MASTER

Campus parking information
which attributes influence the car drivers' parking choice behavior on a campus?

Bekendam, C.E.

Award date:
2015

Link to publication
Campus Parking Information

Which attributes influence the car drivers’ parking choice behavior on a campus?

Eindhoven University of Technology
Faculty Building Environment
Master Construction Management and Engineering

C.E. (Lotte) Bekendam
Which attributes influence the car drivers’ parking choice behavior on a campus?

AUTHOR
Eindhoven University of Technology
Name: C.E. (Lotte) Bekendam
Student number: s093872 / 0727224
E-mail: C.E.Bekendam@student.tue.nl
Telephone: +316 108 070 36

SUPERVISORS UNIVERSITY (INTERN)
Eindhoven University of Technology
Supervisor 1
Prof.dr.ir. B. (Bauke) de Vries
E-mail: B.d.Vries@bwk.tue.nl
Supervisor 2
Dr.ing. P.J.H.J. (Peter) van der Waerden
E-mail: P.J.H.J.v.d.Waerden@bwk.tue.nl
Supervisor 3
Dr. ir. B. (Brano) Glumac
E-mail: B.Glumac@tue.nl

SUPERVISORS COMPANY (EXTERN)
Movares
Supervisor 1
Ivo Bastiaansen
Stedenbouwkundige
Email: Ivo.Bastiaansen@movares.nl
Supervisor 2
Martin Wink
Movares Mobility
Email: Martin.Wink@movares.nl
Preface

Ten months ago I started my thesis with writing my research proposal. After my bachelor of Building Engineering, I started with the master Construction Management and Engineering (CME) where a lot of interesting topics and ideas for my thesis crossed my path. One of these topics is smart cities, which also covers a big part of the master CME. This topic is how my interest for creating smarter cities started. The convergence of several disciplines is one of the things where I see a challenge to improve these city-processes. Mobility is one of the issues, which has a high priority within cities; parking and transportation are strongly connected to this issue.

Eventually this is why I decided to do a research about parking behavior of car drivers in combination with smart parking. As a graduate intern at Movares I had the opportunity to get in contact with a lot of professionals regarding mobility and infrastructure. This internship also inspired me during my research and resulted in having a different view on certain things concerning this topic. I have learned a lot since it was my first time to be in a company that is specialized in these fields.

The main focus of the paper is not about the technology behind smart parking but is rather a step towards the right input for such technologies. By means of this research I would like to add something to the already existing knowledge about parking decisions and smart parking applications.

I would like to thank anyone that helped me to get to this point, including my two supervisors of Movares Ivo Bastiaansen and Martin Wink. Besides that I would like to say thanks to my main supervisor from the University, Peter van der Waerden. In addition to this I would like to thank the University’s Parking Panel, for providing me to distribute my questionnaire through their panel, without this panel I would never be able to get that many respondents for my research in such a short period of time.

At last I would especially like to thank my family, friends and fellow students who did support me during writing this thesis, and always encouraged me to get out the best in me. I hope you will enjoy reading this report.

Eindhoven, June 2015

Lotte Bekendam
Executive Summary

At this moment governments are facing increasing problems concerning global warming and emissions of harmful gasses. These issues partly arise because of the usage of cars has increased exponentially over the years. The exhaust gasses from these cars cause besides environmental problems also health issues for humanity (Pope et al., 2009). Because of these risks and a higher density of people in and around urban areas, measures have to be taken by the government and municipalities to limit these problems. When it comes to car driving, parking causes a lot of issues. To find a parking spot, people cruise around until they have found a parking spot that satisfies them, which leads to even more traffic and harmful emissions, and unsafe situations. By improving the parking facilities and parking information, cruising for parking can be minimized.

To improve parking facilities in and around urban areas and campuses, the concept of Smart Parking did arise. Smart parking can be described as an umbrella term for ways to make parking easier and more efficient in ways such as payment, information, or innovating techniques (Rodier et al., 2004). Not only in urban areas but also campus areas are facing issues when it comes to parking (Barata et al., 2011). These issues are leading to messy and chaotic campus areas. This study focuses on the information side of smart parking combined with parking behavior attributes on a campus area. Implementation of smart parking is not only relevant for the car driver but also for the campus administrator it can be interesting to know which information to provide regarding parking facilities. When providing the right information to the car driver campus areas can be safer, healthier and better accessible. These benefits will make a certain area more attractive for the car driver.

Before the right information can be provided to the car driver it is important to know which information has influence on the car driver. Therefore this study focuses on attributes that play a role when it comes to parking. To find out which attributes have an influence on car drivers’ parking behavior on a campus, a questionnaire is conducted which includes a stated preference experiment. The attributes of parking facilities that are included in this research are: walking distance, parking tariff, occupancy rate, distance from entrance to parking lot, size of the parking lot, conflicts on walking route. By means of this experiment it was possible to get the preference for the different attributes from the respondents. In total 159 respondents have completely filled in the questionnaire. The outcome of the research does match the hypothesis that has been set prior of this study. The aspect that has the most influence on the car-driver is the walking distance from the parking space to the final destination followed by the tariff of the parking spot. It can be concluded that most car drivers prefer an option that is either cheap, fast or these two combined. Providing information about walking distance and/or tariff on forehand might make it easier for car drivers to choose a parking spot.
Samenvatting (Dutch)

In de afgelopen decennia worden overheden en gemeentes geconfronteerd met toenemende problemen op het gebied van milieuvervuiling mede door uitstoot van schadelijke gassen. Deze schadelijke gassen ontstaan gedeeltelijk doordat het gebruik van de auto in de afgelopen jaren exponentieel is toegenomen en nog steeds het belangrijkste vervoersmiddel is. Deze uitaatgassen hebben naast consequenties voor het milieu (zoals bijvoorbeeld smeltende ijskappen) ook consequenties voor de gezondheid van de mensheid (Pope et al., 2009). Vanwege deze risico's en een steeds dichter wordende bevolking in de steden zullen de overheden en gemeentes deze problemen moeten aanpakken. Als het gaat over autogebruik, zorgt parkeren onder andere voor veel problemen. Om een geschikte parkeerplaats te vinden rijden automobilisten rond tot ze een geschikte plaats hebben gevonden om te parkeren. Dit leidt tot meer verkeer en daardoor nog meer uitstoot van schadelijke gassen. Dit zoekgedrag voor een parkeerplaats kan worden geminimaliseerd door verbetering van parkeerfaciliteiten en betere parkeerinformatie voor de automobilist.

Om een helpende hand te bieden aan deze parkeerproblematiek is het concept smart parking ontstaan. Smart parking kan worden omschreven als een overkoepelende term van maatregelen die parkeren eenvoudiger en efficiënter maken als het gaat om betaling, informatie voorziening, en/of innovatieve technieken (Rodier et al., 2004). Niet alleen stedelijke gebieden maar ook campussen worden geconfronteerd met deze parkeerproblematiek. Deze problemen leiden tot een rommelige en chaotische campus situaties. Dit onderzoek richt zich op de informatie voorziening van smart parking, gecombineerd met attributen die invloed hebben op parkeergedrag van de automobilist op een campus. Het implementeren van een smart parking systeem is niet alleen relevant voor de automobilist. Ook voor de campus beheerder kan het interessant zijn om te weten welke informatie van invloed is op de automobilist. Door het verstrekken van de juiste informatie aan de automobilist kunnen campus gebieden veiliger en beter bereikbaar worden. Op deze manier wordt de campus aantrekkelijk voor automobilisten.

Voordat de juiste informatie aan de automobilist kan worden gegeven is het van belang te weten welke informatie invloed heeft. Daarom richt deze studie zich op de attributen die van invloed zijn op de automobilist als het gaat om parkeren op een campus. Om erachter te komen welke attributen invloed hebben op automobilisten, is een stated preference experiment opgezet die verspreid is door middel van een enquête. De attributen die opgenomen zijn in dit onderzoek zijn: loopafstand van de auto naar bestemming, parkeertarief, bezettingsgraad van het parkeerterrein, afstand van campus entree naar ingang van het parkeerterrein, de grootte van het parkeerterrein, en conflicten op de looproute. Met dit experiment was het mogelijk om de voorkeur voor de verschillende attributen te verkrijgen. In totaal hebben 159 respondenten de enquête volledig ingevuld.
De uitkomsten van het onderzoek toont gelijkenissen met de hypothese die voorafgaande aan het onderzoek zijn vastgesteld. Het attribuut dat de meeste invloed heeft op de automobilisten is de loopafstand van de auto naar de eindbestemming, gevolgd door het tarief van de parkeerplaats. Er kan worden geconcludeerd dat de meeste automobilisten een goedkope of snelle optie als het gaat om parkeren. Het verstrekken van informatie over de loopafstand en/of parkeer tarief aan de automobilist zou het vinden van een parkeerplaats gemakkelijker kunnen maken.
# Table of Contents

EXECUTIVE SUMMARY ........................................................................................................3
SAMENVATTING (DUTCH) ......................................................................................................5
1.1 PROBLEM INTRODUCTION .............................................................................................13
1.2 PROBLEM DEFINITION .....................................................................................................13
1.3 RESEARCH INTRODUCTION ..............................................................................................15
1.4 RESEARCH QUESTIONS ..................................................................................................16
1.5 RESEARCH DESIGN ..........................................................................................................16
1.6 EXPECTED RESULTS ......................................................................................................19
1.7 READING GUIDE .............................................................................................................19

## 2. TRAVELING AND PARKING ATTRIBUTES ................................................................. 24

2.1 TRAVELING ....................................................................................................................24
   2.1.1 Different types of travel and travel behavior ..............................................................24
   2.1.2 Travel information ..................................................................................................25
2.2 PARKING .......................................................................................................................26
   2.2.1 Parking supply ........................................................................................................26
   2.2.2 Parking demand ......................................................................................................27
   2.2.3 Parking guidance systems ......................................................................................28
   2.2.4 Parking information ...............................................................................................29
2.3 SMART PARKING ..........................................................................................................30
   2.3.1 Goals of smart parking ..........................................................................................31
   2.3.2 Examples of smart parking ....................................................................................31
   2.3.3 Acceptance of smart parking ................................................................................32
2.4 PARKING CHOICE BEHAVIOR ..................................................................................33
2.5 CAMPUS .......................................................................................................................34
   2.5.1 Parking on a campus ..............................................................................................34
   2.5.2 Stakeholders on a campus ......................................................................................35

## 3. SMART PARKING AND THE INFLUENCING ATTRIBUTES ON PARKING BEHAVIOR .......... 38

3.1 SMART MOBILITY ........................................................................................................38
3.2 GOALS OF SMART PARKING .......................................................................................40
   3.2.1 Payment ................................................................................................................41
   3.2.2 Information ............................................................................................................42
   3.2.3 Techniques .............................................................................................................42
3.3 ASPECTS THAT INFLUENCE THE PARKING CHOICE BEHAVIOR ......................... 43
3.4 PARKING BEHAVIOR ON A CAMPUS ..................................................................45
3.5 PARKING ATTRIBUTES ON A CAMPUS ................................................................45
3.6 PARKING ATTRIBUTES AND SMART PARKING ...................................................... 45
3.7 CONCLUSION ..............................................................................................................46

## 4. THE INFLUENCE ON THE PARKING CHOICE BEHAVIOR OF CAR DRIVERS WITHIN A CAMPUS ENVIRONMENT ................................................................. 52

4.1 INTRODUCTION ............................................................................................................52
4.2 BACKGROUND OF THE STUDY ..................................................................................53
4.3 METHOD ......................................................................................................................54
4.4 RESULTS ........................................................................................................................................62
  4.4.1 Description of the respondents ..............................................................................................63
  4.4.2 Experience with parking information on a campus ...............................................................64
  4.4.3 Experience with parking attributes .........................................................................................66
  4.4.4 Experience with Smart Parking .............................................................................................67
  4.4.5 Model description ..................................................................................................................68

5. CONCLUSION AND DISCUSSION .................................................................................................79
  5.1 OVERALL CONCLUSION ..........................................................................................................79
  5.2 OVERALL DISCUSSION ..............................................................................................................80
    5.2.1 Societal relevance ...................................................................................................................80
    5.2.2 Scientific relevance ...............................................................................................................80
    5.2.3 Beneficiary relevance .........................................................................................................80
    5.2.4 Limitations ...........................................................................................................................81
  5.3 RECOMMENDATIONS FOR FURTHER SCIENTIFIC RESEARCH .......................................82

6. BIBLIOGRAPHY ...............................................................................................................................84

Appendix A: Experimental Design .....................................................................................................VI
Appendix B: Questionnaire ..................................................................................................................VII
Appendix C: Overview collected data questionnaire ..........................................................................XIX
Appendix D: Tables from NLOGIT ....................................................................................................XXII
List of figures and tables

Chapter 1
Figure 1.0    Virtual message sign TU/e campus
Figure 1.1    Workflow model

Chapter 4
Figure 4.0    Approaches to measure preference and choice
Figure 4.1    Questionnaire build-up
Figure 4.2    Respondent gender distribution
Figure 4.3    Respondents age distribution
Figure 4.4    Respondents educational distribution
Figure 4.5    Respondents drivers’ experience
Figure 4.6    Respondents car ownership
Figure 4.7    Respondents drivers’ license position
Figure 4.8    Respondents campus experience
Figure 4.9    Usage parking information
Figure 4.10   Respondents satisfaction of parking information
Figure 4.11   Respondents experience walking distance
Figure 4.12   Respondents experience parking tariff
Figure 4.13   Respondents experience parking lot size
Figure 4.14   Respondents experience occupancy rate
Figure 4.15   Respondents experience distance entrance to parking lot
Figure 4.16   Respondents experience conflicts walking route
Figure 4.17   Familiar with smart parking
Figure 4.18   Smart parking applications
Figure 4.19   Parking information
Figure 4.20   NLOGIT parameters
Figure 4.21   Walking distance utility
Figure 4.22   Parking tariff utility
Figure 4.23   Occupancy rate utility
Figure 4.24   Distance entrance to parking lot utility
Figure 4.25   Conflicts on walking route utility

Table 4.1    Attributes and attribute levels
Table 4.2    NLOGIT parameters
Table 4.3    Attributes and effect coding
Table 4.4    Range per attribute
1. Introduction
This chapter will start off with a definition of the problem of this research. Within this problem a focus needs to be employed, from this the main research question is conducted. To answer the main research question, several sub questions have to be answered, and are discussed within this chapter. After this the research design will be discussed including hypothesis, key deliverables, key resources, and the workflow model. At last a reading guide will be presented to describe the structure of this research.

1.1 Problem introduction
In the last ten years the amount of cars in the Netherlands has increased with 1.5 million cars to an amount of 7.8 million in total (Van Exel & Rietveld, 2009). Predictions are that this amount will increase with one million cars in the next years. Because of this growth there will more traffic congestions, which leads to more air pollutions within urban areas (Geng & Cassandras, 2012). Not only urban areas but also campus areas are facing issues regarding their traffic flow. University and corporate campuses are facing the challenge of maintaining their parking supply and transportation access demands of the area (Fries et al., 2010).

