTime}$: beta parameter for extra travelling time
$\beta_{SearchingTime}$: beta parameter for searching time
$\beta_{Egresstime}$: beta parameter for egress (walking) time
$\beta_{ParkingCost}$: beta parameter for parking cost
β_1: Alternative Specific Constant for Park & Ride
β_2: Alternative Specific Constant for Carpooling

In Table 9 the main parking alternatives and their chosen attributes are presented. More specifically, it can be noticed that the attribute ‘parking cost’ has three levels. The existence of three levels assists the examination of quadratic effect of each attribute in the final model. In general, the more attributes and levels are introduced the more complicated the model becomes. However, due to the nature of the on-street survey, the participants should be able to answer it in a short period of time. Thus, an effort is made to keep the survey’s complexity in low level.

Table 9 Attributes and levels chosen for the Choice Experiment

	Alternatives		
Attributes/factors	Driving Alone	Park & Ride	Carpooling
Additional Travelling time by car (mins)	-	-	+10/+15/+20
Searching time (mins)	4/6/8	-	0/2/4
Egress time (time walking from parking to office)	4/8/12	0/4/8	0/4/8
Cost of Parking (€/day)	3/6/9	2/4/6/	1/2/3

What is more, assumptions are made in order to choose the values of the levels. First, regarding searching time, Park & Ride is not affected from this factor, since it is considered that there is always excess of parking supply in the remote parking areas. In the same concept, carpooling commuter faces less time to search for parking, since he or she do not use his/her car in each travel. What is more, special parking permits for carpooler can reduce the time searching for a parking spot. Second, regarding egress time, Commuters using Park & Ride choice face more walking time. Minibuses in the area of the campus can be used to decrease the egress time of the Park & Ride. Finally, regarding the costs, commuters that will use more sustainable ways of travelling have reduced parking costs, compared to Drive Along alternative.

6.3.2 Mixed Logit Model

Even MNL models are preferred for their simplicity and their quite accurate results; they fail to capture the repeating nature of a single respondent’s successive choices (Hess & Daly, 2010). What is more, in some situations it is possible that two or more alternatives correlate in the non-deterministic part of the utility function. As a result, this phenomenon can lead to unrealistic error distributions and incorrect modeling (Chorus, 2016). To overcome this obstacle, Mixed Logit Models can be employed during the analysis phase. To apply this theory in the present case, the MNL model is unable to capture the correlation between factors of the alternatives means of transport, Park & Ride and Carpooling. In other words the covariance between the non-deterministic components of the utility function can be different than zero (Equation 10).

$$Cov(\varepsilon_{ni}, \varepsilon_{nj}) \neq 0 \tag{10}$$

Equation 10 Non-deterministic components different than zero

Thus, the assumption that the errors of the two alternatives are independent can lead to a biased result. In order to deal with this, an extra error factor is included in the MMNL model; thus, it can be considered as an expanded version of the MNL model.

6.4 Design of the Experiments

Prior to the final survey, a pilot survey is conducted, which constitutes a paramount way of testing and receiving feedback on its design, structure, length and conceivability. The pilot survey consists of two parts, the revealed preferences (RP) and the stated choice experiment, otherwise known as stated preferences (SP). In the following subsection, its design is considered and its results are presented (Figure 17).

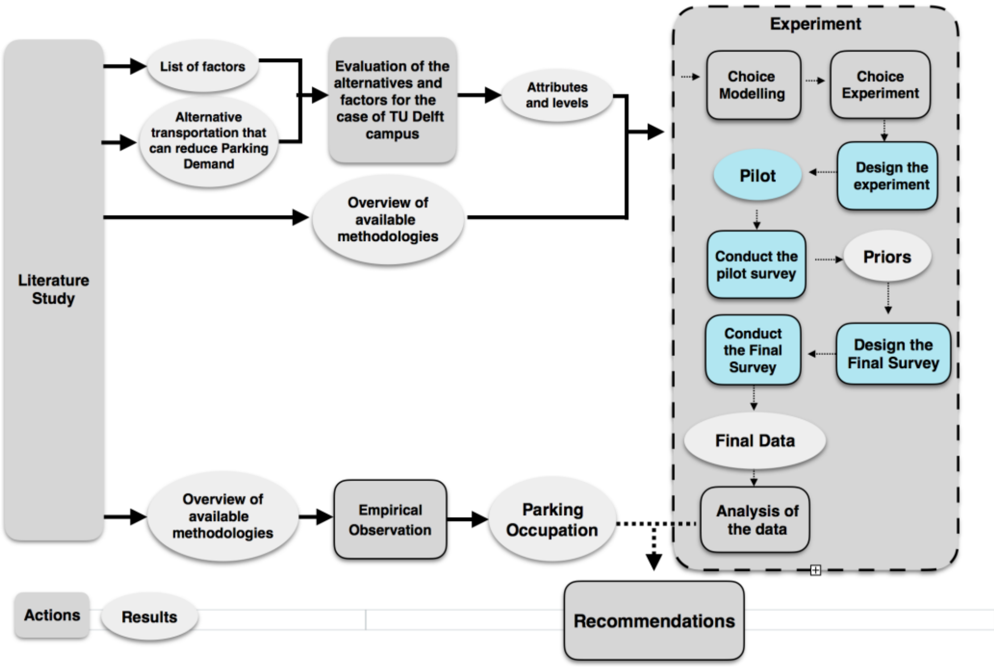


Figure 17 Methodology-Design of the pilot and final survey

6.4.1 Design of the Pilot Survey

As abovementioned, the pilot survey consists of two parts, the revealed preferences (RP) and the state preference (SP). The first concerns the current preferences or habits of the participants, while the latter reveals their tendency of choice in a hypothetical situation.

✦PART A: Revealed Preferences

1. **What was the duration of your trip (from your home to the university campus)?**
   20-30 mins   30-40 mins   40-50 mins   50-60 mins   more than 60 mins
2. **How long did you search for a parking space today?**
   1-2 mins   2-3 mins   3-4 mins   4-5 mins   5-6 mins   more than 6 mins
3. ***How long will you use the parking facility today?***
   1-2 hours   3-4 hours   5-6 hours   7-8 hours   more than 8 hours
4. **How long will you walk from Parking to Office (egress time)?**
   1-3 mins   3-5 mins   5-7 mins   7-9 mins   9-11 mins   more than 11 mins
5. **How frequent do you travel to the University by car (per week)?**
   1   2   3   4   5   6   7
6. **How would you rank the university's Parking Facilities?**
   (Not satisfactory) 1   2   3   4   5   (Satisfactory)
7. **What is your affiliation with the University?**
   Staff   Student   Visitor   Inhabitant

Figure 18 Sample of the Revealed Preferences part of the pilot survey.

The first part, of the revealed preferences is an attempt to comprehend the current behavior of the commuters, who travel by car in the campus of the university. Information, such as the duration of the trip (traveling time), searching time to park and walking time from the parking area to the final destination (egress time) are the main focus of this survey's part. In Figure 18, a sample of the pilot survey's revealed preference part is presented. Worth mentioning is the fact that due to the nature of the survey (direct contact with the participants) personal characteristics are avoided to be asked.

Regarding the second part, -the stated preference- the experiment is conducted with the use of the Ngene software. Ngene is software, which assists in generating experimental designs (ChoiceMetrics, 2014). According to Ngene user's manual, there are three steps to create a Stated choice experiment; the model specification, the generation of the experimental design and the construction of the questionnaire (ChoiceMetrics, 2014).

First, regarding the model specification step, the alternatives, the attributes, the model type and the utility functions need to be addressed. The alternatives and the attributes are chosen after thoroughly consideration, since every additional one increases the complexity of the design. The alternatives that are chosen are related to alternatives ways of transport that involve parking. Thus, the current status quo, *Drive Alone*, and two ways of transport, *Park & Ride* and *Carpooling* are considered as alternatives in the choice experiment. The attributes that are considered in the choice experiment are *additional travelling time, searching time for parking, egress (walking) time, and parking cost*. Finally, regarding the type model MNL and MMNL are considered as the basic models to structure the design. The utility functions are analyzed in the previous section and can be found in the code of Ngene, which is included in Appendix C.

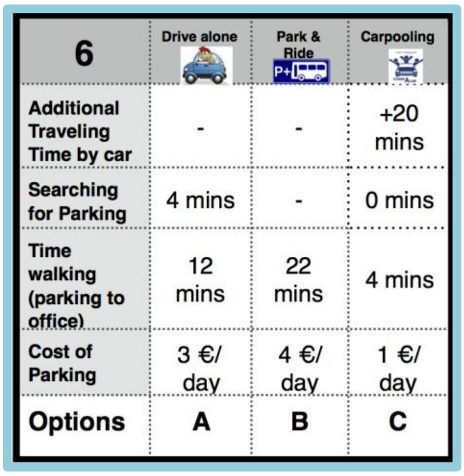
Regarding the generation of the experiment design, dilemmas such as labeled or unlabeled designs, the number and range of attribute levels, the type of design and the number of choice situation challenge this research. First, 'labeled' design is chosen, since the parameters are alternative specific. Second, three levels are chosen for each attribute in order to be able to estimate possible nonlinearities of the attributes. The attribute level range is kept wide (**€**3-**€**6-**€**9) since it is statistically preferable (Rose & Bliemer, 2009). Finally, an efficient orthogonal design with 12 choice set is chosen, targeting to maintain the balance of levels.

The orthogonal is the most suitable design for pilots, since priors for the parameters are not needed. However, in this research an efficient orthogonal design is used. Being able to estimate the attributes possibilities results in a more efficient design. Prerequisite of the efficient orthogonal design is the priors, which are collected from the existing literature. In Table 10 the priors that are obtained from the literature are presented.

Table 10 Values of the priors found in the literature (Arentze & Molin, 2013).

Parameter	**Value**
Travelling time	-0.079
Searching time	-0.079
Egress/walking time	-0.101
Parking cost	-0.178

The third and final step, the construction of the questionnaire, concerns the presentation of the resulting design in a meaningful way for the respondents. An example question from the pilot survey is given in Figure 19. Since the design requires twelve choice sets, twelve of this sample questions are included in the pilot survey. The pilot survey can be found in Appendix C.



6	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+20 mins
Searching for Parking	4 mins	-	0 mins
Time walking (parking to office)	12 mins	22 mins	4 mins
Cost of Parking	3 €/ day	4 €/ day	1 €/ day
Options	A	B	C

Figure 19 Example question from the stated choice experiment of the pilot survey.

If the values of the example question of Figure 19 are incorporated in the respective utility functions given by Equation 7, 8 and 9, then their total values are presented in Table 11.

Table 11 Calculations of the Alternatives' Utilities.

Attributes	Drive alone	Park & Ride	Carpooling
ASC 1	-	0,180	-
ASC 2	-	-	-0,247
Additional travelling time (-0,079)	-	-	-1,58
Searching for parking (-0,079)	-0,316	-	0
Walking time (-0,101)	-1,212	-2,222	-0,404
Parking Cost (-0,178)	-0,534	-0,712	-0,178
Total	**-2,062**	**-2,754**	**-2,409**

According to the methodology of Table 11 for calculating the utilities for each alternative, Table 12 is constructed. Utilities of the first six choice sets are calculated using the Ngene software. The utilities of all 12 choice sets can be found in Table 47 in Appendix C.

Table 12 Utilities of MNL model.

Choice situation	Drive Alone	Park & Ride	Carpool
1	-2.754	-2.706	-2.254
2	-2.104	-2.398	-3.044
3	-1.570	-1.946	-1.514
4	-1.658	-1.590	-1.999
5	-3.446	-1.946	-2.620
6	-2.062	-2.754	-2.304

According to literature, the values of each alternative's utility should be approximately in the same level but not equal. In this way the tradeoffs of the participants can be distinguished. (Louviere, Hensher, & Swait, 2000)

Furthermore, using Equation 6, the relative probabilities are calculated for all the choice sets. Table 13 presents these probabilities of the first six choice sets, while the whole table can be found in Appendix C.

Table 13 Probabilities of the alternatives in the MNL model.

Choice situation	Drive Alone	Park & Ride	Carpool
1	0.27	0.28	0.45
2	0.47	0.35	0.18
3	0.36	0.25	0.39
4	0.36	0.38	0.26
5	0.13	0.58	0.29
6	0.44	0.22	0.34

6.4.2 Design of the Final Survey

Similarly, to the pilot survey the final survey is constructed on the same basis. The first part is based in extracting information regarding the current choices of the commuters (Revealed Preferences). While, the second part focuses in their preferences in hypothetical scenarios (Stated Preferences).

The analysis of the pilot survey is a prerequisite in order to design the final survey. Having obtained the priors through the aforementioned analysis, the new design of the final survey could be done in an efficient way. With the assistance of the Ngene software, an efficient design is aimed this time. The alternatives, as well as their levels, are kept the same, as they are presented in section 6.3.1 Multinomial Logit Model in Table 9. A D-efficient design is used to design the final survey, since the overall reliability of the parameters is aimed. Furthermore, blocking feature is used, targeting the reduction of the number of questions per respondent. The efficiency measures obtained from the design are presented in Table 14.

Table 14 MNL efficiency measures.

D error	0.018
A error	0.024
B estimate	43.241
S estimate	61.827

The D error of the design is estimated approximately to 0,018, while the A error 0,024. The measure of 'S estimate' defines the number of the responses needed in order the 'worst' parameter to become statistically significant. The design of the blocked choice sets, the utilities of each choice set as well as their probabilities can be found in Appendix C.

6.5 Conducting the Pilot and Final Surveys

The pilot survey was distributed in paper to randomly chosen commuters of the TU Delft. More specifically, the survey was printed and handed on the commuters during their arrival or departure from the parking areas. In an effort to avoid biased responses, the survey was available in two languages, English and Dutch. However, regardless the survey's language chosen by the participants, the contact and the explanation was realized in English. The response rate is estimated around 25% (1 out of 4 persons asked), with students to be more consent to answer the survey than employers or visitors. The average time of explaining and filling the survey was approximately 10 minutes. Finally, the average time in combination with the low response resulted to 24 responses. According to a rule of thumb, this number of responses is sufficient for the estimation of valid priors (Molin, 2016). The results of the pilot survey can be found in Appendix C.

The final survey was conducted on the same method as the pilot survey. It was distributed randomly to commuters of the TU Delft in the parking areas. The response rate this time was higher (approximately 1 out of 3 persons approached) due to the length of the survey and the acquired experience of the author. The average time for explaining and filling the survey is estimated to 3 minutes. From the process of the final survey, 110 responses were collected.

6.5 Conclusion

In this chapter, the experimental research was the core concept. More specifically, the available experimental designs were discussed following by an argumentation regarding the chosen designs. Concerning the pilot survey, an orthogonal design was used, while for the final survey a D-efficient design. Furthermore, an introduction to the Discrete Choice models was given. The theoretical background of Multinomial Logit Model (MNL) and Mixed Multinomial Logit Model (MMNL) was discussed and the utility functions of the three alternatives (Drive alone, Park & Ride and Carpooling) were presented. Afterwards, the design of the two surveys was presented step by step, including the results of Ngene software. Finally, information regarding the process of conducting the two surveys was provided.

Chapter 7 Analysis of the Survey's results

7.1 Introduction

This chapter concerns the analysis of the results of the final conducted survey. The chapter begins with a presentation of the results of the commuters' current behavior (e.g. searching time, egress time) and personal characteristics such as their affiliation with the TU Delft (e.g. employee, student, visitor, inhabitant). Afterwards, two models Multinomial Logit (MNL) and Mixed Multinomial Logit (MMNL) are used to estimate the coefficients. These two estimated models are validated with the use of a data set that is separated from the main volume of data. What is more, further analysis is realized to examine the preferences of different segments of the sample. Furthermore, two of the most important properties, Willingness-to-Pay and Elasticity of Demand are employed in order to describe the future responsiveness of the campus commuters. Finally, an estimation of the reduction of CO_2 emissions due to parking demand reduction is presented.

7.2 Revealed Preferences' Results of the Final Survey

The classifications of the 110 participants, as well as three of the questions are presented in Figure 20.

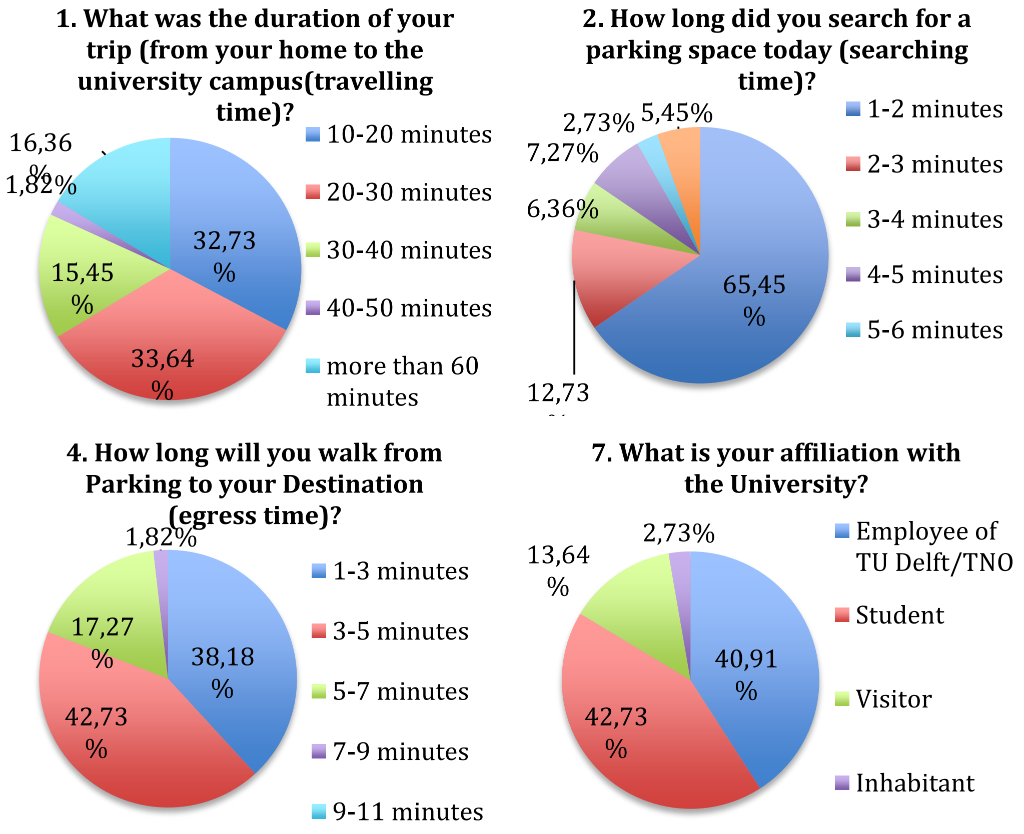


Figure 20 Revealed preferences of the respondents of the final survey.

40,91% of the participants are employees of the TU Delft and TNO, 42,73% students, 13,64% visitors and 2,73% inhabitants. 32,73% of the respondents travels approximately 10-20 minutes, while 33,64% travels 10 minutes more than the first. Furthermore, the majority of them (65,45%) are able to park within 1-2 minutes, while 5,45% spends more than 6 minutes to find a free parking lot. Egress time fluctuates between 1-3 minutes

(38,18%) and 3-5 minutes (42,73%). Finally, 23,64% of the participants are "very satisfied" with the parking facilities of the campus, while only 3,64% declare "very dissatisfied".

7.3 Analysis of the Stated Choice Experiment.

As far as the second part of the final survey is concerned, its data is transferred to a Microsoft Excel spreadsheet, which is later used for the analysis in the BIOGEME software (Bierlaire, 2003). To analyze the data two models MNL and MMNL are used, according to the aforementioned theory. The analysis takes place in two separate steps. For the first step, the data that was gathered are randomly distributed into two parts. The first part (80 responses) is used to estimate the parameters of the model, and the second part (30 responses) is used to validate the model. Afterwards, two models (MNL and MMNL) are generated. Both are validated and compared. In the second step, all the data from the final survey is used to generate again the two models and estimate the coefficients for each segment of responses.

7.3.1 Estimation of the coefficients using the Multinomial Logit model

The first and simpler model to be estimated is the Multinomial Logit and its coefficient are calculated with the use of the BIOGEME software (Bierlaire, 2003). As it can be concluded from the analysis of the final survey's data, the MNL model results to significant parameters. A comparison between the values of the parameters that were found in the literature and estimated from the pilot and the final survey is presented in Table 15.

Table 15 Comparison of the parameters found in the literature, estimated from the pilot and final survey. *p<0.01

Parameter	Priors	Pilot survey			Final survey (MNL)		
		Value	t-test	p-val	Value	t-test	p-val
$\boldsymbol{\beta_1}$	-	-0.800	-1.67	0.10	**-1.97***	**-5.92**	0.00
$\boldsymbol{\beta_2}$	-	-0.210	-0.31	0.76	-0.199	-0.45	0.65
$\boldsymbol{\beta_{ExtraTraveltTime}}$	-0.079	**-0.172***	-4.85	0.00	**-0.135***	**-4.36**	0.00
$\boldsymbol{\beta_{SearchingTime}}$	-0.079	-0.0409	-0.68	0.68	**-0.103***	**-2.75**	0.01
$\boldsymbol{\beta_{Egresstime}}$	-0.101	**0.137***	-5.21	0.00	**-0.0599***	**-3.24**	0.00
$\boldsymbol{\beta_{ParkingCost}}$	-0.178	**-0.442***	-8.47	0.00	**-0.368***	**-8.27**	0.00
	-	Likelihood ratio test: 192.906 Adjusted rho-square: 0.286 Final log-likelihood: -219.947			Likelihood ratio test: 128.485 Adjusted rho-square : 0.166 Final log-likelihood: -287.313		
Number of observations		288			320		

Using the estimated parameters of Table 15 in Equations 7,8 and 9, Equations 11, 12 and 13 are derived. These equations can assist in the interpretation of the coefficients. In fact each parameter influences negatively each utility function. Thus, the product of the parameter and its actual value (e.g. $\boldsymbol{\beta_{SearchingTime}}{*}T_{searchingtime}$) results to the value of the commuters' utility for searching time. Concluding, worth mentioning is the fact that the larger the parameter is, the greater impact has in the total value of the utility.

$$U_{Drive\_alone} = -\mathbf{0.103} * T_{searchingtime_{DA}} - \mathbf{0.0599} * T_{Egresstime_{DA}} - \mathbf{0.368} * C_{ParkingCost\_DA} \quad (11)$$

Equation 11 Transformation of Equation 7 when including the estimated parameters

$$U_{Park\&Ride} = -\mathbf{1.97} - \mathbf{0.0599} * T_{Egresstime\_P\&R} - \mathbf{0.368} * C_{ParkingCost\_P\&R} \quad (12)$$

Equation 12 Transformation of Equation 8 when including the estimated parameters

$$U_{Carpooling} = -\mathbf{0.199} - \mathbf{0.135} * T_{ExtraTravelTime_C} - \mathbf{0.103} * T_{searchingtime_C} - \mathbf{0.0599} * T_{Egresstime_C} - \mathbf{0.368} * C_{ParkingCost\_C} \quad (13)$$

Equation 13 Transformation of Equation 9 when including the estimated parameters

According to the previous explanation of the parameters' effect in the total value of the utility function the following conclusions are made. The impact of the parking cost is higher in both the pilot and the final survey than the one that was found in the literature. This can be considered a reasonable result since sample can differ from study to study. What is more, since more than 40% of the sample are students, it is a reasonable explanation of their high sensitivity in the parking cost. Finally, this can be also due to biased sample towards the rumors of introducing a pricing parking policy. Parameter $\beta_{SearchingTime}$ is found lower, while $\beta_{SearchingTime}$ is higher in the final survey than the pilot. This is probably due to higher contribution of students in the pilot survey (62,5%) than the final survey (42,73%).

7.3.2 Evaluation of the MNL model

As aforementioned, the responses of the final survey are divided randomly into two groups. The first group is used to estimate the model's parameters and the latter group to validate it. The division of the participants' responses is realized in Microsoft Excel environment using the command "RAND" and "VLOOKUP". Afterwards, BIOGEME software is employed once more. This time, the estimated model and its data for validation are used as an input model and input data respectively. In other words, the software estimates the utilities of the three alternatives for each choice set. It is expected that the participants choose the alternative, which generates the highest utility for them. Therefore, a comparison between the "best choice" according to model and what the participants have chosen in reality constitutes the validation of the estimated model. An example of this process is presented in Table 16.

Table 16 Comparison between the estimated utility from simulation and the actual preference of the participants using the estimated MNL model.

Sets	Utility of the Alternative 1	Utility of the Alternative 2	Utility of the Alternative 3	Alternative with the highest utility	Alternative chosen
1	**-2,20**	-4,28	-3,78E	**1**	**1**
2	-4,38	-5,50	**-3,51E**	3	1
3	-4,41	**-3,55**	-3,81E	2	1
4	**-2,23**	-4,52	-2,70E	**1**	**1**

After the simulation and the comparison between the estimated alternative with the highest utility and the actual choice of the participants the following conclusion is made. The model was able to forecast 56,6667% of the participants' choices. The estimations of the alternatives' utilities and the comparison with the actual choices are presented in Appendix C, in Table 64. It is not considered a high forecasting rate, but it is higher than the simple possibility (33,34%) of matching randomly one choice when having three alternatives.

7.3.3 Estimation of the coefficients using the Mixed Multinomial Logit model

The second model that is used for the sake of this thesis is the Mixed Multinomial Model (MMNL). The same methodology as the one followed when using the MNL model is used. First the data set (80 responses) is used to estimate the model and afterwards, the second data set (30 responses) to validate the model. Panel effects are also considered when estimating the MMNL model. Table 17, summarizes the results of the coefficients estimated with the MMNL model in comparison to the ones estimated with the MNL model. The basic MNL model returns Log-Likelihood value of -287.313 and Rho-square value of 0.166. On the other hand, MMNL model results in a significant improvement of the model (Log-Likelihood= -247.826) and Rho-square value of 0.272. It can be concluded, that the MMNL model has higher explanatory power than the MNL model, since the adjusted rho-square of the first is significantly higher than the latter. What is more, significant differences in the values of the coefficients are also noticed during the comparison of the two models.

