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Master Thesis

User acceptance concerning automated driving

The influence of the environment on the acceptance level of the user on automated driving

by

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English summary

Passenger vehicle mobility enables daily activity of business and consumers. It therefore provides a valuable contribution to welfare in the Netherlands. But on the flipside of mobility are the traffic jams and the emissions of the vehicles. A next step in the evaluation of mobility are automated vehicles. The benefits from automated vehicles are a more stable traffic flow and reduce of emissions. But to use automated vehicles people have to give over the control of the vehicle. However, literature indicates that this is a very critical point.

Vehicle users trust more in themselves to operate a vehicle then a system. Literature indicate that there is a lack of information about the preferences of automated driving. Therefore, this thesis aims to gain insights for which level of automated driving in which environment is preferred. With these insights, recommendations concerning policy makers and car manufactures can be given, as it forecast in which driving situations automated driving can be introduced.

Six levels of automated driving are distinguished by SAE international. Starting with level 0 which is no automation at all, to level 5 which is fully automated. The driving environment can be divided into two parts which are the personal environment and the physical environment of the driver. These two types of environments have lead to the following attributes to describe a driving situation:

- Type of Road: highway, main road, local road
- Length of Trip: <20 km, 20-100 km, >100 km
- Traffic Density: high, medium, low
- Passengers: 0, 1, 2 or more
- Familiarity with Route: well-known, partially known, unknown
- Surrounding Area: rural, urban, high urban

With these attributes a choice experiment is executed to determine the level of automated driving in a particular situation. The results of the experiment indicate that the attributes 'type of road' and 'length of trip' have the biggest influence on the desired level of automated driving. Automated driving is desired in particular on highways in combination with trips that are longer than 100 kilometre. Also the traffic density plays a role, which in this case is with medium the most optimal situation for automated driving.

Car manufactures must provide more information about automated driving to convince the public to use automated vehicles. Also, more test about the reliability of these vehicles must be provided to convince the public that it is a safe why to travel. Policy makers must change the legal framework to allow automated driving on public roads. Also, studies must be made to the road design and the feasibility to implement automated driving on the Dutch road network.

Dutch summary

Mobiliteit maakt het mogelijk om dagelijkse activiteiten te kunnen uitvoeren als persoon en als bedrijf. Het is daarom ook een waardevolle bijdrage aan de welvaart in Nederland. Maar mobiliteit brengt ook nadelen met zich mee, zoals uitlaatgassen die het milieu vervuilen en drukte op wegen wat kan leiden to onveilige situaties. De volgende stap in de evolutie van mobiliteit zijn automatische voertuigen. Het voordeel van automatische voertuigen zijn een reductie van uitlaatgassen en een stabielere verkeersdoorstroming. Maar om automatische voertuigen te gebruiken dient de gebruiker de controle aan het voertuig over te geven. De literatuur geeft aan dat dit een kritiek punt is in de implementatie van automatische voertuigen.

Bestuurders vertrouwen meer in zichzelf om een voertuig te besturen dan het over te laten aan een systeem. Literatuur geeft aan dat er een gebrek aan informatie is over de voorkeuren van gebruikers omtrent automatisch rijden. Deze thesis richt zich daarom op het onderzoeken welk niveau van automatisch rijden is gewenst in welke situatie. Met deze informatie advies kan worden gegeven aan overheden en autofabrikanten om het implementeren van automatische voertuigen te stimuleren.

Er zijn zes niveaus van automatisch rijden te definiëren, deze zijn opgesteld door SAE international. Waarbij level 0 het laagste niveau is met totaal geen ondersteuning en level 5het hoogste niveau waarbij het voertuig volledig automatisch is. De rijomgeving van de bestuurder kan worden geschieden in twee componenten. Deze componenten zijn de fysieke omgeving en de persoonlijke omgeving. Aan de hand van deze twee type omgevingen zijn de volgende attributen opgesteld:

- Type weg — snelweg, gebiedsontsluitingsweg, erftoegangsweg
- Lengte van reis — <20km, 20-100 km, >100 km
- Verkeersdrukte — hoog, normaal, laag
- Passagiers — 0, 1, 2 of meer
- Bekendheid met route — goed bekend, deels bekend, niet bekend
- Omliggende omgeving — landelijk, stedelijk, hoog stedelijk

Met deze attributen een keuze experiment is uitgevoerd om te bepalen welk niveau van automatisch rijden is gewenst in welke situatie. De resultaten van het experiment geven aan dat de attributen ‘type weg’ en ‘lengte van reis’ de grootste invloed hebben op het niveau van automatisch rijden. Automatisch rijden is het meest gewenst op snelwegen in combinatie met afstanden over 100 kilometer. Ook speelt de verkeersdrukte een rol in de keuze, waarbij een normale verkeersdrukte de beste situatie is voor automatisch rijden.

Autofabrikanten dienen de gebruiker meer informatie te geven over automatisch rijden om ze te overtuigen het te gaan gebruiken. Verder zijn er meer testresultaten nodig om de betrouwbaarheid van de systemen de bewijzen. Overheden dienen het wettelijk mogelijk te maken om automatisch te rijden op publieke wegen. Verder zijn er studies noodzakelijk naar het wegontwerp van de wegen om automatisch rijden mogelijk en rendabel te maken.

Abstract

Passenger vehicle mobility enables daily activity of business and consumers. It therefore provides a valuable contribution to welfare in the Netherlands. A next step in the evaluation of mobility are automated vehicles. The benefits from automated vehicles are a more stable traffic flow and reduce of emissions. But to use automated vehicles people have to give over the control of the vehicle. However, literature indicates that this is a very critical point. This thesis has investigated the desired level of automated driving in a particular situation. First, the different levels of automated driving are studied. Followed by the investigation of the different environments of the driver. The environment of the driver can be divided in a personal and a physical environment. With the knowledge of this information the desired level of automated driving was researched. The research method that is used for this problem is the stated preferences method. With the use of this method a rating experiment is made. With the gathered data from the experiment an ordinal regression model is made. The results of this model indicate that the type of road and the length of the trip are the most important aspects that influence the level of automated driving. Also the traffic density plays a role, which in this case is with medium the most optimal situation for automated driving. Car manufactures must provide more information about automated driving to convince the public to use automated vehicles. Also, more test about the reliability of these vehicles must be provided to convince the public that it is a safe why to travel. Policy makers must change the legal framework to allow automated driving on public roads. Also, studies must be made to the road design and the feasibility to implement automated driving on the Dutch road network.

1 Introduction

Passenger vehicle mobility enables daily activities of businesses and consumers. It therefore provides a valuable contribution to welfare in the Netherlands. It provides economic and personal growth along with the experience of freedom. However, mobility has also exposed society to some dangers. Traffic accidents occur on daily basis, the dense road network often leads to long traffic jams, and emissions are polluting the environment. These dangers are the result of the everlasting demand for mobility, leading to several key societal challenges (Kennisinstituut voor Mobiliteitsbeleid, 2013) (Ministry of Transport, Public Works and Water Management, 2005).

Transport policymakers in various countries all over the world are increasingly confronted with the negative externalities of the transport systems. Instead of building additional infrastructures and expanding the road network, policy makers are increasingly focusing on developing strategies to stimulate intelligent use of the existing road infrastructure. This is done in order to improve the road capacity, improve traffic safety, and reduce environmental stress. Those strategies can be divided into two main technology concepts. First of all is the development of the automated highway systems such as ramp metering, route guidance and variable speed limits. The second concept concerns the user of the road network, which is implementing a system that automate, to a certain degree, the driver's behaviour as throttling, braking, and steering tasks (Molin & Marchau, 2004).

The development of automated highways has already reached a high level, but the concept of automated vehicles is still in its infancy. In the Netherlands the first tests with automated vehicles on a public road are planned in 2015. With all these new developments standards are going to change. This means that parties such as the government need to adjust their policy regarding automated driving. In the next paragraph the problem definition of this thesis will be addressed, regarding this topic.

1.1 Problem Definition

The literature indicates that in the past there were some attempts to provide insights into the user's acceptance of partially or fully automated driving cars. An example is the research of Molin and Marchau (2004), this research presented a study of perceptions and preferences for an advanced driver assistance system (ADAS). The study of Molin and Marchau described that personal goals have the largest impact on the overall attractiveness of ADAS. Another conclusion of the research is that drivers prefer a system that doesn't actively intervene in their vehicle-driving task. In 2013, KPMG investigated the willingness to use self-driving cars for particular focus groups. Differences in willingness were found in the research, these differences where based on personal characteristics 'age' and 'vehicle owned' (Van der Waerden, Megens, & Schaefer, 2014). The study of Megens (2014) provides insights in terms of automated driving, and current and expected technological capabilities. The most interesting research achievement is the part about the environment that users want by a particular level of automated driving.

The literature provides much information but leads to even more questions. In this master thesis research is done in the field of the automated driving and especially at the driver acceptance. The reason to choose this particular field of interest is that there are opportunities to contribute. As earlier mentioned there is some information available concerning the user acceptance of automated driving but there is not much knowledge to which level of automated driving the user want and in which situation. To provide a study which contributes to the understanding of the user acceptance concerning the level of automated driving, the following research question is created:

- *What is the influence of the physical environment and the personal environment of driver, on the acceptance level of automated driving?*

The objective of this question is to provide an insight of the relationship between the level of automated driving and the interaction with the environment. The environment in this case is the personal environment as well as the physical environment. This research is meant for the government to get more insight in the user acceptance concerning automated driving, because the government is exploring automated driving and has a leadership role in de acceptance of automated driving. This research is also done on behalf of company Grontmij to get knowledge concerning automated driving and take a leading role in the engineering field.

To answer this research question different sub-questions must be answered first. Three sub-questions are defined:

- *Which levels of automated driving can be defined?*
- *Which different physical environments exist for the vehicle users?*
- *Which different personal environments exist for the vehicle users?*

The three sub-questions are important to answer because they are a part of the main research question. The first sub-question about the levels of automated driving must provide a view of which levels of automated driving are available and what they contain. This second sub-question about the physical environment and must provide insight in which physical surroundings the car users are driving and are willing to drive with a certain level of automated driving. The last sub-question must gain insight in the physical environment of the driver, which provides insight in the goals and values of the car users regarding automated driving. With this research sub-question also insights must be gained regarding traffic safety and the ecology perception of the drivers. These are the two main aspects which will be researched in the master thesis.

1.2 Goal of the Research

As mentioned in the previous paragraph, the main objective of this research is to provide insight of the relationship between the level of automated driving and the physical and personal environment. This will lead to more information about the level of automated driving the user want in a particular situation. With the use of the sub-questions, it is also an objective to provide insights what the influence is of automated driving on the aspects of the environment such as the traffic safety and ecology. These objectives will be reached mainly with the understanding of the vehicle users. Transportation and market planners can take measures that are in accordance with preferences of vehicle users and hence maximize the potential benefits of automated driving.

1.3 Expected Results

The findings of this research will provide an insight into the level of driving automation the vehicle users prefer. Because a large group of vehicle users will be asked to participate, a clear result will be developed. The results also provide an insight of the influence of automated driving on aspects of the environment as traffic safety and the ecology. The expectation is that vehicle users will embrace the automated driving if it comes in steps. Because it is easier to learn and accept changes when they come one by one instead of all in once. The expectation is also that it is easier to embrace automated driving when it is preformed at familiar roads and safe environments with low external factors, such as a highways, this statement is based on the research of Megens (2014). Another expectation is that automated driving will benefit the ecology and the traffic safety because of the technology which can set the most safely and economical driving set-up. The research will also provide insight in which groups of the society are most open to automated driving and which groups still must be persuaded.

1.4 Scope

This thesis involves passenger driving in the Netherlands. This means that transport traffic is not taken in consideration because the circumstances for this sector are complete different. Also automated parking is not in this research, because this does not contribute to the acceptance of automated driving. Furthermore, this thesis will provide extra insight in the effects of automated driving towards aspects of the environment. These aspects are traffic safety and the ecology. The reason to highlight these aspects is that these aspects are seen as the two main benefits of automated driving.

1.5 Research Design

Conceptual Framework

To achieve the main goal, which is gaining insights into the acceptance level of automated driving, this thesis is composed into three parts (literature, stated preference experiment, and finalization). Each part contains a number of components which are displayed in figure 1.1. This chapter will describe the meaning and the relevance of these parts.

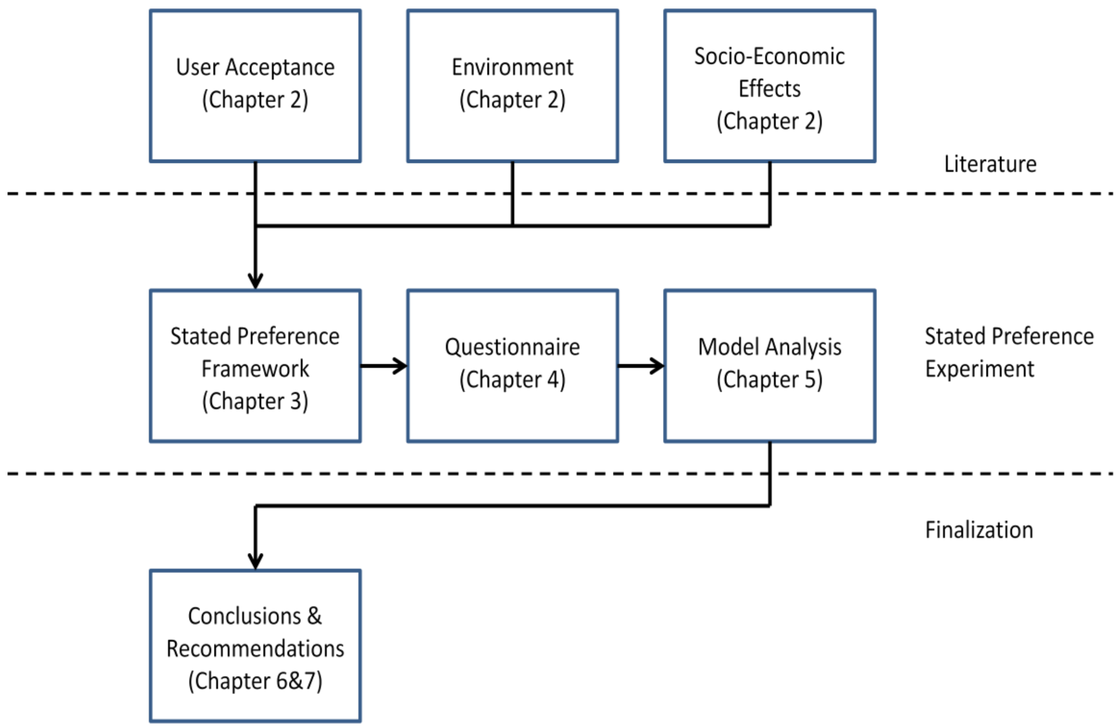

Figure 1.1: Conceptual Framework

<u>Literature</u>

To obtain an extensive understanding about automated driving, a literature study took place covering several articles and case studies. The literature study consists of three main topics which are: user acceptance, environment, and socio-economic effects. With the elaboration of these three elements an overview of the whole situation can be drawn. Evaluating these topics requires that both its benefits and its limitations are considered. Also developments of different aspects are taken in consideration. Several issues of automated driving that need to be resolved are addressed. With the information of these three key elements, the first three sub-questions can be answered. These answers provide the needed information to start the next phase in the conceptual framework. The information for the literature study was collected from scientific journals, reports, books and relevant websites.

<u>Stated Preference Experiment</u>

There are several scientifically research methods available. After extensive exploration of both qualitative and quantitative methods, the decision is made to use the stated preference method. Stated preference is a quantitative research method, used to model the decision process of an individual or segment in a particular context. The use of this method allows a creative construction with plausible hypothetical products. This leads to an experiment where the level of automated driving is dependent on the particular driving situation (Anderson, de Palme, & Thisse, 1992).

After obtaining all the necessary knowledge form the literature study, the next step is to define and select the different attributes for the experiment. For each attribute also different levels must be determined. After that a choice must be made if the experiment will be based on ranking, rating or attribute based choice method. When this is determined alternatives can be constructing for the questionnaire. These alternatives make it possible to investigate the first order effects, and dependent on the experiment, lower order effects with only a small part of the alternatives of the full factorial design.

Depending on the chosen method, regression models or discrete choice models can be used to analyse the results of the questionnaire. With the use of these models, calculations can be made to determine the level of automated driving in the different situations.

Finalization

The third and last part of this research contains the conclusions and recommendations. In this part the results from the experiment are discussed and the research objective is evaluated. Also an answer to the main research questions is given. Also recommendations for policy makers and car manufactures are given. This to provide information what can stimulate automated driving. Finally recommendations concerning points for further research are described.

1.6 Reading Guide

The thesis consists of 7 chapters, in which the research questions as formulated in the problem definition will be answered. Chapter 2 provides a theoretical overview about automated driving. With this information the sub-questions can be answered. Next, chapter 3 describes the research method which is used for this thesis. It explains how preferred driving circumstances and level of automated driving can be measured by modelling choice behaviour. In chapter 4, insights of the experiment design are described to obtain the needed data. Chapter 5 provides the modelling process and the data analysis. In chapter 6, answers the main research question with support of the sub-questions. It also provides recommendations for policy makers and car manufactures. Finally chapter 8, the results will be discussed and further points of research are addressed.

2 Glossary

Adaptive Cruise Control (ACC):) is an optional cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead

Advanced Driver Assistance Systems (ADAS):

Blind Spot Information System (BSIS): is a system to help you detect vehicles in your blind spot when changing lanes

Erftoegangswegen ETW): a type of road to exchange vehicles, on these type of roads the traffic is not uniform

Forward Collision Warning (FCW): is an automobile safety system designed to reduce the severity of an accident

Fuel Efficiency Advisor (FCW): a wealth of information about your vehicle in real-time

Gebiedsontsluitingswegen (GOW): a type of road to exchange vehicles and distribute them to erftoegangswegen and stroomwegen

Intelligence Comfort Systems (ICS): a collective noun to describe all forms of automated system in vehicles which provide comfort to the driver

Infrastructure to Infrastructure (I2I): a type of network in which infrastructures communicate with each other to provide information about the traffic situation

Lane Departure Warning (LDW): is a system designed to warn a driver when the vehicle begins to move out of its lane

Park Assist System (PAS): is a electronic system which helps the driver to park the car

Navigation System (NA): is a (usually electronic) system that aids in navigation

Speed Regulation System (SRS): is an optional system which controls the speed of the car based on the information which is given by traffic signs

Stroomwegen (SW): a type of road to handle a large amount of traffic over long distances

Vehicle to Infrastructure (V2I): a type of network in which vehicle and infrastructure communicate with each other to provide information about the traffic situation

Vehicle to Vehicle (V2V): a type of network in which vehicles communicate with each other to provide information about the traffic situation

3 Literature study

Abstract

In the past 25 years driving has been developed rapidly. There are mobiles that can fully drive themselves but this is only possible in very limited driving situations. Also all the well-known vehicle manufactures are currently working on fully automated vehicles. It is important to get an more information about automated driving to get a clear view of the topic. Also information about the driver's behaviour is important. With this information research can be done with regards to the acceptation of automate driving. There are six different levels of automated driving. Level 0 is the lowest level with no automation at all and level 5 is the highest which are fully automated vehicles. Automated driving has impact on several socio-economic factors. Such as the ecology and the traffic flow, automated driving provides benefits in these categories. Automated driving has also an impact on the road design and the build environment, this needs to change to implement automated driving. Also needs the legal framework changes to make automated driving possible on public roads. Furthermore, the behaviour of the driver is influenced by several aspects. These aspects are come from the personal and physical environment of the driver. Also, the personal characteristics have an influence on the behaviour of the driver.

3.1 Definition of automated driving

3.1.1 History

Since almost a century, planners, engineers, and visionaries are involved in the quest to enable people to travel in passenger vehicles without being constantly attentive. This quest seems to come to an end as several vehicle manufacturers have said that they are close to making automated driving reality (Autoblog, 2013) (Weber, 2014). In 1939 at the General Motors Futurama exhibit, planners forecast that in the 1960s vehicles would drive at a safe distance through automatic radio control on dedicated automated tracks. But in the 1960s, it was only feasible to sense and react with an appropriate movement (Weber, 2014). In the late 1980s the research concerning civil vehicle automation has become crucial, it started with the European project called EUREKA Prometheus which contributed to the conception of the first driverless cars. Since that experiment there are many automated prototypes developed and tested on various roads (Payre, Julien, & Patricia, 2014).