Deferred maintenance and the increasing of mobility on campus areas cause the increase of parking problems on campuses. Because of these issues the parking facilities on some campuses are under high pressure. For example these parking issues are leading to cars being parked outside the legal parking facilities, which therefore leads to unsafe situations and insufficient accessibility (Louw et al., 2004; Riggs, 2014). To park in a convenient parking space car drivers cruise around to find one. This so-called cruising for parking has causes aggregate traffic congestion and noise problems, more accidents because of unsafe situations, waste of fuel and other resources, poor accessibility, and degradation of the pedestrian environment (Barata et al., 2011).

1.2 Problem definition
More cars means that more maintenance is needed for the roads and parking facilities on the campus. This is why campus administrators are searching for ways to use the roads and parking facilities more efficiently. There are already solutions to ban cars from campus areas; such as parking lots outside the campus area where you can park your car (for a lower rate than on campus) and busses will take you to the campus (University of Hertfordshire, 2015; University of Otago, 2015). This is comparable to a Park+Ride system, which municipalities use to have fewer cars in the city center. This is a system where car drivers are parking their car just outside the center and continue their journey by public transport to reach their final destination (Parkhurst, 1995). Another measure is that employers are encouraging employees to travel by bike by making employees pay for parking on the campus (Erasmus University Rotterdam, 2015).

In many cases parking causes frustrations for the car driver. For example finding a suitable spot can result in driving through the same street three times before finally finding a
parking space. Another point of frustration is paying an unfair tariff. Sometimes a situation occurs when you need to pay for a second hour when you are parked for 61 minutes. Furthermore different payment options also leads to a lot of frustration for car drivers. So far there is no standard payment option for parking, especially in unknown areas the car driver does not always know how they can pay: by card, with cash, or maybe both options are possible. Even more irritation arises when the parking payment machine is broken and the car driver cannot pay in the way that is desired. (Tertoolen, 2010). On a campus these issues also arise, there are many examples that prove that campuses are dealing with these parking issues (Lanceta, 2003; Dick et al., 2012; Titus, 2013). Most frustrations for car drivers are about not being able to find a parking space during rush hours, or not being able to find a space that is close to their final destination.

To overcome these parking issues, or at least trying to decrease these issues, smart parking did arise. Smart parking is a very broad term that is used in different ways. One way is to provide the car driver with the right information about the parking possibilities. An example of parking information is the virtual message signs that inform car drivers about the occupancy of the parking facility on the campus. Figure 1.0 shows an example of a virtual message sign that is used on the campus of the Technical University of Eindhoven. On this sign the car driver can see the amount of vacant parking spaces on the parking lot. These signs are placed at the entrance of the parking lot.

![Figure 1.0 – Virtual message sign TU/e campus](image)

Usually there are a lot of different options to park a car, but car drivers are just not familiar with these options (especially when they visit a campus for the first time). By means of
smart parking it is possible to provide travelers with more insight on these different options. Smart parking is not only an efficient solution for the car driver. Also for car park operators and campus administrators it is a way of gathering information about the usage of their parking facilities (Idris et al., 2009). Furthermore pricing strategies can be manipulated according to the obtained information; if a certain parking area is particularly crowded at some period of the day, the tariff can be increased to make other parking areas more attractive. This could also work the other way around: when an area is less popular, and not many cars are parked on that certain parking lot, the price rate of that parking lot could be dropped to make it more popular. Another thing that makes smart parking ‘smart’ is that systems can be implemented to provide car drivers with the right information. With the right information car drivers are able to avoid car parks that are fully occupied and they are able to locate vacant parking spaces with ease elsewhere (Idris et al., 2009). All these measures will lead to less cruising for parking, which will eventually lead to less traffic and a safer environment (Shaheen et al., 2005).

1.3 Research introduction

By the means of smart parking applications it is possible to provide even more information to the car driver. This information can contain several attributes that car drivers take into account when choosing a parking space (e.g. walking route, parking tariff, safety, etc.). When providing real-time information about the parking facilities on a campus, the search for a parking space will be shorter (Fries et al., 2010). Before implementing a smart parking application on a campus area, it is important to know which information actually has influence on the car drivers’ parking choice behavior to make sure the car drivers will adapt this smart parking application. In this research the main focus will be on the different attributes that have influence on the parking choice behavior of car drivers on a campus.

Parking on a campus is something different than in an urban area. The reason why people visit a city center is mostly for leisure reasons (e.g. shopping, dining, and so on) whereas a campus visit is mostly study or work related (Lambe, 1996). The purpose of visiting is also something that has influence on the parking choice behavior of the car driver. When you pay for parking on a campus, it is mostly an amount that you pay for the whole day because most visitors are there for a work- or school day. In a city center where you mostly pay per hour for parking on a parking space, people are just parking for a few hours.

This master thesis research will also define the term smart parking. Furthermore this research will focus on how the discovered parking attributes that are related to parking choice behavior could be used to inform car drivers and how they can be implemented within a smart parking application. Where and how the information is presented to the car driver is also important to know when selecting the information that is presented to the car driver. However in this research the way of providing this information will not be taken into account in the real experiment but will be discussed in the literature review. This study is an intent for the implementation of a smart parking system on a campus, and will mainly
focus on which attributes of information that has influence on the car drivers’ parking choice behavior on a campus.

1.4 Research questions
In this paragraph the research questions will be stated. The main focus of the study is to find out which attributes are important for car drivers when choosing a parking spot on a campus, which can later on be used in an application of smart parking. According to this the following research question is formulated for this study:

**Which aspect(s) influence the car drivers’ parking choice behavior on a campus?**

Aspect(s) refer to the information about the search time for a parking spot, parking fees and location of the parking spot (e.g. walking distance destination). The different attributes that have influence on the car drivers’ parking choice behavior will be defined further on in the research report. The moment of presenting the parking information is also important because the way of influencing is different in different moments of the ‘choice-process’ of the car driver. For this research the choice has been made to focus on providing the parking information when a car driver arrives at the gate of the campus. At the entrance of the campus the car driver will get the information about the surrounding parking possibilities. To answer the main research question there are two sub-questions that need to be answered as well. The questions have been formulated as follows:

**“What does smart parking include?”**

By answering this question it has to be clear what the term ‘smart parking’ will mean in context of this research. Many people and companies use ‘smart parking’ in several different ways. It is important to have a clear overview about this specific topic. For this research it is also necessary to give some examples of the already existing smart parking possibilities. The main focus of this master thesis is about parking choice, so this is why it is important to clarify the meaning of ‘parking choice’, what did lead to the following question:

**“What does parking choice include?”**

Parking choice includes the attributes that have an effect on the car driver, and also how these car drivers make their choice for a specific parking space on a campus. To answer the main question it is important to understand the parking choice behavior, and which attributes play a role in this decision making process. When defining parking choice behavior, there will also be a focus on how parking choice attributes can be implemented within the concept of smart parking.

1.5 Research design
The focus of this master thesis is to get an insight on the different attributes that play a role when making a decision for a particular parking space within a campus area, and also how these attributes can be implemented in a smart parking application on a campus. In this...
case smart parking is referring to the kind of information that is presented to the car drivers about the different parking facilities on the campus. There are a few examples of cities where attributes of smart parking are already implemented on a bigger scale like San Francisco and Amsterdam; these will be explained further on in this report. This research will start off with some background information about traveling in general, parking, smart parking. There will also be a focus on displacement choice and parking choice behavior, in this thesis the meaning of these terms will be determined. The different attributes that play a role in the parking choice process will be compared and explained.

Once these influencing attributes are clear it will give campus administrators the possibility to respond with fitting measures that would actually be adapted by the users. Another focus is related to companies or organizations that are located on a campus. When they know how to inform their visitors/employees in the right way, parking facilities will be used more efficiently.

While this research mainly focuses on campus areas, the results of the research can also be partly implemented in a city center area. The only difference between a campus and a city center is the scale. This scale difference will probably attract a different type of visitors but the problems concerning parking remain the same. By means of smart parking, people can reach their destination faster and parking facilities will be more efficient. With the reduction of so-called ‘search-traffic’ on a campus this will lead to less traffic congestions, less air pollution an overall safer campus environment for both car drivers, cyclists and pedestrians. It is known that by means of smart parking, parking can be made easier, quicker and more efficiently (Shaheen, 2005). The focus of the research is to explore the possibilities of payment options, better real-time travel, and parking information.

The focus of this study is to find out how smart parking information can contribute to a campus’ parking facility. Therefore it is necessary to define the meaning of smart parking within this research. Another focus is to define the different attributes that play a role when it comes to making a parking choice. Also the moment of giving the information about the parking facility is crucial in this decision making process, but it will not be the main focus for this study.

_Hypothesis_

The method that is used for this research is a stated choice experiment. By means of a questionnaire, respondents will be asked to choose between a few hypothetical parking situations based on a campus. In this case the situations consist of three different parking lots with all different characteristics. These characteristics will be defined later on in the report. When people travel they want to do this as quickly, cheaply and as effortlessly as possible (Van Wee & Dijst, 2002). The hypothesis of this study is that car drivers will choose for the cheapest option, the fastest option, or the easiest option (e.g. less hassle to find a parking spot for example).
Key deliverables and resources

The deliverables that will arise from this research are: An improved understanding of the term ‘smart parking’, together with an improved understanding of the term parking choice, and the analysis of the collected data from the designed questionnaire about attributes that influence these parking choices. The key resources for this research are literature that has been found on the Internet through scientific websites and scientific books. Besides this, literature that has been provided by the Eindhoven University of Technology will be used for the theoretical part of the report. For the distribution of the questionnaire the survey program “Berg Enquête Systeem” is used. To spread the questionnaire amongst different respondents the resources of the University’s Parking Panel is used. For the analysis of the data statistical computer program SPSS and NLOGIT are used.

Workflow model

Figure 1.1 shows the workflow model of the research. The workflow model illustrates the main steps that are followed to deliver the final result: the Master Thesis. In order to see the different stages over time they are illustrated with the corresponding deliverables.

The first step of the research was making a research proposal. In this proposal a short literature study was made and the research questions where conducted. The next step was the expansion of the literature study that consists of a glossary and a literature review. After this the data has been collected by means of a stated preference experiment. This experiment has been processed in a questionnaire. In the final stage of the research the data has been analyzed and the research question is answered by means of the literature review and the analyzed data.
1.6 Expected results
The expected result for this research is to have an overview of the different attributes that influence car drivers when it comes to parking choice behavior. By means of a questionnaire where a stated preference experiment is integrated, these attributes and their importance will be discovered. The stated choice model that is used for the purpose of this research is obtained from a literature study and several interviews with professionals in the field of parking and mobility. Campus administrators and their parking facilitators can use the results of this study to improve the parking facilities and mobility on the campus. The outcome of the study could also be used by other organizations (e.g. municipalities) that would like to improve the parking facilities and surrounding road network.

1.7 Reading guide
This master thesis is built up in three different parts: Theory, Research, and Conclusion. The first part of the report consists of a literature study started off with a glossary that is composed of different topics that are covered by the study. The theory part chapters contain previous work and also how the research will proceed. Topics that are covered by the theory are travelling in general, parking in general, smart parking, parking behavior, parking on a campus and lastly a conclusion about the found information will be stated.

The second part is the research part. In this part the used method and questionnaire design will be described. First the questionnaire will be described with all its attributes. Furthermore the stated choice method is explained. Subsequently the multinomial logistic regression model will be described and applied together with the found data from the questionnaire. Lastly the conclusions and discussion of the model analysis will be given.

The third and last part of the report includes an overall conclusion and discussion. This discussion will also include limitations of the research. The relevance of this study and final recommendations can also be found in the last part of the report.
PART I - THEORY
2. Traveling and parking attributes

In the previous chapter the main problem of this research is stated, which is all about defining the attributes that have influence on the car drivers’ parking choice behavior. Now it is important to define some concepts and terms that are related to this problem. This second chapter covers the explanation of concepts of traveling, parking, smart parking, parking choice behavior, and a campus. The different terms that will be used in the literature review and the rest of the paper will be explained according to scientific literature.

2.1 Traveling

Our daily activities have changed in many ways over the past century. For example we travel much more to participate in various activities. Occupations at the destination are mostly the motive for the trip, and thus travelling is an important precondition for participation in many activities. A trip consists of more than only travelling by vehicle; the traveler takes the entire travel chain in consideration. This includes moving from origin to the vehicle (this includes public transport too), time spend in the vehicle, and time spend from vehicle to destination (Carlsson, 2004). According to Van Hagen (2011) people can choose whether they travel by car, public transport or bike. They are mostly opting for that mode of transportation that offers the best quality in relation to the investment of three attributes: money, time, and effort. People want to travel quickly, cheaply and as effortlessly as possible (Van Wee & Dijst, 2002).

2.1.1 Different types of travel and travel behavior

There are four main means of travel: Private car use, public transport, cycling, and walking. Most studies have been limited to compare private car use and the use of public transport. (Gatersleben & Uzzell, 2007). The use of each of those means of travel involves both advantages and disadvantages. When it comes to car usage, attention is mostly drawn to the negative effects of car. Car use would generate in driving stress because of congestion, speed and overstimulation, and poor health caused through air pollution (Bianchi & Varney, 1993). Besides this there are also positive effects such as improved accessibility, speed, and control of our lives. According to multiple studies the use of more sustainable transport modes like walking, cycling, or the use of public transport are mostly related to environmental awareness but also social and personal norms (Nilsson & Kuller, 2000; Hunecke et al., 2001; Joireman et al., 2001).

In the Netherlands there are many different forms of public transportation, that each have different impact on the environment. The forms of public transportation for a metropolitan city are rapid trail or rapid bus transit systems. These services connect multiple activity centers and surrounding villages (Kutz, 2008). Transportation means such as the train, metro, and bus systems all run by a fixed route with a fixed timetable and fixed stops. In
case of the train and metro the vehicle will stop at every single stop even when no one wants to get in or out. Another case is the bus: the passenger has to request the bus to stop; otherwise the stop will be skipped. This requesting system already makes the bus a less reliable mean of transportation with a chance of being either too late, or too early. When making a choice for a means of travel, travelers do weigh the pros and cons of each travel possibility.

Earlier studies have found that when people are asked why they prefer to use the car as pendant to other modes of transport they refer to the advantages of cars in terms of costs, flexibility, convenience, travel time, and protection against the weather (Verplanken et al., 1994; Bamberg & Schmidt, 2001). Together with these instrumental advantages, there are also some affective-symbolic reasons like driving thrill, excitement, feeling of power and status to choose for car driving (Steg et al., 2001). While on the other hand people indicate that the reasons that they walk or cycle are because of the joy they get from it, health, the environment, and costs (Hopkinson & Wardman, 1996). A car trip does not only consist of driving, there are more things involved. According to Gallo et al (2011) a car trip does consist of four basic parts:

- Walking trip between home and personal car (walking access time);
- On-board trip until destination zone (on-board time);
- Cruising for parking at destination (search time);
- Walking trip between parked car and destination (walking egress time).

To make adjustments and improvements to the already existing network it is essential to understand why people are choosing for a specific means of travel. Travel choice behavior is complex because for each journey people have the choice between different means of travel with all different advantages and disadvantages (Beirão & Sarsfield, 2007).