Table 17 Estimated coefficients with the MNL and MMNL (10000 draws, with panel effects) model. (*p<0.02)

Parameter	Multinomial Logit Model			Mixed Multinomial Logit Model		
	Value	t-test	p-val	Value	t-test	p-val
β_1	**-1.97***	-5.92	0.00	**-3.42***	-5.33	0.00
β_2	-0.199	-0.45	0.65	-0.482	-0.70	0.49
$\beta_{ExtraTraveltTime}$	**-0.135***	-4.36	0.00	**-0.245***	-4.93	0.00
$\beta_{SearchingTime}$	**-0.103***	-2.75	0.01	**-0.186***	-3.37	0.00
$\beta_{Egresstime}$	**-0.0599***	-3.24	0.00	**-0.123***	-3.88	0.00
$\beta_{ParkingCost}$	**-0.368***	-8.27	0.00	**-0.628***	-7.13	0.00
Sigma_β_1	-	-	-	**2.19***	4.88	0.00
Sigma_β_2	-	-	-	**2.56***	6.65	0.00
	Likelihood ratio test: 128.485 Adjusted rho-square : 0.166 Final log-likelihood: -287.313			Likelihood ratio test: **207.460** Adjusted rho-square: **0.272** Final log-likelihood: **-247.826**		
Number of observations	320			320		

7.3.4 Evaluation of the MMNL model

The second step, the validation of the MMNL model, is realized in order to evaluate the prediction strength of the estimated coefficients. Therefore, the utilities of the three alternatives are calculated using the simulation function of BIOGEME software according to the estimated MMNL model for each choice set. Then, a comparison of the model's choice and the actual choice of the participants is made. A sample of this process can be found in Table 18.

Table 18 Comparison between the estimated utility from simulation and the actual preference of the participants using the estimated MMNL model.

Sets	Utility of the Alternative 1	Utility of the Alternative 2	Utility of the Alternative 3	Alternative with the highest utility	Alternative chosen
1	**-3,818**	-7,606	-6,809	**1**	**1**
2	-7,34	-9,878	**-6,317**	**3**	**3**
3	-7,658	**-6,326**	-7,003	2	3
4	**-4,012**	-8,102	-4,885	1	3

Finally, the model was able to predict correctly 68 out of 120 choice sets. This can be translated to 56,67% predictability, which is the same as the MNL model. Consequently, the MMNL model might explain the variance of the dependent variable better (higher rho-square), but in the end, their accuracy in forecasting stays the same.

7.4 Grouping respondents by their revealed preferences

While the first model is estimated and validated, a more in depth analysis of the preferences of each commuter's segment seems to be interesting. For this reason, the responses of the participants are divided according to their affiliation with the TU Delft. Therefore, three groups are distinguished; Employees of the TU Delft (45 responses), Students (46 responses) and Visitors (15 responses). Inhabitants are not considered, since their number of responses is low (3 responses) and they would not produce statistically significant results. The same process of estimating the model in the previous section (7.3.2 Evaluation of the MNL model), is followed and realized three times, one for each aforementioned segment. The coefficients of the three different models are presented in Table 19 in comparison to the model derived when considering all the responses (110 responses).

Table 19 Comparison of the parameters estimated for each segment of participants using the MNL model.

Parameter	Employees of the TU Delft/TNO		Students of the TU Delft		Visitors of the TU Delft		All commuters	
	Value	t-test	Value	t-test	Value	t-test	Value	t-test
β_1	**-1.73***	-4.08	**-2.59***	-5.15	-1.59	-1.76	**-1.97***	-6.92
β_2	-0.416	-0.68	-0.0433	-0.07	-1.51	-1.22	-0.347	-0.92
$\beta_{ExtraTraveltTime}$	**-0.124***	-2.85	**-0.164***	-3.74	-0.0749	-0.90	**-0.128***	-4.82
$\beta_{SearchingTime}$	**-0.107***	-2.0	**-0.109***	-2.16	-0.00257	-0.03	**-0.0907***	-2.87
$\beta_{Egresstime}$	**-0.0502***	-2.04	**-0.0799***	-3.03	**-0.110***	-2.17	**-0.0646***	-4.06
$\beta_{ParkingCost}$	**-0.328***	-6.04	**-0.542***	-7.40	**-0.236***	-2.04	**-0.380***	-9.84
	Likelihood ratio test: **61.047** Adjusted rho-square: **0.124** Final log-likelihood: **-167.227**		Likelihood ratio test: **122.313** Adjusted rho-square: **0.267** Final log-likelihood: **-145.383**		Likelihood ratio test: **39.635** Adjusted rho-square: **0.210** Final log-likelihood: **-46.099**		Likelihood ratio test: **184.295** Adjusted rho-square: **0.178** Final log-likelihood: **-411.735**	
Number of observations	180		188		60		440	

$^*p<0.05$

Parking costs coefficient is higher for the students' model, while the visitors are influenced less than all the participants. This means that a potential introduction or increase in parking fees will result in less utility for the aforementioned group of commuters. It seems reasonable, since the low budget of students is driving them towards the most inexpensive solutions to park their cars. In the contrary, visiting the university once per week or even less often (visitors segment) make them almost indifferent to changes in the parking fees. What is more, visitors are influenced more in walking time than the rest of the commuters. Thus visitors prefer to walk less to reach their destination and a potential increase in egress time will decrease their utility more that the rest of the groups of commuters. Remarkable is the fact that when comparing students' and employees' results, the first can be affected more by extra traveling time, searching time and egress time.

Afterwards, the responses are divided according to the commuters' travelling time. For this purpose, three segments are distinguished; 10-20, 20-30 and more than 30 minutes. The resulting coefficients are presented in Table 20.

Table 20 Comparison of the estimated coefficients for the different segments of the 'Travelling Time' using the MNL model.

Travelling time	10-20 minutes		20-30 minutes		More than 30 minutes	
	Value	t-test	Value	t-test	Value	t-test
β_1	**-2.02***	-4.14	**-2.49***	-4.74	**-1.56***	-3.15
β_2	-0.560	-0.85	-0.115	-0.17	-0.322	-0.49
$\beta_{ExtraTraveltTime}$	**-0.0928***	-1.96	**-0.167***	-3.45	**-0.138***	-3.08
$\beta_{SearchingTime}$	-0.0832	-1.47	**-0.152***	-2.69	-0.0596	-1.10
$\beta_{Egresstime}$	-0.0430	-1.54	**-0.0810***	-2.80	**-0.0752***	-2.75
$\beta_{ParkingCost}$	**-0.303***	-4.69	**-0.443***	-6.00	**-0.402***	-6.07
	Likelihood ratio test: 53.750 Adjusted rho-square: 0.132 Final log-likelihood: -131.325		Likelihood ratio test: 77.119 Adjusted rho-square: 0.206 Final log-likelihood: -119.640		Likelihood ratio test: 39.635 Adjusted rho-square: 0.210 Final log-likelihood: -46.099	
Number of observations	144		144		148	

$^*p<0.05$

From Table 20 it can be noticed that commuters who travel more than 20 minutes are affected by parking costs more than the ones who travel less than 20 minutes. The same also applies for the extra travelling time and egress time. This is probably connected with the fact that people who travel longer and their traveling costs are already high, they prefer to keep searching time, egress time and parking costs in low levels.

Table 21 Comparison of the estimated coefficients for the different segments of the 'Searching Time' attribute using the MNL model.

Searching Time	1-2 mins		More than 2 mins	
	Value	t-test	Value	t-test
β_1	**-2.29***	-6.35	**-1.56***	-3.11
β_2	-0.654	-1.44	0.149	0.22
$\beta_{ExtraTraveltTime}$	**-0.115***	-3.40	**-0.149***	-3.32
$\beta_{SearchingTime}$	**-0.0879***	-2.28	-0.105	-1.81
$\beta_{Egresstime}$	**-0.0777***	-3.77	-0.0468	-1.74
$\beta_{ParkingCost}$	**-0.364***	-7.19	**-0.427***	-6.56
	Likelihood ratio test: 141.450 Adjusted rho-square: 0.205 Final log-likelihood: -245.675		Likelihood ratio test: 62.218 Adjusted rho-square: 0.150 Final log-likelihood: -135.880	
Number of observations	144		152	

***p<0.02**

Moreover, Table 21 presents the estimation of the coefficients when the responds are distributed into two segments; 1-2 minutes and more than 2 minutes of searching time. Commuters who search more time are affected more from the parking fee, as well as the extra traveling time. For the rest of the parameters, the interpretation of the results is less meaningful since 'searching time' and 'egress time' are found not statistically significant.

Regarding the segments of egress time, from Table 22, it can be concluded that, the more people walk to their destination the less affected they are towards egress time. What is more, regarding extra traveling time there is not significant difference for the groups '1-3 mins' and '3-5 mins'. Parking costs influence less the commuters who walk more than 5 minutes. Therefore, people who already walk long distance to reach their destination will be less sensitive to parking fees.

Table 22 Comparison of the estimated coefficients for the different segments of the 'Egress Time' attribute using the MNL model.

Egress time	1-3 mins		3-5 mins		More than 5 mins	
	Value	t-test	Value	t-test	Value	t-test
β_1	**-1.77***	-3.97	**-2.78***	-5.78	-0.994	-1.50
β_2	-0.185	-0.29	-0.486	-0.84	-0.222	-0.26
$\beta_{ExtraTraveltTime}$	**-0.143***	-3.24	**-0.142***	-3.26	-0.107	-1.88
$\beta_{SearchingTime}$	**-0.158***	-2.94	-0.0833	-1.73	0.00849	0.12
$\beta_{Egresstime}$	**-0.0851***	-3.33	**-0.0637***	-2.40	-0.0515	-1.44
$\beta_{ParkingCost}$	**-0.365***	-6.10	**-0.441***	-6.37	**-0.348***	-4.08
	Likelihood ratio test: 69.677 Adjusted rho-square: 0.156 Final log-likelihood: -149.728		Likelihood ratio test: 106.049 Adjusted rho-square: 0.257 Final log-likelihood: -153.515		Likelihood ratio test: 25.758 Adjusted rho-square: 0.140 Final log-likelihood: -79.404	
Number of observations	144		188		84	

***p<0.03**

Concerning the occupation time, the more commuters have to stay in the campus the more affected are from the parking costs. What is more, vehicle commuters who stay in campus more than 6 hours they are less prone to walking time and are negatively affected by extra travelling and searching time (Table 23).

Table 23 Comparison of the estimated coefficients for the different segments of the 'Occupation Time' using the MNL model.

Occupation Time	1-6 hours		More than 6 hours	
	Value	t-test	Value	t-test
β_1	**-1.63***	-3.80	**-2.24***	-5.79
β_2	-0.306	-0.53	-0.326	-0.65
$\beta_{ExtraTravelTime}$	**-0.106***	-2.76	**-0.147***	-4.08
$\beta_{SearchingTime}$	-0.0730	-1.54	**-0.101***	-2.36
$\beta_{Egresstime}$	**-0.0723***	-2.99	**-0.0568***	-2.67
$\beta_{ParkingCost}$	**-0.290***	-5.05	**-0.454***	-8.58
	Likelihood ratio test: 63.998 Adjusted rho-square: 0.126 Final log-likelihood: -174.540		Likelihood ratio test: 127.482 Adjusted rho-square: 0.209 Final log-likelihood: -213.109	
Number of observations	188		252	

***p<0.03**

Finally, in Table 24 three estimated models according to commuters' frequency of visiting the TU Delft campus is available. The most important conclusion from this analysis is that the more frequent one travels to the campus the more affected is by the parking costs and the extra travelling time.

Table 24 Comparison of the estimated coefficients for the different segments of the 'Frequency of visit' using the MNL model.

Frequency visit (per week)	1-2 times		3-4 times		More than 5 times	
	Value	t-test	Value	t-test	Value	t-test
β_1	**-1.58***	-3.12	**-2.22***	-4.69	**-2.24***	-4.08
β_2	-0.138	-0.22	**-0.454***	-0.69	**-0.213***	-0.31
$\beta_{ExtraTravelTime}$	**-0.121***	-2.68	**-0.127***	-2.82	**-0.153***	-3.01
$\beta_{SearchingTime}$	-0.0607	-1.15	**-0.148***	-2.65	-0.0597	-1.04
$\beta_{Egresstime}$	**-0.0887***	-3.16	-0.0352	-1.36	**-0.0775***	-2.52
$\beta_{ParkingCost}$	**-0.287***	-4.20	**-0.404***	-6.59	**-0.463***	-5.87
	Likelihood ratio test: 56.790 Adjusted rho-square: 0.142 Final log-likelihood: -129.805		Likelihood ratio test: 71.315 Adjusted rho-square: 0.165 Final log-likelihood: -144.515		Likelihood ratio test: 69.587 Adjusted rho-square: 0.199 Final log-likelihood: -110.223	
Number of observations	144		164		132	

***p<0.02**

7.5 Value of Searching Time and Egress Time reduction (Willingness-To-Pay)

An important method, to assess the commuters' perceived value of the reduction of searching and egress time is the Willingness-to-pay. This method is widely used to develop pricing strategies through forecasting the consumers' response to different changes. While different methods to calculate the WTP exist (e.g. Revealed Preferences, Contingent valuation, Choice modeling techniques etc.) in the present research the responses of the Stated choice experiment will be used (Competition Commission, 2010). More specifically, according to Chorus (2016), the formula that estimates the Value of Searching Time is given by Equation 11.

$$VoST = \frac{\frac{\partial V}{\partial \beta_{SearchingTime}}}{\frac{\partial V}{\partial \beta_{ParkingCost}}} = \frac{\beta_{SearchingTime}}{\beta_{ParkingCost}} \quad (14)$$

Equation 14 Value of Searching Time

While the formula that estimates the Value of Egress Time is given by Equation 12.

$$VoET = \frac{\frac{\partial V}{\partial \boldsymbol{\beta}_{\boldsymbol{Egresstime}}}}{\frac{\partial V}{\partial \boldsymbol{\beta}_{\boldsymbol{ParkingCost}}}} = \frac{\beta_{Egresstime}}{\boldsymbol{\beta}_{\boldsymbol{ParkingCost}}} \quad (15)$$

Equation 15 Value of Egress Time

Calculating the VoST and VoET for the main model and its respective segments, Table 25 is constructed. The values represent how much the commuters are willing to pay to reduce their searching for parking and walking time for one value of time. For sake of convenience all the values are transferred to an hourly scale (€/hour).

Table 25 Value of Searching Time and Egress Time reduction (Willingness-To-Pay) for the different respondents segments. Values with asterisk came from statistically significant coefficients (*p<0.05), estimated with the MNL model.

Affiliation	Employees of the TU Delft/TNO	Students of the TU Delft	Visitors of the TU Delft	All commuters
VoST (€/hour)	19,56*	12,06*	0,65	14,32*
VoET (€/hour)	9,18*	8,85*	27,96*	10,20*
Travelling Time	**10-20 minutes**	**20-30 minutes**	**More than 30 minutes**	
VoST (€/hour)	16,48	4,04*	8,90	
VoET (€/hour)	8,51	10,97*	11,22*	
Egress time	**1-3 mins**	**3-5 mins**	**More than 5 mins**	
VoST (€/hour)	25,97*	11,33	1,46	
VoET (€/hour)	14,00*	8,67*	8,90	
Frequency visit (per week)	**1-2 times**	**3-4 times**	**More than 5 times**	
VoST (€/hour)	12,69	21,98*	7,74	
VoET (€/hour)	18,54*	5,23	10*	
Searching Time	**1-2 mins**		**More than 2 mins**	
VoST (€/hour)	14,49*		14,82	
VoET (€/hour)	12,80*		6,58	
Occupation Time	**1-6 hours**		**More than 6 hours**	
VoST (€/hour)	15,10		13,35*	
VoET (€/hour)	14,95*		7,51*	

Employees of the TU Delft are willing to pay approximately €0,33 (19,56 €/hour) and €0,15 (9,18 €/hour) for every reduced minute in searching and egress time respectively. In the contrary students are willing to pay €0,10 (11,33 €/hour) less than employees to reduce their searching time by one minute and almost the same amount (8,85 €/hour) to reduce their egress time by one minute. Additionally, the higher their travelling time is, the more the commuters are willing to pay over one minute of egress time reduction. On the other hand, the more commuters walk from the parking area to their final destination the less are willing to pay over searching and egress time reduction. Finally, the more the commuters occupy the parking spot, the less are willing to pay for searching and egress time reduction.

7.6 Direct and Cross Elasticities

Two of the most useful properties, when evaluating the possible results of different policies, are the direct and cross elasticities. Direct elasticity consists a measurement of the percentage change in the probability of selecting a specific alternative with respect to a known change –in percentage- of the same alternative's attribute (Louviere, Hensher, & Swait, 2000). In contradiction, cross elasticity measures the same percentage change in probability of selecting a specific alternative (e.g. Drive Alone) with respect to a known change of another's alternative (e.g. Park &Ride or Carpooling) (Louviere, Hensher, & Swait, 2000). However, a distinction between the disaggregate and aggregate elasticities should be made. The disaggregate elasticity concerns an individual's response, while the aggregate elasticity recapitulates the responsiveness of a group of respondents. The estimation of disaggregate direct and cross elasticities of the three alternatives for the chosen stated choice experiment is realized with the use of the Equations 13 and 14 (Ben-Akiva & Lerman, 1985, p. 111).

$$E_{X_{ink}}^{P_n(i)} = \frac{\partial P_n(i)}{\partial X_{ink}} * \frac{X_{ink}}{P_n(i)} = \frac{\partial ln P_n(i)}{\partial ln X_{ink}} = [1 - P_n(i)] X_{ink} \beta_k \qquad (16)$$

Equation 16 (Ben-Akiva & Lerman, 1985, p. 111)

$$E_{X_{jnk}}^{P_n(i)} = \frac{\partial ln P_n(i)}{\partial ln X_{jnk}} = - P_n(i) X_{jnk} \beta_k \qquad (17)$$

Equation 17 (Ben-Akiva & Lerman, 1985, p. 111)

The disaggregate elasticities are prerequisite to estimate their respect aggregate elasticities. The aggregate elasticities are estimated with the use of Equation 15 (Ben-Akiva & Lerman, 1985, p. 113).

$$E_{X_{jk}}^{\bar{P}(i)} = \frac{\sum_{n=1}^{N} P_n(i)\, E_{X_{ink}}^{P_n(i)}}{\sum_{n=1}^{N} P_n(i)} \qquad (18)$$

Equation 18 (Ben-Akiva & Lerman, 1985, p. 113)

The disaggregate direct and cross elasticities of the four different attributes are estimated from the simulation of both of the MMNL and MNL models. Table 26, 27, 28 and 29 present the aforementioned elasticities for the MMNL model. The respective elasticities for the MNL model can be found in Appendix C. Comparing the estimated elasticities for the two models, their values are not found to differ significantly.

Table 26 Direct and cross elasticities of the attribute 'Parking Cost' for the three alternatives using the MMNL model.

Parking Cost	Drive Alone	Park & Ride	Carpooling
Drive alone	**-1,490**	0,116	0,221
Park & Ride	0,741	-0,512	0,271
Carpooling	0,808	0,155	-0,334

As it can be seen in Table 26, regarding the attribute of the Parking cost, the highest disaggregate direct elasticity concerns the alternative 'Drive Alone'. This can be interpreted as following. A percentage increase in price will have an elastic result of -1,490 in the percentage of Parking Demand for the case of driving alone. In other words, 1% of parking fees increase will reduce the commuters who drive alone by 1,49%. What is more, the disaggregate cross elasticity of 'Drive Alone' with respect to 'Park & Ride' in case of a parking fee increase is found 0,116. This value is considered inelastic, since 1% of the parking fees will contribute to 0,116% increase in 'Park & Ride' users. In the contrary, an increase by 1% of the parking fees for the 'Park & Ride' alternative will push more commuters to 'Drive Alone' (0,741% increase) than to 'Carpooling' (0,271% increase) alternative.

Table 27 Direct and cross elasticities of the attribute 'Searching Time' for the three alternatives using the MMNL model. Dashes (-) represent that Searching Time was not considered in Park & Ride alternative.

Searching Time	Drive Alone	Park & Ride	Carpooling
Drive alone	-0,432	-	0,074
Park & Ride	0,140	-	0,055
Carpooling	0,255	-	-0,085

Following the same abovementioned reasoning for Table 27, it can be concluded an inelastic relationship concerning 'Searching time' attribute in case of 'Drive Alone' alternative. However, Park & Ride is not affected from an increase or decrease of searching time, since it was considered minimum for simplicity the survey's design.

Table 28 Direct and cross elasticities of the attribute 'Egress Time' for the three alternatives using the MMNL model.

Egress Time	Drive Alone	Park & Ride	Carpooling
Drive alone	-0,337	0,095	0,054
Park & Ride	0,102	-0,548	0,118
Carpooling	0,186	0,128	-0,114

Concerning Table 28, the aggregate direct elasticity of Park & Ride is considered higher than the other two alternatives. Consequently, 1% of increase in walking time will decrease more Park & Ride (0,548%), than Drive Alone (0,337%) or Carpooling (0,114%) commuters. Finally, in Table 29, regarding 'Extra Travelling Time' the value of the disaggregate cross elasticity of 'Carpooling' is -1,014. Therefore, for 1% of increase in extra travelling time Carpooling Demand decreases 1,014%.

Table 29 Direct and cross elasticities of the attribute 'Extra travelling time' for the three alternatives using the MMNL model. Dashes (-) represent that Extra Travelling Time was only considered in Carpooling alternative.

Extra Travelling Time	Drive Alone	Park & Ride	Carpooling
Drive alone	-	-	0,614
Park & Ride	-	-	0,742
Carpooling	-	-	-1,014

Concluding all the above mentioned, when reducing the Drive Alone alternative is the target then increasing the Parking cost was found to be the most efficient method to achieve it. What is more, increasing searching time can be considered an indirect method to decrease commuters who drive alone. Finally, extra travelling time seems to affect carpoolers.

Elasticity of demand has been proved to be a useful property when it comes for regulation of policies. However, at this point calculation of the future 'drive alone' demand cannot be made for the parking fee level, since there is no current fee and the formula applies only for percentage increase.

7.7 Simulation of the respondents' future preferences

After the estimation of the model's coefficients, an attempt to forecast the future preferences of the respondents is made. For this purpose, the revealed preferences of the respondents are included again in the calculations. More specifically, searching and egress time given by the respondents during the survey are used as inputs in the model and an estimation of their future responsiveness in different policies is realized. Three different values (+10, +15, +20 mins) are considered as 'extra travelling time' for the 'Carpooling' alternative, while two (+5, +10 mins) for the 'egress time' of the 'Park & Ride' depending on the minibus availability. Regarding the pricing policies, four different price relations of the three alternatives (Drive Alone, Park & Ride and Carpooling) are considered ($Cost_{DriveAlone}=3/2*Cost_{Park\&Ride}=3*Cost_{Carpooling}$,$Cost_{DriveAlone}=3*Cost_{Park\&Ride}=3*Cost_{Carpooling}$, $Cost_{DriveAlone}=4*Cost_{Park\&Ride}=3*Cost_{Carpooling}$, $Cost_{DriveAlone}=4*Cost_{Park\&Ride}=3/2*Cost_{Carpooling}$). The range of the simulated prices for the Drive Alone alternative is €1-12 with step €1,0. Table 30 presents an overview of the simulated policies.

Table 30 Overview of the simulated policies.

Policies	Values
Parking fee of Drive Alone (€)	1/2/3/4/5/6/7/8/9/10/11/12
Price relations of Alternatives	$Cost_{DriveAlone}=3/2*Cost_{Park\&Ride}=3*Cost_{Carpooling}$, $Cost_{DriveAlone}=3*Cost_{Park\&Ride}=3*Cost_{Carpooling}$ $Cost_{DriveAlone}=4*Cost_{Park\&Ride}=3*Cost_{Carpooling}$ $Cost_{DriveAlone}=4*Cost_{Park\&Ride}=3/2*Cost_{Carpooling}$
Extra travelling time	10/15/20
Minibus available for P&R	Yes=5 mins /No=10 mins

Regarding the simulated policies the following order is followed. First, the revealed searching and egress time are combined with the initial pricing policy ($Cost_{DriveAlone}=3/2*Cost_{Park\&Ride}=3*Cost_{Carpooling}$). Afterwards, in an attempt to push more commuters to Park & Ride, its price is decreased in one third (1/3) and later in one fourth (1/4) of the cost of Drive Alone fee. What is more, in an effort to make Park & Ride even more appealing than Carpooling, the parking fee of the latter is increased in two third (2/3) of the cost of Drive Alone fee. In the first round of simulations parking supply is assumed constant, while in the second round, a scenario of reduced parking supply is simulated.

For the first simulation of the first round respondents' revealed searching and egress time are used in calculations. Three different values (+10, +15, +20 mins) are considered as 'extra travelling time' for the 'Carpooling' alternative, while two (+5, +10 mins) for the 'egress time' of the 'Park & Ride'. Regarding the parking costs, the cost of driving alone is assumed – according to the initial policy- one and half time more and three times more than the cost of Park & Ride and Carpooling respectively. ($Cost_{DriveAlone}=3/2*Cost_{Park\&Ride}= =3*Cost_{Carpooling}$). The range of the simulated prices for the Drive Alone alternative is €1-12 with step €1,0. The most relevant results for the case of the TU Delft parking demand are presented in Table 31.

Table 31 Simulation of future responsiveness of the 110 respondents including their own searching and egress time, with the initial policy of the alternatives Park & Ride and Carpooling. (1st round, 1st simulation)

$Cost_{DriveAlone}=3/2*Cost_{Park\&Ride}=3*Cost_{Carpooling}$												
Parking fee of Drive Alone (€)	3	**4**	5	6	7	8	4	5	5	6	7	8
Extra traveling time for Carpooling (mins)	10	**10**	15	15	20	20	10	10	15	15	20	20
Minibus (Yes=5 mins/No=10 mins)	10	10	10	10	10	10	5	5	5	5	5	5
Reduction of Parking Demand due to Carpooling (%)	8,5	**17**	8,5	23	12	23	8,5	17	14	23	12	23
Parking Demand pushed in P&R (%)	0	**0**	0	0	0	0	0	0	0	0	0	0

For instance, the results of the simulation show a 17% reduction of parking demand due to commuters' transfer in Carpooling. Moreover, it can be concluded that the higher the extra traveling time of carpooling is, the higher parking fee should be applied in order to achieve the same reduction in demand. Moreover, introducing the minibus (reduce egress time of Park & Ride from 10 minutes to 5) has no significant impact in respondents' preferences.

Afterwards, a second simulation is realized, with a change in the pricing policy. This time, the cost of Park & Ride is reduced to one third of the Drive Alone Parking fee. The results of the second simulation that are presented in Table 32 do not differ significantly from the first one. The only noticeable difference is that for the case of 20 minutes of extra traveling time, 5 minutes of egress time and €8 of parking fee for Drive Alone alternative, resulted to 1% of Park & Ride share.