In the last 25 years there have been three development phases concerning automated driving. The first phase was between the 1980s and 2003, where two main technological concepts emerged. The first concept is automated highway systems, where highways guided vehicles. The second concept is semi-automated vehicles were developed that could insteer or navigate by automation in several circumstances. The second development phase occurs from 2004 until 2008, where the U.S. Defence Advanced Research Projects Administration (DARPA) Grand Challenges were held. The challenge was to automatically navigate vehicles over a course that ran across a desert. DARPA's purpose was to stimulate technological developments of automated vehicles which could ultimately substitute humans in hazardous military operations (Payre, Julien, & Patricia, 2014). The last development phase was in the last years where major technology steps were made. There are mobiles that can fully drive themselves but this is only possible in very limited driving situations. Also all the well-known vehicle manufactures are currently working on fully automated vehicles, manufactures like

Audi, BMW, Mercedes, Ford and Tesla (Autoblog, 2013).

In 2014 the Dutch Ministry of Infrastructure and the Environment has announced to change the law and allow testing for the purpose of automated driving on public roads. The reason for this change of policy is that the ministry wants a leading role in the development of automated driving. Several parties like TNO, DAF, and Havenbedrijf Rotterdam en Transporthaven reacted positively on this proposition (Secretary Schultz van Haegen , 2014). As a result of this legal change Wageningen University and the Province of Gelderland will test the first fully automated vehicle on a public road in the Netherlands, at the end of 2015. The reason for this project is that the Province of Gelderland also wants a leading role in the automated driving scene and wants to stimulate the mobility in the rural and urban areas (Provincie Gelderland, 2015).

3.1.2 Technological Developments

As explained in the previous paragraph automated driving has been more and more developed in the last 25 years. This is mainly because of the technological development that has been made over these years. The technological development of automated driving depends on mainly three factors. The first factor is the in-car systems which provide the driver with information about the traffic situation, such as the weather or traffic congestion. The second factor consists of the applications as Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Infrastructure to Infrastructure (I2I). An example for one of these applications is when a car brakes, this information will be communicated to vehicles in the vicinity with the brake lights. In response, the other drivers take action to maintain a safe distance. The third factor in the technological development is the incorporation of autonomous systems which independently respond to different situations (National Highway Traffic Safety Administration, 2013) (Timmer, Smids, Kool, Spahn, & van Est, 2013) (Wilmink & Schuurman, 2012).

One of the most important technological developments is the Advanced Driver Assistance Systems (ADAS). ADAS are systems developed to automate/adapt/enhance vehicle systems for safety and better driving. ADAS uses environment sensors (e.g. laser, radars, vision) to improve the driving comfort and the traffic safety by reacting to potentially dangerous traffic situations. The primary function of ADAS is to facilitate the task performance of drivers by providing real-time advice, instructions, and warnings. Other names for ADAS are ‘co driver systems’ or ‘driver support systems’ (Gietelink, Ploeg, De Schutter, & VerHaegen, 2006) (Brookhuis, De Waard, & Janssen, 2001).

<u>Levels of Automated Driving</u>

With all the technical developments that take over driving tasks from the driver, it is important to order the level of automated driving. Roughly there are three main categories in which automated driving can be ordered: Driver only, Semi-automated and, fully automated (Flemisch, Nashashibi, Rauch, Schieben, & Glaser, 2010).

The European Union has invested in the HAVEit project the goal of this project is to develop and investigate vehicle automation beyond ADAS systems, especially highly automated driving. To indentify the different levels of semi-automated driving, HAVEit has addressed the transition between the level of assistance and automation. This is done in a way that the driver and automation or co-system can be dynamically influenced by both the driver and the co-system. The assistance and automation scale and dynamic task repartition of the HAVEit project are shown in figure 3.1 (Flemisch, Nashashibi, Rauch, Schieben, & Glaser, 2010) (HAVEit, 2011).

Different organizations have provided a categorization of these different levels of automated driving. The literature indicates that two particular organizations have provided a categorization of levels of automation. Those organizations are the National Highway Safety Traffic Safety Administration (NHTSA) and Society of Automotive Engineers (SAE) International. The similarities between the arrangements of the categories are very high. There is one main difference which is that the SAE International did include an extra category for fully automation, which in this case is divided in a category where the system's capability can be classified as for some driving modes or for all driving modes. This thesis will use the analogy of the SAE International because these categories provide an extra layer which is important for the user perception and are also understandable for non-experts. The different categories of level of automated driving are described on the next page in table 3.1.

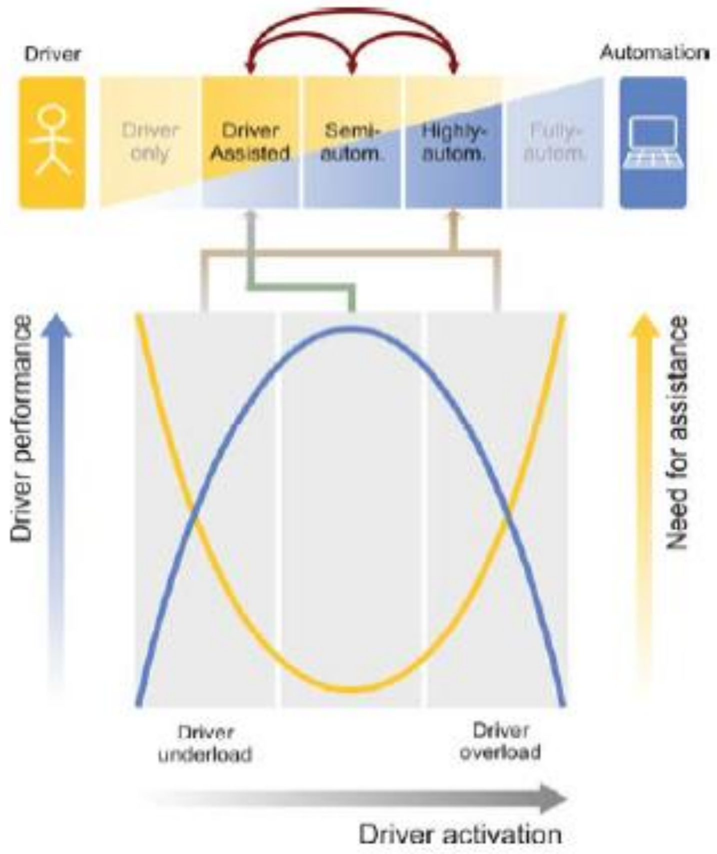

Figure 3.1: HAVEit assistance and automation scale and dynamic task repartition (Flemisch, et al., 2010)

Level	Definition	Steering, Acceleration, and Deceleration	Monitoring of driving Environment	Fallback performance of dynamic driving task	System capability
		Division of roles			
Human driver monitors the driving environment					
Level 0 No Automation	the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human Driver	Human Driver	Human Driver	n/a
Level 1 Driver Assistance	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human Driver and System	Human Driver	Human Driver	Some driving modes
Level 2 Partial Automation	the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human Driver	Human Driver	Some driving modes
Automated driving system ("system") monitors the driving environment					
Level 3 Conditional Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human Driver	Some driving modes
Level 4 High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
Level 5 Full Automation	the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

Table 3.1: Levels of Automated Driving (SAE International's On-Road Automated Vehicle Standards Committee, 2013)

3.2 Context

With all the technological developments for automated vehicles, it can be assumed that the technological part of automated driving will be implemented successfully. The study of KPMG (2013) confirms this statement by stating that the technological innovations are ready and that other parts of introducing automated driving like legalization fall behind. In this part of the literature study the most important socio-economic effects which have an influence on automated driving will be discussed.

3.2.1 Legal

As mentioned in the history part of this chapter, the Dutch government allows testing on public roads for automated driving. This was only possible because of a change in the Dutch law. But to implement full automated driving other legal issues must be countered. The study of Eugensson (2014) concludes that the legal and regulatory frameworks in Europe state that the driver always must be in full control of the vehicle, this makes full automated systems illegal to implement for private usage. Currently some envisioned functionalities are not covered by laws or any standards. The existing legal framework for regulating the requirements on infrastructure, drivers, and motor vehicles offers many challenges on the way towards automated driving. The main reason for this is that when this framework was created, automated driving was unheard of and not really existing. With the technological developments the legal framework needs to be restructured and revised in order not to be an obstacle towards reaching the objectives of automated driving. The current legal framework with implications for autonomous driving can be divided into three parts:

- The Vienna Convention: The Vienna Convention or Convention on Road Traffic was held November 8 1968, this convention was adopted by United Nations Economic Commission for Europe (UN-ECE) under its Working Party on Road Safety (WP1). The rules that were made focuses on the general behaviour in traffic and specifying the requirements on signs, signals, traffic education, speed, and distance between vehicles. It also contains instructions concerning physical and mental condition such as abilities, skills, and alertness. The biggest problem concerning automated driving is Article 8 paragraph 5: ''Every driver shall at all times be able to control his vehicle or to guide his animals''. This paragraph restricts the possibility to hand over the control of the vehicle, from the driver to the in-vehicle system. Several governments are making different interpretations, which it's only about the state of the driver. There already been some proposals put forward suggestion sub-paragraphs, which allows to temporarily hand-over the vehicle to the in-vehicle systems (Eugensson, Brannstorm, Frasher, Rothoff, Solyom, & Robertsson, 2014).
- The Geneva Convention: The convention on Road Traffic signed at Geneva in 1949 was held with the intention of establishing uniform rules for the international traffic. With the underlying idea that visiting motorist would be familiar with the basic rules for travelling in a foreign country. The points of contact with automated driving is also Article 8 paragraph 5 ''Drivers shall at all times be able to control their vehicles or guide their animals. When approaching other road users, they shall take such precautions as may be required for the safety of the latter'. The common perception of this rule concerns unsupervised animals, not vehicles. This means that the convention does not restrict the use of automated driving directly but this is based on an interpretation. Additional rules must clarify this interpretation

and provide no conflicts for automated driving (Eugensson, Brannstorm, Frasher, Rothoff, Solyom, & Robertsson, 2014).

- National Rules and Regulations: Many countries, states and provinces worldwide have restrictions in place for regulating the general behaviour of drivers in relation to the road traffic circumstances. For example the specified distance between vehicles which is different in several countries, states and provinces. But when automated vehicles communicate with V2V technologies to adjust the distance between the vehicles, these rules or regulations could be violated. It is necessary that countries, states and provinces agree on such things (Eugensson, Brannstorm, Frasher, Rothoff, Solyom, & Robertsson, 2014).

The work group of the automation in road transport (2013) approached the legal issues of automated driving from a different point of view, not which rules are holding automated driving back but which functionalities must be covered by new laws and standards. In this research 4 main points of urgency are described:

- Liability: The technology behind automated driving is usually described as a positive influence but liability is often described as an impediment. Because the main question is who can be taken responsible when an accident happens with an automated vehicle? The practical answer is that the manufactures is responsible for any crash caused by the vehicle. But it is interesting to find a legal solution that the liability is divided between the manufacture and the user of the vehicle. A clear legal statement concerning the liability of the use of an automated vehicle would also stimulate the implementation of automated vehicles (Hevelke & Nida-Rumelin, 2014) (Automation in Road Transport, 2013).
- Regulatory: With the coordination of the European Union concerning the regulatory law of automated driving, it is not legal to have a fully automated car. To introduce fully automated cars for the private public, the regulatory law has to change to make this possible. This can be done in combination with the liability issues, because that is the main factor for stimulating implementation of automated driving for the private public (Automation in Road Transport, 2013) (Flemisch, Heesen, Hesse, Kelsch, Schieben, & Beller, 2011).
- Standardization: The development of the technology concerning automated vehicles causes segmentation in the automobile scene. To control this segmentation and keep it user-friendly it is important to introduce standards. Based on these standards for partially and/or highly automated driving, it must ensure that the driver is able to change cars and that it is then still safe to operate it (Automation in Road Transport, 2013).
- Certification and verification: To secure the safety of the automated vehicles certain certification and verification must be introduced. The reason for this is that a safety tests must be defined for introducing highly automated vehicles to the market. Because a ‘normal’ vehicle must pass several tests before it can enter the market, this should be the same for the highly automated vehicles. This also increases the reliability of the vehicles and stimulates the implementation regarding the private public (Automation in Road Transport, 2013).

Other fields where automation is been introduced and applied, for example robotics, standards are already available to stimulate and provide guidance. The example of other industries can be used as a reference for the need for new standards in the area of vehicle automation (Automation in Road Transport, 2013).

3.2.2 Ecology

Globally there are around 1.3 million deaths related to traffic fatalities. To give a perspective as many as 3.1 million deaths are caused by the unhealthy air quality from air pollution. Transportation has the second biggest share in causing air pollution, after electricity and heat generation (Eugensson, Brannstorm, Frasher, Rothoff, Solyom, & Robertsson, 2014).

The emissions of a vehicle have three sources: exhaust emissions, evaporative emissions and attrition emissions. Exhaust emissions are the result of the combustion of the fuel. It is discharge into the atmosphere through an exhaust pipe. Evaporative emissions arise by the evaporation of the gasoline in the tank and the fuel lines. There are enough of these emissions to contribute to air pollution. Finally, attrition emissions are produced by the friction between the tires on the road surface. The nature of these emissions can be divided in to two categories: greenhouse emissions and emissions harmful for the human. The most important and known greenhouse emission is carbon dioxide (CO_2), which is mainly caused by exhaust emissions. In Europe the emissions standards for vehicles are defined by the European emission standards (U.S. Eenvironmental Protection Agency, 1994) (European Commission, 2015).

A positive effect of automated driving is the reduction of emissions, which benefits the ecology. With the development of automated driving the vehicle takes over the control and reduces the input of the human, this leads to lesser mistakes and more efficient use of the car and leads to reduced emissions. This efficiency consists of different parts, first of all is that the vehicles can be significantly lighter. Because the vehicles control the situation, there is no longer need for heavy safety features, such as reinforced steel bodies, crumple zones, and airbags. This leads to lighter and more energy efficient vehicles with reduced emissions. The second part is the more efficient traffic flow, which leads to less traffic congestion and thus fewer emissions (KPMG, 2012).

In the field of reducing emissions by transportation there are done several tests and experiments. Eugensson (2014) describes the European field operational test project (Euro FOT). Euro FOT is an experiment which has demonstrated that driver assistance systems significantly improve the fuel economy of a vehicle. The Euro FOT project was conducted by a partnership of 28 companies and organizations in Europe over a time span of 4 years. The findings of this study show the potential of improving the fuel economy by using the ACC. With the use of the ACC, the fuel consumption can be reduced by 2.1%.

Another research of TNO (2008) indicates that the use of automated vehicles stimulates the traffic flow and reduces the emissions of these vehicles. An average personal vehicle has 20% less CO_2 emissions in traffic congestion if it is an automated vehicle, this is 30% for transport vehicles. When platooning is used in the case of transport vehicles, it can lead to extra reduction of the fuel usage.

3.2.3 Traffic flow

Another positive effect of automated driving is the influence on the traffic flow. The expectation of DAVI (2013) is that the developments of automated driving reduce the traffic congestion for 50%. The reason for this is that the technology increases the interaction between the vehicles. The communication between the vehicles reduces the probability of a traffic breakdown and by the acceleration of the clearance of congestion by increasing the outflow from a queue.

The study of Hoogendoorn (2014) indicates three main topics which automated driving can change and improve the traffic flow. These three aspects are capacity, capacity drop, and traffic stability and will be explained in the text below:

- The capacity of a road is a main factor regarding the traffic flow. In general the capacity of a lane is between the 1800 and 2200 vehicles per hour. Through microscopic simulations it is determined that the capacity of a lane per hour can increase significantly, with the implementation of automated driving. This is based on maximizing the flow speed and the separation between the vehicles. The vehicles communicate with each other which lead to a better adjustment of the cars which leads to more capacity of a lane.
- Capacity drop is the phenomenon that occurs during congestion, drivers maintain larger headways than before the speed dropped. Because the space between the vehicles becomes bigger the capacity drops. It occurs in traffic situations with high densities. Which arise first in an individual lane and then gradually spread over the carriageway. The research that is done to the capacity drop phenomena is scare, most researches only look at the total capacity and don't at look the capacity drop.
- With increasing traffic volume the risk of a traffic breakdown also increases. In general a stable dynamic system, is when perturbed from an equilibrium state tends to return to its equilibrium state. Traffic stability can be indentified into three types: local stability, string stability, and flow stability. Local stability entails a pair of vehicles in a car-following situation. The process of the car-following is assumed to be stable if the magnitude of the disturbance decreases over time. String stability entails a platoon of following vehicles and focuses on the propagation of the disturbance from one vehicle to another vehicle in the platoon. Flow stability concerns a traffic flow consisting of a series of platoons, characterized by platoon sizes and inter-platoons gaps. Automated driving can improve the traffic stability but research to this subject is scares.

The study of Bose & Ioannou (1999) addresses another problem regarding the traffic flow, which is the mix of automated vehicles with manual vehicles. Automated vehicles have a much better response and can adjust faster to a particular situation then manual vehicles which are controlled by a human. The results of the simulation tests of this research indicate that the mix of manual and automated vehicles will benefit the traffic flow. But it is not an optimal situation because the manual vehicles can still be labelled as unpredictable which can lead to unexpected situations.

3.2.4 Safety

The most serious impact on daily transportation are safety issues. Traffic accidents have a negative impact on the economy. In the European Union (EU), there are over 40,000 fatalities and around 1.3 million accidents every year. The cost of these 1.3 million accidents is around 200 billion euro, which is equivalent to 2 percent of the EU Gross Domestic Product (Forrest & Konca, 2007).

Literature indicates that the main reason for implementing automated vehicles is that it improves traffic safety. With all the technology for automated driving it is possible to reduce the number of accidents significantly on the roads. According to the Dutch Secretary Schultz van Haegen of the Ministry of Infrastructure and the Environment (2014), 90% of the accidents are caused by human errors, this is confirmed by the study of Forrest & Konca (2007). This means that automated driving can contribute enormously to traffic safety.

Eugensson (2014) supports the standpoint of the Dutch minister by stating that all of the incidents and crashes are 90-95% of the time human errors. Eliminating the human factor is the biggest potential to reduce the accident rate. The research indicates that distraction of the driver and tiredness is the main cause of these accidents. The developments of systems detecting and balancing the driver's workload are anticipated to be part of the future for vehicle safety. Manufactures and governments are playing a huge role in introducing new automated vehicles to the public. But there is a risk that real life benefits will take time to show effect , which can lead to delay of introducing people to automated vehicles.

Netherlands

In the Netherlands the number of traffic fatalities is decreasing each year, with a number of 570 traffic fatalities in 2013. The main reasons for this decline are the new and safer road designs, education, and safer vehicles (CBS, 2013). According to the Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV 2012), the relation between the speed of the driver and traffic fatalities is very important. Speed is one of the basic aspects of collisions and lead to more damage to car and driver. Many drivers are speeding, reasons for that are factors as being in a rush, its fun, and adjusting to the other traffic. The environment of the driver determines if the driver wants to drive faster. Drivers are encouraged to drive faster when there are more driving lanes, the road is straight, or there is no built environment next to the road (SWOV, 2012). The potential of automated driving depends totally on the driving situation, but can make a difference because it takes the human component out of the driving. Already systems as Adaptive Cruise Control (ACC) Lane Departure Warning (LDW) and Lane Keep Assist (LKA) has been tested and results show that 50% of the participants stay in their lane and don't want to overtake other car users because the speed is controlled by the ACC (Rijkswaterstaat, 2007).

3.2.5 Road Design

Today's roads are designed for human drivers, who are too often inexperienced, distracted, or impaired. This leads to design implementations of roads with supporting infrastructure, because the safety of the human must be secured. With the development of automated driving, the infrastructure has to provide new needs to the vehicles and their users. As earlier mentioned in the safety paragraph of this chapter, automated vehicles need less safety measures to support them (e.g. wide shoulders, guardrails etc.). In the same sense the maintenance of the road network will be effected, because with less infrastructure needed the less has to be maintained. With the increasing capacity of the road network, it is prospected that the capacity of a highway lane will increase with 500%. This means that adding extra lanes to highways to increase their capacity are not longer needed (KPMG, 2012).