2.1.2 Travel information

When it comes to travel information there are three kinds, which can be distinguished: static information (e.g. books or newspapers), dynamic information (e.g. a website), and real-time information (e.g. traffic information) (Grotenhuis et al., 2007). When it comes to information not only the content is important but also the condition and composition of the information. People who are traveling by car (or in general) do not all have the same purpose to fulfill of their travel. The difference between trips for work or for leisure can also be noticeable when making a decision for a certain parking space. Although the purpose of the trip may differ from traveler to traveler, there are multiple locations to provide this information to the car driver, which are the same for all travelers. According to Grotenhuis et al. (2007) three different moments for distributing information can be distinguished:
1. **Pre-trip**: This stage is essential for the travel planning. This step does define which tasks must be done to achieve the goal of the travel. Usually the pre-trip planning takes places at the origin of the travel (e.g. home or the office).

2. **Way-side**: Way-side information is mainly used as travel support rather than for planning the trip. By means of signs along the road the information is presented to the car driver. A way-side location can be a bus stop, a station, a public transport center, a park and ride, and so on.

3. **On-board**: This information is provided inside of the vehicle (car, bus, train etc.), and is always preceded by pre-trip –and wayside information. Like wayside information, on-board information is mainly used for travel support.

### 2.2 Parking
The demand for a parking space – especially in crowded urban areas – is increasing, and is not always correspondent with the existing parking supply. Dutch municipalities and other governmental bodies are coping with this issue. Parking has become a highly noted point on the agenda of the governments’ mobility management programs (CROW, 2004). Not only in the Netherlands but worldwide urban areas are dealing with a decrease in demand for parking space. The problems regarding the lack of parking spaces is becoming more acute, especially in densely populated areas (Arnott & Inci, 2006). These parking issues are not only something urban areas have to deal with, but also campus areas are having troubles with managing their parking facilities (Shang et al., 2007).

#### 2.2.1 Parking supply
When it comes to parking there are a lot of options and possibilities, which all together is covered by the parking supply. The parking supply differs from sizes of the parking lot, different kinds of parking lots (e.g. inside or outside), different tariffs, and various locations of parking lots in and around a certain area. The existing parking supply is very big therefore a large amount of information is available about these parking facilities. The available information is mainly about pricing regimes, the location of parking related to the final activity destination, the security of parking and the supply of such parking in terms of permissible access by time of day for example short versus long stay parking (Hensher & King, 2001).

Because of the large offer of parking facilities, car drivers have a lot of choice when choosing a parking space. When choosing a specific parking space it starts off with the actual place of the parking space, this can vary between on-street parking to off-street parking like a parking garage or a parking lot located in the suburbs (Van Dijken, 2002). The type of parking facility is depending on the size and area where it is located. Larger parking lots are for example mostly located just outside the city centers, where car drivers can park their car and continue their journey by public transport or by foot. Another aspect that is
mostly depending on the actual location of the parking space or the time of day/week is the parking tariff. In a city like Amsterdam parking near the busiest area costs about 5.71 euro per hour, where in Hoofddorp (a smaller city close to Amsterdam) the costs per hour are just 0.80 euro. The average tariff that car drivers have to pay in the Netherlands in parking garages is 2.61 per hour (Detailhandel Nederland, 2013).

2.2.2 Parking demand
Parking needs of car drivers have changed over the years, this partly because of the mixed-used developments of parking spaces (Smith, 2005). Because car drivers have different needs, the parking demand has also changed. This together with the growth of the population and the increase in car-use, makes it that city centers and other highly dense area like campuses are dealing with parking issues. Parking demands are the things that are actually required by car drivers to park somewhere. These demands make car drivers tend to cruise for a parking space that fits their needs accordingly.

Parking needs of the car driver can differ from a parking spot that is free of costs to a parking spot that is on a short walking distance to their final destination. Car drivers have parking demands with mostly a personal preference. There is a lot of choice when it comes to parking. Parking spaces can differ in size, location, tariff, safety, and so on. The large amount of choice in the parking facilities supply is why most people have a pretty specific parking wishes. They do not mind to cruise around until they have found a parking space that fits their needs.

Cruising for parking creates a mobile queue of cars that are searching and waiting for a vacant parking spot (Shoup, 2006). In this same study, 13 major cities worldwide are compared on the level of search time for a parking spot. This study shows that 30% of all the traffic is searching for a parking spot and the average search time is 7.8 minutes. There are several reasons why people are cruising for a parking spot. Of course there can be personal reasons why people are searching for a parking spot. Maybe their regular parking spot is occupied or they prefer to walk a bit further because the sun is shining. Besides these personal reasons there are also general reasons why people are cruising for a parking spot. According to Shoup (1997) these general reasons are: the on –and off-street parking tariff, the parking duration, time spend searching for on-street parking space, fuel costs of cruising, number of people in the car, value of time spend cruising, and walking distance between parking and final destination(s).

Besides these reasons that are considered by a car driver, characteristics of the parking facility are also important to the car driver when making a decision for a parking space. The knowledge of the car driver about the parking facility does have influence on the car drivers parking behavior (Polak et al., 1991). Firstly a car driver has to decide which parking lot to go to. This certain parking facility can have several characteristics that people take into consideration. These characteristics are the size of the parking lot, if the parking lot is...
inside or outside, the presence of guidance, safety for car and person, the parking tariff, and so on. After this the car driver has to choose for a specific parking space on this parking lot. This parking space can also have specific characteristics which can have influence on the car driver; the distance to the entrance, the actual size of the parking space, the position of the parking space (next to a wall, in the middle of the parking lot, etc.), whether other cars are parked near by, whether the parking spot is underneath a tree or not, and so on.

In a lot of urban areas on-street parking is cheaper than off-street parking, which makes people choose for an on-street parking space rather than a more expensive off-street one. According to Shoup (2006) cruising does not have that many impact on the individual as it does collectively. Cruising for parking congests traffic, it causes accidents, it wastes fuel, it causes air pollution, and it degrades the pedestrian environment. By increasing the parking tariff of the available parking spaces to an appropriate level, the number of vacant parking places increases, so the cruising time will be less (Van Ommeren et al., 2012). Besides controlling the parking tariff, cruising for a parking space can also be decreased by providing information to car drivers’ information about the surrounding parking facilities. This information can help the car driver to find a vacant parking spot. The information can be presented by means of so-called parking guidance systems.

2.2.3 Parking guidance systems
Parking guidance systems are not something from the last decade, the first attempt to assist people to a vacant parking spot as fast as possible was set up in the early seventies. At that time it was only possible to show an occupied or vacant status. Twenty years later, when technologies got improved, new parking guidance systems (PGS) were developed. These systems could show more accurate information like the amount of vacant parking spaces (Jogems & Spittje, 2005). After the passage of another twenty years, in which technology developments have gone really fast, even more is possible. Nowadays the parking guidance systems can show different types of information regarding parking. The car driver can receive: information about the location, information about the route to the car park, and occupancy of parking spaces is available for car driver (Van der Waerden et al., 2011).

According to Spencer & West (2004) PGS do has a lot of benefits. Their research is focused on San Jose, California, but the expected benefits can be interpreted in general:

- Reduction of congestion and air pollution;
- Increase garage occupancy;
- Reduction of amount of cruising time for the car-driver;
- Information for the car driver about the amount and location of vacant parking spaces;
- Assistance to the car driver for finding the nearest parking garage.
More efficient use of existing parking spaces, which will lead to a reduction of constructing new parking facilities.

At this moment a lot is possible when it comes to PGS, however car drivers are not committed to rely on such a system completely. When car drivers become more familiar with a certain area, they do not feel the need to (fully) use the PGS. In this case it will be more difficult to influence those car drivers (Bonsall & Palmer, 2004). There is a difference between car drivers who are already familiar with a certain area, and car drivers who are there for the first time. A car driver who is somewhere for the first time would like to receive information about the location of a parking lot as first priority. They will search for a parking space close to their destination: because they are not familiar with the situation. However a car driver, who is familiar with a certain area would like to receive the cheapest option as a first priority. When providing information about the parking facilities that is based on personal needs of the car driver, they will adapt the provided information sooner.

2.2.4 Parking information
According to Van der Waerden et al., (2011) parking information can be defined in eight characteristics: type of route to parking facility, number of parking facilities, parking tariff, number of free spaces, presence of guarding, type of parking facility, size or area around final destination, moment of presenting parking information. These characteristics also have an influence on the car driver.

Type of route to parking facility
The type of route to the parking facility can be an important factor for people when they choose a parking facility. For example car-drivers can take in consideration whether the route they are on is very busy at the moment or if the route has many traffics light.

Number of parking facilities
The number of parking facilities has influence on the car drivers’ parking and cruising behavior. When there are enough parking facilities nearby, and people are aware of this fact it is more likely that they will cruise around for parking space than when there aren’t that many parking facilities around.

Parking tariff
The majority of car drivers do not want or like to pay for parking and will base their decision for a parking space mainly on this fact. Furthermore is also known that people are willing to pay more when the egress time to their destination is minimal. It also works the other way around; car drivers are willing to walk further for their final destination if the parking tariff is lower (or free).

Number of free spaces
The number of free spaces mostly says something about the duration/change to find a vacant parking space. Most car drivers prefer a parking garage or parking lot with 200...
vacant spaces over a garage with only 20 vacant spots. When there are less vacant spots, it will take the car driver longer to find a vacant space.

- **Presence of guarding**
  A car is a precious property of people; cars also get easily damaged. This is one of the reasons why people prefer a guarded parking space over an unguarded one. A guarded parking lot also gives the car driver a feeling of safety. Women for example can feel unsafe when entering a dark and abandoned parking lot.

- **Type of parking facility**
  The type of parking facility means whether a facility is inside or outside. Another thing that is covered by the type of parking facility are the actual facilities that are available at the parking lot or parking garage. For example: an on-street parking spot mostly does not have any facilities, while parking garages off-road mostly offer a toilet facility.

- **Area around final destination**
  The size or area around the final destination is important for the car driver and can influence the parking behavior. For example if the area around the final destination is vague because of for example unclear signs across the road, then it is more likely for car drivers to cruise around longer for a parking spot. Also the close area around the parking space can have influence on the car driver. They will look whether the area looks unsafe or not and whether the area is well maintained or not.

- **Moment of presenting parking information**
  The moment that the parking information is shown is crucial for the decision that the car driver will make. If the information is given too late or too early, then it is possible that the car driver will get confused or does not have any time to think about the options he/she has and starts cruising for a vacant parking spot. As stated before there are three moments when to give the information: pre-trip, on-board, and way-side (Grotenhuis et al., 2007).

With all the upcoming technologies, more and more is possible, also when it comes to parking and providing parking information. With the use of these new technologies and implementing them within areas that are facing parking issues, parking can be made smarter and more efficient.

### 2.3 Smart parking

The concept of smart parking is a recent and also promising contribution to the already existing parking innovations. According to Shaheen (2005) smart parking can be broadly defined as the application of advanced technologies to improve the speed and efficiency of locating, reserving and paying for parking. Smart parking was introduced in the 1970s ever since new ways of smart parking have been developed like smarter information, smarter payment or park and ride facilities. These systems all require input of real-time information
about for example availability of parking spaces or traffic congestions (Chinrungrueng et al., 2007).

The term smart parking is very broad. It is a term that will not automatically mean the same for everyone. Smart parking could mean an implementation of a variety of service according to parking. An example is the parking facility at Schiphol Amsterdam Airport. Schiphol provides its customers with a service where car drivers can choose their own type of parking, that all have their own benefits. For example: short stay or long stay, the choice to park within walking distance from the terminal or to park a bit further and go to the terminal by bus, or the customer can choose for a so called XXL (extra extra large) parking space. They have a personal advice module on their website to help customers find their “smartest” way of parking (Airport Schiphol Amsterdam, 2015). In this way all customers can park in a way that they personally think is convenient.

2.3.1 Goals of smart parking
One of the goals that smart parking is trying to achieve is a more efficient use of the existing land that is dedicated to parking (Rodier et al., 2004). A universal fact is the frustration that comes with the parking shortages. Because of this shortage high-congested areas such as urban areas and campuses already have issues regarding their parking facilities. To face this problem either a decrease in demand or an increase in supply is necessary. With highly promising smart parking technologies it might be possible to solve both. By making more efficient use of existing parking space, they simultaneously increase parking supply (Shaheen, 2005). Smart parking can reduce congestion that is caused by cruising for parking. By means of presenting personal information about the parking facilities to the car drivers and guiding them towards these facilities, will lead to less searching by the car driver for an acceptable parking space (Khattak & Polak, 1993).

2.3.2 Examples of smart parking
In this paragraph a few examples of smart parking will be given. Smart parking is a really broad term. A lot of attributes are covered by this term. Car sharing and Park+Ride are both examples of smart parking but in these cases less attention is drawn to real-time data. In this study there will be a focus on the smart parking applications that use real-time data (e.g. traffic updates and personal data of car drivers). Two examples of systems that use real-time data are the San Francisco Bay Area and Stadtinfokoln.

San Francisco Bay Area
The SFpark is based on demand-responsive pricing for parking in San Francisco, United States. This system opens up parking spaces on each block, reduces cruising for parking, and prevents double parking. The rates for parking can vary by location, time of the day, and day of the week. SFpark wants to achieve the right level of parking. This means that the tariffs will increase until at least one space is available on each block. On the other hand, on places where there are plenty vacant parking spaces the tariffs will decrease until
some spaces are occupied. To determine the right parking tariff, SFpark uses wireless sensors to detect parking space occupancy in metered spaces. The sensors detect availability of the space in real time. In total an amount of 8200 on street spaces are implemented in the pilot area. SFpark used these sensors to conduct demand responsive pricing and also to direct drivers towards available parking by sending real-time availability to mobile apps and to the website (Park, SF, 2015).

\textit{Stadtinfokoln}

Also in Germany smart parking systems are integrated in several cities, for example the STADTINFOKOLN, which is located in Cologne. The system that is integrated gives up-to-the-minute information about parking space availability in and around the center. The information is displayed on VMS that are located along the access routes to the city center. This information allows car drivers to decide in advance where they want to park. They will either decide to leave their car at the suburban park and ride and complete their journey by train or they will decide to continue all the way by car. If the car-driver decides to go all the way by car, he/she will be guided to a parking facility that has vacant parking spaces (Orski, 2003).

2.3.3 Acceptance of smart parking
At this moment there are a lot of positive reactions on the introduction of ‘smart parking’. The only thing that needs to be captured is the large gap between the existing way of parking and the ‘new’ way of parking that is called smart parking. Something that has changed over the past few years is the parking tariff of parking facilities. Because of the rising number of cars and the increase of the population municipalities and campus administrators are being forced to let people pay for their parking spot, or to increase the already existing parking tariff. The increase of parking tariffs is sometimes hard to accept, and causes frustrations and irritations among car drivers. Another example is sharing the parking facilities with others; in certain areas it is not common anymore that a personal parking space is comes along with your house or apartment. Instead the available parking spaces need to be shared with your neighbors (Smith, 2005). These are only two examples of how the concept of parking has changed over the years. With the implementation of new technologies, car drivers need some time to fully adapt these new technologies. Adapting these new parking concepts is necessary for the system to work efficiently.