Table 32 Simulation of future responsiveness of the 110 respondents including their own searching and egress time, with the initial policy of the alternatives Park & Ride and Carpooling for searching and egress time and with reduced costs for Park & Ride. (1st round, 2nd simulation)

$Cost_{DriveAlone}=3*Cost_{Park\&Ride}=3*Cost_{Carpooling}$												
Parking fee of Drive Alone (€)	3	**4**	5	6	7	8	3	4	5	6	7	**8**
Extra traveling time for Carpooling (mins)	10	**10**	15	15	20	20	10	10	15	15	20	**20**
Minibus (Yes=5 mins/No=10 mins)	10	**10**	10	10	10	10	5	5	5	5	5	**5**
Reduction of Parking Demand due to Carpooling (%)	8,5	**17**	8,5	23	12	23	12	23	14	23	16	**22**
Parking Demand pushed in P&R (%)	0	**0**	0	0	0	0	0	0	0	0	0	**1**

The third different policy applied (Table 33), concerns again two different pricing policies. Firstly, Park & ride price is reduced to one fourth of Drive Alone price in an attempt to make it more preferable than Carpooling. This simulation results to 11% reduction of parking demand due to Carpooling and 4% of parking demand pushed in Park & Ride when applying €7 of parking fee for Drive Alone alternative. Secondly, cost of Park & ride is kept one fourth of Drive Alone, while Carpooling cost is doubled. This change in the policy transforms Park & Ride in a more preferable alternative than Carpooling and results to 13% of Park & Ride share, when applying the same parking fee.

Table 33 Simulation of future responsiveness of the 110 respondents including their own searching and egress time, with the initial policy of the alternatives Park & Ride and Carpooling for searching and egress time. Cost of Park & Ride was reduced, while Cost of Carpooling was increased. (1st round, 3rd simulation)

	$Cost_{DriveAlone}=4*Cost_{P\&R}=3*Cost_{Crpl}$						$Cost_{DriveAlone}=4*Cost_{P\&R}=3/2*Cost_{Crpl}$					
Parking fee of Drive Alone (€)	4	5	5	6	**7**	8	6	7	6	7	6	**7**
Extra traveling time for Carpooling (mins)	10	10	15	15	**20**	20	10	10	15	15	20	**20**
Minibus (Yes=5 mins/No=10 mins)	5	5	5	5	**5**	5	5	5	5	5	5	**5**
Reduction of Parking Demand due to Carpooling (%)	17	23	8,5	23	**11**	13	8,5	11	1	1	1	**1**
Parking Demand pushed in P&R (%)	0	0	0	0	**4**	52	1	4	4	13	4	**13**

Finally, the second round of simulations considers the reduction of the total parking supply. A parking supply reduction results in an increase of searching time. This increase is assumed approximately to 2 minutes and the previous simulated policies are realized again (second round). The overall results of the simulations are presented in Appendix C in Tables 72, 73 and 74 while the results of the last two pricing policies are summarized in Table 34.

Table 34 Simulation of future responsiveness of the 110 respondents including their own egress time and their searching time increased by 2 minutes. Cost of Park & Ride was reduced, while Cost of Carpooling was increased. (2nd round, 3rd and 4th simulations)

	$Cost_{DriveAlone}=4*Cost_{P\&R}=3*Cost_{Crpl}$						$Cost_{DriveAlone}=4*Cost_{P\&R}=3/2*Cost_{Crpl}$					
Parking fee of Drive Alone (€)	4	5	5	6	**7**	8	6	7	6	7	6	**7**
Extra traveling time for Carpooling (mins)	10	10	15	15	**20**	20	10	10	15	15	20	**20**
Minibus (Yes=5 mins/No=10 mins)	5	5	5	5	**5**	5	5	5	5	5	5	**5**
Reduction of Parking Demand due to Carpooling (%)	23	45	15	23	**7**	7	13	3	1	0	1	0
Parking Demand pushed in P&R (%)	0	0	0	0	**61**	61	3	62	9	65	9	65

From Table 34 it can be concluded that when the parking demand is decreased and consequently searching time increased, then Carpooling and Park & Ride become more preferable than the previous simulations. Therefore, with the same parking fee it is possible to reduce the parking supply and achieve higher parking demand reduction.

7.8 CO_2 emissions

As aforementioned in the literature review, applying different policies in order to decrease parking demand contributes in the reduction of the CO_2 emissions as well. The average traveling time of the commuters of the TU Delft is approximately 33,5 minutes, which can be translated to 40 km distance according to Google maps (Google maps, 2016). Furthermore if the vehicles used by TU Delft commuters are considered average petrol cars, then it is found that the emissions of CO_2 are approximately 0,135 Kg/km (Heymann, 2014). According to the survey that was conducted the average frequency of the respondents' traveling to the campus of the TU Delft is estimated 3,05 times per week. Assuming that the findings of the conducted survey can be generalized for the whole population of the TU Delft, the estimation of the reduction of CO_2 emissions, compared to annual CO_2 emissions from transport sector in Netherlands is presented in Table 35.

Table 35 Estimated reductions of CO_2 emissions compared to the total CO_2 emissions from transport in Netherlands (33,41 million metric tons in 2011) (Knoema Aata Atlas, 2011). For the calculations, 40km distance per vehicle, 0,135 Kg/km (Heymann, 2014), 3,05 times traveling per week for 10 months were assumed.

Parking Demand Reduction (%)	Reduction of CO_2 tons	Percentage of the total CO_2 in the Netherlands (%)
10	289,754	$9,77x10^{-4}$
15	434,631	$1,46x10^{-3}$
20	579,508	$1,95x10^{-3}$
25	724,386	$2,24x10^{-3}$
30	869,263	$2,92x10^{-3}$
35	1014,140	$3,35x10^{-3}$
40	1159,017	$3,91x10^{-3}$

Concluding, reducing the parking demand –and consequently the car use- in the campus of the TU Delft to 20%, a reduction of almost 0,002% of the total CO_2 emissions produced from transport sector in Netherlands can be achieved.

7.9 Conclusion

In this chapter, the results of the final conducted survey and their analysis were presented. In the first section an overview of the 110 respondents' characteristics were discussed. Afterwards, the responses were distributed randomly into two groups; the estimation data set and the validation data set. According to the theory presented in Chapter 6, the data sets were used to estimate and validate the coefficients of two models generated with the use of MNL and MMNL models. Even the model derived from the MMNL model application has higher rho-squared (0,272) compared to the model derived from then MNL model application (0,166), during the validation process, both of the models were found to have the same forecasting accuracy. The estimation and validation of the two models were followed by an estimation of new models according to the respondents' revealed preferences and characteristics. In this way, the preferences of the individual segments of the population became known. What is more, two useful concepts such as Value of Searching and Egress Time were employed to identify the population's willingness-to-pay. Worth mentioning is the fact that employees are willing to pay more per reduced minute in searching and egress time than students of the TU Delft. Then, two important properties were also employed to assist in the identification of the commuters' future responsiveness to policy changes; direct and cross elasticities. From this process, percentage increase of the parking fee was concluded to be the most efficient strategy to reduce parking demand of 'Drive Alone' alternative. To identify commuters' future responsiveness to different policies, simulations took place. The simulations that resulted in different optimal parking fees and parking demand reduction were presented. Finally, using the commuters' travelling characteristics the reduction of CO_2 emissions was calculated in respect to parking demand reduction of the TU Delft campus.

Chapter 8 Conclusion and Recommendations

8.1 Introduction

The purpose of the present thesis is first to identify and evaluate the current parking demand of the TU Delft campus and second to investigate the effects of different parking management strategies that can contribute in reducing it. This chapter focuses in the results of the previous sections and elaborates in the conclusions of this research. Furthermore, limitations of this research are discussed and recommendations for future research and actions are provided.

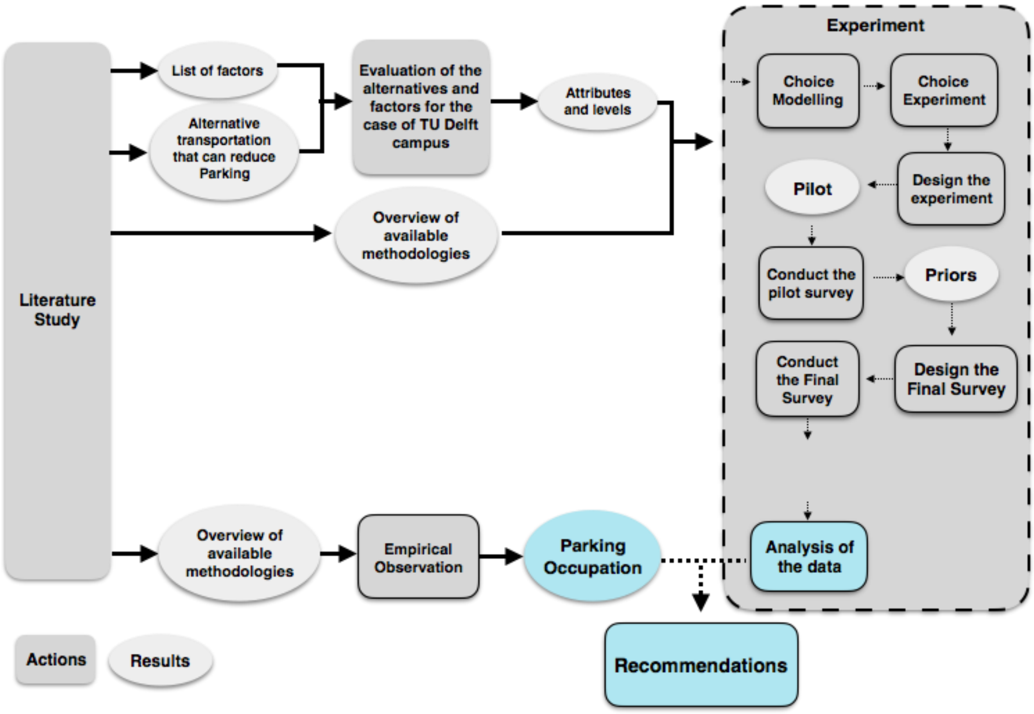


Figure 21 Methodology - Conclusions & Recommendation

8.2 Conclusions

In this thesis, a framework for managing the parking demand of the TU Delft was conceptually identified. The framework specifies essential traveling and parking decision that commuters of a university's campus make. Prerequisite of this framework was first to identify the current parking demand and the needs of supply for the future and then to estimate the commuters' responsiveness in different policies. The observation that took place and the forecasting methods that were applied, in combination with analysis of a stated choice experiment increase the validity of this framework. This framework will constitute a useful tool for managing the parking demand of the TU Delft, as well as an inspiration for other similar organizations to act accordingly. Finally, the sustainable impact of the framework's application was estimated in terms of reduction of CO_2 emissions.

Regarding the current parking situation of the TU Delft campus, the observation that took place assisted in identifying the current parking supply and demand. More specifically, the TU Delft campus has a capacity of 3770 parking spaces, while the total parking demand during the peak hours (13:00-15:00) reaches 86,5% (3263 vehicles) of the total supply. The percentage of the total parking demand is considered inside the acceptable boundaries according to literature (Boamah, 2013; Bodenbender, 2013; Chaturvedi & Mitava, 2013;

Litman, 2006). However, the distribution of the parking demand differs from the distribution of the supply. To strengthen this argument, worth mentioning is the fact that 42% of the parking areas exceeded 95% in demand, while 30% of the parking areas were undersupplied.

Concerning the future parking demand, with the use of forecasting methods, its estimation was realized. However, the results foreshadow a large increase in future parking demand. It is expected that in 2020 the demand for parking in the TU Delft campus will exceed the supply by 17,5%, if no action is taken to restrain the parking demand.

One of the most crucial parking demand management strategies is considered the parking fees introduction. Introduction of parking fee or increase of the existing parking fee has been used as a concept in several transportation researches (Hess & Polak, 2004; Hilvert, Toledo, & Bekhor, 2012; Van der Waerden, Borgers, & Timmermans, 2006; Washbrook, Haider, & Jaccard, 2006; Weis, Vrtic, Widmer, & Axhausen, 2011; Yang, Choudhury, Ben-Akiva, Silva, & Carvalho, 2009). Through a Stated Preference survey, tracking the commuters' responsiveness in a hypothetical parking fee introduction became feasible. The estimation of the model's coefficient revealed interesting details for the traveling and parking behavior of the TU Delft commuters. As expected, parking cost attribute affected the most commuters in their travelling and parking decisions. Furthermore, calculating the elasticities of all the attributes used in the stated choice experiment, confirmed the hypothesis that the price incentivizes commuters in their travelling and parking choices. More specifically, every percentage increase in the parking price will result to approximately 1,5% of decrease in Drive Alone alternative. Consequently, commuters will choose to do Carpooling or park their cars in a remote parking.

As far as searching time is concerned, it was proved to be inelastic. Every percentage increase of searching time results to less than 0,5% decrease in the Drive Alone alternative. Furthermore, a relation between parking price and searching time was identified by the Value of Searching time otherwise known as Willingness to Pay. TU Delft commuters are willing to pay €0,24 per minute decreased in searching time.

Egress time, affects also the parking demand, nevertheless it had slighter impact than parking fees and searching time. Particularly, its estimated elasticities proved that it had a larger impact in Park & Ride than in Drive Alone alternative. This is totally reasonably since egress time is larger and a core attribute in Park & Ride alternative. Therefore, during the simulations that took place campus' internal minibus policy was also considered. Calculating the Value of Egress time for the TU Delft commuters, confirmed the previous argument of having smaller impact than searching time. TU Delft commuters are willing to pay €0,07 per minute egress time decreased less than in searching time.

Extra traveling time for Carpooling -as expected- affects mainly the same alternative. Therefore, for every percentage of extra traveling increase, Carpooling share decreases by 1%. However, its cross elasticities reveal that every percentage change in the extra traveling time affects reversely the shares of Drive Alone and Park & Ride. Thus, a reduction of time spending in extra travelling to pick up the carpoolers will have positive results, reducing the commuters who drive alone. Unfortunately, this factor cannot be control by the administration of the university and requires a governmental approach.

In order to transfer the aforementioned theoretical approaches to practical results, simulations with the estimated model were realized. The revealed behavior –current searching and egress time- of the respondents were used as baseline to begin the simulations. During this process the application of different policies were simulated. A variety of price relations between the alternatives were investigated, while in all simulations a minibus service, which reduces the egress time for Park & Ride, was considered as well. The results of the simulations proved that Carpooling is more preferable than Park & Ride with the initial policies. However, by reducing the cost of Park & Ride, in respect to Carpooling and by introducing minibus service to minimize its egress time their effects were managed to achieve a balance. More specifically, the model showed some remarkable reduction of parking demand due to carpooling and in parallel an increase of Park & Ride share. Finally, the simulations that took place proved that a total annihilation of Drive Alone alternative is possible. Nevertheless, this situation can be achieved with extremely high parking prices. Therefore, parking demand in the central of the campus can be totally pushed in the outskirts transforming it to a sustainable paradigm. Sustainable mobility of the university can be achieved through the application of the aforementioned parking demand management strategies at the TU Delft campus. Nonetheless, an attempt to quantify the increase in sustainability through the estimation of the reduction of the CO_2 emissions was made. Briefly, for every 5% of parking demand reduction in the campus of the TU Delft, 145 tones of CO_2 per year will be avoided.

8.3 Recommendations

The research realized for the purpose of this thesis had undeniably faced several limitations. Narrowing down the scope of this research was a consequence of the time limitations and the explorative character of the stated choice experiment that was conducted. Nevertheless, the results and consequently the conclusions derived from the aforementioned research are possible to find a practical application. Therefore, the last section of this thesis is devoted to a discussion of the scientific limitations and recommendations for practice and further research.

8.3.1 Recommendations for Science

The realization of this research led undoubtedly in a scientific contribution. This contribution concerns a framework, which combines a specific area's current and future parking demand with the effects that the different parking demand management measures have on commuters' traveling and parking behavior. Two alternative travelling and parking options ('Carpool' and 'Park & Ride') were studied at the same time in comparison to the status quo 'Drive Alone'. The results of this study showed that commuters have a clear preference in 'Carpool' option than 'Park & Ride' and this is due to a combination of lower searching and egress time of the first than the latter. What is more, introducing parking fees was found to be the most effective way to stimulate commuters to choose the alternative options. Furthermore, during an analysis of the sample in segments, students expressed higher preference to alternative travelling and parking than employees, with the visitors to be the least influenced by the measures. Unfortunately, the lack of large number of responses available, led to smaller rho-squares when analyzing separately the different segments of the population.

What is more, the sample of the study cannot be characterized as fully representative of the TU Delft community. First, a larger sample would be needed to reassure that the distribution of the proportion of employees, students, visitors and inhabitants is correct when considering them in the model as a whole. Although 110 responses were sufficient to produce statistically significant results, a higher number would increase its external validity. Second, representative sample of all the parking areas was also limited due to low rate of response and small amount of parking spaces in many areas. Conducting the survey in areas with 20 parking spots could be extremely time consuming, thus, three of the largest parking areas were chosen. Finally, personal characteristics such as the gender, age, and income were not considered since the experiment was conducted face-to-face and not online.

Additionally, limitations could not be missing from the model itself. Limitations were identified during the designing process of the model and during its analysis as well. Regarding the designing process of the model an important traveling alternative, public transportation, was neglected since there was a concurrent thesis dealing with this aspect (Keijzer, Investigating the Effectiveness of Mobility-Management Measures in Reducing Car Use, 2016). Although, the 'none' option was also considered during the design process, it was chosen not to implement it due to high bias of respondents to future introduction of parking fees. Therefore, a possible scenario of respondents choosing the 'none' option in every choice set as an expression of opposition to parking fees was avoided. However, it would be interesting to identify how many commuters will move to public or other means of transportation by including the alternative of public transportation or the 'none' option in future similar researches. What is more, interaction effects between variables were not considered for this study. Usually, interaction effects can be neglected in transportation stated choice experiments (Street & Burgess, 2007). Nevertheless, it would be interesting to study the interaction effects between parking costs and egress and searching time. Finally, the way that the experiment was conducted –in person at the parking areas- led to narrow choice of attributes. Including more attributes would have increased the number of choice sets and consequently the length of the survey. In order to keep the survey short important attributes such as the traveling costs, traveling time and safety of parking were neglected.

Concerning the analysis of the retrieved data, limitations of Multinomial Logit and Mixed Multinomial Logit models were also identified. These two models were chosen for their simplicity and easiness of use. More complicated models such as Nested Logit could achieve better model fit.

8.3.2 Recommendations for Practice

The framework to manage the parking demand of a university's campus, which was constructed for the purpose of this study, is not only applicable for other universities but also for organizations (e.g. hospitals, hotels, airport, malls) and general urban areas that follow the same characteristics of the studied case. Therefore, in this section recommendations for the context of the TU Delft will be given, followed by a discussion of how this study's results can be generalized for other settings.

8.3.2.1 Recommendations for the TU Delft context

In order to provide a complete plan of recommendations for the administration of the TU Delft, three scenarios regarding the parking supply were constructed. The first scenario considers the current parking supply to remain constant for the next five years. The second scenario implies the increase of the parking supply, while the third scenario considers the decrease of the number of parking spots in the campus. The following recommendations should not be confused with a similar thesis of Keijzer (2016) for the TU Delft, since the alternatives and their attributes differ.

As far as the first scenario, '***Constant Parking Supply***', is concerned, the total current parking supply serves the total current parking demand successfully. However, as it was discussed in Chapter 5, the distribution of the parking supply differs from the distribution of the parking demand. To avoid this mismatch in the first year, there are two recommendations that the administration should follow. First, by introducing smart parking concepts the commuters can be informed regarding the availability of parking through their navigation devices or through their smartphones (Chaniotakis, 2014). Second, the rules for parking should be better enforced by the responsible authority (Seattle Government, 2008). In this way, incidents such as illegal parked vehicles on the pavements and on grass will be avoided. Regarding the future, the forecasting estimations showed a parking demand increase that should be taken into consideration. For the second year a minimum reduction by 10% of the parking demand will be sufficient. This reduction could be achieved by introducing a parking fee of €3. Regarding the third year an increase by 17% in the parking demand can be confronted by increasing the parking fee to €4. In year four, the price that will be needed in order to confront the 21% increase of parking demand is €5. Finally, the fifth year an increase of €1 in the parking price of the previous year will be needed.

The second scenario, ***'Increase Parking Supply'*** considers that the parking supply should follow the increase of the parking demand. However, in order the TU Delft to be able to meet the increasing parking demand, investments in new parking facilities should be made. Introducing parking fees can fund these investments. For the case of the TU Delft the parking fees to cover the depreciation costs of building new garage and maintenance costs are calculated and presented in Table 75. According to the total costs of the depreciation of the new parking spaces and the maintenance of the total parking supply, the parking fees that should be introduced in each year are presented in Figure 22.

The third scenario, ***'Decrease Parking Supply',*** which targets to transform the TU Delft campus to a sustainable paradigm, dictates the decrease of the current parking supply at least by 10%. Taking into consideration the reduction of CO_2 emissions that the university is willing to achieve, the corresponding parking policy should be adopted. By this action, not only a reduction in CO_2 emissions will be achieved, but also more space for 'greening' will become available. To succeed in this plan a parking fee of €4 should be introduced for the first year. Finally, according to the results of the simulations, an annually increase of €1 would be sufficient to cover the increase in parking demand due to the population growth. In Figure 22 a schematic representation of the aforementioned scenarios is presented.

Figure 22 Recommended scenarios

Concluding, for all the above-mentioned scenarios parking law enforcement, education of the commuters and incentives to move into sustainable transportation should be considered. Parking law enforcement will not only contribute in making sure that the parking supply level is not exceeded but also in assuring that the respective fees are paid. Additionally, educating the commuters about the alternative ways of travelling and parking will result in a more mature community. More specifically, the administration should inform and explain the reason for implementing the new policies. In this way the acceptability of commuters towards the new measures will increase. What is more, the environmental awareness of the commuters can increase through educational activities and seminars. Finally, incentives such as Carpooling or Park & Ride parking permits can motivate commuters to change their traveling status quo.

An important note for the recommendation of the 'Constant Parking Supply' and 'Decrease Parking Supply' is that they depend on the price relation of the three alternatives and whether the option of the minibus is available or not. Therefore, Tables 69-73 should be advised always before every change. Furthermore, 'extra traveling time' for Carpooling alternative cannot be the same for all the commuters and this incommodes the choice of the right price policy. What is more, the application of the price elasticity of demand would be of important assistance to the policy makers of the university. Parking demand can be measured in the future and with the use of elasticity concept, the appropriate percentage increase in the parking fees can be estimated. Finally, since commuters' behavior can change through time it is advised to reconsider conducting the stated choice experiment again before applying new policies.

8.3.2.2 Generalization of the framework for other settings

Technical University of Deft is considered one of the largest educational institutions in the Netherlands. Not only due to its population but also for its academic research and impact to the country it belongs. Therefore, the successful implementation of the abovementioned framework can constitute a source of inspiration and consequently influence other institutions and organization to adopt a philosophy towards sustainable campuses.

Population and characteristics of the TU Delft can be considered similar to other institutions and organizations. For instance, similar measures were studied in Eindhoven University of Technology (Van der Waerden, Borgers, & Timmermans, 2006), in Minnesota State University (Filipovitch & Boamah, 2016), in California State University Stanislaus Campus (OMNI-MEANS, LTD. Engineers & Planners, 2008), in University of California, Berkeley (Nelson/Nygaard consulting associates, 2011) etc. However, in these studies not the same concepts (Drive Alone – Carpooling – Park & Ride) and attributes were used in order to manage their parking demand. Furthermore, the connection to the CO_2 emissions that can be avoided can lead to unexplored ground of the TDM strategies. Concluding, since an interest regarding TDM has already been identified in universities all over the world, the present framework can constitute a scientific step forward, towards sustainable campuses from mobility perspective.

Additionally, the present framework can be useful for organizations such as airports, hospitals, and malls and even in larger scale such as municipalities. Although airports need special confrontation, Aldrige et al. (2006) stress the importance of learning from TDM strategies applied in different contexts. Similarly to this study, parking price was also found to be a core incentive for managing the parking demand management (Ison, Francis, Humphreys, & Rye, 2008; Ison, Humphreysa, & Ryeb, 2007). Furthermore, similar studies have been realized for municipalities such as Enschede (Chaturvedi & Mitava, 2013), Einthoven (Lem, 2014), Zurich (Bodenbender, 2013), Beijing (Strompen, Litman, & Bongardt, 2012). However, not all of the aforementioned studies consider the same alternatives and attributes. Therefore, it is recommended that in different contexts, the coefficients of the model, as well the attributes should be considered again and be adapted according to the needs of the specific occasion. Finally, considering the reduction of CO_2 emissions, the value of this framework increases when it is applied in larger scale such as municipalities (Strompen, Litman, & Bongardt, 2012).

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Appendices

Appendix A

Table 36 Synopsis of the literature discussing the main concepts.