The guidelines for the road design in the Netherlands are determined by the government in combination with knowledge centres, engineering companies, and interest groups. The extent to which guidelines are applied varies between the different road authorities and between the different projects. The use of the guidelines is related to the availability of space, because sometimes the guidelines cannot be applied because the project hasn't the available space. Also a project has some preconditions such as: politics, input of stakeholders, and spatial integration, which can interfere with the guidelines. The guidelines for the Dutch road network can be divided into three categories: Erftoegangswegen, stroomwegen, gebiedsontsluitingswegen. This distribution is made on the basis of the function of each road category. A road consists of a road section and intersections. The functions a road can have are exchange of traffic and traffic flow (CROW, 2013).

The current guidelines are not dealing with the new upcoming development of automated driving. The influence of automated driving effects human aspect of the road design. Because with all the automated systems that are in incorporated into the vehicles, the driver has fewer tasks to do. It also leads to a situation where the car outperforms the human driver because the car never loses its attention or gets tired or distracted by other things. In the following text the human components while driving are described, to get a clear understanding what they mean. The human aspect consists of the parts: attention, perception, cognition, locomotion, and behaviour. Each of these parts will be described in the following text, extracted from CROW (2002):

- Attention: before the actually detection starts, the attention of the road users must be drawn. Several studies indicate that there is a connection between the quality and the distribution of the attention, and the performance. To detect objects in a sequence or multiple objects at once, the driver is asked to pay attention. The ability to focus and refocus is an important component of driving.
- Perception: A road user is constantly searching for guidance from the environment, to indicate which information is important. The visual system of the driver is the most important in this case, with important aspects as sense of sight, adoption, and perception barrier.
- Cognition: Among cognition is defined the human functions as understanding, knowledge, and decision making. These characteristics have influence on the processing of information. Attributes of congestion are: experience, available time, reaction time, and decision making in complex situations.

- Locomotion: To make decisions in traffic, the physical condition of the driver must be in shape. Because the lack of physical condition can influence the level of attention, perception, or cognition.
- Behaviour: The behaviour of drivers consists of the decisions they make. The level of decision making can be divided into three levels: strategic level, tactical level, and operational level. Strategic level describes the preparation of the driver. Which route has the driver chosen and what are the back-up options. Also the determination of the departure and arrival time of the driver. On tactical level is defined the driving skills of the car user. How comfortable is the driver with the car and how good can he handle it, the time constant of this level is between 1 and 10 seconds. Finally, operational level describes the unconscious decisions of the driver. The time constant of this level has a maximum of 1 second.

The elements of road category and the human components regarding automated driving can be combined to see which changes in road design are possible. For this analysis, it is assumed that the automated vehicles are detecting the environment to understand the situation and adjust to particular situations. This means that the automated vehicles aren't programmed on coordinates to know where to drive. The influence of automated driving is organized on the basis of the road types. In the Netherlands three types of roads are applied stroomwegen, gebiedsontsluitingswegen and erftoeganswegen. These types of roads are further referred as highways, main roads and local roads. The effect of automated driving on these types of roads lead to the following interesting points according to Eugensson (2014):

- Highways: The highways could be narrower because the automated car keeps in lane quite simple, as opposed to the human driver who is constantly correcting the direction. The automated vehicles enable to reduce the safety measures as guardrails and extra wide shoulders. Because the reaction time of the car is faster and more accurate, the radius of the vertical and horizontal alignments could be lower. The capacity of the highways will rise which means that additional lanes are not longer necessary. Because the automated vehicle is smart, less road signs are needed. Last point is the lighting on the roadside, this could be reduce because vehicles can communicate with each other with the use of the technology, and notice each other.
- Main roads: For the main roads the most important impacts of automated driving are comparable with the highway measures, but this only applies to the main roads outside of the urban areas. For the main roads inside of the urban areas, it is harder to simplify the roads because the exchange of traffic of these roads is more intense.
- Local roads: The impact of automated vehicles on local roads is mainly to simplify the signage. Because of the cyclist and pedestrians in these areas, safety measures are still needed. The reason for this is that these groups can be unpredictable, even for the automated vehicle.

An important note is that some of these points are made with the assumption that all the vehicles are automated. This means that infrastructure that is taken away because automated vehicles do not need them, are still needed for non-automated vehicles and must stay. This leads to a situation where measures are taken for automated and non-automated vehicles, in the future a situation must exist where there are only automated vehicles to fulfil all these points.

3.2.6 Urban Planning

Another crucial aspect which automated vehicles have impact on is the urban form. But this especially applies for fully automated vehicles and not so much for partially automated vehicles (Issi, 2013). Romem (2013) describes that fully automated vehicles have effect on two major parts of the urban planning, which are expanding a city and freeing up valuable land. Both aspects will be described in the following text.

- Expanding city: Faster and more efficient transportation will convert locations that are currently too remote for most users into feasible alternatives, abundant with space. An example of a comparable phenomena is the suburban rail, in the early twentieth century, which led to a mass consumer automobile. The expectation is that automated vehicles also will have this impact on a city and will lead to expansion of it (Issi, 2013).

- Freeing up valuable land: This is done by uncoupling of buildings and parking. After dropping of passengers, fully automated vehicles could search independently for a parking space outside of the urban area, and will return when the passenger is ready. As soon as fully automated vehicles are common enough, the demand for adjacent parking will drop and parking lots in urban areas will be available for other types of land use (Issi, 2013) (Next City, 2014).

3.2.7 Professional driving

The development of the automated vehicles does not have only impact on the private users, but also on the professional driving field. The three main categories in the professional driving field will be discussed:

- Shipping: There are thousands of trucks on the road every day driving for multiple days to reach their destination. All of these trucks are driven by an employee who is paid to do this job. With all the new automated vehicle techniques this industry will be changed. Because if these trucks can drive themselves there are no longer employees needed. The truck also doesn’t need to stop anymore to take a rest or to eat or sleep (Forrest & Konca, 2007). In the Netherlands the first test of self-driving trucks is done by Swedish truck manufacture Scania. Several trucks are driving in a platoon, with the driver only has to steer. Because with the use of ACC, the trucks determine their speed in relation to their predecessor. This technique must improve the traffic congestion situations and will reduce the emissions of the trucks (Telegraaf, 2015)

- Taxi services: The taxi industry will also be largely affected by the automated vehicles. Nowadays this industry is based on driving somebody around who doesn’t have a car or doesn’t want to drive. With automated vehicles the taxi driver could be eliminated. The automated vehicles could also combine rides from different passengers with the use of the technology on smart phones. This is already done with use of Uber, a app-based transportation network and taxi company. With the use of smart phone application drivers receive request for rides. In combination with automated vehicles the taxi industry could be totally autonomous (Forrest & Konca, 2007) (RTL, 2014).

- Public Transportation: Various forms of public transportation are controlled by a human operator. By rail-based transportation it is easier to accelerate, decelerate, and to stop at stations. By bus transportation automated vehicles could change to use of these vehicles. With the use of the technology busses could be driven fully automatically, which also eliminated the human part (Forrest & Konca, 2007).

Nearly all the forms of professional driving could be taken over by automated vehicles. This development causes lower costs for the companies and stimulates the reduction of the emissions. On the flipside of these development, because the vehicles do not need to have a driver it will put thousands of people out of work or gives them a different task (Forrest & Konca, 2007).

3.2.8 Privacy

Because people are involved with automated vehicles privacy is also an issue. People are the users and purchasers of automated vehicles and will generate, maintain, and analyze information when they use these vehicles. This information will be shared with the outside network of the roads and with other automated vehicles, which leads to decisions which the car itself will make and not the driver. The vehicles will also collect personal information of the drivers about their whereabouts, this information is vulnerable for hacking, burglary, and potential access by investigators, both private and governmental. There are three types of privacy interest that will influence the public acceptance of automated vehicles. These three types are personal autonomy, personal information, and surveillance, these aspects are described in the following text which are retrieved from Glancy (2012):

- Personal autonomy: This aspect is regarding the individual control and self-determination of the abilities of the people, to make independent choices about themselves in particular circumstances. Many of the individuals indentify themselves psychological with the vehicles they drive as the key instrument of personal choice, power, and control. It is still uncertain if the same identification will be made with automated vehicles. Nevertheless, some association between personal mobility and individual autonomy will undoubtedly remain.

- personal information: vehicle users are not willing to provide their personal information to be collected without knowing what will happen to this information and the consequences of it. The personal information which includes automated vehicles is the where, when, and how a person moves geographical from place to place. The main questions concerning this data are how will it be used, how long will it be kept, and who have access to this information. This information can be used to annoy an individual user through marketing and advertising. Another option is to harass an individual through following, stopping, and questioning.

- surveillance: Although surveillance most often means covert collection of information, it can also refer to overt watching aimed at modifying the behaviour of those watched. An example of surveillance is red-light cameras, these devices are often prominently placed as watchers at intersections so that drivers are deterred from entering intersections while the stoplight is red. One of the purposes of the surveillance is to affect the behaviour of those who are being watched, to assure that the individual behaviour conforms to societal norms. If an automated vehicle user were informed that the vehicle continuously reports its speed to the law enforcement authorities, the user will be more likely to drive conform the speed limit. Also monitoring of the state of the driver could be done. For instance if the driver is smoking or drinking alcohol and report this and even stop the vehicle.

3.2.9 Future

In the new world of self-driving cars, there are lots of questions to be answered. As various participants in the automotive ecosystem grapple with the impact of these new technologies. Highly beneficial effects for society could be achieved by automated driving. The achievement of these societal benefits requires usage of automated driving systems. Usage of automated driving systems implies that vehicle users have to release control. All over the world the vision is that the automated vehicles will take over the driving tasks. Literature indicates different scenarios for implication of the automated vehicles. The Dutch government is expecting full automated vehicles in the 2030s on the open road. A global planning of the implementation of automated vehicles by the Dutch government is given in figure 3.2.

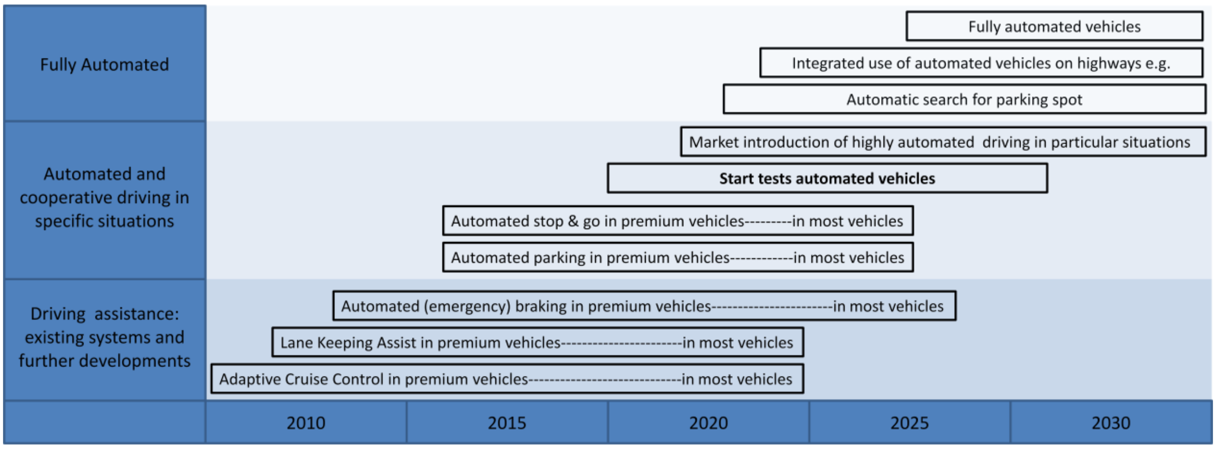

Figure 3.2: Planning implementation automated vehicles (Secretary Schultz van Haegen , 2014)

This forecast of the Dutch government in figure 3.2 is based on the first fully automated vehicles on Dutch roads. The forecast illustrates that step by step more intelligent comfort systems will be introduced to the people. In 2030 this leads to a full automated vehicle which can be used on the public roads.

Litman (2015) describes two different scenarios for a total implication of fully automated vehicles. In this forecast there is an optimistic and a pessimistic scenario, the scenarios are divided into three categories: vehicle sales, vehicle fleet and vehicle travel projections. Figure 3.3 provides a reproduction of these forecasts.

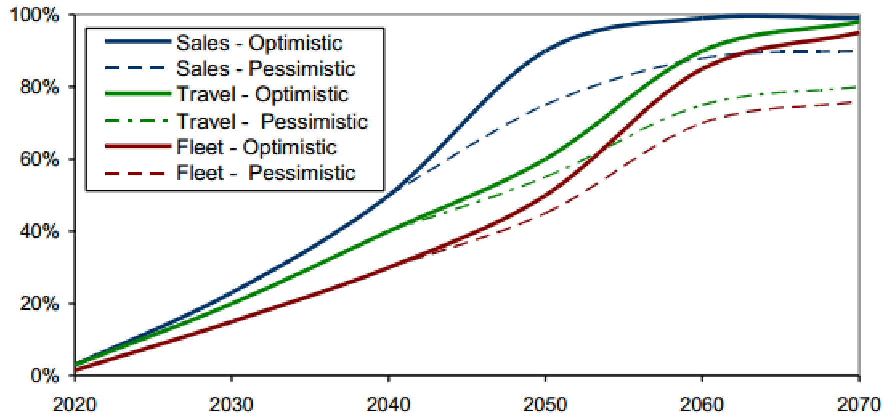

Figure 3.2: Fully automated vehicles sales, fleet and travel projections (Litman, 2015)

Figure 3.3 shows that around the 2060s the top of the total implementation of fully automated vehicles is reached, form both scenarios. The forecast shows that the sales of the vehicles will start at 2020 which is 10 years earlier then the predications form the Dutch government. However, these forecast of the implementation of fully automated vehicles is still very unstable and unpredictable. Several aspects are influencing these development such as technological challenges that are more difficult to solve than expected, the commercially availability of the automated vehicles, expected production and retail costs could be higher than expected. Towards implementing and accepting the automated vehicles there is still a long way to go for both governments and manufactures.

3.3 The driver

The last part of the literature study describes the driver´s influence on automated driving. The user finally determines if automated driving will be accepted. This paragraph will discuss three main factors which are important of the user acceptance of automated driving. Paragraph 3.3.1 describes the user acceptance and user opinion on the topic. Paragraph 3.3.2 examines the environment of the driver and the influences of these aspects on the driver. The last part is paragraph 3.3.3, this part will discuss the influence of the personal characteristics on driving.

3.3.1 User acceptance

With all the technological development concerning automated driving another important part concerns the acceptance of the user. Because the main question is: '*Are the car users interested in all these new techniques?*'. KPMG (2012) has drafted three possible adoption scenarios, which are displayed in figures 3.4 (Aggressive),3.5 (Base Case) and 3.6 (Conservative). These three scenarios are chosen because it provides a maximum, minimum and average scenario, which means that every possible scenario is between these boundaries.

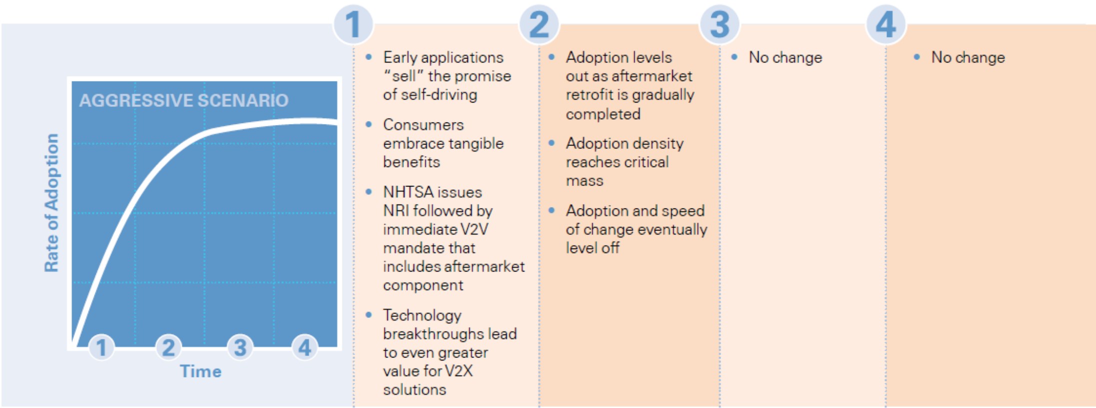

Figure 3.4: Aggressive scenario (KPMG, 2012)

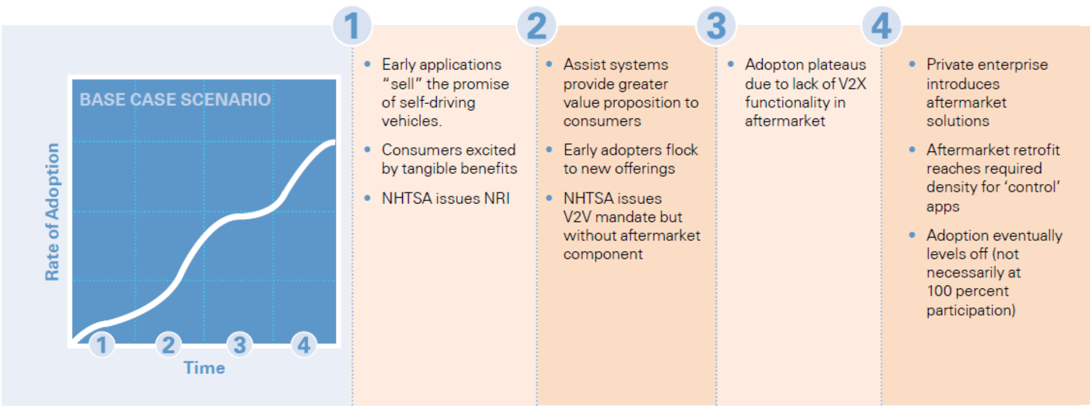

Figure 3.3: Base Case scenario (KPMG, 2012)

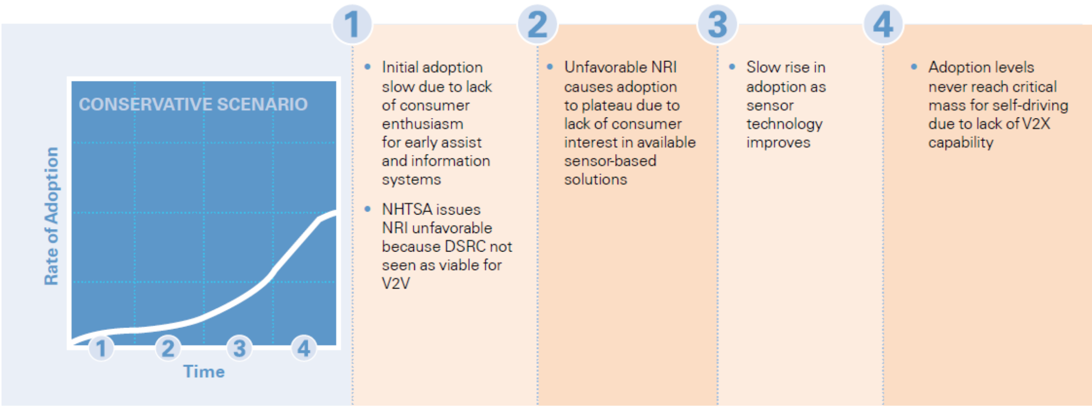

Figure 3.4: Conservative scenario (KPMG, 2012)

Adoption of most new techniques proceeds along an S-curve, in this circumstance the base case which is displayed in figure 3.5. The S-curve means that there are first some early-adopters, followed by the early majority, late majority and the laggards. In the report of KMPG (2012) the expectation concerning adaption of automated cars is that this also will proceed as the base case scenario (figure 3.5). It will be the confluence of multiple, interdependent activities and forces, including regulatory action, business cycles, technological advancements, and market dynamics, that will ultimately determine the trajectory and speed of market adoption.

Public opinion

In name of the University of Michigan, Sivak (2014) has conduct a survey to make an examination of the public opinion regarding automated vehicles. The majority of the respondents had heard before of autonomous and self-driving vehicles (66% of the respondents). The majority of the respondents (57%) had a positive impression of the technology behind the automated vehicles. The interest of the respondents to own or lease a fully automated vehicle is divided into four categories: 17.5% is very interested, 24.2% is Moderately interested, 23,9% is slightly interested, and 34.2 are not interested at all. In table 3.2 the expected benefits regarding using automated vehicles are displayed.