Parking is something that creates a lot of frustration among car drivers. Therefore is smart parking a first step in the right direction. Smart parking pilots are not only deployed in the Netherlands, all over the world smart parking solutions are implemented (Guevara-Stone, 2013). Besides this, many companies are also trying to respond to this new trend by providing more information about their parking facilities. According to the research of Kianpisheh et al. (2011) car drivers do require more parking information and guidance when it comes to choosing a parking spot. The guidance will only be adapted by the car drivers if the information is accurate and given at the right moment in time. That is why it is
important to know which information has influence on the parking choice behavior of car drivers. When smart parking would be implemented on a campus this can have a positive effect on the parking policies of the area. According to Balsas (2003), campus administrators and planners overlook the fact that students would adopt the new parking systems since students are more open-minded. Students have the potential to become the “movers and shakers”. With the implementation of a smart parking application, parking choice behavior of the car drivers can be influenced.

2.4 Parking choice behavior
The parking choice behavior of car drivers consists of a search for the optimal parking facility. This behavior is mostly comparing a set of available parking facilities. A parking facility is defined in terms of physical characteristics that are used to calculate the utility of the facilities together with travel characteristics. Capacity, fee rate, type, and duration limits of the facility are all examples of physical characteristics (Thompson & Richardson, 1998). Travel characteristics are also related to the parking choice behavior such as travel purpose, arrival time, and final destination.

When car drivers arrive at their final destination they select a parking space based on a variety of options to fulfill their personal requirements for a parking space. Parking choice is linked to wider parking and traffic management, as the amount of choice leads car drivers to search for a preferred parking space based on several combinations of factors (Brook et al., 2014). When visiting a certain destination a car driver has to find a parking space for his/her car. For the car parking process a car driver can use a variety of information sources like parking signs, parking guidance systems, internet, and car navigation systems. The information that these sources are providing differs per source and can be interesting for the car-driver (Van der Waerden et al., 2014).

People want to travel quickly, cheaply and as effortlessly as possible (Van Wee & Dijst, 2002). From this the following can be stated: When a car drivers makes a decision for a certain parking space, there is a high chance that the car driver will choose the parking space that takes the least amount of time, the parking space that is the cheapest compared to the other parking spaces nearby and the parking space that costs the least effort. When making the decision for the final parking space, many attributes are taken in consideration by the car driver, which all have influence on the parking choice behavior (Brooke et al., 2014).

Several studies have been focusing on the parking choice behavior in combination with the attributes that have an influence on this behavior. The research of Ji et al. (2007) has found out that the following attributes influence car drivers’ parking choice: walking distance to final destination, type of parking facility, parking tariff, available parking spaces, and driving time. The study of Lam et al. (2006) does also state that the walking distance, parking capacity, and parking tariff influences the car driver together with the travel demand. Aspects that influence the car drivers’ parking choice behavior are specific for every area. A
difference can be made between a city center and a campus when it comes to parking behavior. Little research is done about the parking choice behavior specifically on a campus area.

2.5 Campus
A campus is an area that mostly has facilities that serve educational purposes. This is called a university campus. In some cases the educational facilities are mixed with business related facilities, or there are different types of companies established on the campus. This is called a corporate campus (Becker et al., 2003). In this master thesis the term campus is a collective noun for areas like business parks, industrial areas, universities campuses, and medical research centers. Examples of campuses are the High Tech Campus in Eindhoven, the Eindhoven University of Technology, Universitair Medisch Centrum Utrecht and University & Research Center in Wageningen. The reason for visiting a campus does differ per person, depending on the kind of campus. According to Barata et al. 2011 campuses are communities where people with different lifestyles, backgrounds, incomes, and attitudes come together to live, work, study and recreate. The Eindhoven University of Technology (TU/e) for example, has different visitors for diverse activities on the campus. The two main groups that are visiting are students that go to the University to study and people who work at the University (professors, researchers, administrative employees, and so on). Besides these two groups of visitors there are also a few companies that are located on the campus (Eindhoven University of Technology, 2015). Furthermore housing facilities are located on the campus, which are explicitly meant for foreign students. This is only one example of the kind of visitors of a campus; this of course depends on the kind of campus. A campus has many facilities with different purposes that facilitate all different kind of people. Because a campus is a location that provides all staff and students with a place for their work, study, living and recreation, it makes the provision of parking one of the most difficult tasks at many university campuses (Barata et al., 2011).

2.5.1 Parking on a campus
Like in many urban areas, parking is also a long recognized problem when it comes to land use of a campus. According to Shang et al., 2007 parking is one of the important topics regarding urban transportation planning and traffic management. The same goes for university campuses. Transportation plays a big part considering the functionality of a campus. Anyone who drives a car can relate to the difficulties of finding a parking space in areas of intensive academic, administrative, student residential, and recreational activities. Because of all the different kind of facilities on a campus, campus administrators have issues to meet the parking demand. Campuses need to adopt parking and transportation measures that will facilitate their visitors and staff while in the meantime they also want to create interaction that makes the campus an energetic and pleasant place where knowledge is shared and innovations are made (Riggs, 2014). Not only the car drivers will benefit from enhanced parking facilities, also other stakeholders on the campus will have advantages from this.
2.5.2 Stakeholders on a campus
Depending on the sort of campus, there are different stakeholders presented. Because this research is focusing on parking on a campus, three main stakeholders are defined: the car driver, the campus administrator, and the owner of the parking facilities. As stated in the previous paragraph the stakeholder group “car driver” exists of different kinds of visitor groups. The other two stakeholders have different preferences about how parking is managed on a campus. The campus administrator does prefer to minimize the amount of cars on the campus, or at least the administrator prefers less cars driving around (e.g. prevention of congestion, safer environment for pedestrians, and so on). The owner of the parking facilities prefers (in some cases this position is held by the campus administrator) that all parking facilities will be used equally. In this way there is a better spreading of cars on the campus. For the campus administrator and the owner of the parking facilities it is good to know how the car driver uses their facilities. When they know how the car driver is responding to the parking measurements, only then they can response with fitting measures in the future (Idris et al., 2009).
3. Smart parking and the influencing attributes on parking behavior

C.E. Bekendam

Department of Building Environment, Eindhoven University of Technology, Eindhoven, The Netherlands

c.e.bekendam@student.tue.nl

Abstract

University and cooperate campuses are facing issues with their parking and traffic management. To improve the speed and efficiency of parking, smart parking can be implemented. When it is desired to implement smart parking on a campus, it is necessary to identify the most important attributes that have an influence on people according to finding parking space. A lot of research about parking has already been done, however there is limited knowledge about the different attributes that have influence on peoples parking choice behavior. The knowledge of this research could be used for example by campus owners and municipalities that would like to implement a kind of smart parking to get a better grip on their parking facilities.

Keywords: Smart Parking, Parking Choice Behavior, Campus

3.1 Smart Mobility

In 2030 the urban population will reach the amount of 8.3 billion people, this according to the “World Urbanization Prospects, The 2009 Revision”. This research states that approximately 60% of the world’s population will live in urban areas by 2030 (Desa, 2010). The increase of the urban population will have consequences for the traffic within the urban districts. At the moment most of the major cities are not resistant to the amount of people that visiting and living in the city yet.

Due this change and to anticipate on this growth it is important for cities that there will be a steady plan according to transportation. The population concentration can in this way lead to various transportation problems. Issues that are likely to occur are more emission and noise because of the growing amount of vehicles and traffic congestion. This growing amount of vehicles will also lead to more accidents and more health issues which therefore causes a reduced level of lifestyle satisfaction (Greiner et al., 1998). Smart Mobility can provide solutions to these issues. Smart mobility is one of the six characteristics of a smart city according to Giuffrè et al. (2012). The other characteristics are: smart economy, smart people, smart governance, smart environment, and smart living. Smart mobility is not a ready-to-use solution itself; it is a collective name for more sustainable and efficient ways to arrange mobility and transport within a city. These developments actually make the city
‘smarter’. The goal of this sustainable development is to create an optimal balance between economic, social, and ecological objectives (Litman & Burwell, 2006).

When focusing on smart mobility features important factors are: local and international accessibility, availability of information, communication technologies, and sustainable transport systems. Smart mobility could be the answer to user requests on the area of transport network efficiency and social sustainability. Therefore, smart mobility can contribute to smarter cities. Because of the growth in urban traffic and public transport policy, parking has become an expensive resource in almost every major city (Giuffrèa et al., 2012).

Parking issues are one of the problems that municipalities and campuses are facing when it comes to urban growth. Parking is also covered by smart mobility; this is how smart parking arose. As the name states, it is something that will make parking ‘smarter’. It will make parking smarter in terms of easier paying, better information, and combining techniques. In the study of Rodier & Shaheen (2010) smart parking refers to an application of new and advanced technologies to guide people to free parking spaces in the San Francisco bay area. In this so-called experiment car drivers are guided to a free parking space by means of sensors on the parking spaces which can detect if the spot is vacant or not. This is an example of how smart parking can be implemented in urban areas. There are already a lot of ways how municipalities and campus administrators try to inform car drivers in a smarter way. An example of such a way is the use of parking guidance information (PGI), which can be defined as a subset of different parking signing systems. To inform the car driver about location, direction and availability of parking spaces variable message signs (VMS) are used (Spencer & West, 2004). These VMS’s are placed in and around the city (or campus) to guide the car driver to their destination as quick as possible.

Although a lot of information is already given to the car driver there is a question that remains: Do car drivers get the right information? Besides whether the information is right or not, it also has to be information that is useful for the car driver. The information that is provided to car drivers could be given to them quicker and can be more specific. By means of GPS and real-time data this information can be provided. There are plenty of methods and systems that have been developed to determine the locations of moving objects with various accuracies (Arnott et al., 2005). With the implementation of smart parking personal data can be combined with the real-time data within an urban area. In this way parking will be quicker and more efficient. Besides urban areas also campus areas want to adjust their parking supply to the parking demand. Because of the mobility growth, the campus management also has to think about solutions to make the mobility within the campus smarter.
3.2 Goals of smart parking

For most people, parking can be a frustrating task, especially in areas where there are multiple possibilities for parking and there is a limited view on the possible parking facilities. Usually drivers have to cruise around for a while, searching for a parking space. Ideally drivers know the part of a parking area in which they should park, given their ultimate destination. However, often the driver does not know where the best parking space is located. This means that the car driver has to find a vacant spot by means of hunting (Trajkovic et al., 2002).

Smart parking is pursuing a few goals. By means of interviews with several experts on the area of mobility and parking there can be stated that one of the goals is to help travelers and road-users. Smart parking is making it easier and more convenient for them when it comes to route choices, parking choices, and travel mode choices. This will make the traveler more comfortable and more ensured about their means of travel. Smart parking can also help to improve and control the traffic flow within the city. The effects of implementing these ‘tools’ of smart parking in a city could be: less search-traffic in the city and a better spreading of cars on different parking spots. Smart parking can be implemented on many different levels in society. Not all smart parking solutions are serving the same goal. In Amsterdam, the Netherlands there is an experiment concerning traffic flow and parking (PPA; Parkeer Proef Amsterdam) which is also some kind of smart parking. With this experiment roadside systems, in-car systems, and combining systems are implemented in a certain area of Amsterdam. The goal of smart parking does differ per stakeholder since not all stakeholders have the same goals. This research is based on a campus area where three stakeholders that can be distinguished: the campus administrator, the parking operator, and the car driver.

For the campus administrator it is important to control the traffic flow within the campus. Besides an insight in the traffic flow an insight in the different routes that are on the campus is important. The campus administrator would like to see a decrease in the search-traffic in and around their campus. They want the campus to be attractive and safe environment because then visitors are more likely to come back next time. The campus administrator can be compared to a municipality that wants to control the traffic within their city. The goal of a municipality is also focused on making (a certain area of) the city attractive to attract more visitors. In some cases the campus administrator controls the parking facilities too, but in other cases there is a separate parking operator that controls all the parking facilities.

The parking operator wants to serve the visitors too, by providing them a parking space that the visitor is satisfied with. When a visitor is satisfied, and their needs are met they are happy to come back to the same parking place because they have a good experience with it. An application of a smart parking system is considered beneficial for both the campus
administrators and car park operators. The information that is gathered by means of this system can be exploited to predict future parking patterns. According to the information also pricing strategies can be manipulated to increase the company’s profit (Idris et al., 2009).

The last stakeholder, whom is actually the one that has to use the smart parking system, is the car-driver. The user or in this case the car-driver has other interests when it comes to smart parking. For them it is important that it provides a certain service that makes parking easier. Parking could be easier by making the payment more convenient, for example contactless paying or providing more personal information regarding to the parking needs of the driver.

In general there can be stated that the main purposes of smart parking that have been defined are:

- Make the payment more convenient;
- Make the information that is given to travelers clearer and more personal;
- Make existing smart parking solution more efficient, by improving and combining techniques.

3.2.1 Payment
Paying for parking (also called collective parking) is something everyone is already familiar with. For a long time this was how it worked out: You are driving your car, searching for a parking spot, you park your car, you decide how long you are planning to stay, you go to a parking meter which is close to the parking spot, you put in the amount of money that is required for your stay, you get a ticket and at last you have to put this ticket on the dashboard of your car. In this way the parking controllers can see how long you are allowed to park there. The last years there are also new paying methods emerging, which have made parking and paying a lot easier. An example is that when you get into a parking garage, you get a ticket, you park your car on a vacant parking spot, you go to your destination and when you go back you just have to scan your tickets at the ticket-machine and pay the required amount for your parking time. With the use of “Chipknip” (in the Netherlands) the payment could also been done at the entrance/exit of the parking garage. This card is comparable with a credit card, which can also be used at most parking garages.

With implementing a means of smart parking we could even go a step further, like paying with the use of your mobile phone and/or GPS. There are more benefits regarding paying and parking, which are covered by smart parking. For example campus administrators that would want to have more control of their parking facilities. By making the parking fee depending on the demand, there will be an effect on the amount of people that will park there. If for example the TU/e campus (Eindhoven University) would apply such a system it would work as follows: If the University expects a busy day, they will raise the parking fee,
this so that hopefully less people will choose to take the car to work, and go by public transport or bike instead. If on any day it seems to be a really quite on the campus, the parking fee will be lowered. As a result the parking demand will be lower and maybe people will take the car to work because it is cheaper. In this way the parking spots on the campus will be used more efficient. A municipality can apply a system like this in the city center too: they can raise the parking fee in peak hours, and lower them when there is less demand. For example in San Francisco there are already time-dependent or demand-dependent parking fees to achieve the right level of parking availability in different areas (Park, SF, 2015). In the future modern ways of paying for parking will probably become more common, this because municipalities want to have more control over their facilities. By using more systems and let them work together it could even be possible to pay ‘contactless’. Paying will fully automatically while your car, GPS, mobile phone, and bank account are all working together.

### 3.2.2 Information
Another goal that smart parking serves is the (personal) information that is given to road users. Information about the traffic and amount of parking spaces is already common these systems already use “real-time data”. Like the signs on the highway that tell you to slow down when a traffic jam is occurring, or the signs in city-centers (VSM) with the amount of vacant parking places in a certain parking garage. Personal Guidance Information (PGI) is also an example of an information-based system that will help car drivers to find a parking spot. This system will only work if people would actually responded to the advice that they are receiving from the parking operating system.