Title	Reference	Discipline	Main focusing points
Sustainable university: what can be matter?	(Velazquez, Munguia, Platt, & Taddei, 2006)	Campus Sustainability	✓ Multiple case studies in universities Model comprised of four strategic management processes (education, research, outreach and partnership, implementing sustainability) ✓ Sustainability initiatives in campuses (energy and water efficiency, recycling, non-hazardous waste management, green buildings, **transportation and commuting)**
Putting sustainable development in practice: campus greening as a tool for institutional sustainability efforts.	(Filho, Shiel, Paço, & Brandli, 2015)	Campus sustainability, campus greening	✓ Definition (role and evaluation) of 'campus greening': (green operations and maintenance, green cleaning processes, **alternative transportation strategies**, recycling programs, **landscape planning**, increase community's awareness for energy ad water consumption) ✓ Literature review in campus greening efforts (UK, US, Hungary, Denmark, Portugal, Slovenia) ✓ Lack of critical studies for campus greening (they mainly focus in description and examples) ✓ Recommendations: (**extend green spaces**, **diversity of campus vegetation**, green infrastructure, ecological project etc.)
Greening of the campus: a whole-systems approach	(Koester, Eflin, & Vann, 2006)	Campus sustainability	✓ Greening of Ball State University (administrative policies, facilities management practices, education for sustainability) ✓ Campus planning: (**reforestation program**, green building practices, **planning bicycle and pedestrian paths**) ✓ Sustainability knowledge: 'Green for Green' courses, Conferences etc.
An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices	(Alshuwaikhat & Abubakar, 2007)	Campus sustainability, green campus	✓ Lack of systematic approach to achieve campus sustainability ✓ 3 strategies to enhance sustainability: Environmental Management System, public participation and social responsibility, promotion of sustainability through teaching and research. ✓ University's Environmental Management System: Green buildings, **Green transportation**, Campus preservation) ✓ **Green Transportation: encourage the use of alternative ways of transport, discourage single-car commuting, reduce emissions and congestion**
Development of Sustainable Campus: University Kebangsaan Malaysia Planning and Strategy	(Darus, Rashid, Hashim, Omar, Saruwono, & Mohammad, 2009)	Campus sustainability	✓ Case study in Kebangsaan University ✓ Energy efficiency, reduce waste, identity landscape, public transportation ✓ Public transportation: reduce traffic congestion, conflict for road user and duration of journey ✓ **Reduce CO2 emissions**
Towards greening a	(Lukman,	Campus	✓ Case study of University of Maribor

university campus: The case of the University of Maribor, Slovenia	Tiwary, & Azapagic, 2009)	sustainability	✓ Concentrates in construction and maintenance, energy (heating and lighting) and water consumption
Mobility Management: the case of a large university campus in Rio de Janeiro, Brazil	(Lemos, Balassiano, Santos, & Portugal, 2006)	Campus mobility	✓ Highlights the need of **Mobility Managemen**t in campuses (**reducing private vehicle**) ✓ **Transportation Demand Management** ✓ **Sustainable Mobility (parking fees, car-pooling, alteration of working schedules, public transport)** ✓ **Mobility Management Strategies:** Information and Marketing**, Transport System, Land Use, Road infrastructure** ✓ **Parking Lot Management** ✓ **Reduction of fuel**
The sustainable mobility paradigm	(Banister D. , 2008)	Sustainable mobility	✓ Conventional **Transport planning, Demand** and cost minimization ✓ Policies to improve urban sustainability
Sustainable transportation planning on college campuses	(Balsas, 2003; Banister & Stead, 2004)	Campus Sustainable Transportati on	✓ Modal Shift (from vehicles to bicycle and walking) ✓ Employer trip reduction programs ✓ Sustainable Transportation and Transport Demand Management (**car-sharing**, mass transit, **alternative fuels, park and ride**)
A methodology to promote sustainable mobility in college campuses	(dell'Olio, Bordagaray, Barredaa, & Ibeasa, 2014)	Campus sustainable mobility	✓ Stated Preferences Survey for hypothetical **mobility policies** in college campus ✓ **Car-sharing, Parking policies, park and ride**. ✓ Case Study of Las Llamas Campus
Social - Friendly Sustainable Mobility in Indian Campuses	(Rasool & Mukherjee, 2014)	Sustainable mobility	✓ Issues in implementing sustainable mobility ✓ Handle the motorized vehicles in campus (**reduce and relocate the parking spaces, introduce/increase parking fees**) ✓ **Aesthetic of campus environment** ✓ Sustainable mobility programs in 9 Universities
Sustainable Mobility at a University Campus: Walking Preferences and the Use of Electric Minibus	(Eboli, Mazzulla, & Salandria, 2013)	Sustainable mobility	✓ Investigates commuters' preferences (walking or transit system) ✓ **Discrete choice models to analyze commuters attributes** ✓ **Use of Multinomial Logit and Mixed Logit to model the preferences**
Dealing with parking issues on an urban campus: The case of UC Berkeley	(Riggs, Dealing with parking issues on an urban campus: The case of UC Berkeley, 2014)	Parking in campus	✓ **Factors affecting parking** ✓ **Price sensitivity** ✓ **Greenhouse emissions** ✓ **Highlights the need for systematic analysis of parking behavior** (e.g. every 3 years)
The impact of targeted outreach for parking mitigation on the UC	(Riggs & Kuo, 2015)	Parking in campus	✓ Discuss the effect of promotion of alternative commute options ✓ Pre-post Study (occupancy survey) ✓ Treatment (marketing event)

Berkeley campus			✓ Post survey (interviews, email permit holders etc.)
Parking Problems at the UC campus: Setting the research agenda	(Barata, Cruz, & Ferreira, 2010)	Parking in campus	✓ Case Study in University of Coimbra ✓ Estimation of **Parking Demand and Supply** ✓ Evaluation of the **parking fee policy** ✓ Methodology: Descriptive model (Counting parking demand and model commuters' behavior)
Greening commuters' transportation and parking at the University of Coimbra Campus	(Ferreira, Freire, Cruz, & Barata, 2012)	Parking in campus	✓ Case Study in University of Coimbra ✓ **Balance of Parking Demand and Supply** ✓ **Reduction of Greenhouse gas emissions, fossil fuel consumption: Life-Cycle approach** ✓ 6 Scenarios to calculate the reduction of GHG emissions
Reducing parking demand and traffic congestion at the American University of Beirut	(Aoun, Abou-Zeid, Kaysi, & Myntti, 2013)	Parking in Campus	✓ Case Study in University of Beirut (**TDM strategies**) ✓ Examined 5 American Campuses to define: Impacts of increasing Parking supply Incentivize commuters with high income to use campus transit (proposed solution: Taxi-sharing) ✓ Methodology: **Case studies-Stated Preference Survey**
A systems model for achieving optimum parking efficiency on campus: The case of Minnesota State University	(Filipovitch & Boamah, 2016)	Parking in Campus	✓ Case Study in Minnesota State University ✓ Goal: Identify the optimum parking price level ✓ Balance the Supply/Demand in order to meet the parking expenses (maintenance costs) ✓ Methodology: Data collection, Parking Occupancy Surveys, Model
Parking Demand Forecast Model for Institutional Campus	(Tembhurkar & Khobragade, 2015)	Parking in Campus	✓ Case Study in Indian Institutional campuses ✓ Goal: Identify the parking attributes and forecast future Parking Demand
Attitudes and Behavioral Responses to Parking Measures	(Van der Waerden, Borgers, & Timmermans, 2006)	Parking in Campus	✓ Case Study in Eindhoven University of Technology ✓ Goal: Study the attributes and behavior of car users ✓ Methodology: on-street questionnaire, multinomial logit analysis
Impact of On-Street Parking in the Core of a University Campus	(Fries, Dunning, & Chowdhury, 2009)	Parking in Campus	✓ Case Study in Clemson University campus ✓ Goal: Identify the impact of relocating parking spaces from a central area of a University to the periphery. ✓ Methodology: Simulation model Development (VISSIM)
Empirical Study of Parking Problem on University Campus	(Shang, Lin, & Huang, 2007)	Parking in Campus	✓ Case Study in Beijing University of Aeronautics and Astronautics ✓ Goal: Identify ✓ Methodology: Observation of occupancy, analysis of commuters behavior

Appendix B

Table 37 Parking occupancy on 19/05/2016

Parking Place	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
01. Christiaan Huijgensweg	64	62	**64**	**67**	62	49	32
02. Voorterrein Aula	0	0	0	0	0	0	0
03. Parkeerterrein Aula/Library	296	243	**306**	**339**	275	57	24
04. Binnentuinen TNW/TN	155	124	144	**155**	117	24	18
05. Van der Waalsweg (rest)	107	101	104	**111**	89	11	14
06. Stieltjesweg	36	24	30	31	22	5	1
07. Voorterrein v/m Deltares	**33**	**0**	**0**	**0**	**0**	**0**	**0**
08. Keverling Buismanweg	65	61	**73**	**72**	45	17	11
09. Van Mourik Broekmanweg	57	52	55	55	34	5	5
10. Stevinweg	32	29	**34**	32	21	26	9
11. N.C. Kistweg	94	85	86	90	63	9	6
12. Pieter Calandweg West	19	**39**	**42**	**40**	31	12	3
13. Pieter Calandweg Oost	9	**10**	**11**	**12**	9	4	0
14. Voorterrein Bouwcampus	71	57	67	65	44	8	3
15. Van der Burgweg	47	43	**49**	45	35	3	2
41. Van der Broekweg zuidzijde	73	58	59	62	63	35	18
42. Parkeerterrein Sport	324	193	270	290	293	56	16
43. Watermanweg	170	73	105	101	97	26	21
44. Fokkerweg	19	**22**	**28**	**26**	8	4	2
45. Parkeerterrein Fellowship	58	55	57	53	37	20	3
46. Parkeerterreinen L&R	188	184	195	177	123	43	15
47. Parkeerterrein FMVG	282	**29**	**35**	**54**	**32**	**6**	**0**
48. Parkeerterrein Hoge snelheden	20	16	**24**	**26**	14	7	1
TOTAL of Area A	**2219**	**1560**	**1838**	**1903**	**1514**	**427**	**204**

Table 38 Parking occupancy on 17/05/2016

Parking Place	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
16. Achterterrein EWI	**92**	71	86	78	69	34	17
17. Parkeerterrein Feldmannweg	**218**	145	215	199	187	68	9
18. Leeghwaterstraat (bij living containers)	**28**	20	**29**	19	26	11	3
19. Binnenterreinen Korvezeestraat	**158**	**91**	**101**	**138**	**117**	**73**	**70**
20. Parkeerterrein TNO Leeghwaterstraat	**18**	14	17	14	14	6	4
21. Parkeerterrein Balpol Noord	**111**	85	84	94	75	86	98
22. Parkeerterrein Balpol Oost	**44**	19	40	40	39	38	42
23. Jaffalaan Oost (naast O&S/OTB)	**10**	6	**12**	**11**	**10**	6	4
24. Jaffalaan West (voor TBM)	**16**	5	**22**	**15**	**18**	5	2
25. Parkeerterrein tussen OTB en TBM	**36**	5	23	16	21	9	5
26. Parkeerkelder TBM Landbergstraat	**69**	48	65	57	60	33	5
27. Leeghwaterstraat (achter IO)	**27**	14	25	20	25	15	9
28. Achterterrein 3mE Noordzijde	**39**	14	20	17	21	18	8
29. Binnenterrein 3mE Zuidzijde	**14**	11	**17**	**16**	**18**	9	4
30. Parkeerterrein Leeghwaterstraat	**194**	162	**220**	176	170	81	21
31. Binnenterrein Warmtekrachtcentrale	**43**	28	**52**	37	34	21	2
32. Binnenterrein Drebbelweg	**19**	6	13	15	13	6	0
33. College van Bestuur	**13**	3	7	5	4	2	0
34. Bouwkunde Oostzijde	**176**	134	**212**	**253**	**195**	95	65
35. Bouwkunde Westzijde	**49**	27	**50**	44	33	18	3
36. Zuidplantsoen	**9**	9	**17**	**16**	**15**	**14**	9
37. Binnenterrein Delft Chemtech	**23**	5	15	12	10	4	0
38. Binnenterrein proeffabrieken/Kramerslab	**45**	29	**53**	**55**	**48**	21	3
39. Julianalaan (voorterrein Biotechnologie)	**38**	18	27	27	29	15	9
40. Zij- en achterterrein Science Centre	**62**	56	90	84	80	47	23
TOTAL of Area B	**1551**	**1025**	**1512**	**1458**	**1331**	**735**	**415**

Table 39 Parking occupancy on 23/05/2016

Parking Place	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
01. Christiaan Huijgensweg	64	63	63	63	61	48	28
02. Voorterrein Aula	0	0	0	0	0	0	0
03. Parkeerterrein Aula/Library	296	241	**312**	**314**	273	59	19
04. Binnentuinen TNW/TN	155	124	145	140	115	23	7
05. Van der Waalsweg (rest)	107	106	**112**	**110**	88	8	5
06. Stieltjesweg	36	27	33	27	20	3	0
07. Voorterrein v/m Deltares	**33**	0	0	0	0	0	0
08. Keverling Buismanweg	65	58	56	58	42	16	6
09. Van Mourik Broekmanweg	57	54	54	56	33	4	1
10. Stevinweg	32	**35**	**34**	**33**	18	22	7
11. N.C. Kistweg	94	86	92	90	62	8	3
12. Pieter Calandweg West	19	**39**	**39**	**40**	**29**	7	0
13. Pieter Calandweg Oost	9	11	11	11	8	1	0
14. Voorterrein Bouwcampus	71	56	59	60	42	5	0
15. Van der Burgweg	47	42	45	42	34	5	0
41. Van der Broekweg zuidzijde	73	55	59	**74**	55	49	13
42. Parkeerterrein Sport	324	182	268	264	114	43	12
43. Watermanweg	170	79	98	91	46	18	29
44. Fokkerweg	19	**28**	**29**	18	6	3	0
45. Parkeerterrein Fellowship	58	56	**58**	**60**	34	14	1
46. Parkeerterreinen L&R	188	**203**	**202**	**205**	92	36	17
47. Parkeerterrein FMVG	285	32	61	59	28	5	0
48. Parkeerterrein Hoge snelheden	20	19	**20**	**30**	17	9	0
TOTAL of Area A	**2219**	1596	1850	1845	1217	386	148

Table 40 Parking occupancy on 26/05/2016

Parking Place	Capacity	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	18:30-19:30	23:00-00:00
16. Achterterrein EWI	**92**	68	82	83	75	32	16
17. Parkeerterrein Feldmannweg	**218**	132	162	203	190	65	11
18. Leeghwaterstraat (bij living containers)	**28**	16	28	20	25	9	2
19. Binnenterreinen Korvezeestraat	**158**	88	107	115	111	67	72
20. Parkeerterrein TNO Leeghwaterstraat	**18**	11	15	16	16	8	2
21. Parkeerterrein Balpol Noord	**111**	87	77	85	76	88	103
22. Parkeerterrein Balpol Oost	**44**	22	42	39	40	39	43
23. Jaffalaan Oost (naast O&S/OTB)	**10**	4	9	11	11	4	2
24. Jaffalaan West (voor TBM)	**16**	9	18	18	17	7	3
25. Parkeerterrein tussen OTB en TBM	**36**	7	15	16	19	8	4
26. Parkeerkelder TBM Landbergstraat	**69**	46	63	64	62	32	3
27. Leeghwaterstraat (achter IO)	**27**	14	24	25	23	14	12
28. Achterterrein 3mE Noordzijde	**39**	12	22	21	20	17	7
29. Binnenterrein 3mE Zuidzijde	**14**	9	16	17	17	6	2
30. Parkeerterrein Leeghwaterstraat	**194**	145	177	197	167	76	10
31. Binnenterrein Warmtekrachtcentrale	**43**	23	46	44	39	22	1
32. Binnenterrein Drebbelweg	**19**	7	13	15	10	6	0
33. College van Bestuur	**13**	4	7	8	6	3	0
34. Bouwkunde Oostzijde	**176**	113	187	196	194	97	68
35. Bouwkunde Westzijde	**49**	24	37	34	33	16	2
36. Zuidplantsoen	**9**	8	16	17	16	14	10
37. Binnenterrein Delft Chemtech	**23**	4	10	11	10	3	0
38. Binnenterrein proeffabrieken/Kramerslab	**45**	26	51	50	46	24	2
39. Julianalaan (voorterrein Biotechnologie)	**38**	15	27	34	28	13	7
40. Zij- en achterterrein Science Centre	**62**	43	74	79	80	42	20
TOTAL of Area B	**1551**	**1025**	**1512**	**1458**	**1331**	**735**	**415**

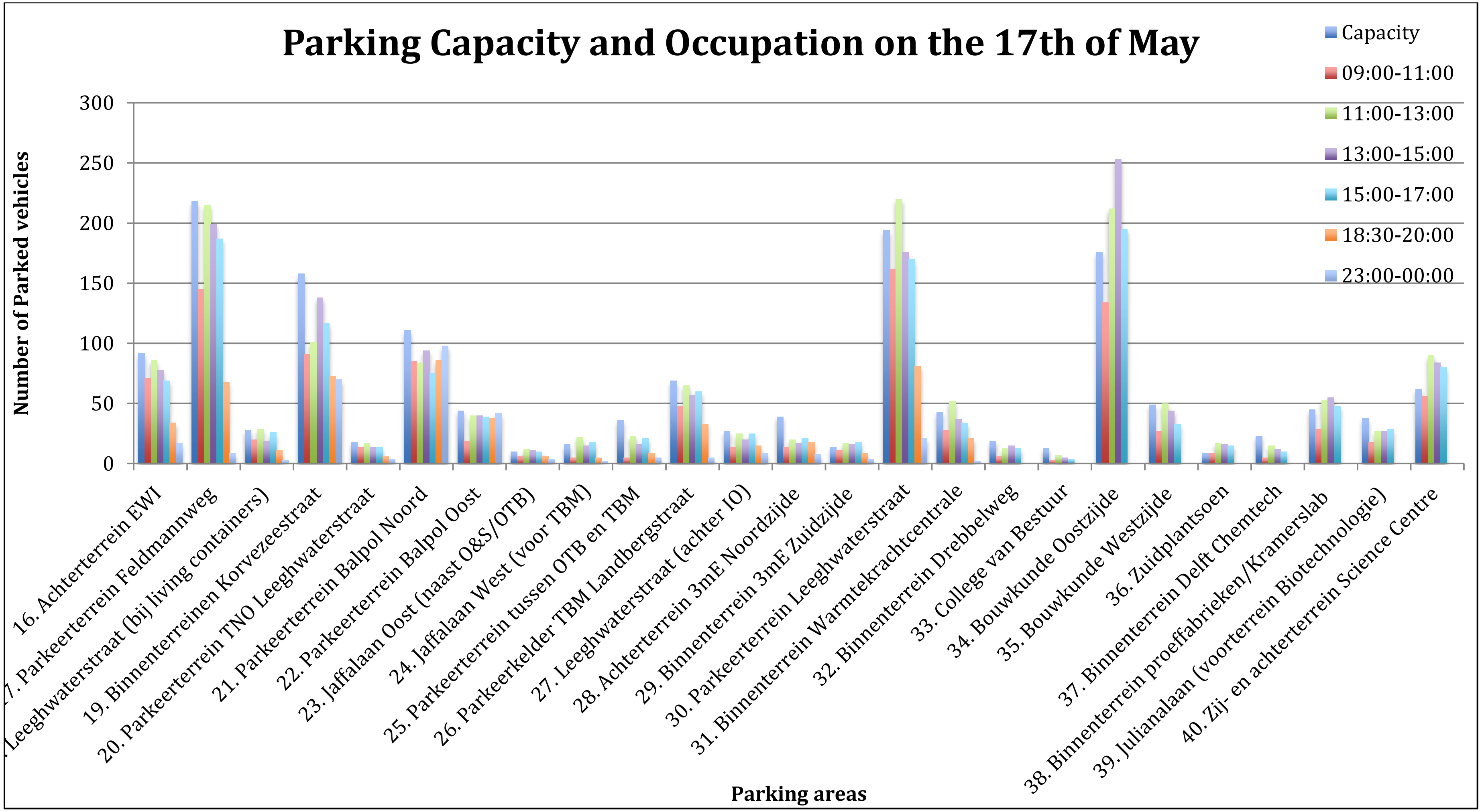

Figure 23Parking Capacity and occupation on 17/05/2016

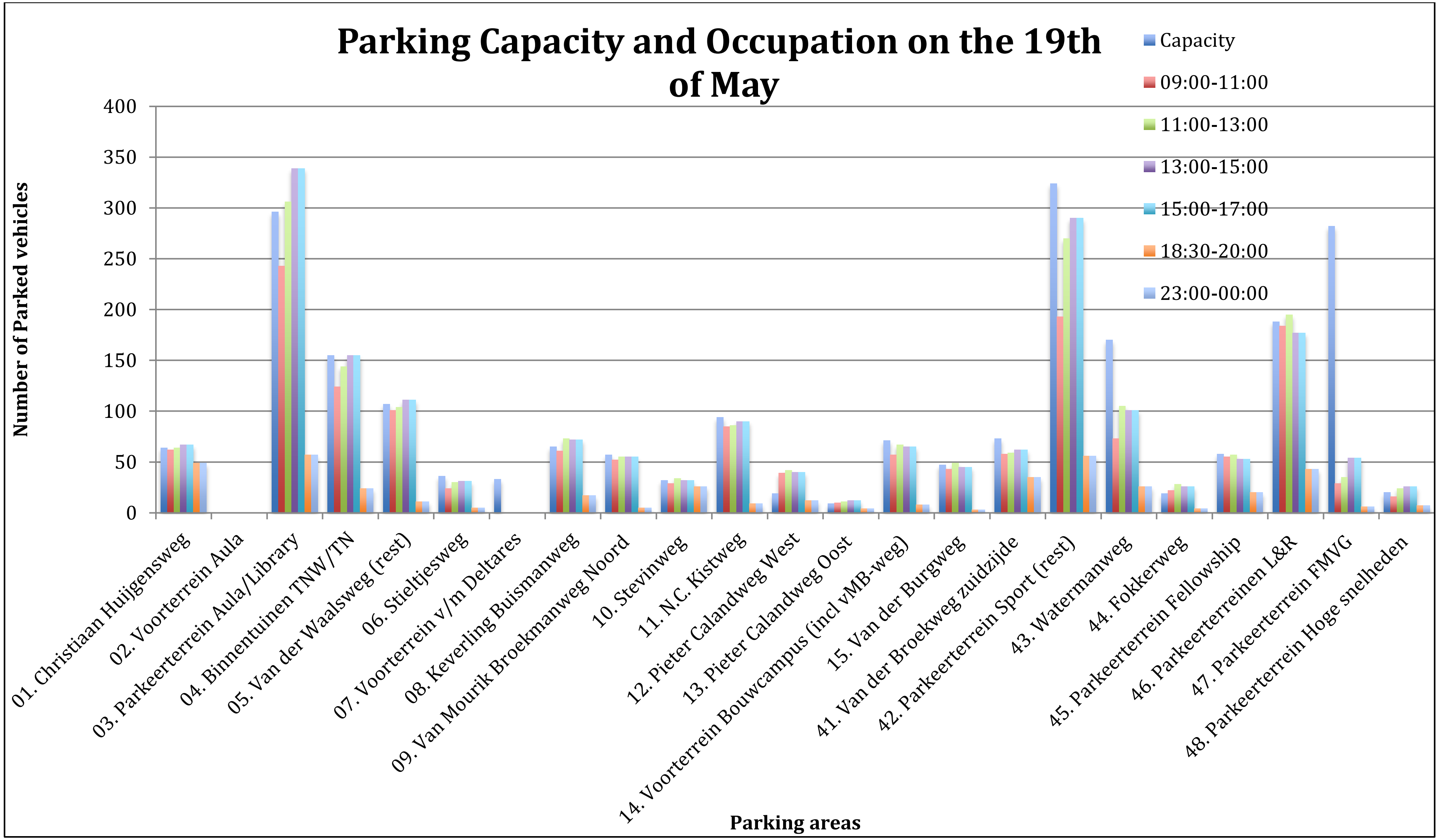

Figure 24 Parking Capacity and occupation on 19/05/2016

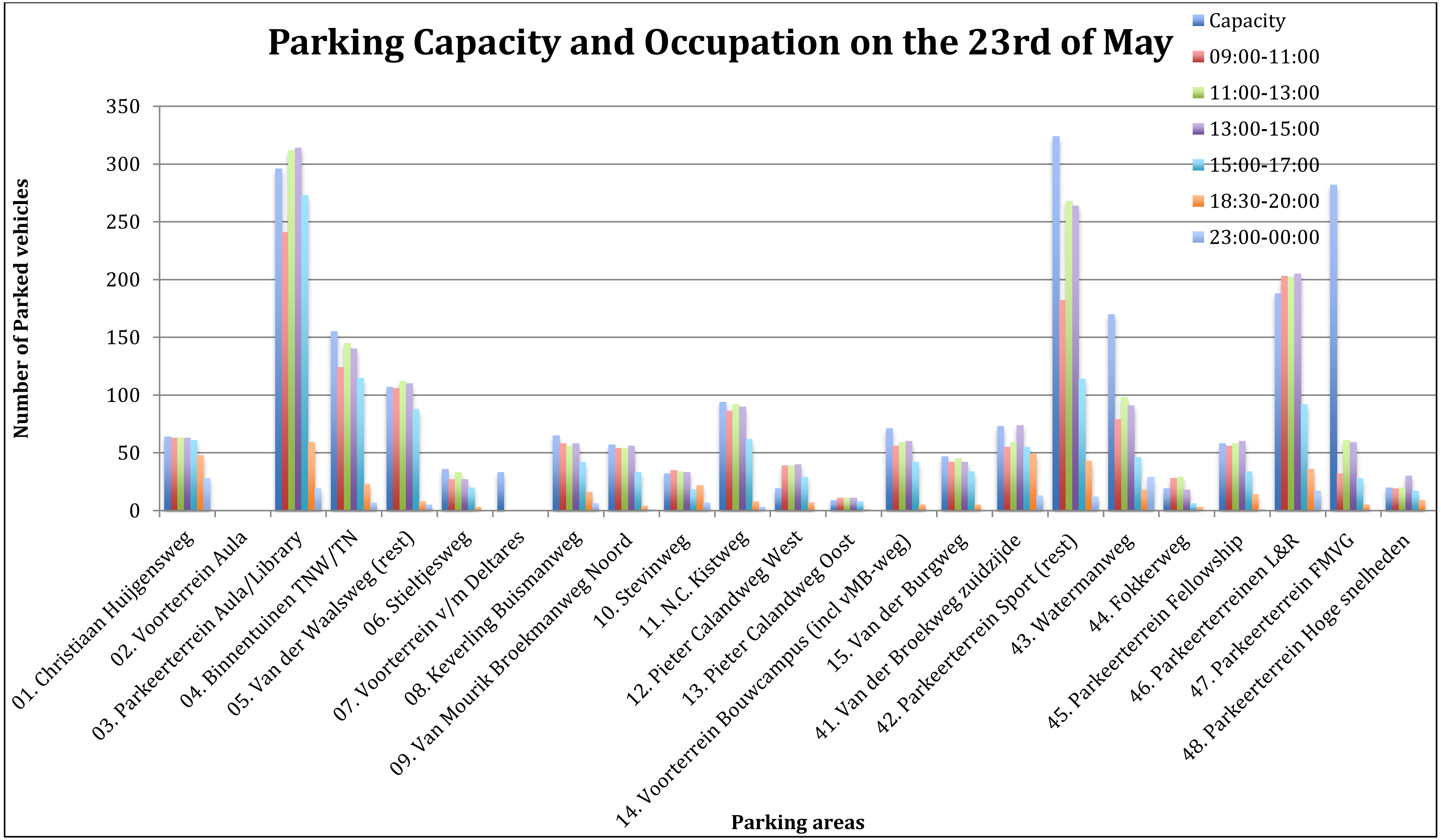

Figure 25 Parking Capacity and occupation on 23/05/2016

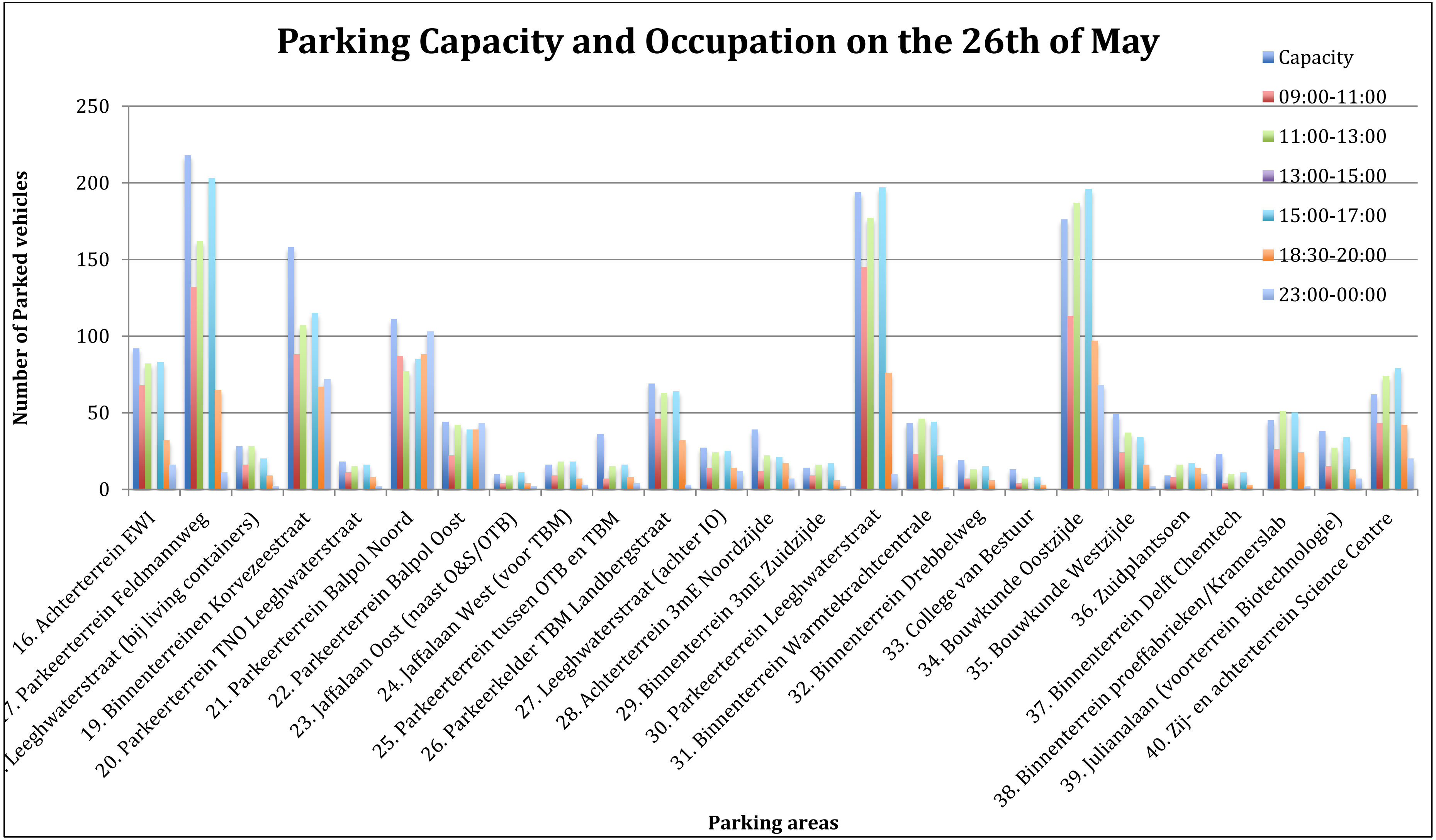

Figure 26 Parking Capacity and occupation on 26/05/2016.