Expected benefit	Response	Percentage
Reduction of crashes	Very Likely	24.6
	Somewhat Likely	45.8
	Somewhat Unlikely	21.7
	Unlikely	7.8
Less traffic congestion	Very Likely	16.5
	Somewhat Likely	31.6
	Somewhat Unlikely	35.5
	Unlikely	16.3
Shorter travel time	Very Likely	13.7
	Somewhat Likely	29.6
	Somewhat Unlikely	40.4
	Unlikely	16.2
Lower vehicle emissions	Very Likely	20.3
	Somewhat Likely	44.0
	Somewhat Unlikely	26.7
	Unlikely	9.0
Better fuel economy	Very Likely	24.6
	Somewhat Likely	47.4
	Somewhat Unlikely	21.2
	Unlikely	6.8

Table 3.2: expected benefits (Sivak, 2014)

The results in table 3.2 show that the respondents expect that automated driving will have a positive influence on the reduction of crashes, emissions and a better fuel economy. This positive expectation is not noticeable for the benefits as less traffic congestion and shorter travel time. A reason for this is that with the implementation of automated vehicles, the total number of vehicles will not reduce but only change to automated vehicles.

In the study of Sivak (2014) possible concerns implementation of automated vehicles is also studied, the results are displayed in table 3.3.

Expected concerns	Response	Percentage
Equipment failure	Very Concerned	46.8
	Moderately Concerned	33.9
	Slightly Concerned	15.5
	Not at all Concerned	3.8
Legal liability	Very Concerned	34.7
	Moderately Concerned	39.4
	Slightly Concerned	18.6
	Not at all Concerned	7.2
System security (from hackers)	Very Concerned	35.2
	Moderately Concerned	33.5
	Slightly Concerned	22.2
	Not at all Concerned	9.1
Learning to use automated vehicles	Very Concerned	21.8
	Moderately Concerned	31.7
	Slightly Concerned	27.6
	Not at all Concerned	18.9
Self-driving vehicles getting confused by unexpected situations	Very Concerned	44.9
	Moderately Concerned	30.8
	Slightly Concerned	19.0
	Not at all Concerned	5.3

Table 3.3: expected concerns (Sivak, 2014)

The results in table 3.3 show that the public still has much concerns regarding automated driving. Learning to control a automated vehicle is the least concern. The biggest concern is equipment failure, which is linked to vehicles which get confused by unexpected situations. In the next paragraph the influences on the acceptance will be further discussed.

Influences on acceptance

The way the public perceives automated vehicles will very directly affect the way they will be introduced to the market. The willingness of the public determines how car manufactures develop and market them. The manufactures will only develop the technology which is accepted by the public. As discussed in the previous paragraph, the public opinion provides several benefits and concerns regarding usage of automated vehicles. The study of Casley et al. (2013) states that the aspects of safety, cost, productivity, legality and the environment influence the public opinion regarding the acceptance of automated vehicles. The results of the study show that safety and legality have to most negative influence on the acceptance level of the public. These results match the results from the study of Sivak (2014). The most positive influence on the acceptance of automated vehicles is the environment. With the use of automated vehicles, the emissions will be reduced. To engage consumers in the adaption of automated vehicles KPMG (2012) provide four main factors. First factor is building trust, there is no margin for an error with the technologies. Consumers will only relinquish full control if they are in a 100 percent sage and reliable environment. The second factor is to appeal to the right demographics. Because certain segments of the population will be less likely to embrace automated driving. Third, selling the value proposition. To adopt new technological development consumers must see the real value for each new feature. This can be done by setting a baseline of self-driving features that would be the standard in every new vehicle. The last factor is facilitating a learning curve. Because automated driving technology will revolutionize the driving experience, consumers need time to learn how to manage and use these new features. They have to feel comfortable and psychological ready to relinquish the control.

3.3.2 Environment

In the previous paragraph a number of aspects regarding the influence of automated driving are described. All these aspects have influence on the behaviour of the driver and it´s environment. To make it possible to react on this new future situation, more information about both physical and personal environments is needed. In this paragraph a closer look is taken to these components.

Interaction environment and driver

Traffic is consisting out of three aspects, which are the driver, the vehicle, and the environment. Each of these aspects has interaction with each other (Lax, 2011). The study of Megens (2014) states that with the introduction of automated vehicles the tasks of the driver are reduced, this leads to a different behaviour of the driver regarding the vehicle but also towards the environment. While performing a task like driving, there are several sub-tasks that have to be done which is more an act of routine. This requires less conscious thought than other sub-tasks. If there is not a implicit or explicit plan, there is also no goal to achieve. Intentions control our actions but not all of these intentions are carried out. The reason for this is that some of these actions are abandoned and some of them are revised to fit the changing circumstances. Important is that not the physical reality decides the behaviour of a driver, but the perceived information. This information can be obtained from the environment where the driver is in (Rasnussen, 1983) (Azjen, 1985). The environment of the driver can be divided into two different kinds of environments, which are the physical and the personal environment.

Physical environment

The physical environment of the driver consist of several parts, the three most important and relevant parts for this research are: type of road, road density and the surrounding area. The influence on the driving behaviour of these two parts will be described in the next paragraphs.

Type of road

As mentioned in paragraph 2.2.5, the Netherlands has divided the road network into three types of roads. Which are Highways, Main roads and Local roads. The behaviour of the driver is different on each type of these roads, this is explained in the following text with information retrieved from Horberry et. al. (2008) and SWOV (2014):

- Highway: On highways the road design is uniform which leads to a consistent and continuing driving environment. The users of a highway are also more uniform then on other roads because only motorized vehicles are allowed. This leads to a situation where the task requirement of the vehicle user is low.

- Main road: The goal of main roads is to collect traffic from local roads and distribute it to highways and vice versa. Because of the different functions of the road, exchange of traffic and traffic flow, the vehicle user must pay much more attention to its driving. This leads to a situation where the task requirement of the vehicle user is much higher than on a highway.
- Local Road: The function of local roads is to make plots and buildings available. The users of this type of road are divers such as motorized vehicles, cyclist and pedestrians. Local roads are not uniform because of the different designs of these roads. This leads to a situation where the vehicle user must be very alert and where the task requirement is very high.

Traffic Density

The traffic density has an influence on the behaviour of the driver. A driver will behave differently when there are other vehicles on the road. For this research three levels of traffic density are useful to determine the traffic situation, which are based on the study of Weeks (2010):

- High traffic density
- Normal traffic density
- Low traffic density

Surrounding area

The surrounding area of the driver has influence on the behaviour. In this case the surrounding area can be divided into two main categories; rural and urban. Both categories will be described in the following text and are based on the research of Weeks (2010)

- Rural: A rural area can be defined as a surrounding area that has a low population density and no built environment. This type of area usually contains highways which provide a connection between urban areas.
- Urban: An urban area can be defined as a surrounding area that contains elements such as a built environment and high population density. In general an urban areas contain local and main roads which provide access to the built environment.

Personal environment

The personal environment of the driver consists of several parts, but the most important parts in this case are the passengers, length of the trip, and familiarization with the route. All parts will be discussed in the text below.

- Passengers: The presence of passengers in a vehicle while driving can affect the driver's attention to the road situation. This can be a positive influence on the driver, because it can lead to more responsibility and a more attentive driver. It can also have negative effect because the driver can be distracted by the passenger(s) (Tefft, Williams, & Grabowski, 2012).
- Length of the trip: The length of a trip has influence on the behaviour of the driver. Because how longer the trip is, how longer the driver needs to pay attention. **Figure X** shows that drivers need more guidance on longer trips. This guidance partly consists of avoiding traffic jams and estimated time of arrival (Sanchez, et al., 2012).
- Familiarity with the route: The drivers of a vehicle seem to have more trust in themselves in a familiar environment. The reason for this is that the driver gains experience while driving in the

same situation over and over again. A counter effect of this is that the driver tends to pay less attention because the road is familiar. The study of Sanchez et al. (2012) shows that drivers make more use of navigation in unfamiliar situations. So it can be said that drivers have more confidence in themselves when they are on a familiar road. Figure 3.7 shows the results of the test from the study of Sanchez et al. (2012).

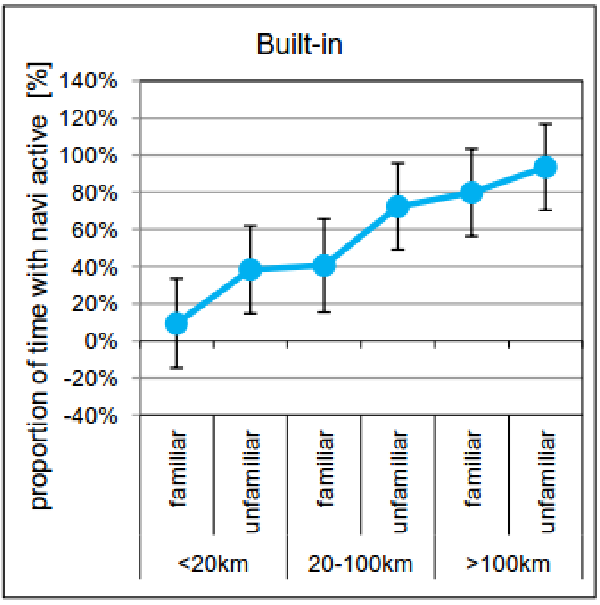

Figure 3.5: Proportion of trips with active navigation system separate for familiarity of route and trip length (Sanchez, et al., 2012).

3.3.3 Personal characteristics

The last aspects of the driver's role concerning automated driving are the personal characteristics of the driver. With gaining experience the driving behaviour of the drivers will change. For this research it is interesting to investigate what kind of influences the personal characteristics have on the driving behaviour. In this paragraph different characteristics that have influence will be described such as gender, age and driving experience.

<u>Gender</u>

The driving behaviour of people is not static, but varies as a function of many factors. One of these factors is the gender of the driver. In the research of Khazan (2014), the driving behaviour from the different genders is studied. The research is based on different driving factors that are combined with the type of passengers. With as goal to investigate the difference between males and females. The different driving factors that are investigated are inattention, interior non driving activity, exterior factor, aggressive act and illegal manoeuvre. The results of the males are shown in figure 3.8 and for the females the results are shown in figure 3.9.

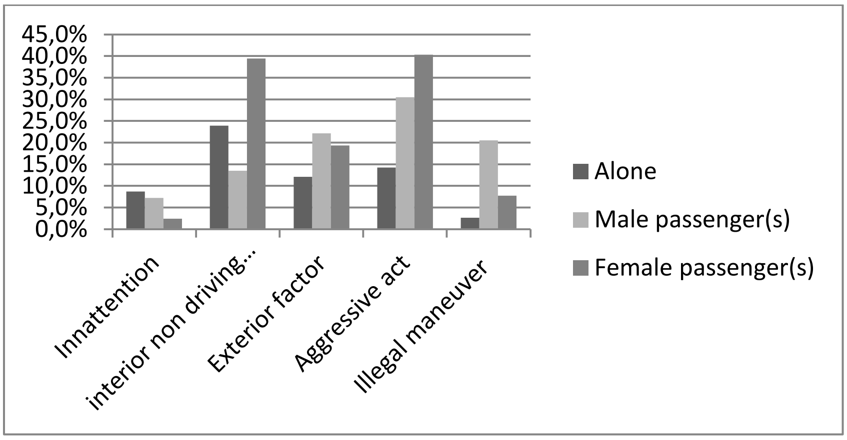

Figure 3.6: Male driving behaviour (Khazan, 2014)

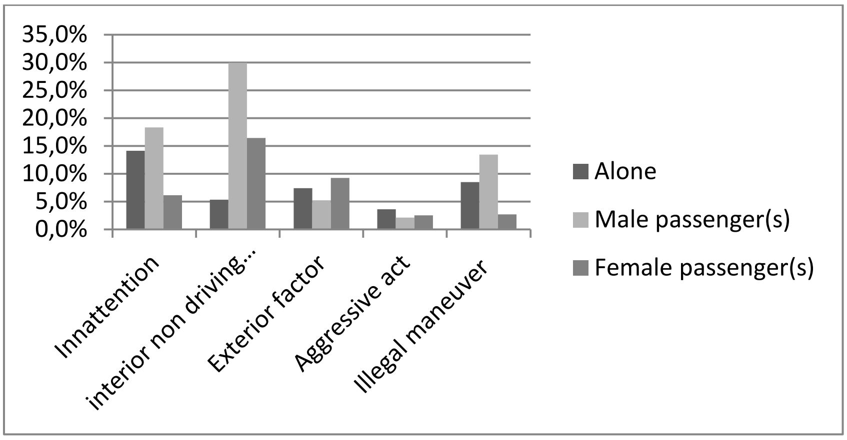

Figure 3.7: Female driving behaviour (Khazan, 2014)

The results of the research show that males or more willing to drive aggressively, because the values of the factors ‘aggressive act’ and ‘illegal manoeuvre’ are much higher than with females. But the results also indicate that males are much more focused on the road then females. The female value of factor ‘inattention’ is almost two times higher than with the males. Another remarkable result is that males are much more willing to take risks and drive more aggressively when there is a female passenger in the car.

The research of SIRC (2004) has investigated the differences between gender in another way. The research is based on the factors of taking risks, exhibit aggression and seeks thrilling sensations. The numbers that were used for the research are based on the insurance claims. The differences of men and women from all over the world are compared (Europe, America, and Asia). In terms of driving behaviour, the differences can be seen clearly in the greater propensity of males to take risks, exhibit aggression and seek thrilling sensations. The results of these differences are highlighted very clearly across the globe in higher accident statistics, more expensive and frequent insurance claims and higher rates of convictions for offences such as dangerous and drink-driving. An explanation for these differences between gender is based on evolutionary psychology.

<u>Age</u>

As people get older, their driving patterns change. Age-related declines in vision. Hearing, and other abilities, as well as certain health condition and medications, can affect driving skills. Also, people have different schedules which are based on their activities. For example, older people retire which creates new driving schedules for them (NIH, 2015). In the research of the NHTSA (2013) several cognitive measures are examined . These cognitive measures will decline over age and affect the driving skills of the people. These cognitive measure are:

- Visuospatial ability: An understanding of spatial relationships among stationary and moving objects. This supports a driver's ability to navigate safely through traffic and to navigate toward a destination.
- Executive functioning: A process that regulates other cognitive processes. Executive functioning allows a driver to use information from the driving environment and from previous experience (e.g., rules of the road, vehicle handling) to manage driving tasks.
- Selective attention: The ability to attend to relevant information in the presence of distracting, irrelevant items.
- Short term memory: The information a person is currently aware of or is thinking about. Short term memory enables a driver to gather information from the driving environment to support executive functioning.
- Mental status: Mental status examinations generally screen for some sort of impairment, such as dementia. People who score poorly on these tests may have difficulty managing the multiple tasks that driving demands.

For this research it is interesting to see if older people are willing to embrace automated driving. Because it can improve their driving skills, with the help of the intelligent comfort systems of an automated car.

<u>Driving experience</u>

The relationship between skills and experience is complex, and it is a challenge to understand the behaviour of the driver. For example, unsafe drivers are not necessarily those with low skills and experience. Skilled drivers who engage in risky activities like speeding might be even more dangerous. People´s willingness to take risks is widely acknowledged to be an important characteristic (Oltedal & Rundmo, 2005).

In the research of Nabatilan et al.(2011), the visual behaviour of the driver is examined based on the experience of the driver. Results demonstrate that the novice drivers fixated more on the dashboard area (36%) than on the front and centre view (14%). On the other hand, the experienced drivers fixated more on the front and centre (40%) as compared to the dashboard area (12%). Same trend was observed for complex driving but with lower percentage of total fixations than the simple driving conditions. Concluded from these results it can be assumed that experienced drivers are more comfortable while driving and can do tasks from habituation.

3.4 Conclusion

Since almost a century, planners, engineers, and visionaries are involved in the quest to enable people to travel in passenger vehicles without being constantly attentive. Vehicles are constantly improved with new technologies which provide more comfort for the users. The last five years major steps were made in the technological development. Currently it is possible to let the system take over control for one or two primary driving tasks. Well-know manufactures as BMW and Audi, are currently working on fully automated vehicles. Since 2015, the Dutch government allows tests of automated vehicles on public roads.

Automated driving could offer many benefits to society. The first major benefit of automated driving is the effect on the ecology. With the techniques that are used for automated driving, the emissions will also be reduced from the vehicles. Because vehicles will drive more efficient, this could lead to less traffic jams and better fuel consumption. The second major benefit of automated driving is the improvement of the traffic safety. With all the technology for automated driving it is possible to reduce the number of accidents significantly on the roads. Approximately 90% of all the accidents are caused by human failure. When an system can take over control and reduce the involvement of the human, the number of accidents can be reduced significantly. The last major benefit is the improvement of the traffic flow. Automated vehicles can drive more constant and closer to each other, this results in a higher capacity of the existing roads. Also, the traffic dynamics will improve because the automated vehicles reaction time is faster. This leads to a more stable traffic flow.
To implement automated driving several issues must be solved. First there are the legal issues, it is still not legal to drive a fully automated vehicles on a public road. The main reason for this is that when this legal framework was created, automated driving was unheard of and not really existing. This means that the current laws and rules must be adjusted to make this possible. Another problem concerning automated driving is privacy. Nowadays privacy is a hot topic and very important for people. With the introduction of automated vehicles people are monitored, this can lead to a situation where people are not willing to drive in these kind of vehicles. Also, with the use of automated vehicles the professional driving sector will change. Because humans will be unnecessary to drive certain vehicles.

The most important factor to make automated driving a success is the driver. The driver must accept that the system is taking over control of the vehicle. The expectation is that automated driving will be accepted, but this is still years away. People are still concerned about the reliability of the automated vehicles. The environment of the driver determines for a large part the behaviour of the driver. Several factors in the physical and personal environment have influence on the behaviour of the driver, such as the distance of the trip and the number of passengers. The personal characteristics are also dependent if the driver will accept their new role. To investigate these findings and determine what people persuade to embrace automated driving a stated preference experiment will be executed. This experiment will be described in the next chapter of this research.

4 Model

Abstract

To understand the acceptance and the behaviour of the driver regarding automated driving an experiment must be made to study this. Because it is still unknown in which situation the driver wants which level of automated driving. To execute this experiment the stated preference method was used. The reason for this is that it attempts to model the decision process of an individual or segment in a particular context. This fits perfectly with the level of automated driving (segment) and the 'environment' (particular context). There is chosen to do a rating experiment for this case to let the respondent determine which level they want in a particular situation. The data is gathered with the use of an online questionnaire. The results of the experiment indicate that the' type of road' and the 'length of the trip' are the most important attributes that have effect on the level of automated driving.

4.1 Introduction

The literature provides much information but leads to even more questions. In this master thesis research is done in the field of the automated driving and especially at the driver acceptance. The reason to choose this particular field of interest is that there are opportunities to contribute. As earlier mentioned there is some information available concerning the user acceptance of automated driving but there is not much knowledge to which level of automated driving the user want and in which situation. To get insights in the preferences of the vehicle users regarding automated driving an experiment will be executed. This chapter describes the research method, experiment design, modelling and results of the experiment.

4.2 Stated preference method

For this research the stated preferences method will be used. The main reason to choose this method is that it attempts to model the decision process of an individual or segment in a particular context. This fits perfectly with the level of automated driving (segment) and the 'environment' (particular context). The use of this method allows a creative construction with plausible hypothetical products (Anderson, de Palme, & Thisse, 1992). An advantage of the stated preference method is that it has the ability to vary attributes independently, which makes it possible to determine the effects separately. A disadvantage of the stated preference method is the external validation of the method. The question is if the choices that are made will be the same in a real world situation (Oppewal & Timmerans, 1993). The stated preference method can be divided into two main categories: preference and choice. These categories can also be subdivided which is shown in figure 4.1 .