Imagine that you are designated to a parking spot by this smart parking system. You are driving to the advised location but upon arrival it turns out to be a spot underneath a tree. Meanwhile ten meters down the street there is an empty parking space, which is not located underneath a tree. Would you park your car on the advised parking spot or would you go for the other place? This is an essential question for the purpose of this research. When the preferences of car drivers for specific information are investigated, systems can be adjusted to this specific information. If car drivers are informed in the wrong way or when information about parking the parking facility is lacking there is much higher change congestion will arise within a certain area (Khattak & Polak, 1993).

### 3.2.3 Techniques
Another aspect that could be achieved with smart parking, or actually something that smart parking cannot do without is the innovation of new techniques. Also combining existing techniques to create smarter and more efficient ways to handle the traffic complications is a means of smart parking (Lu et al., 2009). There are some examples of smart systems that can help solve the problems around parking. Something you can think of that would be applicable in the future is that you can just put in some personal data (like age, gender, type of car, destination, time of stay, and so on) in your GPS system. This
system is connected with your car will give you a few options to choose from. For example an accident happens on your route to your destination. The system will recognize this immediately and will calculate a new route for you. When connecting several systems, they can all work more efficient without counteract each other.

In the study of Lu et al. (2009) a system called Vehicle Ad Hoc Networks is described. With the use of wide deployed wireless communication techniques, many major car manufactories and telecommunications industries work together to implement cars with On Board Unit communication devices. This device allows different cars to communicate with each other and communicate with roadside infrastructure (e.g. Roadside Units), in order to improve road safety and provide a better driving experience for the car driver. With the implementation of these devices it becomes possible to track the parking space occupancy, guide drivers to the empty parking spaces, and provide anti-theft protection in large parking lots through vehicular communications.

Smart parking has a lot of advantages, not only for the individuals that are travelling but there are also advantages for municipalities and companies. By controlling the parking facilities of a certain area, the area will be more attractive to visitors, and therefore the number of visitors is also likely to rise. For smart parking to actually work, the attitude of the user is from high importance. The technique can be really good and detailed but if the user is not satisfied or influenced by it, they might not cooperate with the system. That is why there has to be discovered which attributes have influence on the parking choice behavior of the car driver.

3.3 Aspects that influence the parking choice behavior
Why do people make a choice for a certain type of parking lot and parking space and what attributes play a role in this decision making process? There are many attributes that have an influence on the parking choice behavior of the car driver. There is also a difference between people that are used to taking their car all the time and people that are used to go by bike or public transport. Several studies (Mu Consult BV, 1995; Teknomo & Hokao, 1997; Thompson et al., 1998; Lam et al., 2006; Ji et al., 2007) show that there are many attributes that are considered by the car driver when making a choice for a certain parking space. An overview of the following attributes is given:

- Parking type facility (parking garage, inside, outside, and so on);
- Tariff (parking fee, public transport fee, and so on);
- Accessibility (searching time for a parking space);
- Supervised or unsupervised parking lot;
- Duration of the stay at destination;
- Walking distance to the destination;
- Purpose of the destination (work, leisure, shopping, diner, and so on);
- Occupancy rate of parking facility (how busy is the parking facility)
Travelers that are not used to taking the car will probably be influenced by other attributes than these mentioned above. Searching for a parking spot would probably weigh higher for them in comparison to people that take the car more often. This group of ‘car-users’ is already used and prepared to search for a free parking spot. For example when going for a shopping daytrip most people will think about their way of transportation, and think about the pros and cons of the different possibilities. Thinks that they might think of are; “how can I reach the city center in the fastest and most sufficient way?” With a Global Positioning System (GPS) in almost every car people can easily find their way in cities that they are not familiar with. Finding a parking spot in a crowded city (like Utrecht or Amsterdam) is a struggle for a lot of people. A lot of people (in the Netherlands) prefer the car above public transport; this partly because the car is (especially when going with more people) is most of the time cheaper than by public transport (Beirão & Cabral, 2007).

If an application of smart parking would have any influence on the car drivers parking choice behavior the traveler would definitely consider (some of) these attributes mentioned above. Which of these attributes have the most influence will differ per person or per target group. Smart parking is a tool that is used mainly by car drivers. This because information about parking comes in use when you decide to take the car. If a traveler would choose the car as transportation new choices will follow. Examples of these choices are: which route to pick, whether to drive with or without navigation, and eventually a parking choice, and so on. Although not everyone in one target group can be considered the same, for this research it is necessary to make a division between people that look alike in their behavior. That is why is chosen to focus on a campus area only. Car drivers who have a lot of experience with driving on campus areas will probably act differently from people who are less familiar with those situations.

Previous research has been done about parking and the effects of search-traffic. It is already known that several attributes do play a role when it comes to parking choice behavior. However the information about these influencing attributes are limited. In the research of Thompson et al. (1998) a few attributes are found that have influence on peoples parking behavior. The following attributes have been found in this study: waiting time at car parks, availability of car parks, location of car parks, how to find available car parks, and location of alternative car parks. According to the study of Teknomo & Hokao (1997) the behavior of parkers’ is mainly influenced by the availability of parking spaces, trip purpose, search and queue time, walking time, parking fee, security, and the level of comfort. It is not possible to give the car driver all information that is available. It would be an overload of information, which could confuse the car driver. Therefore it is important to define the attributes of information that is useful for the user.

- Safety of the parking spot (For example: not in a dark alley).
- Number of other parking facilities nearby.
3.4 Parking behavior on a campus
Because of the increasing number of cars, also on campus areas the occupancy rates are rising. With higher occupancy rates the illegal parked cars could also increasing on a campus area. These high occupancy rates cause unsafe situations and activities for all types of traffic (Van der Waerden et al., 2008). In the case of several campus areas the parking management lacks knowledge about parking behavior of their visitors. Especially when it comes to the choice of a parking location. This lack of information about the car drivers’ behavior and preferences makes it difficult to develop new effective parking policies within these areas (Teknomo & Hokao, 1997).

3.5 Parking attributes on a campus
Parking on a campus can be different than parking in a city center or another urban area (Guo et al., 2013). This is different because the purpose of the visit is different, which might have influence on the car driver. In paragraph 3.3 an overview of different attributes is given, which all can have influence on the parking choice behavior of a car driver. Not all of these attributes are from that high importance on a campus, because a campus is a controlled environment. Therefore it is less likely that the same attributes will an equal influence on the car drivers’ parking behavior on a campus. For example the supervision of a parking lot is probably less important on campus because a campus itself is mostly an enclosed area and already supervised in general. The same goes for safety; this is probably a less important issue, because of the controlled environment that gives already a secure feeling among visitors.

People, who are parking on a campus, usually work there or visit with study purposes. This means that most visitors are familiar with the area, which makes attributes like purpose of the destination less relevant. This is because the purpose of the visit is the same for most people on the campus (Deakín et al., 2004). Probably the duration of the stay will also be from less influence when it comes to campus visits. Most people who park on a campus work there and stay at the campus for an entire day. In addition to this the duration can also be connected with the parking tariff. In most cases the parking tariff is for an entire day but in some cases the parking tariff is counted as euro/per hour.

3.6 Parking attributes and smart parking
As mentioned before, an application of smart parking (on a campus) can have several benefits for car drivers, campus administrators and parking facilitators. These benefits have been mentioned before in paragraph 3.2, where all the benefits per stakeholder are explained. When the right attributes are implemented in this smart parking application, it is more likely for car drivers to really stick to the advice the system provides.

In the near future it might be possible to adjust the provided information for every visitor. For example: a campus employee is about to enter the campus, and the smart parking system does immediately recognize this person (by means of their license plate). The
employee could have mentioned that a short walking distance is from high importance, and is more important than any other aspect that is available. The system can search for a parking spot with “short walking distance” as first priority. Before any of these attributes can be implemented it is important to know which attributes have influence on the car drivers parking choice behavior.

3.7 Conclusion
Parking is a major issue that cities and campuses have to deal with. It is not just the availability of parking spaces that is an issue; it is also the search for a parking spot itself. The information about parking facilities has been expanded in the last decade, more information is available and also easy reachable for car drivers. A lot of applications and techniques have been implemented in society to fast-forward the parking process.

As been stated before there are some examples of studies that are related to the effects of parking tariffs, parking supply, parking location on the mode- and destination choices of people. Besides this some studies have been found about parking issues and parking behavior on a campus (e.g. Van der Waerden et al., 2008; Barata et al., 2011; Shoup, 2011). However little is known about the attributes that influence peoples parking behavior on a campus. Without this information it is difficult for the campus administrator to adjust the facilities in a way that it will be used efficiently. This is why this study is focusing on the parking behavior of campus visitors. The information that is been given to the user is crucial for the parking process and the decision someone makes according to parking.

If the car driver is provided with useful information about the parking facilities he/she does not have to cruise around (or at least less time would be spend on cruising) and search for a vacant spot. By providing this kind of information the user can choose a parking space that fits them best. This information had to be based on for the user best selection criteria. This will result in a decrease of search traffic. An indirect result is the reduction of traffic, reduction of harmful emissions, and an improved accessibility of the area.

There are three moments during the journey, the information can be given to the car-driver; pre-trip, during the trip, and when the car-driver (almost) arrives at their destination (Grotenhuis et al., 2007). This study will focus on the information that is given when the car driver almost reaches their destination. This information will be given at the moment of arrival at the campus. The hypothetical idea goes as follows; when the car-driver arrives at the campus gates, he or she will get three parking options to choose from. These options have information about different parking attributes (e.g. tariff, walking distance, and so on). Based on this given information (which is based on real-time information about the parking facilities) the car-driver can pick the one he/she prefers the most. After this the car-driver will be guided to the chosen parking space.

If there is too much information about the parking attributes, users might get confused and cannot choose properly. Therefor this study cannot include all attributes, besides this a
limited amount of attributes is necessary to have boundary conditions for the experiment. This is why a selection of six attributes has been made: Parking tariff, Occupancy rate, Walking distance from parking space to final destination, Size of parking facility, Distance from campus entrance to parking facility, Traffic conflicts on the walking route. The reason why these particular attributes have been chosen is based on several arguments. These arguments are: scientific literature, recommendations from experts in the field of mobility and parking behavior, conditions of a campus, and possibilities for stakeholders.

Traffic conflicts on the walking route are things that might causes delay when walking, for example a traffic light, a cross over for bicycles, a road without a path to walk on, etc. Traffic conflicts on the walking route from the car to the destination of the car driver could be from influence when parking on a campus. The experience with the walking route can encourage or discourage behavior of people especially when the car driver is familiar with the surrounded area (Brown et al., 2007).

The size of the parking lot could also have influence on the car driver, because this is can be an estimation of the change of finding a vacant parking space. Also for the campus administrator and parking facilitator the influence of the size of the parking lot can be interesting when adding parking facilities or adjusting the existing ones.

The distance from the entrance to the parking lot is added to the experiment because this could also be interesting for the campus administrator if this attribute has influence on the car driver. When this attribute has a certain influence on the car driver, and would be implemented in an application of smart parking, it can encourage car drivers to choose the parking lot with the shortage distance, which will results in less traffic on the campus. This will lead to a safer campus environment and less maintenance is needed because in ratio fewer cars will use the campus road network.

According to the scientific literature that has been found about parking and parking choice behavior there are multiple attributes that have influence on the car drivers parking choice behavior. Not all of these found attributes can be implemented in this study because the focus of this research on a campus. On a controlled area like a campus, some attributes don’t or nearly play a role when it comes to parking choice. The most important and relevant attributes that are found in the literature have been chosen to implement in the experiment of this research. These other attributes are; parking tariff, walking distance and occupancy rate.
PART II - RESEARCH
4. The influence on the parking choice behavior of car drivers within a campus environment

C.E. Bekendam
Department of Building Environment, Eindhoven University of Technology, Eindhoven, The Netherlands
c.e.bekendam@student.tue.nl

Abstract
Before implementing an application of smart parking on a campus, it should be investigated which attributes have an influence on car drivers when it comes to choosing a parking space in such an area. By means of smart parking the parking situation on a campus can be improved. Besides the car drivers, the campus administrator and parking management could benefit from a more efficient parking policy. There are previous studies about which parking attributes have influence on the car drivers parking choice behavior and also about parking on campus areas. However little research was found about parking choice behavior on a campus. This study investigates the influence of several attributes when making a parking choice on a campus. This is done by means of a questionnaire that is filled in by 159 respondents. There is discovered that the attributes “Walking distance” and “Parking tariff” have the most influence on car drivers when it comes to parking on a campus. The outcome of this study is a valuable addition to the already existing data that is available about parking behavior on a campus.

Keywords: Stated Choice, Smart Parking, Campus

4.1 Introduction
In this part the model of the study will be described. Firstly a brief introduction of the problem will be stated followed by how the research is conducted and how it is related to the literature. Secondly the parking attributes, which will be used for this study, are explained. These used attributes are: Walking distance, parking tariff, size of the parking lot, occupancy rate of the parking lot, conflicts on walking route, and distance between entrance of the campus and parking lot.

Secondly the method will be explained, and why this specific method is chosen. In this part it will be explained why a stated choice approach is the best fitting approach for this research. Furthermore the designed questionnaire will be explained, including the different attributes that are used for this particular study. Also there will be a focus on the respondents that have filled in the questionnaire: whom are they and what is their experience with smart parking and parking on a campus? At last the results will be analyzed, after the analysis of the data conclusions are conducted.
4.2 Background of the study
The background of the study is conducted from the literature study that has been done for the benefit of this research. As discussed in chapter 2 and 3 the background covers topics smart parking, parking information, and influence of different parking attributes on car drivers.

Smart parking
In the last two decades a lot of research has been done related to smart cities, smart mobility, and smart parking. The list of these researches with the focus on ‘smart’ is almost limitless. For this master thesis research the main focus is on attributes that have influence on car drivers parking information, and how to use these attributes in combination with smart parking. Nowadays, university and corporate campuses struggle with their parking policy. These areas become more and more crowded and – especially in rush hours – it is hard to find a parking space. Car drivers have to cruise around and search for a parking space (Van Ommeren et al., 2012). If the cruising would take less time and parking would be made easier, there would be less search traffic, which leads to less congestions and better access of the campus (Trajkovic et al., 2002). These positive effects will make the area safer and more attractive for visitors.

Smart parking is a way to make parking easier and more efficient. It can be implemented in different ways, like easier payment, application of innovative techniques, and the use of real-time traffic data. Informing car drivers is one of the attributes that can be improved by means of smart parking. Car drivers will only adapt this information if the information that is provided is relevant to them. When implementing an application of smart parking it is possible for campus administrators and other owners of parking facilities to get a better insight in the use of their parking facilities (Idris et al., 2009). With this information of the usage of the parking facilities, campus administrators can response accordingly. For example if it would turn out that the parking supply of the campus does not meet the parking demand consistently, the campus administrator can provide extra parking spaces. The implementation of an application of smart parking could also reduce the search traffic for a parking space, when it directs car drivers to a certain parking space immediately. In this way there will be less campus traffic. The profit for the owner of the parking facilities could be, that the car drivers would be advised to park in a way that there is a convenient spreading of cars across the different parking lots on the campus.