Forecast of the population of Employees and Students for the next five years

Table 41 Forecasting Parking Demand for the upcoming years. Source: (TU Delft, department Communication, 2015; TU Delft, department of Marketing & Communication, 2014; Delft University of Technology, 2013; TU Delft, Marketing & Communications, 2012; TU Delft, Marketing & Communication, 2011; TU Delft, Marketing & Communications, 2010; TU Delft, Marketing & Communications, 2009; TU Delft, Marketing & Communications, 2008; TU Delft, Marketing & Communications, 2007; TU Delft, Marketing & Communications, 2006)

Year	Students	Employees
2004	13335	4545
2005	13253	4441
2006	13469	4571
2007	14170	4640
2008	15166	4691
2009	16263	4595
2010	16893	4599
2011	17179	4490
2012	17461	4440
2013	18583	4536
2014	19509	4652
2015	20980	4566
2016	21681	4703
2017	22755	4843
2018	23886	5037
2019	25077	5292
2020	26328	5615

Table 42 Parkind Demand of TU Delft

Parking Area	2016	2014
01. Christiaan Huijgensweg	63	61
02. Voorterrein Aula	0	0
03. Parkeerterrein Aula/Library	314	291
04. Binnentuinen TNW/TN	140	126
05. Van der Waalsweg (rest)	110	103
06. Stieltjesweg	27	36
07. Voorterrein v/m Deltares	0	4
08. Keverling Buismanweg	58	64
09. Van Mourik Broekmanweg Noord	56	55
10. Stevinweg	33	29
11. N.C. Kistweg	90	88
12. Pieter Calandweg West	40	18
13. Pieter Calandweg Oost	11	4
14. Voorterrein Bouwcampus (incl vMB-weg)	60	70
15. Van der Burgweg	42	47
16. Achterterrein EWI	83	85
17. Parkeerterrein Feldmannweg	203	142
18. Leeghwaterstraat (bij living containers)	20	19
19. Binnenterreinen Korvezeestraat	115	111
20. Parkeerterrein TNO Leeghwaterstraat	16	18
21. Parkeerterrein Balpol Noord	85	95
22. Parkeerterrein Balpol Oost	39	44
23. Jaffalaan Oost (naast O&S/OTB)	11	10
24. Jaffalaan West (voor TBM)	18	16
25. Parkeerterrein tussen OTB en TBM	16	36
26. Parkeerkelder TBM Landbergstraat	64	64
27. Leeghwaterstraat (achter IO)	25	17
28. Achterterrein 3mE Noordzijde	21	24
29. Binnenterrein 3mE Zuidzijde	17	17
30. Parkeerterrein Leeghwaterstraat	197	188
31. Binnenterrein Warmtekrachtcentrale	44	37
32. Binnenterrein Drebbelweg	15	11
33. College van Bestuur	8	8
34. Bouwkunde Oostzijde	196	195
35. Bouwkunde Westzijde	34	52
36. Zuidplantsoen	17	9
37. Binnenterrein Delft Chemtech	11	15
38. Binnenterrein proeffabrieken/Kramerslab	50	57
39. Julianalaan (voorterrein Biotechnologie)	34	33
40. Zij- en achterterrein Science Centre	79	82
41. Van der Broekweg zuidzijde	74	51
42. Parkeerterrein Sport (rest)	264	46
43. Watermanweg	91	17
44. Fokkerweg	18	17
45. Parkeerterrein Fellowship	60	46
46. Parkeerterreinen L&R	205	178
47. Parkeerterrein FMVG	59	69
48. Parkeerterrein Hoge snelheden	30	19
TOTAL	3263	2824

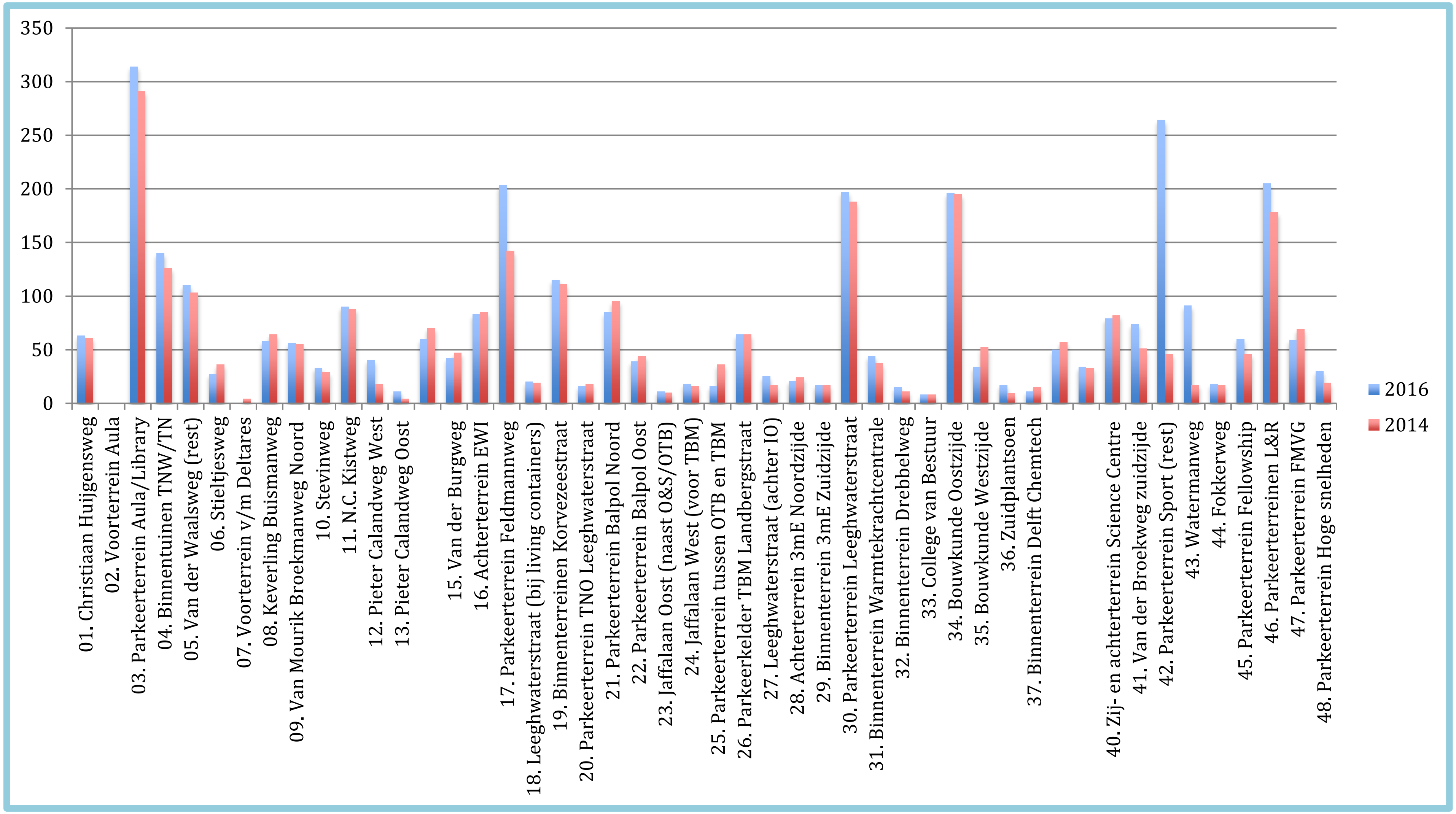
350
300
250
200
150
100
50
0
2016
2014
01. Christiaan Huijgensweg
02. Voorterrein Aula
03. Parkeerterrein Aula/Library
04. Binnentuinen TNW/TN
05. Van der Waalsweg (rest)
06. Stieltjesweg
07. Voorterrein v/m Deltares
08. Keverling Buismanweg
09. Van Mourik Broekmanweg Noord
10. Stevinweg
11. N.C. Kistweg
12. Pieter Calandweg West
13. Pieter Calandweg Oost
15. Van der Burgweg
16. Achterterrein EWI
17. Parkeerterrein Feldmannweg
18. Leeghwaterstraat (bij living containers)
19. Binnenterreinen Korvezeestraat
20. Parkeerterrein TNO Leeghwaterstraat
21. Parkeerterrein Balpol Noord
22. Parkeerterrein Balpol Oost
23. Jaffalaan Oost (naast O&S/OTB)
24. Jaffalaan West (voor TBM)
25. Parkeerterrein tussen OTB en TBM
26. Parkeerkelder TBM Landbergstraat
27. Leeghwaterstraat (achter IO)
28. Achterterrein 3mE Noordzijde
29. Binnenterrein 3mE Zuidzijde
30. Parkeerterrein Leeghwaterstraat
31. Binnenterrein Warmtekrachtcentrale
32. Binnenterrein Drebbelweg
33. College van Bestuur
34. Bouwkunde Oostzijde
35. Bouwkunde Westzijde
36. Zuidplantsoen
37. Binnenterrein Delft Chemtech
40. Zij- en achterterrein Science Centre
41. Van der Broekweg zuidzijde
42. Parkeerterrein Sport (rest)
43. Watermanweg
44. Fokkerweg
45. Parkeerterrein Fellowship
46. Parkeerterreinen L&R
47. Parkeerterrein FMVG
48. Parkeerterrein Hoge snelheden

Figure 27

Appendix C
Design of the pilot survey

Ngene Code

```
Design
? This will generate an orthogonal design of 12 rows
; alts= drivealone, carpool, parkandride
; rows= 12
; orth= sim
; eff=(mnl,d)
; model:
U(drivealone)= Bst[-0.079]*STcar[4,6,8]+Bet[-0.101]*ETcar[4,8,12]+Bpc[-
0.178]*Pcar[3,6,9] /
U(parkandride)=ASC1[0.180]+Bet*ETparkandride[14,18,22]+Bpc*Pparkandride[
2,4,6] /
U(carpool)=ASC2[-0.142]+Btt[-
0.079]*TTcarpool[10,15,20]+Bst*STcarpool[0,2,4]+Bet*ETcarpool[0,4,8]+Bpc
*Pcarpool[1,2,3]
$
```

MNL efficiency measures

Table 43 MNL Efficiency Measures of the pilot survey (1/2)

D error	0.030409
A error	0.037391
B estimate	78.290559
S estimate	43.916815

Table 44 MNL Efficiency Measures of the pilot survey (2/2)

Prior	bst	bet	bpc	btt
Fixed prior value	-0.079	-0.101	-0.178	-0.079
Sp estimates	43.916815	4.68487	5.198979	14.094629
Sp t-ratios	0.295761	0.905539	0.859601	0.522071

Design

Table 45 Choice Sets of the pilot survey.

Choice situation	drivealone.stcar	drivealone.etcar	drivealone.pcar	parkandride.etparkandride	parkandride.pparkandride	carpool.ttcarpool	carpool.stcarpool	carpool.etcarpool	carpool.pcarpool
1	6	12	6	18	6	10	2	8	2
2	8	4	6	22	2	20	2	8	2
3	8	4	3	14	4	10	0	4	1
4	4	8	3	14	2	15	4	0	2
5	8	12	9	14	4	20	4	4	1
6	4	12	3	22	4	20	0	4	1
7	6	4	6	18	6	20	2	0	3
8	6	8	3	18	6	15	4	8	3
9	8	12	6	22	2	10	2	0	3
10	4	8	9	14	2	15	0	8	3
11	4	4	9	22	4	10	4	4	1
12	6	8	9	18	6	15	0	0	2

MNL probabilities

Table 46 Probabilities of the choice sets for the alternatives of the pilot survey.

Choice situation	drivealone	carpool	parkandride
1	0.270424	0.445854	0.283721
2	0.468186	0.182886	0.348928
3	0.364405	0.385394	0.250201
4	0.359528	0.255646	0.384826
5	0.128769	0.294129	0.577102
6	0.437516	0.343475	0.219009
7	0.477573	0.299082	0.223345
8	0.580945	0.180487	0.238568
9	0.158793	0.57571	0.265497
10	0.193314	0.204653	0.602034
11	0.304433	0.497926	0.197641
12	0.181216	0.602262	0.216522

MNL utilities

Table 47 Utilities of the choice sets for the alternatives of the pilot survey.

Choice situation	drivealone	carpool	parkandride
1	-2.754	-2.254	-2.706
2	-2.104	-3.044	-2.398
3	-1.57	-1.514	-1.946
4	-1.658	-1.999	-1.59
5	-3.446	-2.62	-1.946
6	-2.062	-2.304	-2.754
7	-1.946	-2.414	-2.706
8	-1.816	-2.985	-2.706
9	-2.912	-1.624	-2.398
10	-2.726	-2.669	-1.59
11	-2.322	-1.83	-2.754
12	-2.884	-1.683	-2.706

MNL Covariance Matrix

Table 48 Covariance Matrix of the design of the pilot survey.

Prior	bst	bet	bpc	asc1	asc2	Prior
bst	0.071347	0.002082	0.004027	0.409076	0.32717	bst
bet	0.002082	0.01244	0.001416	-0.112058	0.069671	bet
bpc	0.004027	0.001416	0.042879	0.08434	0.207733	bpc
asc1	0.409076	-0.112058	0.08434	4.281878	1.879194	asc1
asc2	0.32717	0.069671	0.207733	1.879194	7.996343	asc2
btt	-0.00149	-0.000579	-0.001891	-0.006644	-0.35031	btt

MNL fisher matrix

Table 49 Fisher Matrix of the design of the pilot survey.

Prior	bst	bet	bpc	asc1	asc2	Prior
bst	79.08146	-86.602958	24.360195	-9.236589	-2.556502	bst
bet	-86.602958	463.844205	29.372653	29.129053	-22.32669	bet
bpc	24.360195	29.372653	49.171999	0.438076	-7.118435	bpc
asc1	-9.236589	29.129053	0.438076	2.387768	-1.244812	asc1
asc2	-2.556502	-22.32669	-7.118435	-1.244812	2.5109	asc2
btt	-36.825118	-324.593583	-102.386994	-18.179148	36.73345	btt

Results of the Pilot Survey

The classification of the participants of the pilot survey and three of the most important answers can be seen in Figure 28. Twenty-five percent of the participants were employees of the TU Delft or the TNO, 62,5% students and the rest of them visitors. What is more the majority of the sample (70,83%) travels around 20-30 minutes from home to the university, which was the shortest travelling time available. When designing the pilot, 20-30 minutes seemed a logical time frame as the lowest value to travel in the campus by car. However, after the feedback of the participants, it was realized that a lower value is needed to be included. 66,67% of the respondents are able to find a parking spot in 1-2 minutes and egress time -from the parking area to the final destination- for half of the population was approximately 1-3 minutes.

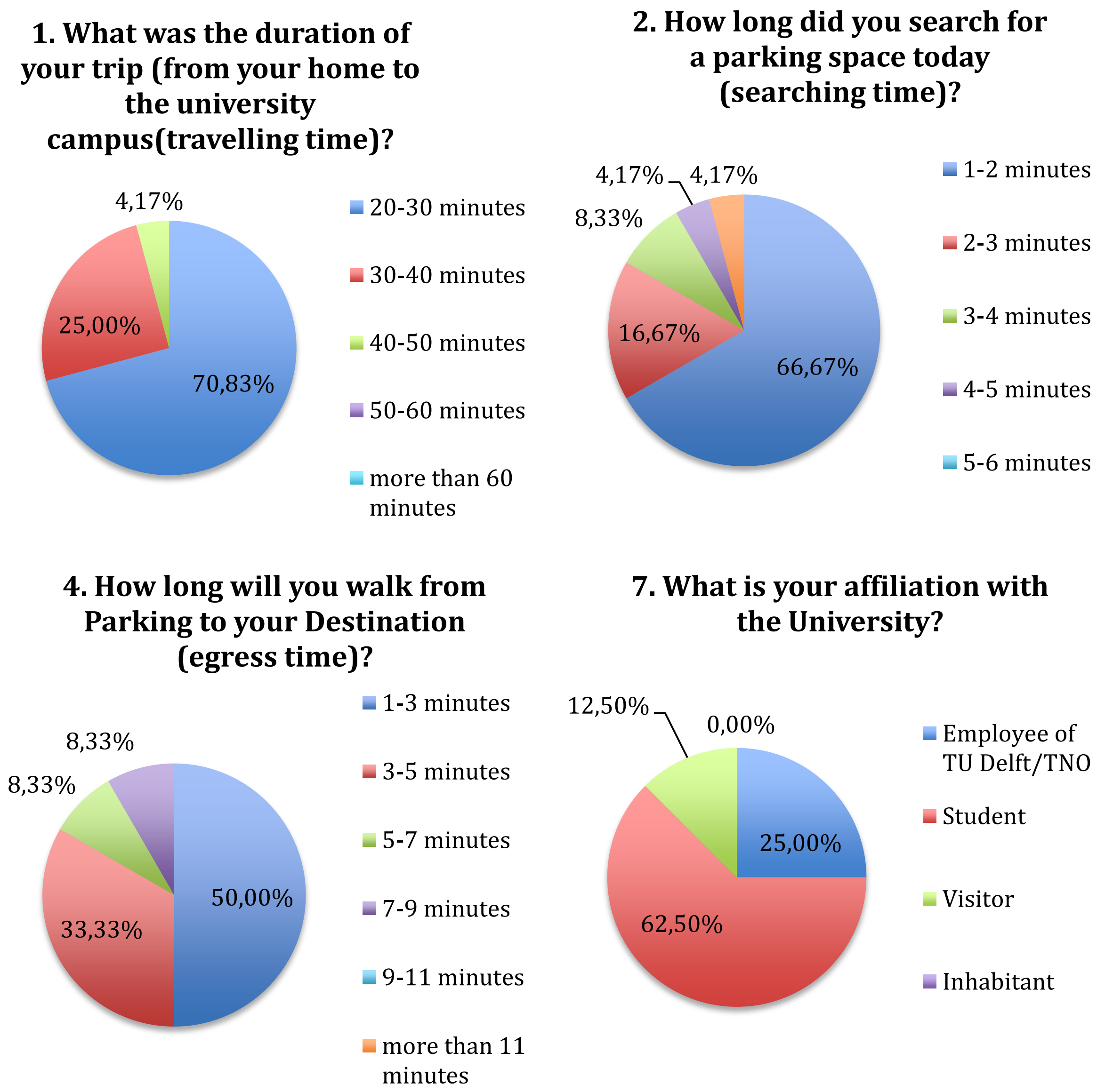

Figure 28 Results of the current behavior of the respondents.

Concerning the second part of the pilot survey, the duration of the stated choice experiment was considered from the participants to be long. Thus, the conclusion when realizing the second part of the pilot survey was that the choice set per respondent should be decreased. After having a satisfactory number of responses for the pilot, the answers of the surveys were transferred into raw data in Microsoft Excel. The analysis of the collected data was realized with the BIOGEME software (Bierlaire, 2003).

Table 50 Values of the parameters after analysing the pilot survey's responses.

Name of parameter	Value	Std error	t-test	p-value	Rob. Std error	Rob. t-test	Rob. p-value
β_1	-0.800	0.480	-1.67	0.10 *	0.472	-1.70	0.09 *
β_2	-0.210	0.686	0.31	0.76 *	0.702	-0.30	0.77
$\beta_{ExtraTraveltTime}$	-0.172	0.0354	-4.85	0.00	0.0368	-4.66	0.00
$\beta_{SearchingTime}$	-0.0409	0.0603	-0.68	0.50 *	0.0618	-0.66	0.51 *
$\beta_{Egresstime}$	-0.137	0.0263	-5.21	0.00	0.0272	-5.04	0.00
$\beta_{ParkingCost}$	-0.442	0.0522	-8.47	0.00	0.0490	-9.01	0.00

As it can be concluded from Table 50, the significance of almost all the parameters was achieved. The parameters β_1 and $\beta_{SearchingTime}$ were not found to be significant since more respondents were needed. However, the purpose of the pilot survey is to estimate approximately the parameters (priors) to be used in the design of the final survey, thus, its significance is not mandatory. Concluding, in Table 51 the priors used for the pilot survey and its actual result are compared.

Table 51 Values of the priors acquired from literature in comparison to the results of the pilot analysis.

Parameter	Value of parameter according to literature	Value of parameter according to analysis
β_1	-	-0.800
β_2	-	-0.210
$\beta_{ExtraTraveltTime}$	-0.079	-0.172
$\beta_{SearchingTime}$	-0.079	-0.0409
$\beta_{Egresstime}$	-0.101	-0.137
$\beta_{ParkingCost}$	-0.178	-0.442

Table 52 This table maybe needs to go in appendix

Coeff1	Coeff2	Covariance	Correlation	t-test	Rob. covar.	Rob. correl.	Rob. t-test
ASC2	BETATT	-0.0197	-0.813	-0.05 *	-0.0211	-0.816	-0.05 *
ASC2	BETAET	0.00578	0.320	-0.11 *	0.00675	0.354	-0.11 *
ASC2	BETAST	0.0229	0.554	-0.26 *	0.0225	0.517	-0.25 *
ASC2	BETAPC	0.0124	0.347	0.35 *	0.0129	0.376	0.34 *
BETAET	BETATT	-0.000109	-0.117	0.75 *	-0.000167	-0.167	0.71 *
ASC1	BETAPC	0.00805	0.322	-0.77 *	0.00678	0.293	-0.78 *
ASC1	ASC2	0.120	0.364	-0.87 *	0.0981	0.296	-0.82 *
ASC1	BETATT	-0.000780	-0.0460	-1.30 *	0.000418	0.0241	-1.33 *
ASC1	BETAET	-0.00488	-0.387	-1.35 *	-0.00533	-0.416	-1.37 *
BETAET	BETAST	0.000257	0.163	-1.55 *	0.000295	0.176	-1.52 *
ASC1	BETAST	0.0207	0.717	-1.73 *	0.0208	0.714	-1.77 *
BETAST	BETATT	-0.000375	-0.176	1.74 *	-0.000292	-0.128	1.72 *
BETAPC	BETATT	-1.04e-005	-0.00562	-4.28	-2.75e-005	-0.0152	-4.38
BETAET	BETAPC	7.73e-005	0.0564	5.35	0.000139	0.104	5.70
BETAPC	BETAST	0.000389	0.124	-5.37	0.000572	0.189	-5.63

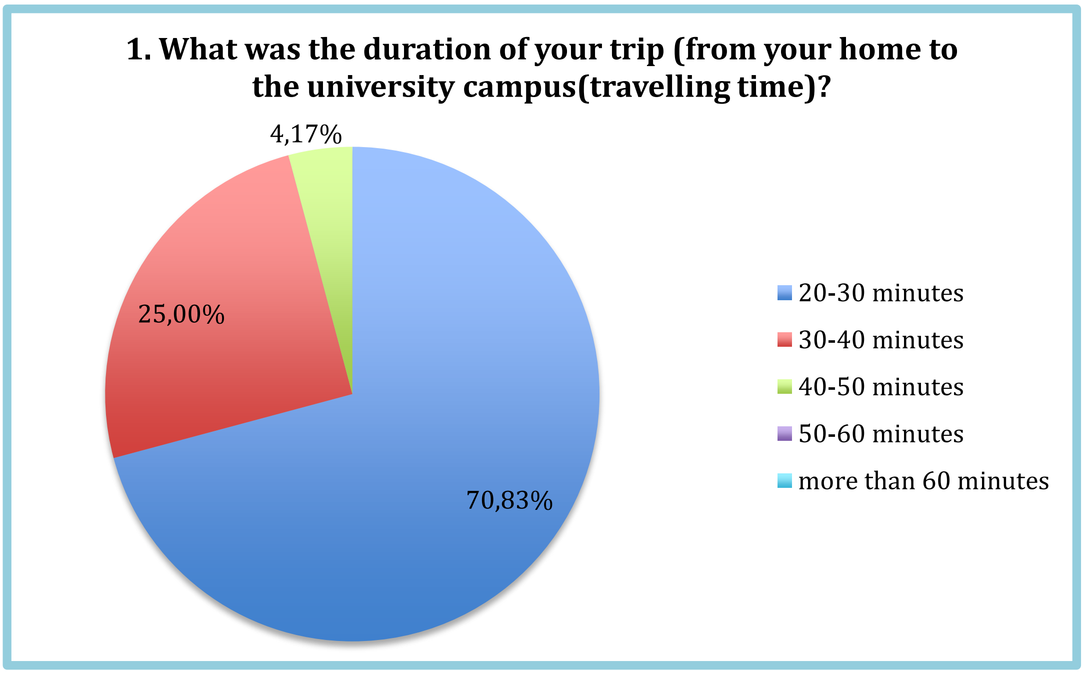

Figure 29 Responses of question 1 of the pilot survey.