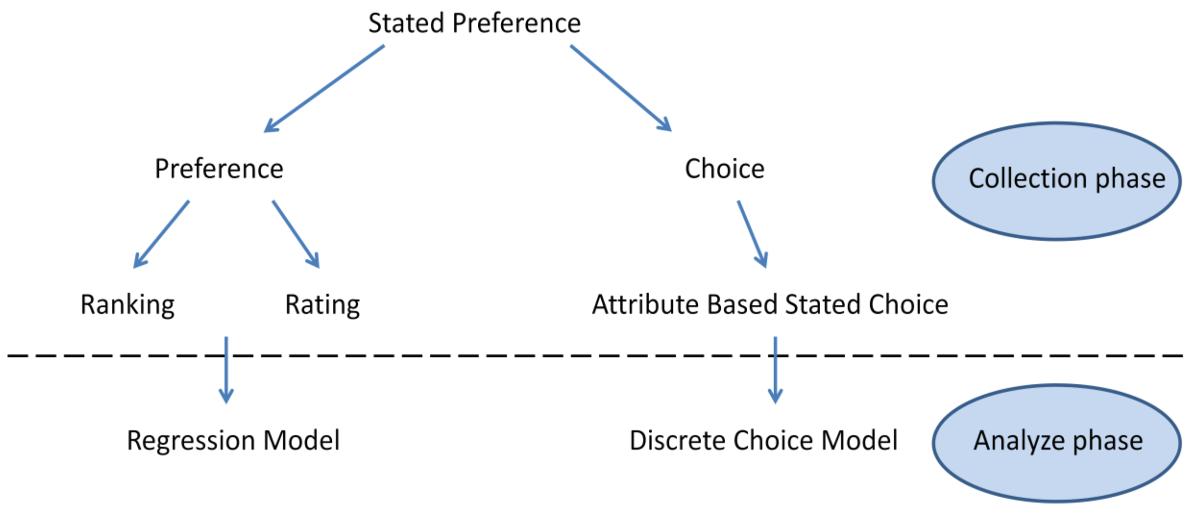

Figure 4.8: Stated Preference Method

For this research there is chosen to use preference rating method. The reason to choose this method is that respondents require to indicate their strengths of preference for each profile. Which in this case is the level of automated driving. The ratings provide information on both order and degree of preference (Kemperman, Borgers, & Timmermans, 2000). As shown in figure 3.1 the stated preference method consist of a collection phase and an analyze phase. Both phases of the chosen method will be described in the next paragraphs after the pros and cons of the method.

4.2.1 Pros and Cons SP

To analyze the choices that are made by individuals, the stated preference and revealed preference research method are most suitable. In this case the stated preference method is chosen because the given situations are hypothetical. The main advantages and disadvantages of the stated preference method are described which are obtained from the research of Sanko (2001):

Advantages:

- Stated preference method van obtain ranking, rating and choice information, whereas revealed preferences can obtain only choice results;
- Stated preference can suggest hypothetical behaviour and non-existing alternatives;
- No measurement errors exist in stated preferences data;
- The range of attributes levels can easily be extended;
- The ability to control multi-colinearity among attributes;
- The choice set can be defined in a brief and clear way, and more responses can be gathered per respondent.

Disadvantages:

- The behaviour of the respondents can be inconsistent because no correlation with answers exits;
- Biases can occur because respondents try to justify their actual behaviour and try to control policies;
- Stated preference data must be collected in a highly specific fashion in order to avoid temporal, learning and segment biases.

4.2.2 Collection phase

The collection phase of the preference rating method consists of four steps. Each step will be briefly described and is based on the work of Kemperman et. al.:

Step 1: Identification of Attributes
The first step is to identify which attributes are needed for the experiment. The attributes must serve as description of the different profiles. These attributes can be derived from literature studies. If the attributes cannot be obtained from literature studies, qualitative methods can be used to discover the attributes.

Step 2: Define levels to the Attributes
The found attributes from step 1 must be levelled. The number levels must be kept low, and the levels should cover the whole range of the examined attribute for the research purpose.

Step 3: Design Experimental Task
When the attributes and their levels are determined, combinations off the different attribute levels can be made to construct the different choice alternatives. In most of the cases, the number of possible combinations of attributes is very high. To reduce the number of choice alternatives, a special design can be used to construct the select number of choice alternatives. These designs make it possible to investigate the first order effects, and dependent on the experiment lower order effects with only a small part of the alternatives of the full factorial design.

Step 4: Data Collection
The data collection step is the actual execution of the experiment. The different rating alternatives that are been made in step 3 can now be provided for the target audience. This can be done with a questionnaire or interview.

If these four steps have been done the collection phase can be closed and the analyzing phase can be started. The analyzing phase is described in the next paragraph.

4.2.3 Analyzing phase

When the data is obtained from the experiment it can be analyzed. In this rating experiment the answers are the 6 levels of automated driving. These answers are ordinal because there are no values between these levels of automated driving. To analyze the results of the experiment a ordinal regression model will be used. This model describes, predicts, and explains the relationship between the variables.

<u>Ordinal regression model</u>

The data analysis is based on an ordinal regression model. This model was chosen because the respondents will rate the different driving situations with a level of automated driving, on an ordinal scale. The ordinal regression model is a model used for analysing preferences gathered on an ordinal measurement level. By using this model, which is specifically developed for ordinal data in which the distances between categories are unknown, the ordinal categories can be used as directly dependent variables. In ordinal regression, an underlying score is estimated as a linear function of the independent variables and a set of cut-off points. The probability of observing outcome i corresponds to the probability that the estimated linear function, plus random error ε, lies within the range of the cut-off points estimated for the outcome:

Pr (outcome$_j$ = i) = Pr ($k_{i-1} < \sum_{i=1}^{k} \beta_i x_{ij} + \varepsilon \leq k_i$)

The regression coefficients, β_1, β_2, ... β_k, which are related to the physical characteristics (x_{ij}) together with the cut-off points, k_1,k_2, ...k_{i-1}, where i is the number of possible outcomes, are estimated: k_0 is taken as – ∞ and k_i is taken as +∞.

In this research, six levels of automated driving are distinguished. Respondents are assigned a level of preference on the basis of the level of the linear function plus random error term. The probabilities enter the log-likelihood function as usual, and maximization of the likelihood function provides estimates of the parameters.

Model's goodness of fit

To get insight whether the model can analyze and predict the data well, the model's fit must be calculated. This can be tested if the estimated parameters of the model provide an improvement of the model without estimations. Also, different models with both estimated parameters can be compared to know which one has the best predictive power. For this research maximum Pseudo R^2 and the likelihood ratio will are used.

The basis of both tests is the maximum likelihood estimation. This is a method of estimating the parameters of a statistical model, it selects a set of values of the model parameters and maximizes the likelihood function. This gives a unified approach to estimation, which is well-defined in the case of the normal distribution. The formula of the maximum likelihood estimation which is defined as:

$LL_M = \sum_{n=1}^{N} \sum_{i} f_{ni} (P_{ni})$

Where
LL_M is the log likelihood function for the estimated model, maximed with respect to estimated parameters.
N is the sample size.
f_{ni} is the choice of individual n for alternative i, which is equal to 1 if i is chosen and 0 otherwise;
P_{ni} is the probability of individual n chooses alternative i.

Likelihood ratio

The likelihood ratio is a popular form of testing the model fit. It is based on the likelihood function and therefore has the same foundation as the pseudo R^2. The likelihood ratio is the likelihood of the estimated model divided by the likelihood of the base model with zero parameters. The likelihood ratio-test expresses how much more likely the data under one model is than under the other model. This ratio is between 0 and 1 and the less likely assumption is, the smaller the ratio will be. The likelihood ratio van be compared to a critical value to decide if the estimated model outperforms the base comparison model. The formula for the likelihood ratio is described as:

$D = -2(LL_0 – LL_M)$

Where
D is the likelihood ratio of two models.

LL_0 is the log likelihood function for the estimated model with all parameters equal to *0*
LL_M is the log likelihood function for the estimated model.

It should be compared to a chi-square statistic with degrees of freedom equal to the difference in number of parameters between the compared models. If D is larger than the chi-square the ratio the assumption is rejected, and the estimated model is preferred over the model with restrictions. If D is less than the chi-square, it cannot be concluded that the estimated model is better than the base model (Hensher, Rose, & Greene, 2005).

Pseudo R^2

The pseudo R^2 shows how the estimated model performs against a model in which all parameters are set to zero. The value of Pseudo R^2 of a model should be between 0.2 and 0.4, where a value of 0.3 represent a decent model fit. A model is considered weak when it has a Pseudo R^2 value below 0.1. The formula for Pseudo R^2 is described as (Louviere, Flynn, & Carson, 2000) (Hensher, Rose, & Greene, 2005):

$R^2 = 1 - \frac{LL_M}{LL_0}$

Where
R^2 suggest the level of improvement between the two model and falls between 0 and 1.
LL_M is the log likelihood function for the estimated model.
LL_0 is the log likelihood function for the model estimated with no parameters.

When the number of parameters increases, the adjusted Pseudo R^2 should be examined. When the value of this estimation increases with parameters raising, it indicates the existence of heterogeneity in the data.

Adjusted $R^2 = 1 - \frac{LL_M - p}{LL_0}$

Where
p is the number of parameters.

4.3 Experiment design

This chapter will provide insight into the experimental design that was used in this research. A discrete choice experiment is set up to predict discrete choices of vehicle users with regard to the level of automated driving in a particular situation. To structure the design the guidelines provided by Hensher, et al. (2005) were applied. In paragraph 4.1 the problem statement of this research is refined. Paragraph 4.2 provides the attributes and the attribute-levels which are obtained from the literature part of this research. Next, in paragraph 4.3 the experimental design is generated and attributes are allocated. Paragraph 4.4 describes the composition of the choice sets. Finally, paragraph 4.5 describes the survey instrument that was made for this experiment.

4.3.1 Research question refinement

As described in the previous chapters, automated driving has the potential to improve the general traffic situation. This leads to improvements in the areas of traffic safety, ecology and travel time. On the other hand there are still some drawbacks to implement automated driving such as legal issues, privacy aspects and a new road design. The most important aspect of all this is the willingness of the driver to embrace the automated vehicles. Several predictions are made which all have different findings. It is important to see that the willingness to embrace automated driving differs per user group. Also the situation of the driver dictates if automated driving is desired. All this new information leads to the following refined research question:

'What is the influence of the physical environment and the personal environment of driver, on the acceptance level of automated driving?'

4.3.2 Identification and refinement of attributes and attribute-levels

To investigate the research question a choice set of different alternatives must be made. The choice set has fixed number of alternatives. The alternatives consist of different attributes. These attributes are based on the findings in the literature. The respondents must indicate which level of automation is desired in the particular alternative situation.

The first step is to identify which attributes are useful for this particular situation. The research question states that the influence of the personal and physical environment of the driver is important. So it is the attributes must be based on those two aspects. The literature review indicates that both aspects have three important factors that influence the behavior of the driver. That's why for this experiment six attributes will be used which are based on these conclusions. The next step is to determine the number of levels of each attribute. For this research every attribute is chosen to be divided into three levels. The main reason for this is that making a fractional factorial design of the different alternatives is much easier when all the attributes have the same number of levels. In table 4.1 the selected attributes and their corresponding levels are displayed.

Attribute	Level	Label
Type of Road	1	Highway
	2	Main Road
	3	Local Road
Traffic Density	1	Low
	2	Normal
	3	High
Familiarity with Route	1	Well known
	2	Partially known
	3	Unknown
Distance of Trip	1	<20 km
	2	20-100 km
	3	>100 km
Environment	1	Highly Urban
	2	Urban
	3	Rural
Number of Passengers	1	2 or more passengers
	2	1 passenger
	3	0 passengers

Table 4.1: selected attributes and corresponding levels

- Type of road
  This attribute indicates the type of road that the driver is situated at. The literature study indicates that the behavior of drivers is different on each type of road. This attribute is divided in the following levels based on the Dutch road level system of the CROW (2013):
  - Highway: Road for high speed motorized traffic, function is to guide the traffic from area to area. Also each driving direction has its own lane.
  - Main road: Road for motorized traffic, road connects highways and local roads with each other.
  - Local road: Road for all kinds of traffic, collects the traffic to guide it to bigger roads in the network.

- Traffic density
  This attribute indicates the level of use of the particular road. As mentioned in the literature study of this research, the density of the traffic has influences on the behavior of the driver. The attribute is divided into the following three levels based on Weeks (2010):
  - Low;
  - Normal;
  - High.

- Familiarity with route
  The attribute familiarity with route is also based on the literature review; it indicates that drivers feel much safer when they know the route. This attribute is divided into the following three levels based on Sanchez et al. (2012).:
  - Well known;
  - Partially known;
  - Unknown.

- Distance of trip
  The distance of the trip also influences the behavior of the driver because the driver is much more focused on a short trip then on a longer trip. This attribute is divided into the following three levels based on Sanchez et al. (2012).:
  - >20 km;
  - 20-100 km;
  - <100 km.

- Environment
  The surrounding environment is another influence on driving behavior. Because people are more comfortable when there is less built environment. This attribute is divided into the following three levels based on Weeks (2010):
  - Highly Urban: center of cities where the whole environment consist of buildings.
  - Urban: Small cities and villages where the environment is been built.
  - Rural: When there is no build environment surrounding the road.

- Number of passengers
  The last attribute is passengers. This is also an important attribute because when somebody is driving with you there is a bigger responsibility for you as the driver. This attribute is divided into the following three levels based on the study of Tefft et al. (2012):
  - 2 or more passengers;
  - 1 passenger;
  - No passengers.

4.3.3 Generation of experimental design and allocation of attributes

The next step is to combine the different attributes with their different levels and make alternatives. A full-fractional design would result in 729 alternatives (3^6). This is based on an unlabeled experiment where the number of alternatives is calculated by L^A, *L* represents the number of levels from an attribute and *A* represents the number of attributes with this level. It is impossible to let respondents adequately evaluate this number of alternatives; this means that the number of alternatives must be reduced. This can be done by making assumptions on how decision-makers combine part-worth utilities into structural utilities. This method results in a fractional factorial design, which in this case consists of 18 alternatives. The reduction is calculated with the statistics program SPSS. The reduction of the profiles does not lead to a loss of interaction between the effects of the different attributes. This leads to a structural utility with an assumed equal to the sum of separate part-worth utilities. In table 4.2 a matrix shows the 18 alternatives that will be used for this experiment.

	Attributes					
Treatment combination	**Type of Road**	**Traffic Density**	**Familiarity with Route**	**Distance of Trip**	**Environment**	**Passengers**
1	2	2	1	2	2	3
2	1	3	3	2	2	2
3	3	1	1	2	3	3
4	3	1	3	2	1	2
5	2	1	2	3	3	2
6	1	2	1	3	3	2
7	1	1	2	1	2	3
8	2	1	3	3	2	1
9	1	2	3	3	1	3
10	3	3	2	3	1	3
11	2	3	1	1	1	2
12	2	2	2	2	1	1
13	3	2	3	1	3	1
14	3	3	1	3	2	1
15	1	1	1	1	1	1
16	3	2	2	1	2	2
17	1	3	2	2	3	1
18	2	3	3	1	3	3

Table 4.2: alternatives with attribute levels

4.3.4 Generation of choice tasks

The 18 profiles are divided in randomly generated groups of 6 profiles that are present to 1 respondent. With the randomly generated profiles there are no fixed groups. This means that every respondent is asked to fill in answers for 6 profiles in the questionnaire. Figure 4.2 illustrates an example of a profile, the respondent has to choose which level of automated driving is desired in this situation.

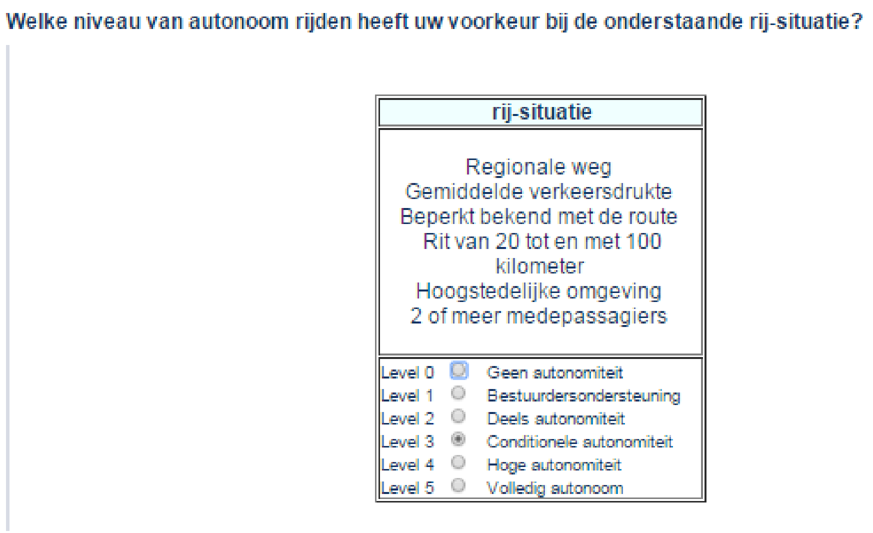

Figure 4.2: Example of stated choice part of questionnaire

When the level of automated driving is determined the respondent is asked to indicate which aspect can stimulate a higher level of automated driving, for that particular profile. The aspects from which can be chosen are: fuel reduction, travel time reduction and cost reduction. Figure 4.3 illustrates an example of this question.

In welke mate dragen de volgende factoren bij aan het kiezen voor een hoger niveau van autonoom rijden gelet op de bovenstaande rij-situatie?

	Geringe mate	Gemiddelde mate	Hoge mate	Geen mening
Kostenreductie	○	○	◉	○
Brandstofreductie	○	○	◉	○
Reistijdredutie	○	◉	○	○

Figure 4.3: Example of reduction factors question of questionnaire

4.3.5 Survey instrument

The questionnaire that is made for this experiment is set up in the Berg Enquete System, which is an online survey tool. The questionnaire that is made is in Dutch and distributed among a random sample of respondents in the Netherlands.

The respondents are shortly informed about the objectives and procedure of the survey. As the concept of automated driving is not well-known, respondents are smoothly introduced with this. The aim is to construct the survey with appropriate questions and information established in such a way that it is understandable for the respondents. Moreover, questions and information should relate to the respondent's current level of experience and should appear realistic (Ortuzar & Willumsen, 2011). Besides, there should be no ambiguity, include different vernacular and it should not contain biased questions (Hensher, et al., 2005). The questionnaire is tested against these sorts of flaws by around 10 test respondents.

There are two sources which influence the choice behavior. Firstly, attributes relate to the description of the alternative. Secondly, characteristics that relate to the individual's prejudice which is represented by its socio-economic variables and its context influence (Hensher, et al., 2005). To get insights in both sources of influence, the questionnaire consists, besides a stated choice part, of individual's background questions. The aim is to find homogeneity within groups and heterogeneity between groups. With this information, different groups can be addressed more appropriately. Driver characterization can be done by socio-demographic factors, perceptions, attitudes and habits (Beirão & Cabral, 2007).The questionnaire is divided into four parts, in the following paragraphs these parts will be described. In appendix A the total questionnaire is presented.

But for that the questionnaire starts, the question is asked if the respondent has a driver’s license. When this is answered with ‘yes’ the questionnaire will be started. When this is answered with ‘no’, the questionnaire will not be started. This distinction is made to only have respondents with a drivers license. The reason for that is the respondents must answer questions that only can be answered when you have driven a vehicle.

4.3.5.1 Part 1: Driving experience and behavior

The first part of the questionnaire consists of two segments, first a set of characterizations of the respondents driving experience, average number of kilometers per annum, ownership of a vehicle and the use of it. These characteristics can give insights in the respondents´ use of the car. In table 4.3 the four characterizations are displayed which are asked in the questionnaire.

Do you own a car?	Average number of kilometers you drive per year?	How many years of driving experience do you have?	Is driving a car your main means of transport?
Yes	Less than 10.000	Less than 5	Yes
No	10.000-30.000	5-19	No
	More than 30.000	20-34	
		35-49	
		More than 50	

Table 4.3: Characterizations of respondents

Secondly propositions are submitted to the respondents, each followed by the question in how much the respondent agrees or disagrees. Those propositions are divided into two parts, first there are four propositions about traffic safety followed by four statements about ecology. With the use of these propositions it is possible to see how the respondents interact in the traffic system and what their opinion is regarding the ecology and traffic safety. These propositions, related with one of the personality traits come from(Taubman-Ben-Ari, et al., 2004) If respondents agree with the proposition more than average, they are assumed to have a certain personality trait.