Parking information
There are already some studies that focused on parking and car drivers in relation to parking information. For example the study of Van der Waerden et al. (2015) focuses on the preferences of car drivers when it comes to of parking information. The kind of information that is given to the car driver is important in the level that it will be adapted. If car drivers get the wrong information or not enough information to make a satisfying choice, they might cruise around to find a parking space elsewhere (Trajkovic et al., 2002). If the right information is given to the driver, he/she is more likely to really adapt the
information and handle accordingly. The study of Van der Waerden et al. (2015) points out that there are six different information groups when it comes to parking information; Occupation, Accessibility, Facilities, Safety, Service, and Location. Each of these groups covers a set of information attributes, which could be preferred by car drivers. The attributes that are preferred by car drivers can also have influence on their parking choice behavior.

There are quite a few attributes that do influence car drivers’ parking choice behavior, however it would be impossible to give information about all these attributes. If a car driver is confronted with too many information, he/she does not have the time to process it within the limited timeframe when a parking choice is made. Therefore his study aims on discovering the most important parking attributes that have influence on the parking choice behavior of the car driver on a campus.

Influence of different parking attributes on car drivers
Several studies have been focusing on the parking choice behavior in combination with the attributes that have an influence on this behavior (Lam et al., 2006; Ji et al., 2007). In these studies several attributes are mentioned like walking distance to the final destination, type of parking facility, parking tariff of the parking lot, parking capacity and occupancy of the parking lot, and so on. For this study a limited list of attributes is chosen to implement in the experiment. The selected attributes are based on the found literature, recommendations of experts in the field, benefits for stakeholders, and personal insights. As been stated before, according to previous literature there are several attributes that play a role when it comes to parking choice behavior. However, for this study the focus is on parking on a campus, so not all of these attributes are relevant in this case. When focusing on a campus, most relevant attributes seem to be; walking distance, parking tariff, and occupancy rate. Besides this there are three other attributes that are implemented within this research: size of the parking lot, distance from the entrance to the parking lot, and conflicts on walking route. The distance from the entrance to the parking lot is chosen because if this attribute has influence the campus administrator can benefit from this, by trying to let the car driver travel the shortest route on campus, which leads to less traffic. Less traffic leads to less congestion on the campus, which also means a saver and pleasant environment for the visitors. For future adjustment to the parking facilities and road network on the campus, it can be interesting to know if conflicts on walking route and size of the parking lot have any influence on the car driver. Later on in this chapter a broader explanation of the selected attributes is given.

4.3 Method
This research wants to provide an insight into the parking attributes that have influence on the car drivers’ parking behavior. There are several methods to approach this matter, which all are aiming on collection of data and analyze this data after they are collected. A few methods are qualified to use when it comes to this research. For this study there is chosen for a stated preference method. With a stated preference respondents will be
asked to give their choice given a few hypothetical alternatives. The other method that is a pendant of this stated choice is the revealed preference or revealed choice. Figure 4.0 shows how the field of choice modeling is structured.

Figure 4.0 – Approaches to measure preference and choice (Kemperman, 2000).

The difference between stated modeling and revealed modeling is the used type of data. The choice models are identical when it comes to the specification. Where revealed models are based on observations in real market situations, are stated models based on observations in controlled hypothetical situations (Kemperman, 2000). Since there are not many researches or examples of parking choice behavior on a campus, there has been chosen for a stated choice experiment.

Stated preference is covered by choice modeling, the attempt of this approach is to describe the decision process of an individual or groups. Within choice modeling, stated preference or stated choices is the most common used subset. From a practical standpoint stated preference has several advantages. Firstly, a stated preference allows the analyst to pre-specify the attributes and their levels. Secondly, with stated preference, respondents get multiple-choice sets, each of which has different attribute levels. In this way, multiple observations are gained per respondent. A third benefit of the stated preference is that the influence of the different attributes can be measured independently from each other (e.g. Hensher et al., 2005).

This study is mainly based on the research method of applied choice analysis of Hensher et al. (2005). According to Hensher et al. (2005) the preparations of the stated choice method consists of eight different stages. The first stage is the problem refinement where there will be focused on the actual problem. The second stage is the stimuli refinement, which actually consist of three parts: alternative identification, attribute identification, and attribute level identification. In the third stage (experimental design consideration) there will be focused on the type of design and the model specification, which means additive versus the interactions and the reducing of the experiment size. The fourth stage is where the experimental design is generated. In the fifth stage the attributes will be allocated to
the design columns, where there will be zoomed in on the main effects versus the interactions. Stage six is where the choice sets are generated. Stage seven is where these choice sets, which are generated in the previous stage, are randomized. The final stage (eight stage) is the construction of the survey instrument, in this case the questionnaire. According to these eight stages the experiment is prepared. All the different stages will be discussed in this paragraph.

To eventually analyze the collected data a suitable analysis model is needed. Various operational models have been suggested and applied when it comes to choice behavior in the past. The multinomial logit model is the most used model within the discrete choice analysis Therefore the multinomial logit model is used within this research to analyze the stated choices. By means of NLOGIT 5.0 software the choice data is processed. The multinomial logit model is used to predict the probability that a choice alternative will be chosen (see Formula 1.1). This model derives from the assumption that error distributions are independently and identically distributed. The multinomial logit is based on the research of Kemperman (2000). This all, results in the multinomial logit model of the following form:

\[
P(i|A) = \frac{\exp(\mu V_i)}{\sum_{i'\in A} \exp(\mu V_{i'})}
\]

where,
- \(P(i|A)\) is the probability that alternative \(i\) is chosen from choice set \(A\);
- \(V_i\) is the structural utility of the alternative
- \(\mu\) is a scale parameter

The \(\mu\) is known as the Gumbel scale factor, and is a scalar quantity. When dealing with just a single data set, the Gumbel scale factor is arbitrarily set to one (see Formula 1.2) The model can include both main and interaction effects, when focussing on the systematic component is as follows:

\[
V_i = \sum_k \beta_k X_{ik}
\]

where,
- \(\beta_k\) is a parameter indicating the effect of the \(k\)th \((k=1,2,...,K)\) attribute of alternative \(i\);
- \(X_{ik}\) is the \(k\)th attribute of alternative \(I\) (Kemperman, 2000).

**Now that a suitable model is chosen to**

**Stage 1: Problem refinement**

Nowadays major cities already have to cope with a lot of traffic and congestions, especially during rush hours (Shaheen et al., 2005). When focusing on a trip by car, these trips always end in parking somewhere. Parking is also one of the issues that are related to the traffic problems that major cities coping with. Municipalities are trying to solve these problems by means of convincing people to take another means of transportation to these areas or
large car parks outside the city centers. Not only city centers are coping with these problems; also university and corporate campuses do have issues when it comes to parking (Barata et al., 2011). Less research is been done according to these parking problems on campus areas.

When it comes efficient parking, there are more measures that can be taken. More detailed and up-to-date information about parking facilities in and around a campus could already solve a lot of these problems. These new tools to cope with parking problems are called ‘smart parking’. Smart parking can be implemented in different ways (Eaken et al, 2004). It can be used to make the payment for parking more convenient, like paying with an application on your smart phone. Smart parking can also be the application of advanced technologies like adjusting the parking tariff according to the demand. Besides this it can also be used to provide detailed and real-time information to car drivers about the parking facilities.

Even though there already is a lot of information available, it is not always used and adopted by car drivers. A logical explanation for this is, that car drivers do not know what to do with the information, because the information is too vague or incomplete to really make a satisfying choice for a parking space. There are many factors that have an influence on people when it comes to parking choice behavior. There are some general factors that are considered by the majority of the car drivers (e.g. parking tariff, walking distance, and so on). For example: almost all car drivers would pick a parking spot of 1 euro per hour over one that costs 5 euro per hour, if the parking facility would have the same characteristic. Besides these factors there can also be personal factors that are crucial for the decision making process. An example of a personal factor can be that a car driver desires to walk a bit before they arrive at their destination because the sun is shining. There are more factors that can be important when making a choice for a certain parking spot. When it comes to useful parking information, it is necessary to know which information car drivers think is important to receive and which actually have influence on their behavior.

This master thesis will focus on which attributes have influence on the car drivers parking behavior on a campus area. The particular place where this information is reached does not fall within the boundaries of this study. The main question of this study is: “Which attributes influence the car drivers’ parking choice behavior on a campus?” This study wants to introduce a new idea of an application of smart parking that will be used in a campus setting. The idea is to give the car-driver (visitor of the campus) an overview of different parking space possibilities to choose from when they arrive at the campus (e.g. when they are about to enter through the gate). This information could be given by means of the GPS system in the car, or it could be given on a large screen next to the gate.

The way of how this information is given is not subject of this research and therefor excluded from the study. The information that is given to the car-driver will consist of three
alternatives of parking lots on the campus, that are selected for them based on real-time information of the parking spaces and the final destination of the car-driver. Because the study focuses on a controlled environment with mostly the same visitors (employees and/or students) the system can recognize the visitor and knows where he/she has to go. The car-driver can pick the preferred alternative and will be guided according to this choice. In this way car drivers do not have to search for a parking spot and there will be less search-traffic on the campus.

The list of attributes that could influence is quite broad, because these attributes could differ per person. It is not possible to give information about all of these attributes, because car drivers would get an overload of information. To design an optimal system it is important to know which attributes car drivers prefer.

Stage 2: Stimuli refinement
In the second stage of the preparation of this experiment the alternative, attributes, and attribute levels have to be identified. The alternative of this research is a parking spot. The alternative can be described as a place to park a motor vehicle (a car or motorcycle). All parking spots are located on a campus area in open air.

The amount of information that could be given as parking information is very large; it would be impossible for car drivers to process all this information when making a parking choice. Therefore six attributes have been selected for the purpose of this research that all have an influence on parking choice behavior of the car-driver. These different attributes can all be divided in three attribute levels, which can be seen in table 4.1. The six attributes that have been selected are: Walking distance, parking tariff, size of the parking lot, occupancy rate, conflicts on walking route, distance between entrance and parking lot.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Attribute Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking distance</td>
<td>50; 150; 450 (meters)</td>
</tr>
<tr>
<td>Parking tariff</td>
<td>2; 4; 6 (euro’s per day)</td>
</tr>
<tr>
<td>Occupancy</td>
<td>50%; 70%; 90% (percentage that is occupied)</td>
</tr>
<tr>
<td>Distance entering and parking lot</td>
<td>200; 400; 600 (meters)</td>
</tr>
<tr>
<td>Size parking lot</td>
<td>100; 200; 300 (parking spaces)</td>
</tr>
<tr>
<td>Conflicts on walking route</td>
<td>None; Some; A lot (of conflicts)</td>
</tr>
</tbody>
</table>

When using different attributes, it is important to define the meaning of each of these attributes. These descriptions are also used in the questionnaire to make the respondent familiar with these attributes, which allows the respondent to answer more accurately. The amounts of the attribute levels have been mainly conducted from found literature completed with recommendations of experts and personal insight.

Walking distance
The walking distance is the distance in meters from the parked car to the entrance of the final destination. These attribute levels have been chosen because these are regarded as acceptable walking distances in the case of a campus. All attribute levels have an equal difference, except for the walking distance. The reason that the distance between 50 and 150 (100 meter) is less than the distance between 150 and 450 (300 meter) is because in this way it is easier for respondents to have a small, medium and large walking distance. If the medium walking distance had been 250 meters, respondents would most likely also consider that as a ‘large’ walking distance. This is why attribute levels of 50, 150, and 450 are chosen. The only disadvantage of anomalous values is that it might be harder to compare the data outcome.

Parking tariff
The tariff is the amount in euros that the user has to pay for the use of a parking spot for a day. According to several resources and examples the average parking tariff does differ per campus. If we compare the parking tariff of the High Tech Campus in Eindhoven, which is free and the parking tariff of Eindhoven University campus, which is €2,00 a day for employees and €7,50 per 24 hours for visitors and the Erasmus University Rotterdam, which is €2,50. Bases on these facts there can be stated that parking tariff does really differ per campus. This is why attribute levels of 2, 4, and 6 (euro per day) have been selected (Erasmus University Rotterdam, 2014; Cursor, 2014; High Tech Campus Eindhoven, 2015).

Occupancy
The occupancy of a parking lot can be described in an amount of percentage. The respondent will notice three different kinds of percentages (50%, 70%, and 90%) that are described below. The given percentage represents the amount of occupied spaces.

50% ...means that there are plenty of vacant parking spaces, and the car driver will immediately find a free parking space.
70% ...means that the parking lot is quite full, and the driver has to search for a vacant parking spot.
90% ...the parking lot is almost full, and the driver has to until there is a vacant parking spot. They should wait in this case for another driver (with parked cars) leave the parking lot.

Distance entrance and parking lot
The distance from entrance (entry point campus) to the parking lot (in meters) is the distance that must be traveled in the car on the campus. The situation of the Eindhoven University of Technology has been used as reference for this attribute. This is the main reason that has been chosen for the attribute levels 200, 400, and 600. The distance between the parking lots and entrance of the campus, is somewhere between the 100 and 600 meters, depending on the entrance and final destination of the car driver. The distance between the entrance and the parking lot depends on the size of the campus.

Size parking lot
The number of parking spaces, which are located on the parking lot, determines the size of the parking lot. The campus of Eindhoven University of Technology is again used as reference. The size of the parking lots differs between the 100 and 400 spaces. That is why in this case the attribute levels of 100, 200, and 300 have been chosen.

Conflicts on walking route
A conflict on the walking route can mean several things. For example crossing a road while walking, waiting for a traffic light, walking alongside a road because there is no sidewalk available, or a junction of several footpaths etc. So this attribute describes the amount of conflicts that the user will experience on the walking route from his/her parked car to arrival at the final destination. The reason that there has been chosen for the attribute levels; none, some, many is because there is expected that the exact amount of conflicts on the walking route would be hard to imagine for car drivers. With these attribute levels the car driver is asked an indication of the conflicts that they experience.

Stage 3: Experimental design consideration
For this design a total of 6 attributes are used, that all have 3 attribute levels. This means that a total of $3^6$ (729) of different alternatives can be generated. This amount of possibilities is too much to process all in this research. To proceed with the research a fractional factorial design has to be used. By means of SPSS, a statistical software program, this fractional factorial design is generated. A fractional factorial design is based on a design with only main-effects and without two stage or more interaction effects. Interaction effects mean that the separate attributes also have effect on one another. By means of a fractional factorial design in total 18 alternatives of the 729 alternatives are considered which are formed by using SPSS.

Stage 4 – 7: Choice set generation
The fourth stage is where the experimental design is actually generated. In the fifth stage the attributes will be allocated to the design columns, where there will be zoomed in on the main effects of the attributes. Stage six is where the choice sets are generated. The choice sets have been generated by means of randomization. Stage seven is where these choice sets, which are generated in the previous stage, are randomized.