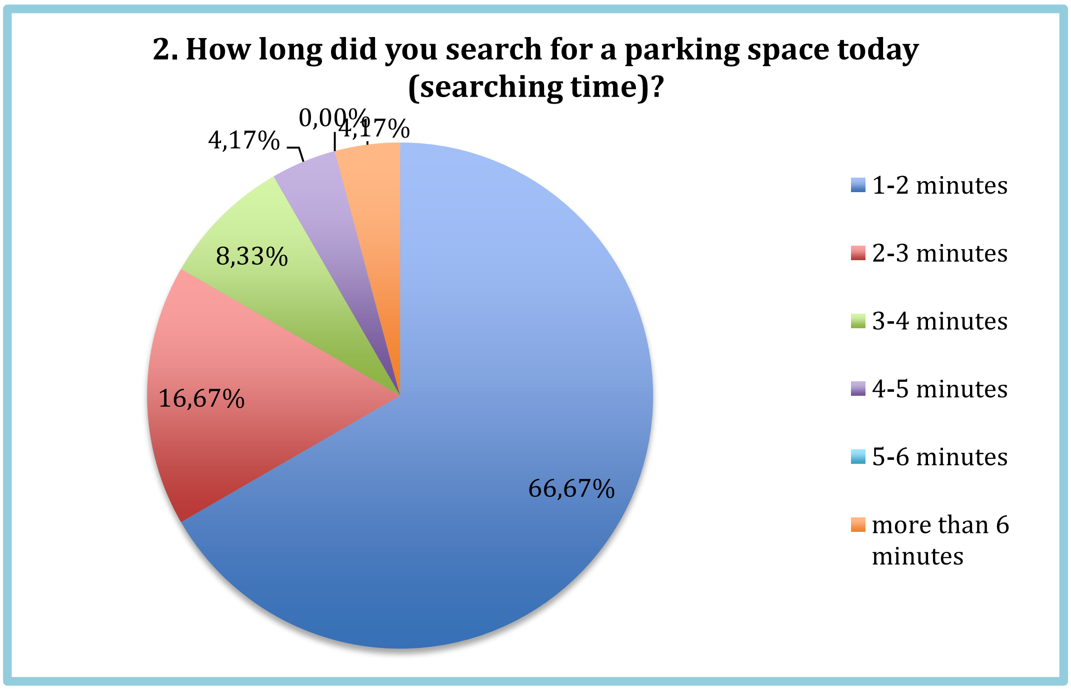

Figure 30 Responses of question 2 of the pilot survey.

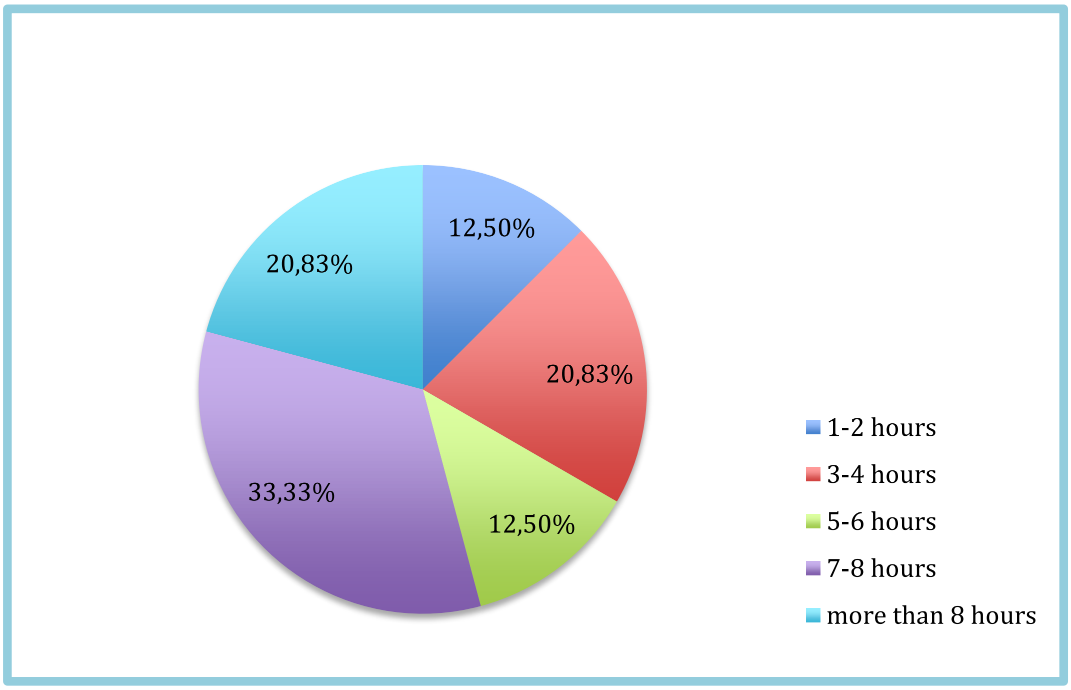

Figure 31 Responses of question 3 of the pilot survey.

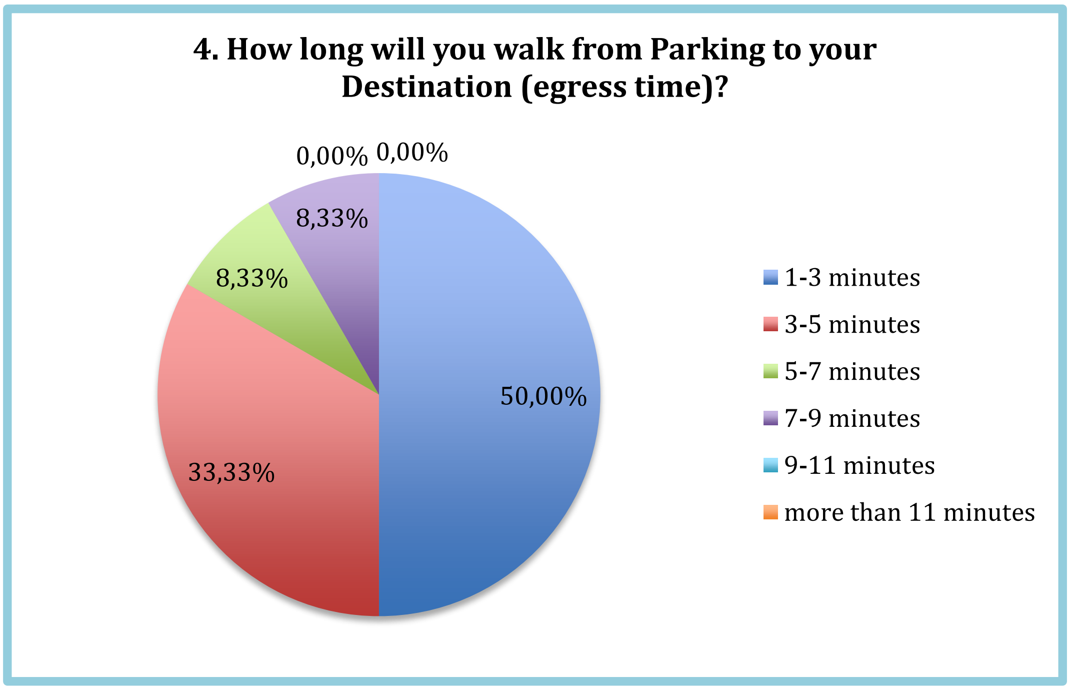

Figure 32 Responses of question 4 of the pilot survey.

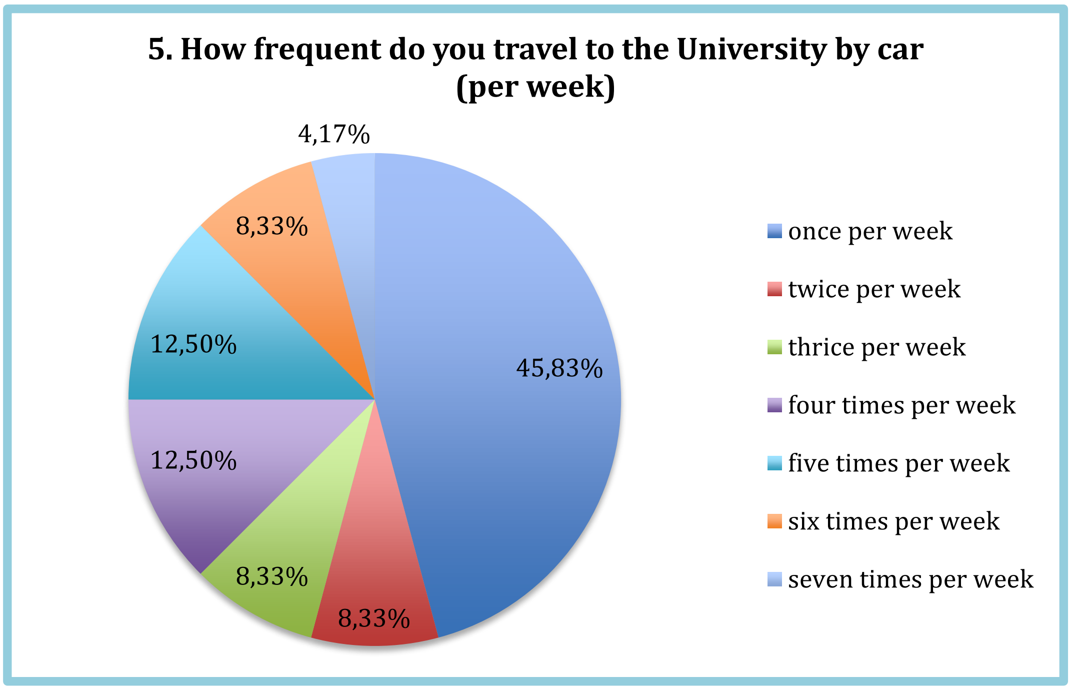

Figure 33 Responses of question 5 of the pilot survey

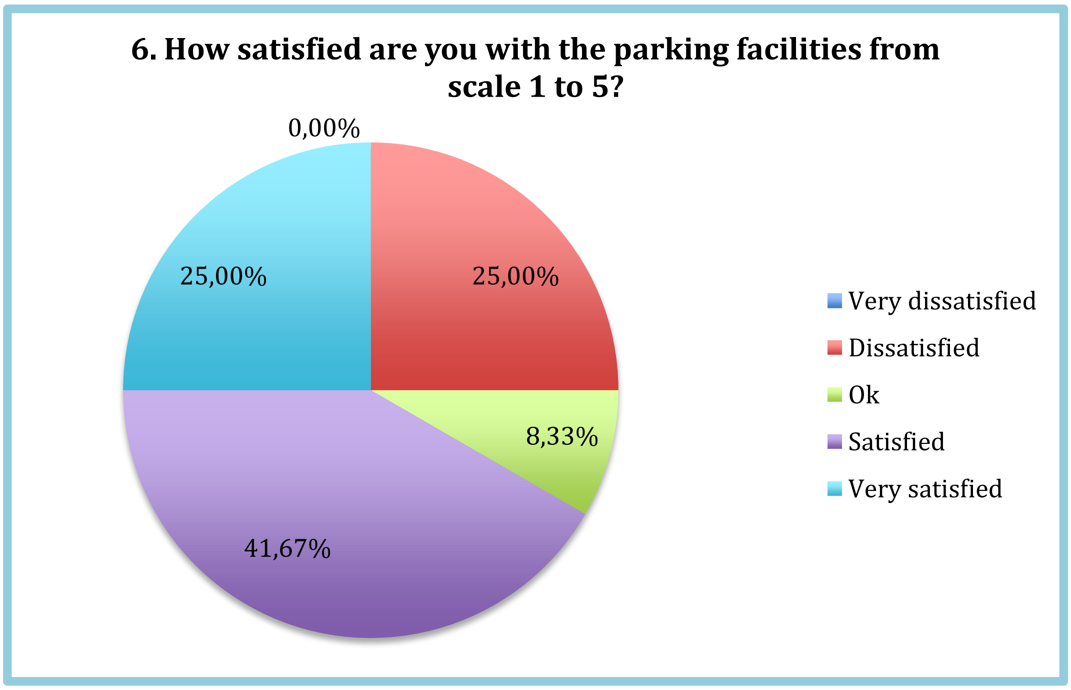

Figure 34 Responses in question 6 of the pilot survey.

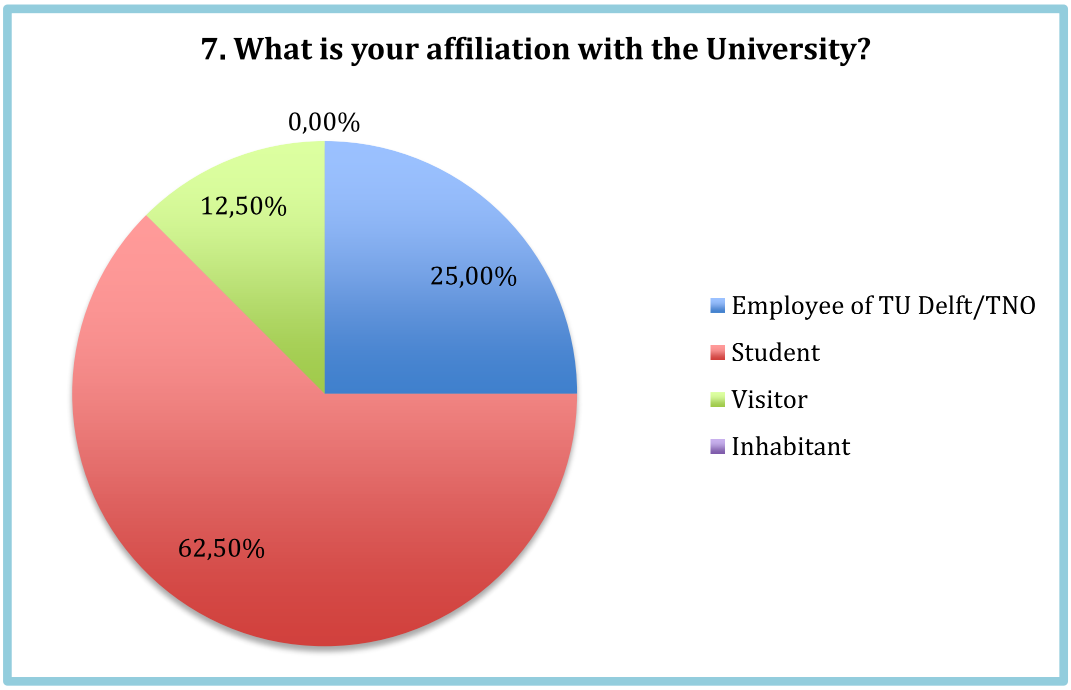

Figure 35 Responses in question 7 of the pilot survey.

Results generated using BIOGEME software

```
// This file has automatically been generated.
// 06/02/16 14:53:05
// Michel Bierlaire, EPFL 2001-2008
BIOGEME Version 1.8 [Sat Mar 7 14:36:56 CEST 2009]
Michel Bierlaire, EPFL

          Model: Multinomial Logit
Number of estimated parameters: 6
   Number of observations: 288
    Number of individuals: 288
     Null log-likelihood: -316.400
      Cte log-likelihood: -300.131
     Init log-likelihood: -1584.545
    Final log-likelihood: -219.947
    Likelihood ratio test: 192.906
         Rho-square: 0.305
     Adjusted rho-square: 0.286
     Final gradient norm: +4.780e-003
         Diagnostic: Convergence reached...
         Iterations: 25
          Run time: 00:00
     Variance-covariance: from finite difference hessian
         Sample file: data_setara.dat
Utility parameters
******************
Name   Value  Std err t-test p-val  Rob. std err Rob. t-test Rob. p-val
----   -----  ------- ------ -----  ------------ ----------- ----------
ASC1   -0.800 0.480   -1.67  0.10 * 0.472        -1.70       0.09       *
ASC2   -0.210 0.686   -0.31  0.76 * 0.702        -0.30       0.77       *
BETAET -0.137 0.0263  -5.21  0.00   0.0272       -5.04       0.00
BETAPC -0.442 0.0522  -8.47  0.00   0.0490       -9.01       0.00
BETAST -0.0409 0.0603 -0.68  0.50 * 0.0618       -0.66       0.51       *
BETATT -0.172 0.0354  -4.85  0.00   0.0368       -4.66       0.00

Utility functions
*****************
1  Alt1  av1  $NONE + ( ( BETAST * X12 ) + ( BETAET * X13 ) ) + ( BETAPC * X14 )
2  Alt2  av2  $NONE + ( ( ASC1 * one ) + ( BETAET * X23 ) ) + ( BETAPC * X24 )
3  Alt3  av3  $NONE + ( ( ( ( ASC2 * one ) + ( BETATT * X31 ) ) + ( BETAST * X32 ) ) + ( BETAET * X33 ) ) + ( BETAPC * X34 )
Correlation of coefficients
***************************
Coeff1 Coeff2 Covariance Correlation t-test  Rob. covar. Rob. correl. Rob. t-test
ASC2   BETATT -0.0197    -0.813      -0.05 * -0.0211     -0.816       -0.05 *
ASC2   BETAET 0.00578    0.320       -0.11 * 0.00675     0.354        -0.11 *
ASC2   BETAST 0.0229     0.554       -0.26 * 0.0225      0.517        -0.25 *
ASC2   BETAPC 0.0124     0.347       0.35  * 0.0129      0.376        0.34 *
BETAET BETATT -0.000109  -0.117      0.75  * -0.000167   -0.167       0.71 *
ASC1   BETAPC 0.00805    0.322       -0.77 * 0.00678     0.293        -0.78 *
ASC1   ASC2   0.120      0.364       -0.87 * 0.0981      0.296        -0.82 *
ASC1   BETATT -0.000780  -0.0460     -1.30 * 0.000418    0.0241       -1.33 *
ASC1   BETAET -0.00488   -0.387      -1.35 * -0.00533    -0.416       -1.37 *
BETAET BETAST 0.000257   0.163       -1.55 * 0.000295    0.176        -1.52 *
ASC1   BETAST 0.0207     0.717       -1.73 * 0.0208      0.714        -1.77 *
BETAST BETATT -0.000375  -0.176      1.74  * -0.000292   -0.128       1.72 *
BETAPC BETATT -1.04e-005 -0.00562    -4.28   -2.75e-005  -0.0152      -4.38
BETAET BETAPC 7.73e-005  0.0564      5.35    0.000139    0.104        5.70
BETAPC BETAST 0.000389   0.124       -5.37   0.000572    0.189        -5.63

Smallest singular value of the hessian: 1.91073
```

Figure 36 Results of the analysis of the pilot survey using the BIOGEME software

Pilot survey

Survey on Alternative Travelling and Parking Preferences

for the purpose of MSc Thesis of Makis Gravanis, TBM faculty, S.Gravanis@student.tudelft.nl

✦PART A: Revealed Preferences

1. **What was the duration of your trip (from your home to the university campus)?**

   20-30 mins *30-40 mins* *40-50 mins* *50-60 mins* *more than 60 mins*

2. **How long did you search for a parking space today?**

   1-2 *mins* *2-3 mins* *3-4 mins* *4-5 mins* *5-6 mins* *more than 6 mins*

3. ***How long will you use the parking facility today?***

   1-2 hours *3-4 hours* *5-6 hours* *7-8 hours* *more than 8 hours*

4. **How long will you walk from Parking to Office (egress time)?**

   1-3 mins *3-5 mins* *5-7 mins* *7-9 mins* *9-11 mins* *more than 11 mins*

5. **How frequent do you travel to the University by car (per week)?**

   1 *2* *3* *4* *5* *6* *7*

6. **How would you rank the university's Parking Facilities?**

   (Not satisfactory) 1 *2* *3* *4* *5* *(Satisfactory)*

7. **What is your affiliation with the University?**

   Staff *Student* *Visitor* *Inhabitant*

✦PART B Stated Preferences

In the following 12 table questions, you will be shown three types of travelling options and you will be asked to indicate which one of the three options would you prefer (**A. Drive Alone, B. Park & Ride, C. Carpooling**) assuming that these are the only travelling options available. The concepts of the three options are explained below:

Drive alone: Driving alone as usual, travelling time stays the same.

Park&Ride: Park the vehicle in a remote area, where parking demand is low and use public transport or bike or on foot to reach the final destination.

Carpooling: 2-3 persons travel together, sharing travelling and parking costs, extra travelling time occurs from collecting passengers from a meeting point.

1	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+10 mins
Searching for Parking	6 mins	-	2 mins
Time walking (parking to office)	12 mins	18 mins	8 mins
Cost of Parking	6 € / day	6 € / day	2 € / day
Options	A	B	C

2	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+20 mins
Searching for Parking	8 mins	-	2 mins
Time walking (parking to office)	4 mins	22 mins	8 mins
Cost of Parking	6 € / day	2 € / day	2 € / day
Options	A	B	C

3	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+10 mins
Searching for Parking	8 mins	-	0 mins
Time walking (parking to office)	4 mins	14 mins	4 mins
Cost of Parking	3 € / day	4 € / day	1 € / day
Options	A	B	C

Figure 37 Pilot Survey in English, (1/2).

4	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+15 mins
Searching for Parking	4 mins	-	4 mins
Time walking (parking to office)	8 mins	14 mins	0 mins
Cost of Parking	3 €/ day	2 €/ day	2 €/ day
Options	**A**	**B**	**C**

5	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+20 mins
Searching for Parking	8 mins	-	4 mins
Time walking (parking to office)	12 mins	14 mins	4 mins
Cost of Parking	9 €/ day	4 €/ day	1 €/ day
Options	**A**	**B**	**C**

6	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+20 mins
Searching for Parking	4 mins	-	0 mins
Time walking (parking to office)	12 mins	22 mins	4 mins
Cost of Parking	3 €/ day	4 €/ day	1 €/ day
Options	**A**	**B**	**C**

7	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+20 mins
Searching for Parking	6 mins	-	2 mins
Time walking (parking to office)	4 mins	18 mins	0 mins
Cost of Parking	6 €/ day	6 €/ day	3 €/ day
Options	**A**	**B**	**C**

8	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+15 mins
Searching for Parking	6 mins	-	4 mins
Time walking (parking to office)	8 mins	18 mins	8 mins
Cost of Parking	3 €/ day	6 €/ day	3 €/ day
Options	**A**	**B**	**C**

9	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+10 mins
Searching for Parking	8 mins	-	2 mins
Time walking (parking to office)	12 mins	22 mins	0 mins
Cost of Parking	6 €/ day	2 €/ day	3 €/ day
Options	**A**	**B**	**C**

10	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+15 mins
Searching for Parking	4 mins	-	0 mins
Time walking (parking to office)	8 mins	14 mins	8 mins
Cost of Parking	9 €/ day	2 €/ day	3 €/ day
Options	**A**	**B**	**C**

11	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+10 mins
Searching for Parking	4 mins	-	4 mins
Time walking (parking to office)	4 mins	22 mins	4 mins
Cost of Parking	9 €/ day	4 €/ day	1 €/ day
Options	**A**	**B**	**C**

12	Drive alone	Park & Ride	Carpooling
Additional Traveling Time by car	-	-	+15 mins
Searching for Parking	6 mins	-	0 mins
Time walking (parking to office)	8 mins	18 mins	0 mins
Cost of Parking	9 €/ day	6 €/ day	2 €/ day
Options	**A**	**B**	**C**

Thank you for participating!

Figure 38 Pilot Survey in English, (2/2).

Enquête Alternatieve Reis and Parkeer Voorkeuren

Ten behoeve van Het afstudeer onderzoek van Makis Gravanis, Faculteit TBM; S.Gravanis@student.tudelft.nl

✦*Deel A: Revealed Preferences*

1. **Wat was uw reistijd (van thuis tot de campus)?**
   20-30 minuten   30-40 minuten   40-50 minuten   50-60 minuten   meer dan 60 minuten
2. **Hoe lang heeft u naar een parkeer plek moeten zoeken?**
   1-2 *minuten   2-3 minuten   3-4 minuten   4-5 minuten   5-6 minuten   meer dan 6 minuten*
3. ***Hoe lang denkt u daar vandaag te parkeren?***
   1-2 uren   3-4 uren   5-6 uren   7-8 uren   meer dan 8 uren
4. **Hoe lang is het lopen van deze parkeer plaats naar uw kantoor of werkplek?**
   1-3 minuten   3-5 minuten   5-7 minuten   7-9 minuten   9-11 minuten   meer dan 11 minuten
5. **Hoe vaak gebruikt u de auto om naar de campus to komen (per week)?**
   1   2   3   4   5   6   7
6. **Hoe zou u de parkeer gelegenheden op de campus beoordelen?**
   (Niet tevreden)   1   2   3   4   5   (Tevreden)
7. **Wat is uw aansluiting met de universiteit?**
   Medewerker   *Student   Bezoeker   Inwoner*

✦*Deel B Stated Preferences*

In de volgende 12 tabellen worden elke keer 3 reis opties voorgesteld (**A. Alleen reizen, B. Park & Ride, C. Carpooling)**. De vraag aan u is of u wilt aangeven welke van deze drie opties uw voorkeur zou hebben.
De drie opties worden hieronder verder uitgelicht:

Alleen reizen: Alleen reizen, de reistijd blijft onveranderd.
Park&Ride: Parkeer het voertuig in een afgelegen gebied waar altijd voldoende parkeergelegenheid is. Gebruik vergolgens het openbaar vervoer, de fiets, of loop van hier naar uw eindbestemming.
Carpooling: samenreizen met twee of drie andere personen om zo samen parker kosten te delen. De extra reistijd is een gevolg van het ophalen van medereizigers op een afgesproken locatie.

1	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+10 minuten
Zoeken naar een parkeerplek	6 minuten	-	2 minuten
Looptijd (parkeerplats naar kantoor)	12 minuten	18 minuten	8 minuten
Parkeerkosten	6 € / dag	6 € / dag	2 € / day
Opties	**A**	**B**	**C**

2	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+20 minuten
Zoeken naar een parkeerplek	8 minuten	-	2 minuten
Looptijd (parkeerplats naar kantoor)	4 minuten	22 minuten	8 minuten
Parkeerkosten	6 € / dag	2 € / dag	2 € / dag
Opties	**A**	**B**	**C**

3	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+10 minuten
Zoeken naar een parkeerplek	8 minuten	-	0 minuten
Looptijd (parkeerplats naar kantoor)	4 minuten	14 minuten	4 minuten
Parkeerkosten	3 € / dag	4 € / dag	1 € / dag
Opties	**A**	**B**	**C**

Figure 39 Pilot Survey in Dutch, (1/2).