4.3.5.2 Part 2: Intelligent comfort systems

Intelligent comfort systems provide a positive influence on the behavior of the driver. Automated driving is based on these intelligent systems in vehicles. Hence, the probability of usage of intelligent comfort systems can increase the interest in automated driving. In the questionnaire eight intelligent systems are tested. First the respondents are asked to fill in if they have heard of the particular system. Secondly they are asked if they use these systems. In the questionnaire the following eight intelligence systems are tested, the selection is based on the EuroFOT (2012) research:

- Adaptive Distance Control (instead of Adaptive Cruise Control, as many people read ACC as cruise control which is not the same) is an optional cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.
- Forward Collision Warning: is an automobile safety system designed to reduce the severity of an accident.
- Speed Regulation System: is an optional system which controls the speed of the car based on the information which is given by traffic signs.
- Blind Spot Information System: is a system to help you detect vehicles in your blind spot when changing lanes
- Lane Departure Warning/Lane Keeping Assist: is a system designed to warn a driver when the vehicle begins to move out of its lane
- Navigation System: is a (usually electronic) system that aids in navigation.
- Fuel Efficiency Advisor: provides a wealth of information about your vehicle in real-time
- Park Assist System: is a electronic system which helps the driver to park the car

Another important factor is the willingness to use automated vehicles. The second segment of this part of the questionnaire is used to get a better understanding of this willingness. Respondents are asked to give a score on a 5-point scale on propositions regarding the willingness to accept automated driving.

4.3.5.3 Part 3: Choice experiment level of automated driving

The third part of the questionnaire consists of the stated choice experiment. This stated choice experiment is based on the 18 profiles which are explained in the previous paragraph. Respondents are asked to determine which level of automated driving is desired for the particular profile. Further along the questionnaire is asked which factors can influence the respondent to choose a higher level of automated driving. With the results of this experiment it can be determined which attributes influence the level of automated driving.

4.3.5.4 Part 4 : Socio-demographic information

The socio-demographic factors that are questioned are gender, age education level and household situation, as described in table 4.4. The reason these are studied is because according to previous research they appear to have influence and because their link with automated driving is interesting to research. The reason to ask the socio-demographic characteristics of the respondents last, is because people are not always willing to give this information. When this is asked last, people have already filled in the information about driving which is crucial for the research. So when they decided to not further fill in the questionnaire the most vital part of the questionnaire is already filled in.

Gender	Age	Education level	Household situation
Male	Less than 25	No or primary education	Single person household
Female	25-39	Secondary education	Multiple person household with children
	40-54	Lower education (MBO)	Multiple person household without children
	55 or more	Higher education/university	Different

Table 1.4: Socio-demographic factors

Finally a comment section is made to provide the respondent to give feedback on the questionnaire. The comments that have been made will be displayed in appendix B**.**

4.4 Results

The questionnaire that was set up provides data that enables modelling the stated choice behaviour of the respondents. This chapter describes the data collection and the analysis of this data. Paragraph 4.4.1 describes the data collection approach of the experiment. Paragraph 4.4.2 continues by describing the descriptive analysis of the research sample. With these results, interesting user groups can be determined for the model analysis. In paragraph 4.4.3 the model analysis is described based on the ordinal regression method. Finally chapter 4.4.4 gives information about the results regarding the reduction factors.

4.4.1 Data collection

Several approaches are applied to invite respondents to this questionnaire. The first approach was to address the personal network. This was done via social media and directly e-mailing personal contacts. Another approach was to address the business network, in this case Grontmij. All the employees at Grontmij were approached via the company's internal communication network. The last approach was to distribute the questionnaire at the organization of Connekt, a business network of people with affection to mobility. These approaches resulted in 165 responses, whereof 130 questionnaires were completely filled in.

To determine the required sample size of the experiment several methods can be used. Literature indicates that there is not one clear rule for this. The sample size of conjoint studies varies greatly. In commercial studies the sample size usually ranges from 70 to 100 respondents. In hypothetical studies sample sizes less than 100 are typical. As always the sample size must be large enough to ensure the reliability of the experiment. The study of Xu & Yuan (2001) states that the sample size can be determined as followed:

((K-k)+1)) * ratio

Where
K is total number of parameters (sum of all attribute levels)
k is total number of attributes
ratio is the relation between the number of parameters and the number of respondents which is a value between 5 and 10

Within this experiment, *K* is 18 (6^3); *k* is 6; and *ratio* has a minimum of 5. Therefore, the desired minimal number of respondents is 65 (((18—6)+1)*5). The maximum value with a ratio of 10 is 130 (((18-6)+1)*10). In the present study, 130 complete questionnaires are obtained, which is sufficient to the rule of thumb. It is also assumed that this number is also sufficient to analyze the differences between different target groups (Xu & Yuan, 2001).

4.4.2 Descriptive analysis

This section describes information gathered from the data of the experiment. Information is presented about: how user characteristics are divided over the sample, the differences in familiarity with intelligent conform systems, the degree of influence several factors have on trust in automated driving and the behaviour of the vehicle users in respect to the traffic safety and the ecology. Additionally, a description is provided of which user groups are likely to prefer automated driving and which groups do not.

4.4.2.1 Description of the research sample

The results of this experiment are based on the answers from the 130 respondents, who filled in the entire questionnaire. The personal characteristics of the respondents were collected in the fourth part of the questionnaire. These characteristics of the respondents are illustrated in table 4.5.

Research Sample

Personal Characteristics	
Gender	
Male	77%
Female	23%
Age (Years)*	
<25	21%
25-39	30%
40-54	18%
>55	11%
Education*	
Primary education	1%
Secondary education	4%
Lower education	12%
Higher education/University	65%
Household Situation*	
Single person household	15%
Multiple person household with children	36%
Multiple person household without children	22%
Different household composition	9%

Driving Characteristics	
Drivers license	
Yes	98%
No	2%
Car ownership*	
Yes	76%
No	22%
Driving experience (Years)*	
>5	16%
5-19	43%
20-34	22%
35-49	16%
<50	1%
Kilometres a year*	
>10.000	26%
10.000-30.000	40%
<30.000	29%
Car primary transport option*	
Yes	68%
No	30%

Table 4.5: Characteristics of Research Sample

As can be concluded from table 4.5 Characteristics of research Sample, Males are highly represented. They are over-represented given the population in the Netherlands, which is divided into 50% male and 50% female (CBS, 2015). In this research sample, most respondents are aged between 25 and 39 years. This also explains the high education level of the research sample, because nowadays younger people are higher educated than they were in the past. The household situation consists mostly of multiple person households. Where households with children are more represented in the sample which is a good reflection of the total population of the Netherlands. The driving characteristics show that almost every respondent has a driver's license. Of these respondents 76% owns a car. The car is for 68% of the respondents the main transportation option. The driving experience of the respondents varies, but the main part of the research sample has driving experience between 5 and

* The total sample of the different characteristics is not always 100%. This is caused by rounding-off, or because respondents indicated that they did not know the answer to the question, or because they indicated that their suiting option was not in the option list.

19 years. This corresponds with the age of the respondents. The driving characteristics show that more than half of the respondents drive over 10.000 kilometres per year.

4.4.2.2 Driving Behaviour

Besides the description of the research sample, also insights are gained on the driving behaviour of the respondents. The behaviour is divided into two categories which are traffic safety and traffic ecology. The reason to explicitly use these two categories is that automated driving has the biggest positive influence on them, according to the literature. This can lead to interesting insights of potential improvements. In table 4.6 the results of the propositions regarding traffic safety are displayed.

Propositions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	No idea
I always follow the traffic rules	3	19	16	46	14	2
I am more confident when the traffic is uniform	3	21	37	33	4	2
I rather drive myself then be a passenger	4	12	28	28	26	2
Intelligent comfort systems improve my driving skills	4	2	12	24	38	20

Table 4.6: Propositions regarding traffic safety (answer in percentages)

The results of table 4.6, show that only 22% (strongly disagree 3% and disagree 19%) not always follows the traffic rules. Also 54% (strongly agree 26% and agree 28%) rather drives themselves instead of being a passenger. With the combination of these numbers it can be concluded that the respondents have the feeling that they are capable and reliable drivers. It is possible that this could lead to overestimating behaviour and eventually to traffic accidents.

The respondents also show that they do not necessarily feel more comfortable in a situation where the traffic is uniform. These results are concentrated at the neutral answer. But the respondents indicated clearly that intelligent comfort systems improve their driving skills. Over 50% indicates that intelligent comfort systems are stimulating their driving skills. Automated driving consist of these intelligent comfort systems, hereby it can be assumed that automated driving will improve the driving skills and behaviour even more.

Propositions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	No idea
I only drive my car when it is necessary	12	37	24	19	6	2
The effects of car use on the ecology are important for me	4	18	33	34	9	2
I am conscious of the fuel consumption when I drive	3	17	22	41	15	2
I pay more for a car when it is better for the ecology	11	26	31	25	4	3

Table 4.7: Propositions regarding traffic ecology (answer in percentages)

The results of table 4.7, show that the effects of driving on the ecology are important to the respondents. Only 22% (strongly disagree 4% and disagree 18%) disagree with this proposition. The effect might be important to the respondents but they don't only drive their car when it is necessary, only 25% (strongly agree 19% and agree 6%) is willing to do that. Also, more than half of the respondents (55%) are conscious about the fuel consumption of their car. This can be related to the costs of the fuel, because when the respondents are asked about paying more for a car that is better for the ecology, only 29% (strongly agree 4% and agree 25%) is willing to do that.

4.4.2.3 Intelligent comfort systems

Another important aspect to determine the relationship of the research sample with automated driving is the affection with intelligent comfort systems. The results of the behaviour propositions of the previous paragraph, shows that people are more comfortable while driving with intelligent comfort systems. In part 2 of the questionnaire eight different intelligent comfort systems were used to test the knowledge and the use of these systems by the respondents. The results concerning the intelligent comfort systems are displayed in table 4.8.

	Known	Used
Adaptive Distance Control	79	16
Forward Collision Warning	57	9
Speed Regulation System	52	15
Blind Spot Information System	53	14
Lane Departure Warning	61	15
Navigation system	95	92
Fuel Efficiency Advisor	65	54
Park Assist System	92	35
Average	69	31

Table 4.8: Intelligent comfort systems knowledge and usage (answer in percentages)

The results of table 4.8 Intelligent comfort systems knowledge and usage, show that the most commonly known intelligent comfort systems are the 'navigation system' and the 'park assist system'. When looked at the usage of these two systems, a big difference in usage can be found. The results also indicated that the 'speed regulation system' and 'blind spot information system' are the least known intelligent comfort systems. Concluded from these results it can be stated that the intelligent comfort systems are well know by the respondents, with an average of 69%. But the usage of these systems falls behind, with an average of 31%. The main reason for this can be that these systems are not commonly integrated into current vehicles.

4.4.2.4 Willingness to accept automated driving

Another important aspect is to determine the relationship of the research sample with the willingness to accept automated driving. The results of the knowledge and usage of intelligent systems, shows that most systems are well known but not used yet. Hereby it is important to know what the drawbacks are from the respondents. To get a better understanding of this situation two aspects are threated, which are the willingness to hand over driving tasks and factors that stimulate automated driving. In table 4.9 the results of the willingness to hand over driving tasks is shown.

Willingness to hand over driving tasks	Very low degree	Low degree	Neutral	High degree	Very high degree	No idea
Speed regulation	8	19	37	23	9	4
Route guidance	5	13	27	37	14	4
Steering	15	38	26	13	4	4

Table 4.9: Willingness to hand over driving tasks (answer in percentages)

The results of table willingness to hand over driving tasks, show that route guidance is the best scoring driving tasks to hand over to a system. 51% (high degree 37% and very high degree 14%) are certainly willing to handover this task. The results of speed regulation of the vehicle vary, with most answers that are concentrated around the neutral level. The results of the last driving task, steering, indicates that this driving task is not ready to hand over to a system. 53% (low degree 38% and very low degree 15%) are unwilling to hand over the steering task while driving. An explanation for these results can be the fact that route guidance systems are already well known by the people. This is in contrast with a system that takes over steering. It can be assumed that over time this driving task will also be more accepted to hand over, because it provides more comfort for the driver.

Factors that stimulate automated driving	Very low degree	Low degree	Neutral	High degree	Very high degree	No idea
Costs of automated driving	5	10	29	33	15	8
More information about automated driving	5	16	29	39	4	7
More tests concerning the reliability of automated driving	5	10	21	30	28	6
Other people who drive automated vehicles	7	20	32	24	11	6

Table 4.10: Factors that stimulate automated driving (answer in percentages)

The results of the factors that stimulate automated driving in table 4.10**,** show that the biggest factor to stimulate automated driving, for the respondents, is more tests about the reliability of automated vehicles. Also the costs of automated vehicles and more information about the phenomena itself are important to the respondents. The least important factor is if other people drive in automated vehicles. Concluded from these results it can be stated that automated driving is still not well know by the respondents. When there is more information and the benefits of automated driving are clearer, people are willing to embrace it more.

4.4.3 Model Analysis

The present research is based on the ordinal choice data that is gathered with the questionnaire. Ordinal choice data attempts to model the decision process of an individual or segment in a particular context. This leads to a situation where an alternative is chosen or is not chosen. This results into ordinal data (i.e. 0, 1, 2, 3, 4 or 5). The alternative that is chosen produces the highest level of utility, or the least amount of negative utility. In this case there is direct information about the order of preferences. With the repeated observations, enough information can be collected to analyze the preference formation.

To be able to estimate the preferred levels of attributes in the model, the attribute-levels were coded. There are two general ways to code this particular data, which are effect coding and dummy coding. For this case dummy coding is used to 'trick' the regression algorithm into correctly analyzing attribute variables. This coding is used because the different categories are based on ordinal scale which means that category 2 has not twice as much value as category 1.
Dummy coding means that *n* levels of attributes are coded by *n-1* indicator variables. The *n-1* levels are coded 1 on the corresponding indicators and coded 0 on all the other variables. The last *n* level is coded 0 for all the indicators. This coding only works with exclusive not overlapping attributes. In this case all the attributes have 3 levels which lead to the same coding system per attribute. Table 4.11 shows the dummy coding of the attributes for this experiment.

Attribute	Label	Level	Indicator 1	Indicator 2
Type of Road	Highway	1	0	0
	Main Road	2	1	0
	Local Road	3	0	1
Traffic Density	Low	1	1	0
	Medium	2	0	1
	High	3	0	0
Familiar with Route	Well known	1	1	0
	Partial known	2	0	1
	Unknown	3	0	0
Distance of Trip	<20 km	1	0	0
	20-100 km	2	1	0
	>100 km	3	0	1
Environment	High Urban	1	1	0
	Urban	2	0	0
	Rural	3	0	1
Passengers	2 or more	1	1	0
	1 passenger	2	0	1
	0 passengers	3	0	0

Table 4.11: Attributes with dummy coding

In this research, SPSS 22 was used to estimate the parameters of the preference models. With the results of the evaluation sets, the utility of each alternative can be estimated. For each attribute-level, parameter β can be estimated. To derive the part-worth utilities of the attribute-levels, the parameters are multiplied with the coded values which are determined in table 4.11. In table 4.12 the part-worth utility calculation for the attributes is displayed.

Attribute level	Indicator 1	Indicator 2	Derived part-worth utility
Level 1	1	0	$\beta_1 * 1 + \beta_2 * 0$
Level 2	0	1	$\beta_1 * 0 + \beta_2 * 1$
Level 3	0	0	$\beta_1 * 0 + \beta_2 * 0$

Table 4.12: Part-worth utilities

4.4.3.1 Ordinal regression model

This section of the chapter provides the ordinal-regression analysis of the data that was obtained in part 3 of the questionnaire. This is the data concerning the level of automated driving in a particular situation. The analysis of this data will be done with an ordinal regression model. First there is started to model all the data that was obtained from the questionnaire in the same model, which is named as general model. Some of the respondents that have filled in the questionnaire, might not have a good idea of automated driving. This could have lead to filled in questionnaires where every answer in each situation is the same. For this situation a refined model is made to separate this data from the sample. Finally, an aged based model is made to see the differences between the different age categories. For the models in this paragraph, a 90% confidence interval is used to identify the significant parameters. All the calculations and modeling tasks are executed with computer program SPSS 22. This program is used because it can explore different relations between questions and can handle ordinal regression data very well (University of Sheffield, 2012).

General model levels of automated driving

Model's goodness of fit

The general multinomial logit model is in this case a model which represents the user's preferences, assuming that the error terms (ε_i), are identically and independently distributed. As mentioned in chapter 3**,** the model goodness-of-fit needs to be tested. The results of the model fitting test can be find in table 4.13**.**

Model		**-2 Log Likelihood**	**Chi-Square**	**Df**	**Sig.**
Intercept only	LL_c	407.098			
Final	LL_M	387.642	19.456	0.12	0.078
Pseudo R^2	0,025				

Table 4.13: Model fitting information

The Pseudo R^2 value for the current model is 0,025, this means that the model is considered as weak, because the value is <0,1. For this research the value of 0,025 for Pseudo R^1 is accepted because this model provides meaningful information about the general preferences of drivers. The likelihood of the model is 387.642 and for the model with all parameters equal to 0 the value is 407.098. The likelihood ratio of this model is 19,456(D). This value must be compared to a chi-square statistic with a degrees of freedom of 0.12, equal to the number of parameters between the compared models this is approximated 18,5. When D is larger than the chi-square the ratio assumption is rejected, and the estimated model is preferred over the model restriction. If D is less than the chi-square, it cannot be concluded that the estimated model is better than the base model. In this case the model is better with a few constants. However, the model is limited in a position back to predict the observed behavior and thus acceptable in this case.

Parameter estimates

For the investigation of the preferences of the respondents, it is necessary to calculate the estimate value and the signification value of the attributes and the levels of automated driving. For each of the 3 levels from the attributes these values are calculated. Because dummy coding is used, 1 of the 3 levels is set to the value 0 and the other two levels are calculated relative to that level. The results are displayed in table 4.14.

Thresholds		**Estimate**	**Signification p<0.1**
Levels of automated driving	**Level 1**	-2.081	0.000
	Level 2	-0.740	0.001
	Level 3	0.334	0.142
	Level 4	1.092	0.000
	Level 5	2.011	0.000
Variables			
Traffic Density	**Low**	0	0
	Medium	0.076	0.626
	High	-0.126	0.412
Environment	**High Urban**	-0.033	0.827
	Urban	0	0
	Rural	0.058	0.713
Type of Road	**Highway**	0	0
	Main Road	-0.175	0.259
	Local Road	-0.390	0.012
Passengers	**2 or more**	-0.119	0.444
	1 passenger	0.151	0.334
	0 passengers	0	0
Distance of Trip	**<20 km**	0	0
	20-100 km	0.296	0.059
	>100 km	0.453	0.004
Familiarity with Route	**Well known**	0.105	0.504
	Partial known	0.062	0.686
	Unknown	0	0

Table 4.14: Parameters estimates

The results of parameters estimates in table 4.14, show that the levels of automated driving are all significant except for level 3. Because this value is slightly over the permitted value this will be ignored, because it is expected that this doesn't have an influence on the results. From the six attributes that are investigated only 'distance of trip' and 'type of road' have a value which is significant enough. Concluded from these results it can be say that the other four attributes don't have an effect on the level of automated driving. The part-worth utility and the indicator of the variables that are relevant for the research are shown in table 4.15.

Attributes	**Level**	**Indicator 1**	**Indicator 2**	**Part-worth Utility**
Type of Road	Highway	0	0	0
	Main Road	1	0	-0.175
	Local Road	0	1	-0.390
Distance of Trip	<20 km	0	0	0
	20-100 km	1	0	0.296
	>100 km	0	1	0.453

Table 4.15: Part-Worth Utility

The results of table 4.15 Part-Worth utility, display that the respondents are more willing to drive automated when the distance of the trip is longer. Also the respondents are more willing to drive on highways with an automated vehicle then on main and local roads. When these two aspects are combined it can be assumed that automated driving is desirable when people make long trips on uniform roads where the circumstances don't change that much.

When the values of the part-worth utility from both attributes are combined it can be determined which level of automated driving is desired in the particular situation. The combination of the part-worth utility values is given in table 4.16.