By means of randomization all the alternatives were categorized into choice sets with each three alternatives. In Appendix A the division of all the selected attributes and generated choice sets are shown. In total there are six choice tasks generated for the experiment. It would be too much to give six choice tasks to respondent; this is why two questionnaires have been made, with each three choice tasks. The survey system uses randomization to divide the questionnaires among the respondents. A respondent would either get questionnaire 1 (with choice task 1,3, or 5) or questionnaire 2 (with choice task 2,4, or 6). This means that every respondent would get three different choice tasks with a choice set that consists of three alternatives.
The 18 alternatives have been randomly selected with the use of SPSS. All attribute levels are equally present within the alternatives. In this way a fair distribution has been made. By means of randomization the different alternatives have been put together in choice sets of 3. To make the 6 different choice tasks, randomization is used again among the 18 alternatives, which resulted in the choice tasks that are used in the experiment.

**Stage 8: Survey instrument**

In the case of this research an online questionnaire is used as survey instrument. To conduct a meaningful questionnaire a good design is necessary. It is important to translate the collected information into a questionnaire. To do so, a questionnaire is designed and distributed by means of the Berg System of the Eindhoven University of Technology is chosen. This software program is especially designed for the use within the faculty of the Build and Environment of the university.

The designed questionnaire that has been sent to the respondents consists of three parts. The first part is about the user experience, in this part is asked about their experience with a campus and their experience with the six selected attributes. To figure out what the experience of the respondent is with a campus, several examples of campuses are given to the respondent. In this way the respondent know if their experience relates to the questionnaire. These questions are followed by six questions about the attributes that will come back later in the hypothetical situations. These questions serve two purposes; to determine the level of experience of the respondent and to introduce the attributes to the respondent.

When asking people about their experience when it comes to Smart Parking and parking-information, there are three different ways to ask about their experiences of the different attributes. One way is asking people about their last experience they had with the specific aspect, another way is to ask about their average experience (this can be used especially when asked about a certain number, like the amount of the parking tariff). Another different way to ask users about their experience is to ask about their most common experience with the aspect. For the questionnaire of this master research has been chosen for the last approach that is described above. The reason why this way of asking has been chosen is because it is possible that respondents visited more than one campus. To close the first section the respondent is asked if they are familiar with Smart Parking applications. The level of knowledge of the respondent could be of influence on the choice of the respondent when it comes to the hypothetical situations.

The second part of the questionnaire is the actual experiment with the hypothetical situations. In this part the stated choice method will be used. The respondent is asked to pick their preference from three different parking lot alternatives; A, B or C. All three parking lots contain information about the six attributes that are used for this experiment. The respondent will first get a question to practice; in this way the probability of a
respondent misunderstanding the actual questions is much lower. After this the respondent will get three choice sets of three options.

The third part of the questionnaire consists of questions about personal characteristics. These questions are important to form different demographic groups later on. The reason why these questions are placed at the end of the questionnaire is because people will be more eager to fill it in, and in addition to this people also know what kind of questionnaire they filled in. For a complete overview of the questionnaire see Appendix B.

The questionnaire was officially launched on April 17th of 2015. With a total number of 159 completed questionnaires. In total a number of 622 people are approach through the University’s Parking Panel. The Universities Parking Panel (www.parkeerpanel.nl) is an initiative of the Eindhoven University of Technology and parking consultancy Empaction BV. The aim of the panel is create a platform of people that are interested in parking and are willing to participate in different parking related studies. The questionnaire that is used for this research is designed in Dutch. The most important motif to do so is because the Universities Parking Panel consists of mostly Dutch participants.

4.4 Results
In chapter 4.3 the methods and model that are used for this study are explained. The construction of the questionnaire is also explained, which will be analyzed in this chapter. Firstly the research sample will be described according to the received data, this means the description of the respondents who participated. Secondly the experience data will be described which contains the experience of the respondents. The reason that a detailed overview of the respondent is given is because this information can be useful when conclusions are conducted. Thirdly the choice data will be analyzed. The outcome of this analysis will allow us to tell which parking attributes have the most influence on car drivers when it comes to their parking choice behavior.

This study does include the analysis of the respondents’ characters and the influence of the parking attributes on the parking choice behavior. The relationship between the different attributes will not be analyzed due the limited time span of the graduation project. The database could be useful for further research in the field of parking choice behavior on campuses.

The Internet based questionnaire was send to 622 people that are all registries in the Universities Parking Panel. There has been a total response of 185, of these filled in questionnaires 159 questionnaires could be fully used for further research. This means that there is a total response rate of 30%. The unfinished questionnaires will be excluded from further research, these unfinished sample profiles cannot be used due lack of information. According to Baarda & De Goede (2006) the minimal amount of respondents for a good quantitative research is 30. For this research the minimal amount of respondents is 60
(2*30) because there are two different questionnaires. This means that with the amount 159 completed questionnaires this amount is easily met.

4.4.1 Description of the respondents
The sample data is the data that is obtained about the respondents to get a better insight on their personal profile. The personal information that has been asked from the respondents are; gender, age, education, possession drivers license, driving experience, and car ownership.

The majority of the respondent (66%) that has filled in the questionnaire is male (see figure 4.2). The parking panel that is used to reach out to respondents is set up in an environment, where there are on average more males than females represented. This could explain the fact that the majority of the respondents are male. This why the data used for this research is not representative for the Dutch population. The ratio between male and female is almost equal (CBS, 2014). Also age and education differ from the national Dutch standard. The national percentage of higher education (HBO and WO) is around the 20%, while the percentage of higher education within the respondents is the 60% or more (CBS, 2013). The complete overview of the collected data can be found in Appendix C.

The age of the respondents lies between 20 and 83, where the majority’s age lies under the 50 years old. The overview with different age-clusters is shown in figure 4.3. The average of age within this research does slightly correspond with the Dutch average. The biggest group of society is the group with the age between 41 and 70, which also is the highest group within this research (CBS, 2014).

In figure 4.4 the levels of education are shown. The levels of education are based on the Dutch standards, to cluster the different levels of education three levels are distinguished. Where level I stand for all education between “Basissschool” and “MBO”, level II stands for HBO, which can be compared with a college degree, and level III stands for WO and higher which stands for university or PhD. The education levels are based on the Dutch educational system.
For this study it is important to know if the respondents own a drivers license and how experienced they are with driving. In figure 4.5 and 4.7 the frequencies of the respondents with a driver’s license and their experience are shown. The vast majority of the respondents do have a driver’s license, with an exception of 3.0%. Most respondents already have more than 26 years of driving experience (72%). There are 12 questionnaires invalid when it comes to this question, presumably because the respondent did not fill in a valid date or did not fill in anything at all.

When making a decision for a parking space it might be important if it is your own car or the car from the company. An explanation would be that the fuel of a lease car, might be compensated and therefor will influence the car drivers’ behavior. In figure 4.6 the division of car ownership is shown.

4.4.2 Experience with parking information on a campus
Not only it is important to know who did fill in the questionnaire according to personal details about gender, age, etc. It is also interesting to know what the existing experience of the respondent is according to the topics that are related to the experiment. In this case it is interesting to know if the respondents are familiar with a campus, and parking on a campus. Figure 4.8 shows the percentage of respondents who are familiar with four different campuses that are used as examples in the questionnaire. There was also an option for the respondent to fill in another campus that they are familiar with. The other
The majority of people are familiar with one or more of the campuses.

Respondents have also been asked about their experience with parking info on (one or more of) these campuses, and if so, how often they used this info. Figure 4.9 shows that the majority of the respondents often uses parking information when driving on a campus, only 8.5% of the questioned people say they never use parking info. In most cases parking info is available, and the respondents are quite positive about this info. Respondents have been asked about their satisfaction of the parking information they have received in the past, the results of this question is showed in figure 4.10. In this figure, where 1 stands for not very useful and 5 for very useful.

From the data that is gathered among the respondents regarding to their experience with parking on a campus and parking information on a campus there can be stated that the majority of the respondents is familiar with parking information on campuses.
4.4.3 Experience with parking attributes

The actual experiment, which is the second part of the questionnaire consists of different hypothetical parking spaces which all contain information about different attributes. To introduce these attributes to the respondents are asked about their experience with the different attributes. Figures 4.11 till 4.16 show the different percentages of the six attributes that are used in this study. The actual frequencies can be found in Appendix C. It is notable that a high percentage of the people do not know what they are paying for parking (38,5%). Another thing that is notable is that most respondents (40,2%) have a walking distance from their car to their destination between the 50 meters and 149 meters.

Figure 4.11 Walking distance

Figure 4.12 – Parking Tariff

Figure 4.13 Size of the parking lot

Figure 4.14 Occupancy rate

Figure 4.15 Distance from entrance to parking lot

Figure 4.16 Conflicts on walking route
4.4.4 Experience with Smart Parking

The findings of this research can be used to develop strategies to implement smart parking applications to inform car drivers. Smart parking is a very broad (and quite new) term. Not everyone is already familiar with this term. This is why respondents have been asked about their experience with smart parking (see figure 4.17). Figure 4.18 shows the percentages of respondents who would like to receive information (by means of smart parking) about several aspects that could be implemented by the means of smart parking. In this table it is shown that the majority of the respondents would like to receive information about finding a suitable parking space. Respondents would also like to get information about payment and parking possibilities, but this amount is far less than the information about a vacant parking space.

![Figure 4.17 – Familiar with smart parking](image)

![Figure 4.18 – Smart parking applications](image)

To compare the preferred information with the results of the stated preference experiment, respondents have been asked about different kinds of information related to the costs and the distance from their car to their destination. In figure 4.19 there can be seen in which extent respondents would follow the advice for a parking space that they would receive by means of smart parking. It is striking that the majority of the respondent (86.3%) would follow the advice when receiving information about cheap parking, but only if the distance is short. If the distance were long, only 23.1% would follow up the given advice. Another fact that is notable that respondents will not follow the advice when receive information about expensive parking in combination with a long walking distance, only 1.7% of the respondents would follow this information.
From this there can be concluded that it really does makes a difference of what kind of information is provided to the car driver. If the car driver is not satisfied with the information that he/she receives, the car driver will less likely follow the advice that is given to them regarding available parking spaces. The description of the respondent and the experience of the respondents with the different topics give a detailed overview about the respondents that have filled in the questionnaire. This information will come in use when the experiment data will be discussed.

4.4.5 Model description

In this part the results, the used model, and output of this model will be described. Firstly the model performance will be explained. The model performance consists of the description of the likelihood ratio and the R-square. Secondly the parameters of the model will be described. There will be focused on the significance of the used attributes. In this part the part-worth utilities of all the six attributes will be calculated and described. To make a description of the model the program NLOGIT is used to get the output of the used data.

Within the model performance the log-likelihood statistic and R-square the most important factors that need to be discussed. In this chapter will be explained how these two have been conducted for this particular research.

Log-likelihood ratio statistic (LRS)

The log likelihood per model can be calculated by means of formula 1.3. The outcomes of the log likelihood of the optimal and constant model are: -491.04 and -317.52. The larger the values of the log-likelihood the more unexplained observations there are (Referentie). The calculation is as follows:

$$log - likelihood = \sum_{i=1}^{N}[Y_i \ln (P(V_i)) + (1 - Y_i) \ln(1 - P(V_i))]$$  \hspace{1cm} \text{(Formula 1.3)}$$

It is possible to calculate the log-likelihood for different models and to compare these models by looking at the difference between their log-likelihoods. By comparing the state
of a logistic regression model against the log likelihood baseline, results in the log likelihood ratio statistic (LRS). The baseline state is the model where only the constant is included. The baseline model is the one that gives the best prediction when nothing is known other than the values of the outcome; in logistic regression the outcomes that occur the most. But when one or more predictors are added to the to the model, the improvement of the model is as follows:

\[
LRS = 2[LL(\text{optimal}) - LL(\text{constant})]
\]  
(Formula 1.4)

Based on this formula and the outcomes from NLOGIT the LRS of the model that is found is: -2[-491.04+317.52]= 347.04. If we compare the value with the found value of the LRS in the \( \chi^2 \) which is 19.7 (\( df =11, \alpha = 0.05 \)), there can be concluded that the model is very significant. Which means that the model of this research with these variables does fit the data better than a model without these variables.

**R-square**

The second part of the model performance is the R-Square. The outcome of the R-Square is the satisfactory level of the model. According to the outcome of NLOGIT the R-square of the model is 0.3534. The R-square is calculated as follows:

\[
R - \text{square} = 1 - \frac{LL(\text{optimal})}{LL(\text{constant})}
\]  
(Formula 1.5)

According to Hensher et al (2005) values for r-squared between the 0.2 and 0.4 represent an excellent fit. Therefore can be concluded that the fit for this model is excellent.

The parameter performance consists of three important part; the significance, the influence, and the range of the attribute. For all six attributes there will separately focused on these three attributes. To describe what has been done for all attributes the first attribute (walking distance) will be used as an example to explain the steps.

To use the model, all parameters have to be estimated. Not all parameters could be estimated in the case of this model. An explanation would be that the combination of attributes and the choosing behavior of the respondents resulted in that not all alternatives have been chosen equally. Firstly an optimum has to be found, before the model can be used. By means of trial-and-error the optimum for the model is generated. Which in this case resulted in that the second parameter of parking tariff (ITAR2) is regarded from the model.

**Example walking distance**

NLOGIT does give the level of significance for every parameter of every attribute. If the significance is high, NLOGIT will give three stars (***), which means the significance is 99% or higher. If the significance is between 95% and 99% NLOGIT will give two stars (**). If the significance level is between the 90% and 95% one star (*) will be assigned. If the significance is lower than 90%, the parameter is not significant enough. Every attribute does have two parameters (see table 4.2).
Another fact that can be noticed is that the IOMV1 and IOMV2, which are both parameters of the “size of the parking lot” and are both not significant, which means that they are both, based on coincidence and therefore cannot be used for further research.

For the walking distance parameter 1
(ILOOP1) = 1.6668
and parameter 2
(ILOOP2) = -0.03694.

This means that parameter 2 is not significant and zero (0.0) will be filled in instead of the actual value. Because this value is not significant, the value does not have any influence. Now the utility of the walking distance on the total utility can be calculated. Effect coding will be used to measure the utility. The calculation of the utility of the walking distance is as follows:

Walking distance 1 (50) = Parameter 1 (1.6668) * Effect code (1) + Parameter 2 (0) * Effect code (0) = 1.6668
Walking distance 2 (150) = Parameter 1 (1.6668) * Effect code (0) + Parameter 2 (0) * Effect code (1) = 0.0
Walking distance 3 (450) = Parameter 1 (1.6668) * Effect code (-1) + Parameter 2 (0) * Effect code (-1) = -1.6668

The reason that effect coding is used in this study is because it provides a way of using categorical predictor variables in various kinds of estimation models, such as linear regression. Effect coding (in contrast to dummy coding) uses ones, zeros and minus ones to convey all of the necessary information. In Table 4.3 the different attribute levels and their effect code are shown. As can be seen, the effect code that is been linked with the different attribute levels is used for the calculation that is previously explained.