4	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+15 minuten
Zoeken naar een parkeerplek	4 minuten	-	4 minuten
Looptijd (parkeerplats naar kantoor)	8 minuten	14 minuten	0 minuten
Parkeerkosten	3 €/ dag	2 €/ dag	2 €/ dag
Opties	A	B	C

5	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+20 minuten
Zoeken naar een parkeerplek	8 minuten	-	4 minuten
Looptijd (parkeerplats naar kantoor)	12 minuten	14 minuten	4 minuten
Parkeerkosten	9 €/ dag	4 €/ dag	1 €/ dag
Opties	A	B	C

6	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+20 minuten
Zoeken naar een parkeerplek	4 minuten	-	0 minuten
Looptijd (parkeerplats naar kantoor)	12 minuten	22 minuten	4 minuten
Parkeerkosten	3 €/ dag	4 €/ dag	1 €/ dag
Opties	A	B	C

7	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+20 minuten
Zoeken naar een parkeerplek	6 minuten	-	2 minuten
Looptijd (parkeerplats naar kantoor)	4 minuten	18 minuten	0 minuten
Parkeerkosten	6 €/ dag	6 €/ dag	3 €/ dag
Opties	A	B	C

8	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+15 minuten
Zoeken naar een parkeerplek	6 minuten	-	4 minuten
Looptijd (parkeerplats naar kantoor)	8 minuten	18 minuten	8 minuten
Parkeerkosten	3 €/ dag	6 €/ dag	3 €/ dag
Opties	A	B	C

9	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+10 minuten
Zoeken naar een parkeerplek	8 minuten	-	2 minuten
Looptijd (parkeerplats naar kantoor)	12 minuten	22 minuten	0 minuten
Parkeerkosten	6 €/ dag	2 €/ dag	3 €/ dag
Opties	A	B	C

10	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+15 minuten
Zoeken naar een parkeerplek	4 minuten	-	0 minuten
Looptijd (parkeerplats naar kantoor)	8 minuten	14 minuten	8 minuten
Parkeerkosten	9 €/ dag	2 €/ dag	3 €/ dag
Opties	A	B	C

11	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+10 minuten
Zoeken naar een parkeerplek	4 minuten	-	4 minuten
Looptijd (parkeerplats naar kantoor)	4 minuten	22 minuten	4 minuten
Parkeerkosten	9 €/ dag	4 €/ dag	1 €/ dag
Opties	A	B	C

12	Drive alone	Park & Ride	Carpooling
Extra reistijd met de auto	-	-	+15 mins
Zoeken naar een parkeerplek	6 minuten	-	0 minuten
Looptijd (parkeerplats naar kantoor)	8 minuten	18 minuten	0 minuten
Parkeerkosten	9 €/ dag	6 €/ dag	2 €/ dag
Opties	A	B	C

Hartelijk dank voor uw medewerking!

Figure 40 Pilot Survey in Dutch, (2/2).

Design of the final Survey

Syntax in Ngene

```
Design
? This will generate a D-efficient Design
; alts= drivealone*, parkandride, carpool
; rows= 16
; block= 4
; eff=(mnl,d)
; model:
U(drivealone)= Bst[-0.0409]*STcar[4,6,8]+Bet[-0.137]*ETcar[4,8,12]+Bpc[-
0.442]*Pcar[3,6,9] /
U(parkandride)=ASC1[-
0.800]+Bet*ETparkandride[14,18,22]+Bpc*Pparkandride[2,4,6] /
U(carpool)=ASC2[-0.210]+Btt[-
0.172]*TTcarpool[10,15,20]+Bst*STcarpool[0,2,4]+Bet*ETcarpool[0,4,8]+Bpc
*Pcarpool[1,2,3]
$
```

MNL efficiency measures

Table 53 MNL efficiency measures of the design of the final survey (1/2).

D error	**0.018247**
A error	0.024306
B estimate	43.241331
S estimate	61.827161

Table 54 MNL efficiency measures of the design of the final survey (2/2).

Prior	bst	bet	bpc	btt
Fixed prior value	-0.0409	-0.137	-0.442	-0.172
Sp estimates	61.827161	1.529797	0.837432	2.628297
Sp t-ratios	0.249268	1.584671	2.141811	1.208979

Design

Table 55 Choice Situations of the design of the final survey.

Choice situation	drivealone.stcar	drivealone.etcar	drivealone.pcar	parkandride.etparkandride	parkandride.pparkandride	carpool.ttcarpool	carpool.stcarpool	carpool.etcarpool	carpool.pcarpool	Block
1	6	4	3	22	2	15	2	4	2	3
2	4	4	9	22	2	20	2	4	2	4
3	4	4	6	18	4	10	4	8	1	2
4	6	8	3	14	4	15	2	4	3	1
5	6	8	9	14	2	20	2	4	2	2
6	8	4	9	22	6	20	0	4	1	1
7	6	8	9	14	2	15	0	8	3	1
8	4	12	3	14	6	15	4	0	2	4
9	8	8	6	22	4	20	0	0	1	3
10	8	12	3	18	4	10	0	0	3	2
11	8	4	6	18	6	10	0	8	1	3
12	4	4	6	22	2	10	4	8	1	3
13	6	8	9	14	2	15	2	8	3	4
14	8	12	3	14	6	10	0	0	3	4
15	4	12	6	18	6	20	4	0	1	2
16	4	12	3	18	4	10	4	0	2	1

MNL probabilities

Table 56 Probabilities of the alternatives in each choice set of the final survey.

Choice situation	drivealone	parkandride	carpool
1	0.84145	0.063849	0.094701
2	0.382553	0.379353	0.238094
3	0.512012	0.096346	0.391642
4	0.77677	0.126033	0.097197
5	0.129226	0.719792	0.150982
6	0.410347	0.081794	0.507859
7	0.130151	0.724942	0.144907
8	0.624436	0.066716	0.308848
9	0.453523	0.100509	0.445968
10	0.450827	0.079383	0.469789
11	0.464567	0.042534	0.492899
12	0.493042	0.129826	0.377132
13	0.131649	0.733288	0.135063
14	0.461277	0.058044	0.480679
15	0.406685	0.094598	0.498717
16	0.431344	0.06449	0.504166

MNL utilities

Table 57 Utilities of the alternatives in each choice set of the final survey.

Choice situation	drivealone	parkandride	carpool
1	-2.1194	-4.698	-4.3038
2	-4.6896	-4.698	-5.1638
3	-3.3636	-5.034	-3.6316
4	-2.6674	-4.486	-4.7458
5	-5.3194	-3.602	-5.1638
6	-4.8532	-6.466	-4.64
7	-5.3194	-3.602	-5.212
8	-3.1336	-5.37	-3.8376
9	-4.0752	-5.582	-4.092
10	-3.2972	-5.034	-3.256
11	-3.5272	-5.918	-3.468
12	-3.3636	-4.698	-3.6316
13	-5.3194	-3.602	-5.2938
14	-3.2972	-5.37	-3.256
15	-4.4596	-5.918	-4.2556
16	-3.1336	-5.034	-2.9776

MNL Covariance Matrix

Table 58 Covariance Matrix of the design of the final survey.

Prior	bst	bet	bpc	asc1	asc2	btt
bst	0.036852	0.000828	0.005746	0.230072	0.159476	0.000766
bet	0.000828	0.009891	0.010839	-0.053992	0.032373	0.00412
bpc	0.005746	0.010839	0.058645	0.109849	0.058096	0.016478
asc1	0.230072	-0.053992	0.109849	3.039958	0.941985	0.023239
asc2	0.159476	0.032373	0.058096	0.941985	5.822407	-0.294439
btt	0.000766	0.00412	0.016478	0.023239	-0.294439	0.025875

MNL fisher matrix

Table 59 Fisher Matrix

Prior	bst	bet	bpc	asc1	asc2	btt
bst	108.938024	-23.053429	48.960605	-6.751206	-8.269885	-114.725973
bet	-23.053429	459.934965	-8.580808	19.94068	-22.055785	-336.616243
bpc	48.960605	-8.580808	74.13677	-2.315014	-9.175498	-144.11776
asc1	-6.751206	19.94068	-2.315014	1.744306	-0.780897	-12.349311
asc2	-8.269885	-22.055785	-9.175498	-0.780897	3.156091	45.265366
btt	-114.725973	-336.616243	-144.11776	-12.349311	45.265366	711.050986

Correlations (Pearson Product Moment)

Table 60 Pearson Correlations of the design of the final survey.

Attribute	drivealone.stcar	drivealone.etcar	drivealone.pcar	parkandride.etparkandride	parkandride.pparkandride	carpool.ttcarpool	carpool.stcarpool	carpool.etcarpool	carpool.pcarpool	Block
drivealone.stcar	1	-0.002479	-0.003306	-0.020661	0.252893	-0.002479	-0.922314	-0.085124	0.179339	-0.038569
drivealone.etcar	-0.002479	1	-0.458678	-0.558678	0.352893	-0.085124	0.071074	-0.740496	0.461157	-0.038569
drivealone.pcar	-0.003306	-0.458678	1	0.08843	-0.376033	0.534711	-0.17686	0.552066	-0.21157	-0.032141
parkandride.etparkandride	-0.020661	-0.558678	0.08843	1	-0.085124	0.152893	-0.003306	-0.003306	-0.649587	0.025713
parkandride.pparkandride	0.252893	0.352893	-0.376033	-0.085124	1	-0.11157	-0.11157	-0.476033	-0.285124	-0.044998
carpool.ttcarpool	-0.002479	-0.085124	0.534711	0.152893	-0.11157	1	-0.085124	-0.167769	-0.167769	-0.032141
carpool.stcarpool	-0.922314	0.071074	-0.17686	-0.003306	-0.11157	-0.085124	1	-0.002479	-0.258678	0.038569
carpool.etcarpool	-0.085124	-0.740496	0.552066	-0.003306	-0.476033	-0.167769	-0.002479	1	-0.102479	-0.038569
carpool.pcarpool	0.179339	0.461157	-0.21157	-0.649587	-0.285124	-0.167769	-0.258678	-0.102479	1	0.038569
Block	-0.038569	-0.038569	-0.032141	0.025713	-0.044998	-0.032141	0.038569	-0.038569	0.038569	1

Correlations (Spearman Rank)

Table 61 Correlations (spearman Rank) of the design of the final survey.

Attribute	drivealone.stcar	drivealone.etcar	drivealone.pcar	parkandride.etparkandride	parkandride.pparkandride	carpool.ttcarpool	carpool.stcarpool	carpool.etcarpool	carpool.pcarpool	Block
drivealone.stcar	1	-0.002479	-0.003306	-0.020661	0.252893	-0.002479	-0.922314	-0.085124	0.179339	-0.038569
drivealone.etcar	-0.002479	1	-0.458678	-0.558678	0.352893	-0.085124	0.071074	-0.740496	0.461157	-0.038569
drivealone.pcar	-0.003306	-0.458678	1	0.08843	-0.376033	0.534711	-0.17686	0.552066	-0.21157	-0.032141
parkandride.etparkandride	-0.020661	-0.558678	0.08843	1	-0.085124	0.152893	-0.003306	-0.003306	-0.649587	0.025713
parkandride.pparkandride	0.252893	0.352893	-0.376033	-0.085124	1	-0.11157	-0.11157	-0.476033	-0.285124	-0.044998
carpool.ttcarpool	-0.002479	-0.085124	0.534711	0.152893	-0.11157	1	-0.085124	-0.167769	-0.167769	-0.032141
carpool.stcarpool	-0.922314	0.071074	-0.17686	-0.003306	-0.11157	-0.085124	1	-0.002479	-0.258678	0.038569
carpool.etcarpool	-0.085124	-0.740496	0.552066	-0.003306	-0.476033	-0.167769	-0.002479	1	-0.102479	-0.038569
carpool.pcarpool	0.179339	0.461157	-0.21157	-0.649587	-0.285124	-0.167769	-0.258678	-0.102479	1	0.038569
Block	-0.038569	-0.038569	-0.032141	0.025713	-0.044998	-0.032141	0.038569	-0.038569	0.038569	1

Correlations (J Index)

Table 62 Correlations (J Index) of the design of the final survey.

Attribute	drivealone.stcar	drivealone.etcar	drivealone.pcar	parkandride.etparkandride	parkandride.pparkandride	carpool.ttcarpool	carpool.stcarpool	carpool.etcarpool	carpool.pcarpool	Block
drivealone.stcar	1	0.264591	0.124514	0.194553	0.229572	0.264591	0.684825	0.159533	0.264591	0.047748
drivealone.etcar	0.264591	1	0.229572	0.36965	0.194553	0.159533	0.159533	0.404669	0.194553	0.124146
drivealone.pcar	0.124514	0.229572	1	0.194553	0.194553	0.264591	0.159533	0.299611	0.404669	0.200543
parkandride.etparkandride	0.194553	0.36965	0.194553	1	0.159533	0.299611	0.124514	0.124514	0.264591	0.276941
parkandride.pparkandride	0.229572	0.194553	0.194553	0.159533	1	0.089494	0.194553	0.194553	0.089494	0.085947
carpool.ttcarpool	0.264591	0.159533	0.264591	0.299611	0.089494	1	0.159533	0.194553	0.194553	0.085947
carpool.stcarpool	0.684825	0.159533	0.159533	0.124514	0.194553	0.159533	1	0.264591	0.264591	0.047748
carpool.etcarpool	0.159533	0.404669	0.299611	0.124514	0.194553	0.194553	0.264591	1	0.124514	0.047748
carpool.pcarpool	0.264591	0.194553	0.404669	0.264591	0.089494	0.194553	0.264591	0.124514	1	0.162345
Block	0.047748	0.124146	0.200543	0.276941	0.085947	0.085947	0.047748	0.047748	0.162345	1

Results of the Final Survey

Revealed preferences results

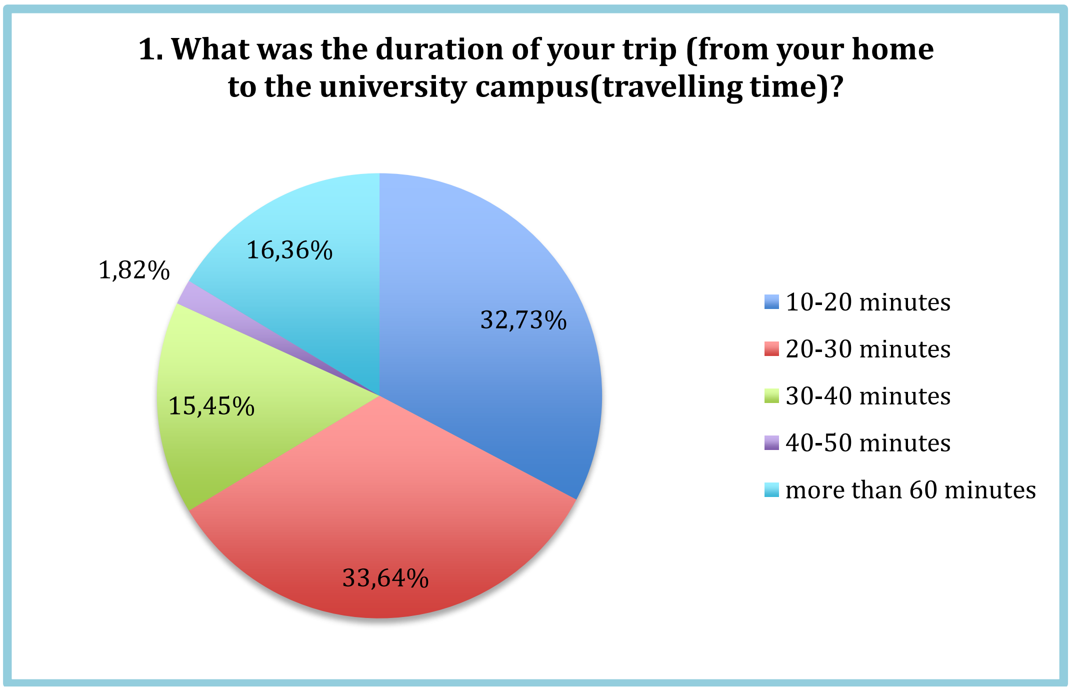

Figure 41 Responses of question 1 of the final survey.

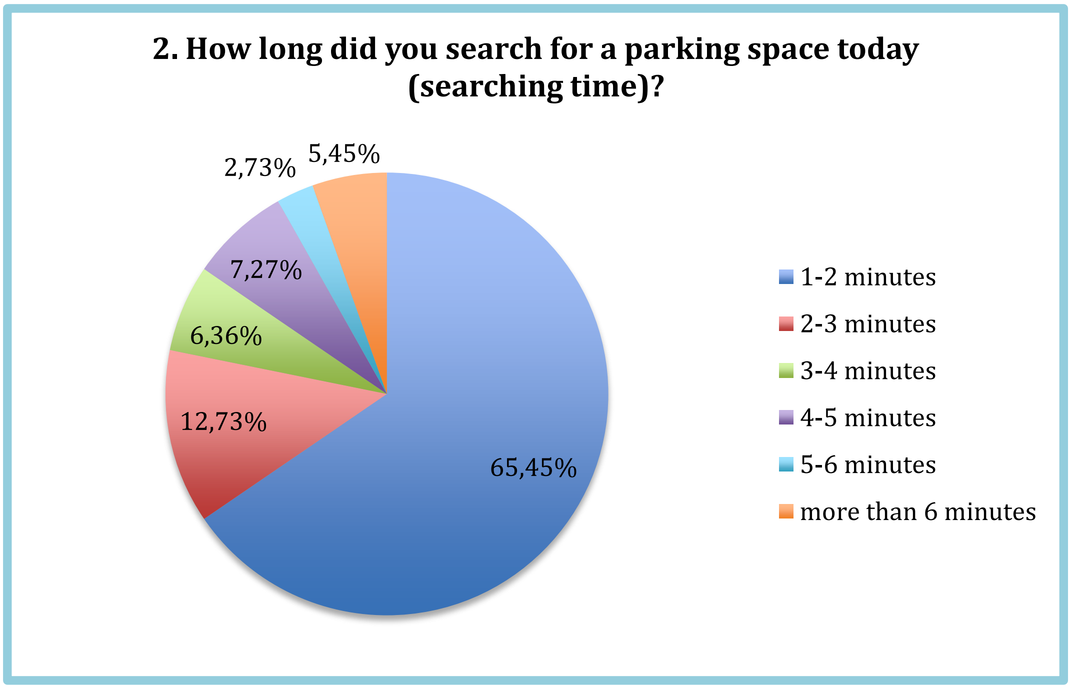

Figure 42 Responses of question 2 of the final survey.

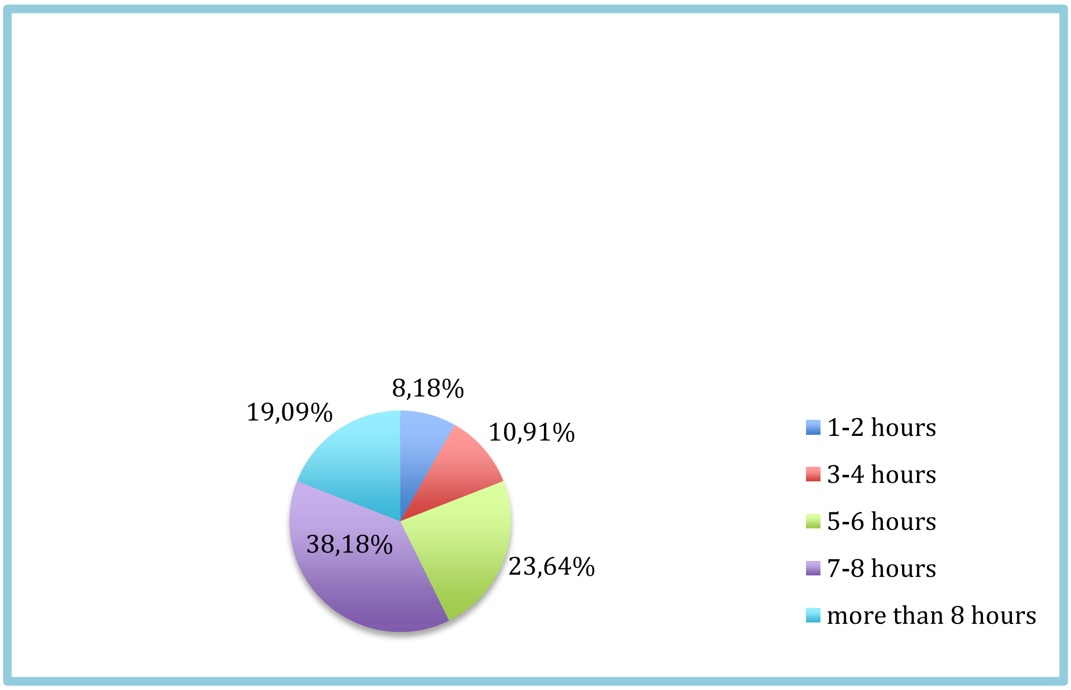

Figure 43 Responses of question 3 of the final survey.

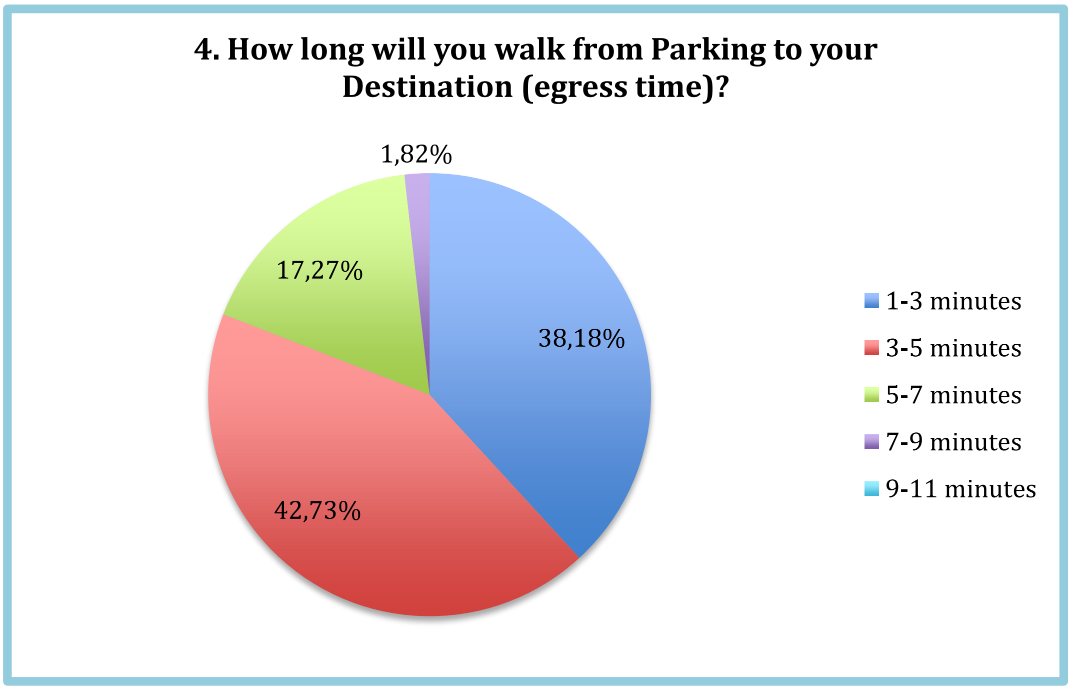

Figure 44 Responses of question 4 of the final survey.

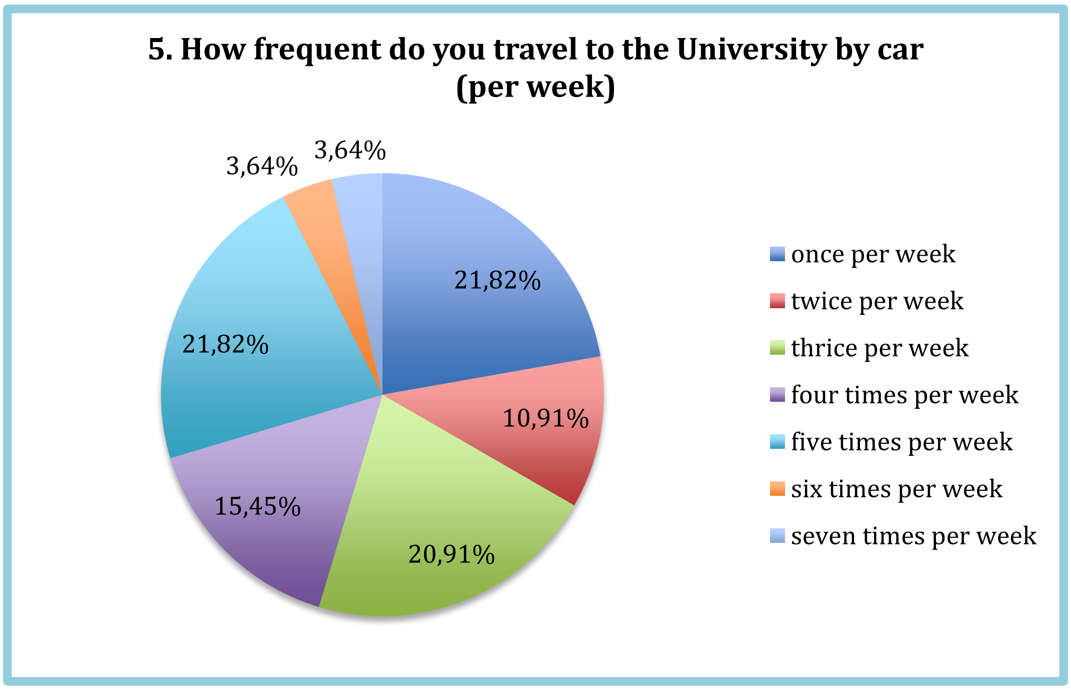

Figure 45 Responses of question 5 of the final survey.