Attribute 1	Part-worth Utility	Attribute 2	Part-worth Utility	Total Part-worth Utility
Highway	0	<20 km	0	0
Highway	0	20-100 km	0.296	0.296
Highway	0	>100 km	0.453	0.453
Main Road	-0,175	<20 km	0	-0.175
Main Road	-0,175	20-100 km	0.296	0.121
Main Road	-0,175	>100 km	0.453	0.278
Local Road	-0,390	<20 km	0	-0.390
Local Road	-0,390	20-100 km	0.296	-0.094
Local Road	-0,390	>100 km	0.453	0.063

Table 4.16: Combined part-worth utility

With the results of table 4.16, it can be determined which level is desired in the every situation. The distribution of the levels of automated driving are displayed in figure 4.4, on the basis of the results of table 4.14 of the thresholds from the levels.

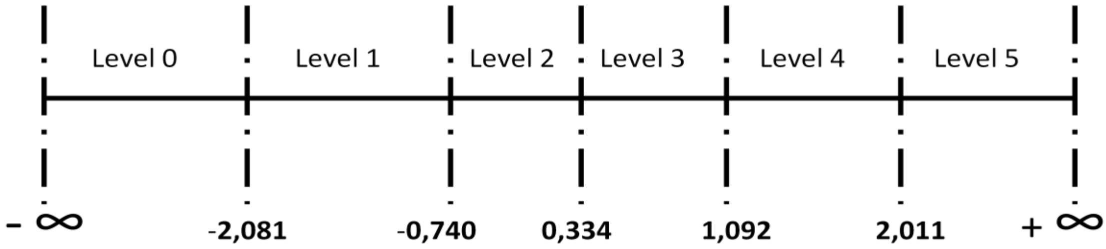

Figure 4.4: Distribution levels of automated driving

The results of table 4.16, show that the combination of the attributes 'highway' and '>100 km' have the highest part-worth utility with a value of 0,453. If this value is compared with figure 4.4, it can be stated that in this situation automation level 3 is desired. All the other combinations have values which are between the boundaries of level 2. So from these results it can be concluded that driving on a highway for more than 100 kilometres is the most desired situation for automated driving. When the values of the other attributes where significant these could be added up to these values to determine which situation overall has the highest level of automated driving.

<u>General model refined</u>

Some of the respondents that have filled in the questionnaire, might not have a good idea of automated driving. This could have lead to filled in questionnaires where every answer in each situation is the same. This leads to results that are not that useful for this research, because the effect of different attributes is tested. To investigate this, the results of the respondents that have filled every situation with the same level of automated driving are removed from the sample. This leads to a total of 105 filled in questionnaire that are used for this experiment. This part of the thesis describes the modelling process to investigate this proposition.

Model's goodness of fit

Also for this case the multinomial logit is used because this is a model which represents the user's preferences, assuming that the error terms (ε_i), are identically and independently distributed. As mentioned in chapter 3**,** the model goodness-of-fit needs to be tested. The results of the models fitting tests can be find in table 4.17**.**

Model		**-2 Log Likelihood**	**Chi-Square**	**Df**	**Sig.**
Intercept only	LL_c	388.616			
Final	LL_M	358.382	30.233	0.12	0.003
Pseudo R^2	0,047				

Table 4.17: Model fitness test refined model

The Pseudo R^2 value for the current model is 0,047, this means that the model is considered as weak, because the value is <0,1. For this research the value of 0,047 for Pseudo R^1 is accepted because this model provides meaningful information about the general preferences of drivers. The likelihood of the model is 358.382 and for the model with all parameters equal to 0 the value is 388,616. The likelihood ratio of this model is 30.233(D). This value must be compared to a chi-square statistic with a degrees of freedom of 0.12, equal to the number of parameters between the compared models this is approximated 18,5. When D is larger than the chi-square the ratio assumption is rejected, and the estimated model is preferred over the model restriction. If D is less than the chi-square, it cannot be concluded that the estimated model is better than the base model. In this case the model is better with a few constants. However, the model is limited in a position back to predict the observed behaviour and thus acceptable in this case.

Parameter estimates

For the investigation of the preferences of the respondents, it is necessary to calculate the estimated value and the signification value of the attributes and the levels of automated driving. For each of the 3 levels from the attributes these values are calculated. Because dummy coding is used, 1 of the 3 levels is set to the value 0 and the other two levels are calculated relative to that level. The results are displayed in table 4.18.

Thresholds		Estimate	Signification p<0,1
Levels of automated driving	**Level 1**	-2.088	0.000
	Level 2	-0.767	0.003
	Level 3	0.412	0.104
	Level 4	1.265	0.000
	Level 5	2.441	0.000
Variable			
Traffic Density	**Low**	0	0
	Medium	0.107	0.536
	High	-0.275	0.110
Surrounding Environment	**High Urban**	0.005	0.975
	Urban	0	0
	Rural	0.034	0.847
Type of Road	**Highway**	0	0
	Main Road	-0.238	0.171
	Local Road	-0.468	0.007
Passengers	**2 or more**	-0.226	0.193
	1 passenger	0.136	0.435
	0 passengers	0	0
Distance of Trip	**<20 km**	0	0
	20-100 km	0.436	0.003
	>100 km	0.675	0.000
Familiar with Route	**Well known**	0.029	0.869
	Partial known	0.023	0.893
	Unknown	0	0

Table 4.18: Parameters estimates refined model

The results of parameters estimates refined model in table 4.18, show that the levels of automated driving are all significant except for level 3, bit this value is negligible. From the six attributes that are investigated only 'distance of trip', 'type of road' and 'traffic density' have values which are significant enough. Concluded from these results it can be say that the other three attributes do not have an effect on the level of automated driving. The part-worth utility and the indicator of the variables there are relevant for the research are shown in table 4.19.

Attributes	Level	Indicator 1	Indicator 2	Part-worth Utility
Type of Road	Highway	0	0	0
	Main Road	1	0	-0.238 (-0.175)
	Local Road	0	1	-0.468 (-0.390)
Distance of Trip	<20 km	0	0	0
	20-100 km	1	0	0.436 (0.296)
	>100 km	0	1	0.675 (0.453)
Traffic Density	Low	1	0	0
	Medium	0	1	0.107
	High	0	0	-0.275

Table 4.19: Part-worth utility refined model

The results of table 4.19 part-worth utility refined model, show that with the refined model also the attributes 'type of road' and 'distance of trip' have influence on the behaviour of the respondents. The values of the normal model are between brackets. When comparing these results, it can be concluded that the refined model values strengthens the assumptions that were made. This means that the respondents are more willing to give over the control when they are on a highway, in comparison with local and main roads. Also it is confirmed that how longer the trip is, how more the respondents are willing to drive automated. In the refined model another attribute shows influence on the behaviour, this attribute is 'traffic density'. The results show that with a higher traffic density the respondents are not willing to give over control. Assumed could be that the driver wants control in difficult situations because there is no trust in the system reliability of the vehicle.

When the values of the part-worth utility from the three attributes are combined it can be determined which level of automated driving is desired in the particular situation. The combination of the part-worth utility values is given in table 4.20.

Attribute 1	**Part-worth Utility**	**Attribute 2**	**Part-worth Utility**	**Attribute 3**	**Part-worth Utility**	**Total Part-worth Utility**
Highway	0	<20 km	0	Low	0	0
Highway	0	20-100 km	0.296	Low	0	0.296
Highway	0	>100 km	0.453	Low	0	0.453
Highway	0	<20 km	0	Medium	0.107	0.107
Highway	0	20-100 km	0.296	Medium	0.107	0.403
Highway	0	>100 km	0.453	Medium	0.107	0.560
Highway	0	<20 km	0	High	-0.275	-0.275
Highway	0	20-100 km	0.296	High	-0.275	0.021
Highway	0	>100 km	0.453	High	-0.275	0.178
Main Road	-0,175	<20 km	0	Low	0	-0.175
Main Road	-0,175	20-100 km	0.296	Low	0	0.121
Main Road	-0,175	>100 km	0.453	Low	0	0.278
Main Road	-0,175	<20 km	0	Medium	0.107	-0.068
Main Road	-0,175	20-100 km	0.296	Medium	0.107	0.228
Main Road	-0,175	>100 km	0.453	Medium	0.107	0.385
Main Road	-0,175	<20 km	0	High	-0.275	-0.450
Main Road	-0,175	20-100 km	0.296	High	-0.275	-0.154
Main Road	-0,175	>100 km	0.453	High	-0.275	0.003
Local Road	-0,390	<20 km	0	Low	0	-0.390
Local Road	-0,390	20-100 km	0.296	Low	0	-0.096
Local Road	-0,390	>100 km	0.453	Low	0	0.063
Local Road	-0,390	<20 km	0	Medium	0.107	-0.283
Local Road	-0,390	20-100 km	0.296	Medium	0.107	0.013
Local Road	-0,390	>100 km	0.453	Medium	0.107	0.170
Local Road	-0,390	<20 km	0	High	-0.275	-0.665
Local Road	-0,390	20-100 km	0.296	High	-0.275	-0.396
Local Road	-0,390	>100 km	0.453	High	-0.275	-0.212

Table 4.20: Combined part-worth utility refined model

With the results of table 4.20, it can be determined which level is desired in the every situation. The distribution of the levels of automated driving are displayed in figure 4.5, on the basis of the results of table 4.18 of the thresholds from the levels.

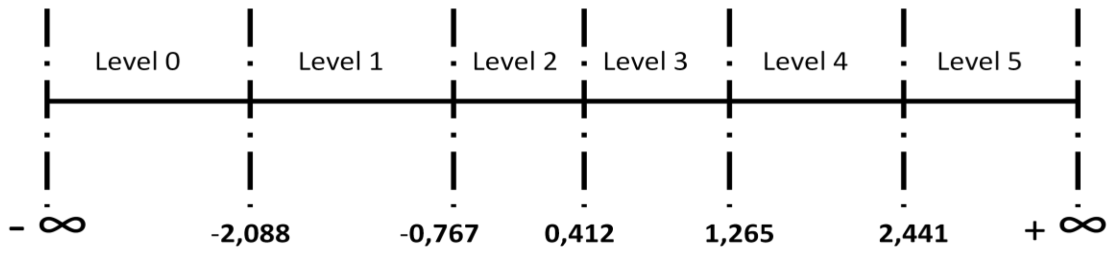

Figure 4.5: Distribution levels of automated driving refined model

The results of table 5.16, show that the combination of the attributes 'Highway', '>100 km' and 'Medium traffic density' have the highest part-worth utility with a value of 0,560. If this value is compared with figure 4.5, it can be stated that in this situation automation level 3 is desired. The only other combination that falls into the category of automated driving level 3 is the composition of the attributes 'Highway', '>100km'and 'Medium traffic density'. The results of table 5.15 also show that the combination of the attributes 'Local Road', '<20km' and 'High traffic density' has the lowest value with -0.665. This value corresponds with level 2 of automated driving according to figure 4.5. All other combination are corresponding with level 2 of automated driving. When the values of the other attributes where significant these could be added up to these values to determine which situation overall has the highest and lowest level of automated driving.

<u>Preferences in combination with gender</u>

Because males and females have different mindsets about driving it is interesting to see the differences in willingness to accept automated driving. This part describes the modelling process to investigate this proposition. For this case the dataset of the refined model is used. The reason for this is that the data from this model provides values with higher signification.

Model's goodness of fit

Also for this case the multinomial logit is used because this is a model which represents the user's preferences, assuming that the error terms (ε_i), are identically and independently distributed. As mentioned in chapter 3**,** the model goodness-of-fit needs to be tested. The results of the models fitting tests can be find in table 4.121. The results are split between the male model and the female model.

Model Male		**-2 Log Likelihood**	**Chi-Square**	**Df**	**Sig.**
Intercept only	LL_c	362.013			
Final	LL_M	329.850			
Pseudo R^2	0.066		32.162	12	0.001
Model Female		**-2 Log Likelihood**	**Chi-Square**	**Df**	**Sig.**
Intercept only	LL_c	217.087			
Final	LL_M	212.335			
Pseudo R^2	0.030		4.752	12	0.996

Table 4.21: Model fitting information male and female model

The Pseudo R^2 value of the male model is 0.066 and for the female model 0.030, this means that both models are considered as weak because the value is <0,1. These values will be accepted for this case because these models can provide meaningful information about the general preferences of driving males and females.

The likelihood of the male model is 329.850 and for the model with all parameters equal to 0 the value is 362.013. The likelihood ratio of this model is 32.162(D). This value must be compared to a chi-square statistic with a degrees of freedom of 0.12, equal to the number of parameters between the compared models this is approximated 18,5. When D is larger than the chi-square the ratio assumption is rejected, and the estimated model is preferred over the model restriction. If D is less than the chi-square, it cannot be concluded that the estimated model is better than the base model. In this case the model is better with a few constants. However, the model is limited in a position back to predict the observed behaviour and thus acceptable in this case.

The likelihood of the female model is 212.335 and for the model with all parameters equal to 0 the value is 217.087. The likelihood ratio of this model is 4.752(D). This value must be compared to a chi-square statistic with a degrees of freedom of 0.12, equal to the number of parameters between the compared models this is approximated 18,5. In this case D is smaller than 18,5 this in combination with the signification value of 0.996 it is determined to not take this model into account. The reason for this is that the values of this model are not reliable.

Parameter estimates

For the investigation of the preferences of the male respondents, it is necessary to calculate the estimate value and the signification value of the attributes and the levels of automated driving. For each of the 3 levels from the attributes these values are calculated. Because dummy coding is used, 1 of 3 levels is set to the value of 0 and the other two levels are calculated relative to that level. The results of the male model are displayed in table 4.22.

Thresholds		Estimate	Signification p<0,1
Levels of automated driving	**Level 1**	-2.098	0.000
	Level 2	-0.782	0.008
	Level 3	0.365	0.214
	Level 4	1.150	0.000
	Level 5	2.329	0.000
Variable			
Traffic Density	**Low**	0	0
	Medium	0.238	0.238
	High	-0.279	0.160
Surrounding Environment	**High Urban**	-0.017	0.932
	Urban	0	0
	Rural	0.086	0.670
Type of Road	**Highway**	0	0
	Main Road	-0.382	0.061
	Local Road	-0.599	0.003
Passengers	**2 or more**	-0.279	0.346
	1 passenger	0.191	0.162
	0 passengers	0	0
Distance of Trip	**<20 km**	0	0
	20-100 km	0.493	0.015
	>100 km	0.751	0.000
Familiar with Route	**Well known**	0.046	0.822
	Partial known	0.054	0.787
	Unknown	0	0

Table 4.22: Parameters estimates male model

The results of parameters estimates male model in table 4.22, show that the levels of automated driving are all significant except for level 3, bit this value is negligible. From the six attributes that are investigated only 'distance of trip' and 'type of road' have values which are significant enough. Concluded from these results it can be say that the other four attributes do not have an effect on the level of automated driving. The part-worth utility and the indicator of the variables there are relevant for the research are shown in table 4.23.

Attributes	Level	Indicator 1	Indicator 2	Part-worth Utility
Type of Road	Highway	0	0	0
	Main Road	1	0	-0.382
	Local Road	0	1	-0.599
Distance of Trip	<20 km	0	0	0
	20-100 km	1	0	0.493
	>100 km	0	1	0.751

Table 4.23: Part-worth utility male model

The results of table 4.23, indicate that also for this case the highest values were found for driving on a highway and for a trip length from over 100 kilometres. When these results are compared with the refined model it can be seen that there is 1 attribute less significant. This means that the female drivers are more influenced by this attributes which was 'traffic density'. There is chosen not to go further with these results in terms of determining which level of automated driving is corresponding to the different combination of attributes. The reason for this is that the results will be the same because of the results that are similar to the previous models.

4.4.4 Reduction factors

Now it is clear which attributes are important for the willingness to drive automated, the last step of the analysis is to investigate which factors stimulate automated driving. In the questionnaire is asked which factor would stimulate the driver to select a higher level of automated driving. There were three factors which must be rated: cost reduction, fuel reduction and travel time reduction. In table 4.24 the results of these reduction factors are showed.

Cost reduction	
Low degree	22%
Average degree	39%
High degree	38%
No opinion	1%
Fuel reduction	
Low degree	23%
Average degree	40%
High degree	36%
No opinion	1%
Travel time reduction	
Low degree	19%
Average degree	34%
High degree	45%
No opinion	2%

Table 4.24: Reduction factors

The results of table 4.24 reduction factors, show that these three factors all stimulate a higher level of automated driving. Only about 20% of respondents says at each factor that it only has a low degree of influence. The results show that especially time travel reduction will influence a higher level of automated driving.

Preferences in term of ages

It is also interesting to investigated if the results of the reduction factors are different in terms of age. There is chosen not to investigated this in terms of gender because there were not that many female respondents and as shown in the earlier analysis are these results not significant. In terms of age it is interesting to see which age categories are more triggered by these reduction factors. In table 4.25 the results of the reduction factors in terms of age are displayed.

Cost reduction	<25 years	25-39 years	40-55 years	>55 years
Low degree	18%	24%	28%	22%
Average degree	37%	32%	46%	43%
High degree	44%	42%	25%	35%
No opinion	1%	2%	1%	0%
Fuel reduction				
Low degree	17%	26%	26%	22%
Average degree	35%	37%	52%	36%
High degree	47%	35%	21%	42%
No opinion	1%	2%	1%	0%
Travel time reduction				
Low degree	12%	18%	25%	23%
Average degree	33%	32%	26%	55%
High degree	54%	47%	47%	22%
No opinion	1%	3%	2%	0%

Table 4.25: Reduction factors in terms of age

The results of table 4.25 reduction factors in terms of age, show that in particular the age category <25 years is influenced by these reduction factors. Cost, fuel and travel time reduction will stimulate this category to except a higher level of automated driving. The age category 25-39 years, is divided with the cost and fuel reduction factors. But is positive when there is a travel time reduction. The results of the age category 40-55 years show that cost and fuel reduction does not have a big influence. In contrast travel time reduction has a big influence on the acceptance of a higher level of automated driving. A reason that cost and fuel reduction are not that big of a factor in this age category is that these people have a company car which means they don't have to make costs when driving. The last age category >55 years, have similar results with age category 40-55 years. But the travel time reduction factor results show that this also influences the respondents with an average degree.

4.4.5 Conclusion

The experiment is based on the findings of the personal and physical environment of the driver. These aspects are translated into attributes. These attributes are rated with the use of the levels of automated driving. The retrieved data from the experiment provides insight in the desires of drivers regarding the level of automated driving in a particular situation. In this case there are three models made, which is a general model, a refined model, and a gender based model.

The general model indicates that there are two attributes that have the biggest influence on the choose of the level of automated driving. These two attributes are 'Type of Road' and 'Length of Trip'. The results show that on highways and longer travel distances the desired level of automated driving is the highest. The results also indicate that driving on a local road for a short trip, the desired level of automated driving is the lowest.

The refined model has the same results as the general model regarding to the attributes 'Length of Trip' and 'Type of Road'. But the refined model shows that the attribute 'Traffic Density' also has an influence on the respondents' choice. When there is a high traffic density the driver is less willing to choose a higher level of automated driving. The highest value for this attribute is when the traffic density is medium. The most preferred situation for the respondent to drive automated is when there are on a highway for more than 100 kilometres and when the traffic density is medium.

The results of the gender based model show that the female model is not significant enough to take into account. The male model shows the same results as the general model. The values of the male model are higher, which means that the statement of driving on a highway for more than 100 kilometres is the most optimal situation.

The results of the other parts of the questionnaire show that the respondents are more willing to drive automated when this reduces the travel time. Also costs are important to stimulate automated driving. Another major factor is the lack of information regarding automated driving and the reliability. In general the opinion is that the respondents want more guarantees before they will drive in automated vehicles.

5 Conclusions and recommendations

This chapter presents the conclusion of the results of the research which is the answer to the research question. First the sub-research questions will be answered and thereafter the main research question. In the second part of this chapter recommendations regarding the results are made.

5.1 Conclusions

Automated driving has a positive impact on several socio-economic aspects within the society. To implement automated driving two main aspects need to adjust. First there is the environment to make it possible to let automated vehicles drive on public roads. The second and most important factor is the user. In this research the user's role regarding automated driving was studied. Literature shows that there is almost no information about which level of automated driving is desired. To investigate this proposition first the sub-questions will be answered, in order to give insights in the desired level of automated driving, which is the main question of the research.