Table 4.3 – Attributes and effect coding

<table>
<thead>
<tr>
<th>Level</th>
<th>Walking distance (meters)</th>
<th>Parking Tariff (euro’s)</th>
<th>Occupancy rate (percentage)</th>
<th>Distance entrance and parking lot (meters)</th>
<th>Size parking lot (number of parking spaces)</th>
<th>Conflict s on walking route</th>
<th>Effect code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>2</td>
<td>50</td>
<td>200</td>
<td>100</td>
<td>None</td>
<td>1 0</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>4</td>
<td>70</td>
<td>400</td>
<td>200</td>
<td>Some</td>
<td>0 1</td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td>6</td>
<td>90</td>
<td>600</td>
<td>300</td>
<td>Many</td>
<td>-1 -1</td>
</tr>
</tbody>
</table>
With these values of the walking distance for the different attribute levels a graph of the part worth utility can be generated (see figure 4.21). This part-worth utility graph can be generated for all attributes, except for the size of the parking lot.

**Walking distance**
In the graph of the part worth utility of the walking distance can be seen what the effect of the walking distance is on the total utility. Notable is that the can be seen that an alternative becomes less attractive when the walking distance is larger. Another thing that is noticeable from figure 4.21 is that a walking distance of 50 meters contributes the most to the utility of the alternative and 450 meters contribute the least. Attribute level 150 meters has neither a positive or negative effect. The graph declines slower between 150 meters and 450 meters this means that the negative influence of these attributes on the parking choice is from less influence than the positive effect of a walking distance of 50 meters.

**Parking tariff**
For the part worth utility of the parking tariff can be stated that the alternative will be less attractive for the car driver when the parking tariff is higher. In figure 4.22 can be seen that how higher the parking tariff, the less attractive the alternative becomes. Because the second parameter of parking tariff (ITAR2) is disregarded from the study, the outcome of this attribute is only based on linear effect.

**Occupancy rate**
The part worth utility of the occupancy rate can be seen in figure 4.23, it actually shows similarities with the walking distance and the tariff in sense of the shape of the graph. However the difference between the different attribute levels is smaller in this case. The higher the occupancy rate (in this case 90% is the highest) the less attractive the alternative becomes, and therefor the choice for the alternative.

**Distance from entrance to parking lot**
The distance from the entrance to the parking lot is also important to the car drivers; a thing that is remarkable is that the difference between attractiveness between the distance of 200 and 400 is very strong, while 200 still has a positive effect on the choice of the car drivers, with 400 meters there already is a negative effect on the total utility. The difference between 400 and 600 meters is not that high.

**Conflicts on walking route**
As expected, figure 4.25 shows that “None” conflicts on the walking route have the most positive effect on the total utility. As can be seen, the attribute level of “some conflicts” have a negative effect on the total utility, while “many conflicts” on the walking route do have a positive effect on the total utility. This is a remarkable outcome because what was expected was that “many conflicts” would have a more negative effect on the alternative than “some conflicts”.
Figure 4.21 – Part worth utility walking distance

Figure 4.22 – Part worth utility parking tariff

Figure 4.23 – Part worth utility occupancy rate

Figure 4.24 – Part worth distance from entrance to parking lot

Figure 4.25 – Part worth utility conflicts on walking route
Range
The final matter is the range of the all the attributes. The range derives from the model, and is the difference between the highest and the lowest utility of the attribute. In the case of the walking distance the range is: 1.6668 + 1.6668 = 3.3336. An overview of the different ranges (which are all conducted from the graphs) per attribute can be seen in table 4.2.

Table 4.2 – Range per attribute

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking distance</td>
<td>3.3336</td>
</tr>
<tr>
<td>Tariff</td>
<td>1.9409</td>
</tr>
<tr>
<td>Size parking lot</td>
<td>Not significant</td>
</tr>
<tr>
<td>Occupancy rate</td>
<td>0.9810</td>
</tr>
<tr>
<td>Distance from entrance to parking lot</td>
<td>1.5502</td>
</tr>
<tr>
<td>Conflicts walking route</td>
<td>1.4041</td>
</tr>
</tbody>
</table>

The higher the range the more influence the attribute has on the total utility of the alternative and consequently the probability that car drivers will choose for that alternative. From this data there can be concluded that the walking distance has the most influence on the total utility of the alternative, and therefor has the most the influence on the respondents.

4.5 Conclusion and discussion of the model analysis
The data shows that all used attributes within this research have influence on the car drivers’ parking choice behavior on a campus. The only aspect that did not is the size of the parking lot. This aspect probably has no influence on the car driver because size does not directly attribute to a cheap, fast or efficient choice for a parking spot. What can be derived from the results is that the walking distance from the car to the final destination has the biggest influence on the parking choice behavior on a campus, followed by the parking tariff.

The attributes occupancy rate and conflicts on the walking route show some special results, which need some explanation. Previous studies show that occupancy rate has quite some influence on the car drivers’ parking choice behavior; while in this research the influence seems minor (Lam et al., 2006; Ji et al., 2007). A reason for this might be the use of percentages instead of an actual number of vacant spaces on the parking lot. Even though the explanation of the attribute levels is clear, respondents could have interpreted this as vague.

The conflicts on the walking distance shows that the attribute level of “some” conflicts have a negative effect on the total utility, while the attribute level of “many” conflicts on the walking route does have a positive effect on the total utility. This outcome is unexpected because with logic reasoning we can state that expected would be that “many” conflicts would have a more negative effect than “some” conflicts. An explanation would be that the terms none, some, and many are too vague for the respondent. On the other
hand the explanation could be good, but the different respondent could have interpreted in different ways. The terms none and many are easier to imagine than some. This could be the reason for the deviant outcome for the utility of the aspect.

While this research mainly focused on the attributes independently from each other, a link between the walking distance and parking tariff emerges when respondents are asked about receiving information about parking space location and parking tariff. When the information is about a cheap parking space on a short distance to the final destination, 86% of the respondents want to receive information. When giving information about parking spaces where the distance is longer, or the parking tariff is higher, the majority (60%) of the respondents is not sure about this information, and did choose maybe.

When implementing a smart parking system that provides information about the available parking spaces, it is recommended to include information that lead to the parking space with the shortest walking distance and the lowest parking tariff. According to this research the walking distance has more influence on them when choosing a parking space than the parking tariff.

**Acknowledgements**

The Eindhoven University of Technology supported the work described in this research paper. I would like to thank everyone who did help me during this research. Besides this I would especially like to thank my super visor from the University, Peter van der Waerden, for all his help and support during this research.

**References**


PART III – CONCLUSION AND DISCUSSION
5. Conclusion and discussion

In this chapter the overall conclusion and discussion of the research will be stated. This does include the relevance and limitations of the study. Finally recommendations for further scientific research will be given. Besides these research recommendations, there will be recommendations given towards campus administrators and parking facility operators will be given.

5.1 Overall conclusion

The main question of this research is about which attributes have an influence on the car drivers’ parking choice behavior on a campus. The reason why this question has been asked in the first place is because this information can be used when implementing a smart parking information system on a campus. The hypothesis that has been set in the beginning of the research is that car drivers would choose the cheapest, fastest and most efficient parking spot. To answer this main question two sub-questions need to be answered. Firstly it is important to determine the meaning of smart parking. Secondly to find out which attributes are influencing car drivers when it comes to parking behavior the meaning of parking choice needs to be answered.

The term smart parking can be described as the application of advanced technologies to improve speed and efficiency of locating, reserving, and paying for parking. Parking choice behavior is the behavior that the car drivers exhibits when searching for a parking space. This behavior can be influenced by several factors like for example how well known the car-driver is with a certain area, or the location of the parking space. To delimit the size of the study the following six parking attributes have been selected: walking distance, parking tariff, size of the parking lot, occupancy rate, distance from entrance of the campus, and the amount of conflicts on the walking route. By means of a stated choice experiment that is processed in a questionnaire and distributed online there has been given insight on the which parking attributes have influence on car drivers’ parking choice behavior on a campus and also how much influence these attributes have.

Besides the stated choice experiment the respondent is also asked about their experience with the different attributes that have been selected for this research. It is noticeable that in the case of almost all attributes, the majority of the respondent does not know what their experience is with these attributes. An explanation for this could be that the majority is not really paying attention to these attributes when picking a parking spot (on a campus). In the questionnaire the respondents have also been asked about their experience with smart parking and parking information. The majority of the respondents often use parking information on a campus. Around 70% of the respondents are already familiar with smart parking. When asking them about which information they would like to receive when it comes to parking, the majority answers that they would like to receive information of finding a suitable parking space. Other options that the respondent could have choose where: paying for parking and obtaining information on parking possibilities.
Furthermore the respondents did get four possibilities with a parking advice. The question was about whether they would follow up the information or not. They could answer with either yes, no, or maybe. It seems that the kind of information that is provided is indeed of influence on the car driver. From the results of the experiment can be concluded that all attributes that have been selected have influence on the car drivers’ parking choice behavior on a campus except for the size of the parking lot. Within this research the walking distance does have the most influence on the parking choice behavior, followed by tariff, distance from entrance to parking lot, conflicts on walking route, and with the least influence the occupancy rate.

5.2 Overall discussion
In this chapter the societal, scientific and beneficiary relevance of this research will be explained. This is followed by the explanation of the limitations of the research. At last recommendations towards further research will be given.

5.2.1 Societal relevance
The societal relevance of this study derives from the fact that urban areas and campus areas do have issues regarding to parking. Car drivers have to cruise around for a parking spot, this cruising contributes to traffic congestions and therefore more harmful emissions than necessary. By means of smart parking problems can be tackled by for example providing more information about available parking spaces. This research focuses on the type of information that is necessary to influence the parking choice behavior of car drivers.

5.2.2 Scientific relevance
This research does adds valuable knowledge about parking choice behavior of car driver’ on a campus to the already existing knowledge. There already are previous studies, which focus on the parking choice behavior of car drivers, but little is known about these the attributes that influence car drivers on a campus area. The scientific relevance of this study is that it is a stepping-stone towards more research about parking choice behavior (on a campus) and the implementation of smart parking. In paragraph 5.3 recommendations are given for further scientific research.

5.2.3 Beneficiary relevance
This research did try to identify the most important attributes that have influence on car drivers’ parking choice behavior. Several stakeholders can use the information that is found within this study when implementing new parking measures or when improving the already existing ones. When a stakeholder does decide to implement a means of smart parking, the data from this study might be useful when choosing different aspects to provide to the car drivers. There are two important stakeholders besides the car driver that this study might be relevant for. These stakeholders are the campus administrators and the operators of parking facilities within these campuses.
Campus administrator
The goal of the campus administrator is to create a pleasant, healthy, and safe environment for visitors. If an application of smart parking would be implemented, the campus administrator can use the information of this research when providing information to car drivers. This study shows that the walking distance from the car to the final destination has the most influence on car drivers when it comes to their parking choice behavior. A recommendation towards the campus administrator would be to definitely use this attribute when implementing smart parking on the campus. Besides this the study also shows that the distance from the entrance to the parking lot has influence on the car driver. When implementing this attribute, the campus administrator will have even more benefit. If the road network of the campus is used less, than the environment of the campus will be safer and there will be less noise from cars.

Parking facilities operators
At this moment operators of parking facilities do not always like the fact that they have to give away information about their parking facility (e.g. How many vacant parking spaces are available, or the tariff) because this might discourage potential visitors to go to the parking facility in the first place. On the other hand, if the right information would be given to the car driver, a certain parking facility will get more attractive for a car driver than without this information. With this study there is been tried to find out which attributes might help to make a parking facility more attractive and which information has influence on the car driver. The size of the parking lot did was not significant. Therefor no recommendation could be given according this attribute.

5.2.4 Limitations
For this research there were a few limitations, which might have had influence on the final outcome of the results. Firstly the outcome of the research is based on the six used attributes, if other or more attributes would be implemented too the size of the research would be too big to complete within the timespan of the master thesis. The limitation here is that the outcome of the research and thus the conclusions are only based on a limited amount of attributes and not on all aspects that are playing a role when it comes to parking choice behavior. When more attributes are implemented the outcome would probably be different. Besides this, would a too extensive list of attributes be too much to proceed properly for the respondents.

Secondly a limitation that has occurred during this research is the division of respondents. Compared to the Dutch average the used respondents used for this research do differ from this average. For example the male/female ratio: for this research the response of males was much higher than the national average. Therefore this research does not represent the nation wide standard about the influence of parking attributes on parking choice behavior of car drivers’ on a campus.
5.3 Recommendations for further scientific research

The outcome of the data that has been found within this research could be used for further scientific research. In this paragraph several recommendations will be stated according to further research.

Different target groups

The outcome of this study is based on a large group of people that all have different backgrounds and experience. Different attributes might be from other importance to different kind of target groups. For example the walking distance: for elderly people this might be from a bigger importance, because on average this target has a limited mobility when it comes to walking. The aspect “walking distance” could have a different influence on this target group than target groups that have less difficulty with walking. Another example of differences in target groups is gender; it could be possible that man prefer different attributes than women. This because in general men do value their car on another levels than women, and this might influence their parking choice behavior.

Different attributes

This research is limited to six selected attributes that have influence on the parking choice behavior. The influence of these attributes is measured independently but when using different attributes the output and level of influence could be different. That is why for further research it might be interesting to include other attributes, and see if there this has impact on the level of influence of the different attributes. An interesting aspect that can be implemented would be the amount of green (e.g. trees) on the walking route, this because this research shows that the state of the walking route does influence car drivers’ parking choice behavior. Because of the increase of the usage of hybrid and electrical cars (CBS, 2015) it would be interesting to add an attribute that says something about the availability of a charging your car. In the future this might have more and more influence on the parking choice behavior of the car driver. Also the actual size of the parking spot would be interesting to add to the list of attributes, and see if this would have any influence on the parking choice behavior.

Presenting information

The focus of this research was the type of information that is preferred by the car driver when using parking information on a campus. Another important factor is the way of presenting it, and when. The information could be presented on a general screen or on the car drivers GPS system in the car. The information could even be integrated or distributed through an app. This research does not answer the question of how and when, but this information might be crucial for the whole system to work and to make car drivers follow the instructions.
Parking information effect
This research does answer the question of which attributes do have influence on the parking choice behavior. This research did not zoom in on the actual effects of these attributes they would be really used as parking information. By means of a pilot the attributes could be implemented within a smart parking application and by means of observation there can be displayed how these attributes would have influence on the parking behavior in a non-hypothetical experiment.

Use of data
For the research not all data that is collected is actually used. For additional research some of the data could be used again for new research. The data that is re-used can be complemented with more detailed information about other attributes that might also have an influence on the car drivers’ parking choice behavior on a campus.

Qualitative research
Parking is something that is really specific for every situation but there are a few regularities. This is why it makes it so difficult to set one standard form of measures. Of course much can be learned from observing several parking situations, whether they are successful or not. This study can be used as a stepping-stone for studies that follow after this research related to the parking choice behavior. Asking specific questions to people about locations and situations where they park daily, other attributes may influence the parking choice behavior then when asking question about the influence of parking attributes in general. This could be interesting topic for further research.

At last there can be stated that the right kind of parking information will have an influence on the car drivers’ parking choice behavior. Car drivers are sensitive for valuable information regarding parking attributes of the parking facilities. When this information is useful for the car drivers, it is more likely that they would follow up the parking advice. By means of this information, parking can be made more efficient and will lead to a more sustainable and safer (campus) environment. Parking issues are just a small part of the worldwide traffic and mobility issues, but when small parts are being improved, this will eventually contribute to solve bigger issues as well.
6. Bibliography


**Websites**