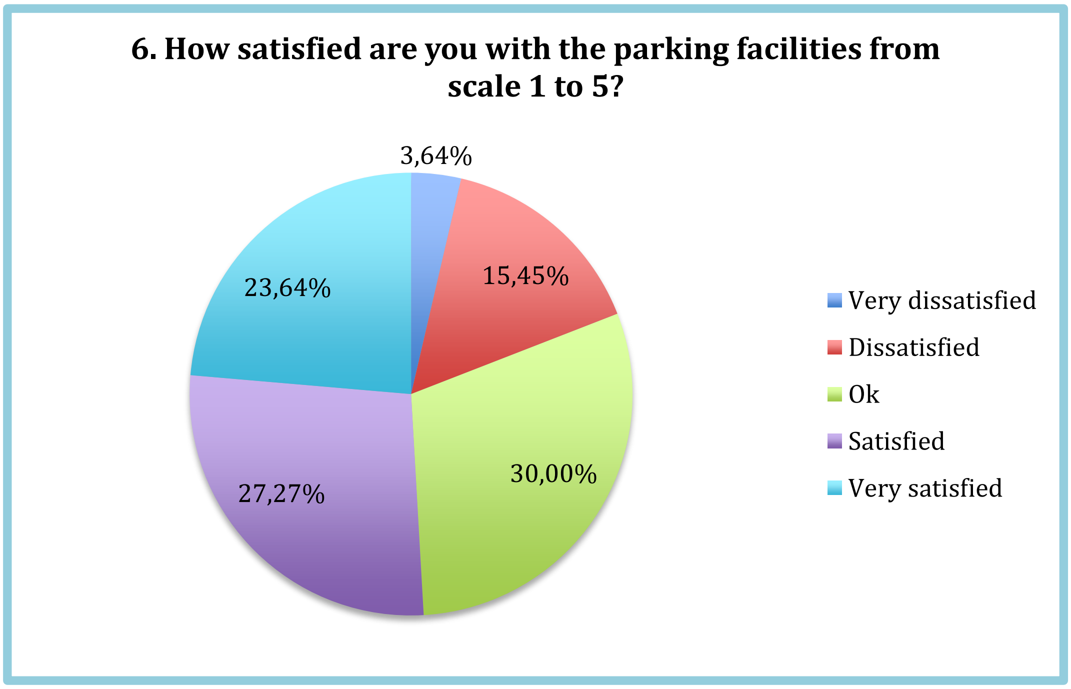

Figure 46 Responses of question 6 of the final survey.

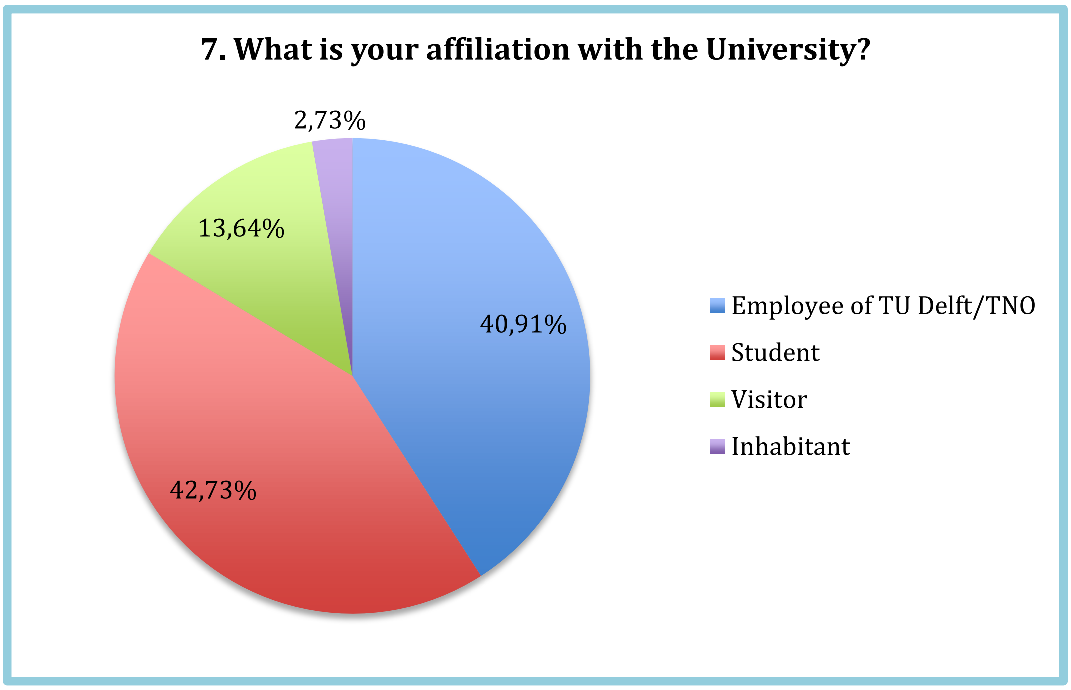

Figure 47 Responses of question 7 of the final survey.

Results of the analysis of the final survey using the BIOGEME software

Table 63 Estimated parameters from the final survey using the MNL model.

Name of parameter	Value	Std error	t-test	p-value	Rob. Std error	Rob. t-test	Rob. p-value
$\boldsymbol{\beta_1}$	**-1.97**	**0.333**	**-5.92***	**0.00**	**0.329**	**-5.99**	**0.00**
$\boldsymbol{\beta_2}$	-0.199	0.442	-0.45	0.65	0.445	-0.45	0.65*
$\boldsymbol{\beta_{ExtraTraveltTime}}$	**-0.135**	**0.0311**	**-4.36***	**0.00**	**0.0318**	**-4.25**	**0.00**
$\boldsymbol{\beta_{SearchingTime}}$	**-0.103**	**0.0373**	**-2.75***	**0.01**	**0.0378**	**-2.71**	**0.01**
$\boldsymbol{\beta_{Egresstime}}$	**-0.0599**	**0.0185**	**-3.24***	**0.00**	**0.0187**	**-3.20**	**0.00**
$\boldsymbol{\beta_{ParkingCost}}$	**-0.368**	**0.0445**	**-8.27***	**0.00**	**0.0441**	**-8.35**	**0.00**

Likelihood ratio test	Adjusted rho-square	Final log-likelihood
128.485	0.166	-287.313

```
// This file has automatically been generated.
// 06/17/16 14:45:08
// Michel Bierlaire, EPFL 2001-2008
BIOGEME Version 1.8 [Sat Mar 7 14:36:56 CEST 2009]
Michel Bierlaire, EPFL
                 Model: Multinomial Logit
Number of estimated parameters: 6
      Number of observations: 320
       Number of individuals: 320
         Null log-likelihood: -351.556
          Cte log-likelihood: -329.143
         Init log-likelihood: -302.411
        Final log-likelihood: -287.313
       Likelihood ratio test: 128.485
                  Rho-square: 0.183
         Adjusted rho-square: 0.166
         Final gradient norm: +1.111e-003
                  Diagnostic: Convergence reached...
                  Iterations: 9
                    Run time: 00:00
         Variance-covariance: from finite difference hessian
                 Sample file: Estimation_data_set_80.dat
Utility parameters
******************
Name   Value   Std err t-test p-val   Rob. std err Rob. t-test Rob. p-val
----   -----   ------- ------ -----   ------------ ----------- ----------
ASC1   -1.97   0.333   -5.92  0.00    0.329        -5.99       0.00
ASC2   -0.199  0.442   -0.45  0.65  * 0.445        -0.45       0.65      *
BETAET -0.0599 0.0185  -3.24  0.00    0.0187       -3.20       0.00
BETAPC -0.368  0.0445  -8.27  0.00    0.0441       -8.35       0.00
BETAST -0.103  0.0373  -2.75  0.01    0.0378       -2.71       0.01
BETATT -0.135  0.0311  -4.36  0.00    0.0318       -4.25       0.00

Utility functions
*****************
1   Alt1   av1   $NONE + ( ( BETAST * X12 ) + ( BETAET * X13 ) ) + ( BETAPC * X14 )
2   Alt2   av2   $NONE + ( ( ASC1 * one ) + ( BETAET * X23 ) ) + ( BETAPC * X24 )
3   Alt3   av3   $NONE + ( ( ( ( ASC2 * one ) + ( BETATT * X31 ) ) + ( BETAST * X32 ) ) + ( BETAET * X33 ) ) + ( BETAPC * X34 )

Correlation of coefficients
***************************
Coeff1 Coeff2 Covariance Correlation t-test   Rob. covar. Rob. correl. Rob. t-test
------ ------ ---------- ----------- ------   ----------- ------------ -----------
ASC2   BETATT -0.0108    -0.786      -0.14  * -0.0112     -0.794       -0.14      *
ASC2   BETAST 0.00454    0.275       -0.22  * 0.00463     0.275        -0.22      *
ASC2   BETAET 0.000692   0.0846      -0.32  * 0.000156    0.0187       -0.31      *
ASC2   BETAPC 0.000811   0.0412      0.38   * 0.000532    0.0271       0.38       *
BETAST BETATT 9.49e-005  0.0818      0.70   * 9.57e-005   0.0795       0.69       *
BETAET BETAST -6.80e-006 -0.00985    1.02   * -3.43e-005  -0.0485      0.99       *
BETAET BETATT 0.000133   0.232       2.34     0.000163    0.273        2.34
ASC1   ASC2   0.0210     0.143       -3.45    0.0214      0.146        -3.45
BETAPC BETAST 0.000101   0.0606      -4.72    0.000154    0.0921       -4.80
ASC1   BETAPC 0.00441    0.298       -4.97    0.00382     0.263        -5.00
BETAPC BETATT 0.000570   0.413       -5.49    0.000592    0.422        -5.53
ASC1   BETATT 0.00195    0.189       -5.59    0.00185     0.177        -5.65
ASC1   BETAET -0.00198   -0.321      -5.63    -0.00212    -0.345       -5.69
ASC1   BETAST 0.00824    0.663       -6.04    0.00873     0.701        -6.15
BETAET BETAPC 0.000315   0.382       7.49     0.000317    0.384        7.56

Smallest singular value of the hessian: 4.97773
```

Figure 48 Results of the final survey, generated applying the MNL in BIOGEME software

Table 64 Output of BIOGEME simulation

A/A	Utility of the Alternative 1	Utility of the Alternative 2	Utility of the Alternative 3	Alternative with the highest utility	Alternative chosen
1	-2,20E+07	-4,28E+07	-3,78E+07	1	1
2	-4,38E+07	-5,50E+07	-3,51E+07	1	3
3	-4,41E+07	-3,55E+07	-3,81E+07	1	2
4	-2,23E+07	-4,52E+07	-2,70E+07	1	1
5	-2,86E+07	-4,52E+07	-2,81E+07	2	3
6	-4,41E+07	-3,55E+07	-4,09E+07	3	2
7	-2,64E+07	-4,52E+07	-2,66E+07	1	1
8	-3,34E+07	-5,26E+07	-3,68E+07	1	1
9	-1,96E+07	-4,02E+07	-3,41E+07	1	1
10	-3,51E+07	-4,76E+07	-3,27E+07	1	3
11	-3,27E+07	-5,26E+07	-2,40E+07	1	3
12	-2,86E+07	-4,02E+07	-2,81E+07	1	3
13	-2,20E+07	-4,28E+07	-3,78E+07	1	1
14	-4,38E+07	-5,50E+07	-3,51E+07	3	3
15	-4,41E+07	-3,55E+07	-3,81E+07	2	2
16	-2,23E+07	-4,52E+07	-2,70E+07	1	1
17	-2,86E+07	-4,52E+07	-2,81E+07	3	3
18	-4,41E+07	-3,55E+07	-4,09E+07	2	2
19	-2,64E+07	-4,52E+07	-2,66E+07	1	1
20	-3,34E+07	-5,26E+07	-3,68E+07	3	1
21	-2,20E+07	-4,28E+07	-3,78E+07	1	1
22	-4,38E+07	-5,50E+07	-3,51E+07	1	3
23	-4,41E+07	-3,55E+07	-3,81E+07	2	2
24	-2,23E+07	-4,52E+07	-2,70E+07	1	1
25	-2,20E+07	-4,28E+07	-3,78E+07	3	1
26	-4,38E+07	-5,50E+07	-3,51E+07	3	3
27	-4,41E+07	-3,55E+07	-3,81E+07	3	2
28	-2,23E+07	-4,52E+07	-2,70E+07	3	1
29	-2,86E+07	-4,52E+07	-2,81E+07	1	3
30	-4,41E+07	-3,55E+07	-4,09E+07	1	2
31	-2,64E+07	-4,52E+07	-2,66E+07	3	1
32	-3,34E+07	-5,26E+07	-3,68E+07	3	1
33	-3,96E+07	-4,02E+07	-4,09E+07	2	1
34	-2,23E+07	-5,02E+07	-3,38E+07	1	1
35	-4,41E+07	-3,55E+07	-4,02E+07	3	2
36	-2,64E+07	-5,02E+07	-2,66E+07	3	1
37	-1,96E+07	-4,02E+07	-3,41E+07	1	1
38	-3,51E+07	-4,76E+07	-3,27E+07	3	3
39	-3,27E+07	-5,26E+07	-2,40E+07	3	3
40	-2,86E+07	-4,02E+07	-2,81E+07	3	3
41	-2,20E+07	-4,28E+07	-3,78E+07	3	1
42	-4,38E+07	-5,50E+07	-3,51E+07	3	3
43	-4,41E+07	-3,55E+07	-3,81E+07	3	2

A/A	Utility of the Alternative 1	Utility of the Alternative 2	Utility of the Alternative 3	Alternative with the highest utility	Alternative chosen
44	-2,23E+07	-4,52E+07	-2,70E+07	3	1
45	-1,96E+07	-4,02E+07	-3,41E+07	1	1
46	-3,51E+07	-4,76E+07	-3,27E+07	3	3
47	-3,27E+07	-5,26E+07	-2,40E+07	3	3
48	-2,86E+07	-4,02E+07	-2,81E+07	1	3
49	-3,96E+07	-4,02E+07	-4,09E+07	1	1
50	-2,23E+07	-5,02E+07	-3,38E+07	1	1
51	-4,41E+07	-3,55E+07	-4,02E+07	1	2
52	-2,64E+07	-5,02E+07	-2,66E+07	1	1
53	-2,86E+07	-4,52E+07	-2,81E+07	1	3
54	-4,41E+07	-3,55E+07	-4,09E+07	2	2
55	-2,64E+07	-4,52E+07	-2,66E+07	2	1
56	-3,34E+07	-5,26E+07	-3,68E+07	2	1
57	-1,96E+07	-4,02E+07	-3,41E+07	1	1
58	-3,51E+07	-4,76E+07	-3,27E+07	3	3
59	-3,27E+07	-5,26E+07	-2,40E+07	3	3
60	-2,86E+07	-4,02E+07	-2,81E+07	3	3
61	-3,96E+07	-4,02E+07	-4,09E+07	3	1
62	-2,23E+07	-5,02E+07	-3,38E+07	1	1
63	-4,41E+07	-3,55E+07	-4,02E+07	3	2
64	-2,64E+07	-5,02E+07	-2,66E+07	1	1
65	-3,96E+07	-4,02E+07	-4,09E+07	3	1
66	-2,23E+07	-5,02E+07	-3,38E+07	3	1
67	-4,41E+07	-3,55E+07	-4,02E+07	2	2
68	-2,64E+07	-5,02E+07	-2,66E+07	3	1
69	-1,96E+07	-4,02E+07	-3,41E+07	1	1
70	-3,51E+07	-4,76E+07	-3,27E+07	3	3
71	-3,27E+07	-5,26E+07	-2,40E+07	3	3
72	-2,86E+07	-4,02E+07	-2,81E+07	3	3
73	-1,96E+07	-4,02E+07	-3,41E+07	1	1
74	-3,51E+07	-4,76E+07	-3,27E+07	3	3
75	-3,27E+07	-5,26E+07	-2,40E+07	3	3
76	-2,86E+07	-4,02E+07	-2,81E+07	3	3
77	-3,96E+07	-4,02E+07	-4,09E+07	2	1
78	-2,23E+07	-5,02E+07	-3,38E+07	1	1
79	-4,41E+07	-3,55E+07	-4,02E+07	2	2
80	-2,64E+07	-5,02E+07	-2,66E+07	3	1
81	-2,86E+07	-4,52E+07	-2,81E+07	1	3
82	-4,41E+07	-3,55E+07	-4,09E+07	2	2
83	-2,64E+07	-4,52E+07	-2,66E+07	1	1
84	-3,34E+07	-5,26E+07	-3,68E+07	1	1
85	-2,20E+07	-4,28E+07	-3,78E+07	1	1
86	-4,38E+07	-5,50E+07	-3,51E+07	1	3
87	-4,41E+07	-3,55E+07	-3,81E+07	1	2
88	-2,23E+07	-4,52E+07	-2,70E+07	1	1
89	-2,86E+07	-4,52E+07	-2,81E+07	1	3

A/A	Utility of the Alternative 1	Utility of the Alternative 2	Utility of the Alternative 3	Alternative with the highest utility	Alternative chosen
90	-4,41E+07	-3,55E+07	-4,09E+07	2	2
91	-2,64E+07	-4,52E+07	-2,66E+07	1	1
92	-3,34E+07	-5,26E+07	-3,68E+07	1	1
93	-2,86E+07	-4,52E+07	-2,81E+07	3	3
94	-4,41E+07	-3,55E+07	-4,09E+07	3	2
95	-2,64E+07	-4,52E+07	-2,66E+07	1	1
96	-3,34E+07	-5,26E+07	-3,68E+07	3	1
97	-3,96E+07	-4,02E+07	-4,09E+07	3	1
98	-2,23E+07	-5,02E+07	-3,38E+07	3	1
99	-4,41E+07	-3,55E+07	-4,02E+07	2	2
100	-2,64E+07	-5,02E+07	-2,66E+07	1	1
101	-1,96E+07	-4,02E+07	-3,41E+07	1	1
102	-3,51E+07	-4,76E+07	-3,27E+07	1	3
103	-3,27E+07	-5,26E+07	-2,40E+07	1	3
104	-2,86E+07	-4,02E+07	-2,81E+07	1	3
105	-2,20E+07	-4,28E+07	-3,78E+07	1	1
106	-4,38E+07	-5,50E+07	-3,51E+07	3	3
107	-4,41E+07	-3,55E+07	-3,81E+07	2	2
108	-2,23E+07	-4,52E+07	-2,70E+07	3	1
109	-2,86E+07	-4,52E+07	-2,81E+07	2	3
110	-4,41E+07	-3,55E+07	-4,09E+07	2	2
111	-2,64E+07	-4,52E+07	-2,66E+07	1	1
112	-3,34E+07	-5,26E+07	-3,68E+07	1	1
113	-2,86E+07	-4,52E+07	-2,81E+07	1	3
114	-4,41E+07	-3,55E+07	-4,09E+07	1	2
115	-2,64E+07	-4,52E+07	-2,66E+07	1	1
116	-3,34E+07	-5,26E+07	-3,68E+07	1	1
117	-2,20E+07	-4,28E+07	-3,78E+07	3	1
118	-4,38E+07	-5,50E+07	-3,51E+07	3	3
119	-4,41E+07	-3,55E+07	-3,81E+07	3	2
120	-2,23E+07	-4,52E+07	-2,70E+07	3	1
			TOTAL	**68/120**	**56,6667%**

Table 65 Direct and cross elasticities of the attribute 'Parking Cost' for the three alternatives. (MNL model)

Parking Cost	Drive Alone	Park &Ride	Carpooling
Drive alone	-1,490148831	0,11580718	0,22096897
Park & Ride	0,741031799	-0,51236596	0,27145435
Carpooling	0,807627302	0,155422212	-0,3336851

Table 66 Direct and cross elasticities of the attribute 'Searching Time' for the three alternatives. (MNL model)

Searching Time	Drive Alone	Park &Ride	Carpooling
Drive alone	-0,432208933	-	0,074338912
Park & Ride	0,139529658	-	0,055406402
Carpooling	0,254702908	-	-0,085404433

Table 67 Direct and cross elasticities of the attribute 'Egress Time' for the three alternatives. (MNL model)

Egress Time	Drive Alone	Park &Ride	Carpooling
Drive alone	-0,336956039	0,094868278	0,053973101
Park & Ride	0,102121265	-0,548454388	0,118164
Carpooling	0,186425136	0,128361775	-0,113826722

Table 68 Direct and cross elasticities of the attribute 'Extra travelling time' for the three alternatives. (MNL model)

Extra Travelling Time	Drive Alone	Park &Ride	Carpooling
Drive alone	-	-	0,614024113
Park & Ride	-	-	0,741747145
Carpooling	-	-	-1,013586054

Simulation of the respondents' future responsiveness

Table 69 Simulations (1/6)

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	96	82	72	28	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	14	28	38	82	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	11												
	0	110	110	108	104	96	72	72	72	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	6	14	38	38	38	110	110	110	110

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	104	90	72	72	72	28	28
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	2	2	6	20	38	38	38	82	82

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	96	82	72	28	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	14	28	38	82	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	104	103	87	72	72	28	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	6	7	23	38	38	82	110	110	110	110

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	104	90	72	72	72	28	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	2	2	6	20	38	38	38	38	110

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	96	82	72	28	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	14	28	38	82	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	104	96	72	72	72	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	6	14	38	38	38	110	110	110	110

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	104	90	72	44	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	28	72	72	72
Carpooling	0	0	0	2	2	2	6	20	38	38	38	38	38

Table 70 Simulations (2/6)

Extra traveling time for Carpooling: +20mins						Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	104	90	72	44	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	28	72	72	72
Carpooling	0	0	0	2	2	2	6	20	38	38	38	38	38

Extra traveling time for Carpooling: +10mins						Egress time for Park & Ride: +5mins					$C_{DA}=3*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	106	90	72	72	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	4	20	38	38	110	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins						Egress time for Park & Ride: +5mins					$C_{DA}=3*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	104	103	87	72	72	28	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	6	7	23	38	38	82	110	110	110	110

Extra traveling time for Carpooling: +20mins						Egress time for Park & Ride: +5mins					$C_{DA}=3*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	104	103	73	72	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	1	73	73	73	73
Carpooling	0	0	0	2	2	6	7	27	38	37	37	37	37

Extra traveling time for Carpooling: +10mins						Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	96	82	72	28	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	14	28	38	82	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins						Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	104	96	72	72	72	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0		0	2	6	14	38	38	38	110	110	110	110

Extra traveling time for Carpooling: +20mins						Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	104	90	72	0	0	0	0
Park & Ride	0	0	0	0		0	0	0	0	72	73	73	73
Carpooling	0	0	0	2	2	2	6	20	38	38	37	37	37

Extra traveling time for Carpooling: +10mins						Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	96	82	72	28	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	14	28	38	82	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins						Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	104	96	72	72	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	70	70	70	70	70
Carpooling	0	0	0	2	6	14	38	38	38	40	40	40	40

Extra traveling time for Carpooling: +20mins						Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$		
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	102	86	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	2	6	86	104	104	104	104
Carpooling	0	0	0	2	2	2	6	18	22	6	6	6	6

Table 71 Simulations (3/6)

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	110	106	95	86	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	1	6	108	110	110	110	110
Carpooling	0		0	0	0	4	14	18	0	0	0	0	0

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	110	110	102	86	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	6	22	108	110	110	110	110
Carpooling	0	0		0	0	0	2	2	0	0	0	0	0

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	110	110	102	86	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	6	22	108	110	110	110	110
Carpooling	0	0	0	0	0	0	2	2	0	0	0	0	0

Simulation of the respondents' future responsiveness with parking supply reduction (increased searching time)

Table 72 Simulations (4/6)

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	109	86	72	28	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	1	24	38	82	110	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	103	86	72	72	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	7	24	38	38	110	110	110	110	110

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +10mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	103	86	72	72	28	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	2	2	7	24	7	24	38	82	110

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	109	86	72	28	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	1	24	38	82	110	110	110	110	110	110	110

Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	103	86	72	72	0	0	0	0	0
Park & Ride	0	0	0	0		0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	7	24	38	38	110	110	110	110	110

Table 73 Simulations (5/6)

Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +5mins					$C_{DA}=3/2*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	103	86	72	72	28	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	2	2	7	24	38	38	82	110	110
Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	109	86	72	28	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	1	24	38	82	110	110	110	110	110	110	110
Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	103	86	72	72	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	7	24	38	38	110	110	110	110	110
Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +10mins					$C_{DA}=3*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	103	86	72	72	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	72	72	72
Carpooling	0	0	0	2	2	2	7	24	38	38	38	38	38
Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	109	86	72	28	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	1	24	38	82	110	110	110	110	110	110	110
Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	103	86	72	72	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	0	2	7	24	38	38	110	110	110	110	110
Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +10mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	103	84	72	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	2	2	75	76	76
Carpooling	0	0	0	2	2	2	7	24	36	35	34	34	34
Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	109	86	72	28	0	0	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpooling	0	0	1	24	38	82	110	110	110	110	110	110	110
Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	103	86	72	2	0	0	0	0	0
Park & Ride	0	0	0	0	0	0	0	71	71	71	72	73	72
Carpooling	0	0	0	2	7	24	38	37	39	39	38	37	36
Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	108	108	108	93	2	2	0	0	0	0
Park & Ride	0	0	0	0		0	10	101	101	108	108	108	108
Carpooling	0	0	0	2	2	2	7	7	7	7	7	7	7

Table 74 Simulations (6/6)

Extra traveling time for Carpooling: +10mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	109	105	83	2	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	5	103	108	110	110	110	110
Carpooling	0	0	0	0	1	5	22	5	0	0	0	0	0
Extra traveling time for Carpooling: +15mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	110	110	93	2	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	15	108	108	110	110	110	110
Carpooling	0	0	0	0	0	0	2	0	0	0	0	0	0
Extra traveling time for Carpooling: +20mins					Egress time for Park & Ride: +5mins					$C_{DA}=4*C_{P\&R}=3/2*C_C$			
Parking fee (€)	0	1	2	3	4	5	6	7	8	9	10	11	12
Drive Alone	110	110	110	110	110	110	93	2	2	0	0	0	0
Park & Ride	0	0	0	0	0	0	15	108	108	110	110	110	110
Carpooling	0	0	0	0	0	0	2	0	0	0	0	0	0

Table 75 Calculation of the parking fee for 'Increase Parking Supply' scenario.

Year	**1**	**2**	**3**	**4**	**5**
Parking Spaces needed (garage)	285	595	765	961	1182
Annually depreciation of building costs (€/space)	625	625	625	625	625
Total depreciation costs	**178125**	**371875**	**478125**	**600625**	**738750**
Maintenance costs garage (€/space)	360	360	360	360	360
Total maintenance costs garage	**102600**	**214200**	**275400**	**345960**	**425520**
On-street parking Spaces	3485	3485	3485	3485	3485
Maintenance costs on-street (€/space)	250	250	250	250	250
Total maintenance costs on-street	**871250**	**871250**	**871250**	**871250**	**871250**
Total maintenance costs	**973850**	**1085450**	**1146650**	**1217210**	**1296770**
Depreciation of building costs and Maintenance Cost (annually)	**1151975**	**1457325**	**1624775**	**1817835**	**2035520**
Total parking spaces	3770	4081	4250	4667	4922
Total depreciation and maintenance costs (per day)	3156,10	3992,67	4451,44	4980,37	5576,77
Total depreciation and maintenance costs (per day & space) (€/space)	0,84	0,98	1,05	1,07	1,13

Building a parking space in a garage costs on average €12.500. The depreciation of the building costs is assumed to happen in a period of 20 years. Therefore, the annually depreciation cost for each parking space is €625. The interest rate is assumed zero (0) Maintenance costs for garage parking spaces is €360, while for on-street spaces €250. Assuming that the parking demand will be 90% of the total supply, each parking space will cost €0,84 per day for the first year. In case that the calculated costs are introduced as parking fees, they will not have any impact on the parking demand (according to the simulations). Therefore the future parking demand is assumed as calculated in Chapter 4.