Which levels of automated driving can be defined?

Different organisations have provided a categorization of the different levels of automated driving. Two organisations have provided a categorization which is most commonly used. Those organizations are the National Highway Safety Traffic Safety Administration (NHTSA) and Society of Automotive Engineers (SAE) International. The similarities between the arrangements of the categories are very high. There is one main difference which is that the SAE International did include an extra category for fully automation, which in this case is divided in a category where the system's capability can be classified as for some driving modes or for all driving modes. In this thesis the analogy of the SAE International is used because these categories provide an extra layer which is important for the user perception and are also understandable for non-experts. The levels of automated driving are rated from level 0 to level 5, where level 0 is no automation and level 5 is fully automated.

Which different physical environments exist for the vehicle users?

Literature indicates that traffic consist of three different aspects, which are the driver, the vehicle, and the environment. Each of these aspects has interaction with each other. With the introduction of automated driving the tasks of the driver will be reduced. While performing a task like driving, there are several sub-tasks that have to be done which is more an act of routine. This requires less conscious thought than other sub-tasks. If there is not an implicit or explicit plan, there is also no goal to achieve. Intentions control our actions but not all of these intentions are carried out. The reason for this is that some of these actions are abandoned and some of them are revised to fit the changing circumstances. Important is that not the physical reality decides the behaviour of a driver, but the perceived information. This information can be obtained from the environment where the driver is. The environment of the driver can be divided into two different kinds of environments, which are the physical and the personal environment. The physical environment consists of three main parts for this research which are the type of road, the traffic density, and the surrounding area. Each of these parts can be further specified to make a clear distribution. For the aspect type of road, there are in the Netherlands three main types. Which are the highways, main roads, and local roads. To determine the traffic density, three levels are specified which are high, normal, and low. Finally for the surrounding area, there are also three levels determined. Which in this case are rural, urban and high urban.

Which different personal environments exist for the vehicle users?

As mentioned in the previous sub-question, the environment of the driver also exists in a personal environment. This part of the environment has three main parts which were included in this research. These parts are the passengers, length of the trip, and the familiarity with the route. Also these aspects are divided into three categories. For passengers it is 0, 1 or 2or more passengers. The length of trip can be divided into 0-20km, 20-100km, and +100km. Finally familiarity with the route can be divided into unknown, well-known, and partially known. Another aspect of the personal environment of the driver are the personal characteristics. Because there is a difference in the driving behaviour of males and females. Another important personal characteristic is the age of the driver. Because more experienced drivers will react different to particular situations.

In what kind of 'environment' is which level of automated driving desirable to the willingness of different vehicle user groups?

The answer of this question is based on the choice experiment of the research. The experiment is based on the findings of the personal and physical environment of the driver. These aspects are translated into attributes. These attributes are rated with the use of the levels of automated driving. The retrieved data from the experiment provides insight in the desires of drivers regarding the level of automated driving in a particular situation. In this case there are three models made, which is a general model, a refined model, and a gender based model.

The general model indicates that there are two attributes that have the biggest influence on the choose of the level of automated driving. These two attributes are 'Type of Road' and 'Length of Trip'. The results show that on highways and longer travel distances the desired level of automated driving is the highest. The results also indicate that driving on a local road for a short trip, the desired level of automated driving is the lowest.

The refined model has the same results as the general model regarding to the attributes 'Length of Trip' and 'Type of Road'. But the refined model shows that the attribute 'Traffic Density' also has an influence on the respondents' choice. When there is a high traffic density the driver is less willing to choose a higher level of automated driving. The highest value for this attribute is when the traffic density is medium. The most preferred situation for the respondent to drive automated is when there are on a highway for more than 100 kilometres and when the traffic density is medium.

The results of the gender based model show that the female model is not significant enough to take into account. The male model shows the same results as the general model. The values of the male model are higher, which means that the statement of driving on a highway for more than 100 kilometres is the most optimal situation.

The results of the other parts of the questionnaire show that the respondents are more willing to drive automated when this reduces the travel time. Also costs are important to stimulate automated driving. Another major factor is the lack of information regarding automated driving and the reliability. In general the opinion is that the respondents want more guarantees before they will drive in automated vehicles.

In short, it can be concluded that the following attributes regarding the environment have the biggest influence on the level of automated driving:

- Type of road
- Length of trip
- Traffic density

5.2 Recommendations

Several stakeholders have stakes regarding automated driving. For example there are vehicle manufactures who want to get a market share by designing automated vehicles. On the other hand there is the Dutch government, which want to have a leading role in the implementation of automated driving. In this part of the chapter, recommendations are made to these two groups regarding the implementation of automated driving in the Netherlands.

Car manufactures

The results from the questionnaire indicate that people are willing to drive into automated vehicles. They are willing to give over driving tasks as route-guidance and speed regulation. But the willingness to give over steering is not that high. A reason for this is that people still want to keep control over the vehicles because there is no trust in the intelligent comfort systems. Over the last years speed regulation is just became normal to give over to a system. People want to see if these systems are truly reliable before they will use them. This means that fully automated vehicles cannot be implemented straight away. Because people are more comfortable when systems take over driving tasks step by step. When there is prove of a system that works, other systems can be introduced to make the next step to a fully automated vehicle.

Policy makers

The best environment to implement automated driving is on highways according to the results of the choice experiment. But the question is of highways are ready to facilitate automated vehicles. Therefore, the government needs to study what changes are needed to provide the needed infrastructure for these vehicles. Another issue that the government need to tackle is the legal system. Because it is not legal to drive a fully automated vehicle on a public road. There are tests allowed on public roads these days. On the basis of the results of these tests the government can decided what needs to change to implement automated vehicles. The results of the choice experiment show that the combination of highways and long distances the most preferred options is. This combination is most common in the transportation sector. Therefore, the advice is to take this group of vehicle user to start with the implementation of automated vehicles.

6 Discussion

In this part of the research, the findings are discussed. The results in the light of previous research are explained. Additionally, this chapter provides limitations of the research and opportunities for further research.

Not much research is done regarding vehicle user preferences of automated driving. Literature indicates that are differences between the behaviour of males and females. The results of the models that were used in this research show that there are not any differences between genders regarding automated driving. Also literature indicates that people use intelligent comfort systems when driving. But the results of the questionnaire show that this is not the case. When the results of the choice experiment are compared with the results of the study of Megens (2014). The proposition that automated driving is most desired on highways can be confirmed. Also the results indicate that level 3 is the highest preferred level of automated driving in this situation. This confirms the statement of Megens (2014) that partial automation is the most desired.

There are some limitations of this research concerning the respondent's sample. Only people that possess a passenger vehicle driver's license are taken in account for the experiment. This was due to the fact that for people who do not own a driving license it is very hard or impossible make a solid choice concerning their driving preferences. However, when fully automated driving is enabled on Dutch roads, it may also be possible that people without driving experience can use an automated vehicle. Their preferences could influence the results.

Another limitation of the research is the signification level of some attributes. In the modelling process it came forward that only 2 attributes had the required signification level. Because of this, it was not possible to determine the perfect situation for automated driving. A reason for the signification level of the other attributes can be the number of respondents. When there are more respondents, it is most likely that the signification level will be better. Another reason for this can be the dummy coding that was used. Maybe if effect doing is used the signification level of the other attributes will be better.

Furthermore, with this research insights are gained in which situation users are willing to release control. Also is examined how factors as costs and travel time influence the level of automated driving. These results can be a guideline to do further research of environmental implications.

This thesis showed how vehicle-users perceived automated driving on different levels and with different driving circumstances. The proposed recommendations can be used as guidelines to work to a successful implementation of automated driving.

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8 Appendices

Appendix A – Questionnaire

Rijbewijs

(Readonly)

Bent u in het bezit van het rijbewijs B (autorijbewijs)?

- (•) Ja
- ( ) Nee

[Vorige] [Volgende]

Berg Enquête System © 2007 Design Systems

Deel 1: Rijervaring en -gedrag

(Readonly)

Bent u in het bezit van een auto?

- ( ) Ja
- (•) Nee

Hoeveel kilometer rijdt u per jaar?

- ( ) Minder dan 10.000 kilometer
- ( ) 10.000 - 30.000 kilometer
- (•) Meer dan 30.000 kilometer
- ( ) Weet ik niet

Hoeveel jaar rijervaring heeft u?

- ( ) Minder dan 5 jaar
- ( ) 5 - 19 jaar
- (•) 20 - 34 jaar
- ( ) 35 - 49 jaar
- ( ) 50 jaar of meer
- ( ) Weet ik niet

Is de auto uw voornaamste vervoermiddel?

- ( ) Ja
- (•) Nee

[Vorige] [Volgende]

Berg Enquête System © 2007 Design Systems

Deel 1: Rijervaring en -gedrag

(Readonly)

In hoeverre bent u het eens met de volgende stellingen omtrent verkeersveiligheid?

	Zeer oneens	Oneens	Neutraal	Eens	Zeer eens	Weet niet / geen mening
Ik houd me altijd aan de verkeersregels.	◉	○	○	○	○	○
Ik voel me zekerder wanneer de samenstelling van het verkeer uniform* is.	◉	○	○	○	○	○
Ik bestuur liever zelf de auto dan dat ik met iemand meerijd.	◉	○	○	○	○	○
Intelligente comfortsystemen** bevorderen mijn rijgedrag.	◉	○	○	○	○	○

* Hetzelfde soort verkeer, bv. alleen auto's
** bv. cruise control, park assist, navigatie etc.

In hoeverre bent u het eens met de volgende stellingen omtrent milieubewustzijn?

	Zeer oneens	Oneens	Neutraal	Eens	Zeer eens	Weet niet / geen mening
Ik rijd alleen met de auto als het echt nodig is.	◉	○	○	○	○	○
Ik vind het effect van autorijden op het milieu belangrijk.	◉	○	○	○	○	○
Ik ga bewust om met het brandstofverbruik tijdens het rijden.	◉	○	○	○	○	○
Ik wil meer voor een auto betalen als deze milieuvriendelijker is.	◉	○	○	○	○	○

Vorige | **Volgende**

Deel 2: Intelligente comfortsystemen

(Readonly)

Van welke van de volgende intelligente comfortsystemen heeft u weleens gehoord?

- [ ] Adaptive Distance Control
  systeem houdt een bepaalde snelheid en afstand tot andere auto's en past deze automatisch aan wanneer nodig.
- [ ] Forward Collision Warning
  systeem helpt om botsingen te voorkomen of de effecten te verminderen.
- [ ] Speed Regulation System
  systeem past snelheid aan aan de toegestane maximale snelheid of ingegeven gewenste snelheid.
- [ ] Blind Spot Information System
  systeem detecteert wanneer een ander voertuig zich in de dode hoek van de bestuurder bevindt.
- [ ] Lane Departure Warning / Lane Keeping Assist
  systeem helpt de bestuurder om een goede positie op de rijweg te behouden.
- [ ] Navigatiesysteem
  systeem biedt informatie over locatie en routebegeleiding.
- [ ] Fuel Efficiency Advisor
  systeem biedt informatie over het verbruik van brandstof.
- [ ] Park Assist System
  systeem helpt met het inparkeren van de auto.

Vorige | **Volgende**

Deel 2: Intelligente comfortsystemen

(Readonly)

Van welke intelligente comfortsystemen heeft u ooit gebruik gemaakt?

- [x] Adaptive Distance Control
  systeem houdt een bepaalde snelheid en afstand tot andere auto's en past deze automatisch aan wanneer nodig.
- [ ] Forward Collision Warning
  systeem helpt om botsingen te voorkomen of de effecten te verminderen.
- [x] Speed Regulation System
  systeem past snelheid aan aan de toegestane maximale snelheid of ingegeven gewenste snelheid.
- [x] Blind Spot Information System
  systeem detecteert wanneer een ander voertuig zich in de dode hoek van de bestuurder bevindt.
- [ ] Lane Departure Warning / Lane Keeping Assist
  systeem helpt de bestuurder om een goede positie op de rijweg te behouden.
- [x] Navigatiesysteem
  systeem biedt informatie over locatie en routebegeleiding.
- [x] Fuel Efficiency Advisor
  systeem biedt informatie over het verbruik van brandstof.
- [x] Park Assist System
  systeem helpt met het inparkeren van de auto.

Vorige | **Volgende**

Deel 2: Intelligente comfortsystemen

(Readonly)

In welke mate bent u bereid de volgende rijtaken over te dragen?

	Zeer lage mate	Lage mate	Gemiddelde mate	Hoge mate	Zeer hoge mate	Weet niet / geen mening
Snelheidsregulering	○	●	○	○	○	○
Route-bepaling	○	●	○	○	○	○
Stuurtaken	○	●	○	○	○	○

Wat beïnvloedt uw bereidheid om gebruik te maken van een autonome auto?

	Zeer lage mate	Lage mate	Gemiddelde mate	Hoge mate	Zeer hoge mate	Weet niet / geen mening
Kosten voor het gebruik van autonoom rijden.	●	○	○	○	○	○
Meer informatie over het gebruik en de effecten van autonoom rijden.	●	○	○	○	○	○
Het aantal toetsingen en de betrouwbaarheid van het autonoom rijden.	●	○	○	○	○	○
Andere mensen om mij heen die autonoom rijden.	●	○	○	○	○	○

Vorige | **Volgende**

Deel 3: Rijsituaties (voorbeeldvraag)

(Readonly)

Welke niveau van autonomiteit heeft uw voorkeur met betrekking tot de gegeven situatie?

Hieronder staat een voorbeeldvraag. Het is de bedoeling dat u eerst aangeeft welke mate van autonomiteit u gegeven de omstandigheden wenst. Vervolgens wordt gevraagd om aan te geven in welke mate de genoemde factoren u zouden stimuleren om een hoger niveau van autonomiteit te kiezen.

rij-situatie

Landelijke omgeving
Snelweg
Rit van 20-100 km
Gemiddelde verkeersdrukte
Bekend met de route
Geen passagiers

Level 0	○	Geen autonomiteit
Level 1	○	Bestuurdersondersteuning
Level 2	○	Deels autonomiteit
Level 3	●	Conditionele autonomiteit
Level 4	○	Hoge autonomiteit
Level 5	○	Volledig autonoom

In welke mate zouden de volgende factoren invloed hebben op een hoger niveau van autonomiteit van de bovenstaande situatie?

	Geringe mate	Gemiddelde mate	Hoge mate	Geen mening
Kostenreductie	○	●	○	○
Brandstofreductie	○	●	○	○
Reistijdredutie	○	●	○	○

Op de volgende pagina's zijn nog zes rij-situaties waarvoor uw oordeel wordt gevraagd.

Vorige | **Volgende**

Deel 4: Persoonlijke kenmerken

(Readonly)

Wat is uw geslacht?

- Man
- Vrouw

Wat is uw leeftijd?

- Jonger dan 25 jaar
- 25 - 39 jaar
- 40 - 54 jaar
- 55 jaar of ouder

Wat is uw hoogst genoten opleiding?

- Geen, lager- of basisonderwijs
- Voortgezet onderwijs
- Middelbaar beroepsonderwijs
- Hoger beroepsonderwijs of universiteit

Wat is de samenstelling van uw huishouden?

- Eenpersoonshuishouden
- Meerpersoonshuishouden met kind(eren)
- Meerpersoonshuishouden zonder kinderen
- Anders

Vorige | **Volgende**

Afsluiting

(Readonly)

Heeft u naar aanleiding van deze vragenlijst nog opmerkingen en/of suggesties?

Zodra u op volgende drukt zal de enquête worden afgesloten en wordt u doorverwezen naar de site van Grontmij.

Vorige | **Einde Enquête**

Appendix B – Comments on questionnaire

- Een rit over lokale (hoogstedelijke) wegen van meer dan 100km? Een dergelijk gebied ken ik nog niet in Nederland.
- Ik ben fervent gebruiker van cruise control en snelheidsbegrenzer. Een aantal van de andere huidige systemen ken ik wel, maar heb ik niet tot mijn beschikking. Nut van hoge autonomiteit herken ik zeker, maar het zou alleen werken als iedereen het zou doen. Systemen zijn altijd defensiever dan bestuurders en dat leidt tot 'achterstanden'.
- Is er geen tussenvorm van autonomie waarbij de bestuurder stuurt, snelheid regelt en de omgeving monitort. En dat het systeem in kan grijpen? Dit zal dan het tegenovergestelde zijn van Conditionele autonomiteit.
- De rijsituaties betrekken de invloed van de bestuurder op de medepassagiers mijn insziens niet op de juiste wijze. De mate van 'autonoom rijden' is voor mij bepalend hoeveel passagiers ik bij mij heb. Ik als uiteindelijke bestuurder ben altijd voor hen verantwoordelijk. Gevolg: passagiers bij in de auto, niet autonoom rijden. Alleen in de auto, dan wel autonoom rijden.
- Vragen met 6 situaties zijn niet goed, verschillen te klein tussen situatie. Ik heb 1 mening over autonoom rijden, maakt daarbij niet uit of het nu een rit van 10 of 20 km is.
- Mij valt op dat gevraagd wordt naar de omstandigheden waarin autonoom rijden wel/niet gewenst is. Wat mij betreft zijn deze omstandigheden minder van belang, maar gaat het om de tijdwinst (onderweg wat anders doen) die autonoom rijden biedt. Bv. wel of geen passagiers, (on)bekende route, maakt mij daarbij niet uit. Daarmee zijn voor mij relevante factoren: veiligheid, kosten, tijdwinst.
- succes met je onderzoek! Tip: probeer de matrix bij elke vraag te zetten, dan ga je betere (eerlijkere) antwoorden krijgen. Nu moet je telkens terug klikken en dat kan aanleiding geven om gewoon maar iets te klikken.
- Succes met je onderzoek - maak je je resultaten bekend binnen Grontmij?
- Er wordt alleen gesproken over auto's. Maar worden de zachter weg gebruikers hierin niet vergeten ?. Alle verhalen die ik lees over dit onderwerp mist in mijn ogen de nodig aandacht daar voor. Te denken aan motorrijders, bromfietsers etc
- Ik kan eigenlijk niet wachten tot de verplaatsing of vervoer per auto volledig automatisch gaat, fantastisch lijkt me dat!
- De tabel met autonomiteit was een beetje lastig om te begrijpen wat je nou precies onder een bepaald level verstaat, waarschijnlijk handiger om dit meer met voorbeelden/icoontjes weer te geven zodat het duidelijker is. Niet echt duidelijk of er verband is tussen die eerder genoemde comfort systemen en de autonomiteit tabel. Is deels-autonomiteit dan dat je navigatie en cruise control hebt bijv?
- Moeilijke vragenlijst v.w.b. het inbeelden van de diverse situaties van het uit handen geven van controle in meer of mindere mate. Die moeilijkheid vraagt geduld en rust bij het invullen om je goed te kunnen inleven. Ik vraag me af of dit verschijnsel zorgt voor een niet-representatief resultaat van de enquete.
- meer uitleg over autonoom rijden. wat houdt dat precies in
- Succes Bob!
- Wanneer is deze vorm van auto rijden in het huidige verkeer in te voeren? Hoe staat het er technisch voor? En de laatste echt Nederlandse vraag is het kosten plaatje.

- er wordt niets over de mae van stress gevraagd. Automatisch rijden is zeer relaxed. dat is de belangrijkste factor voor mij om zoveel mogelijk autmatisch te rijden
- Goeie enquete, succes met je onderzoek!
- Zet bij rijsituaties nog even het schema/tabel aan de zijkant. als je niet meer weet wat deels/hoog/lage autonomiteit is heb je geen backup om terug te kijken.
- de stelling dat de variatie in passagiers/ bekendheid met de route en/of de omgeving de mate van autonoom rijden beÃ¯nvloedt bevreemdt mij. (dit heeft op mijn wens voor autonoom rijden geen invloed)
- nee
- De ladder met levels van mate van autonomie sluit niet aan bij mijn wens of beleving. Op eenvoudige wegen is level 4, hoge autonomie prima, maar daarna is wellicht level 1 het maximaal haalbare. In de vragen er na wordt gevraagd wat de redenen zijn om meer autonoom te rijden. Ik mis "veiligheid" als reden. De items in de vragen gaan vooral om geld en beetje tijd.
- Voor mij mogelijk belangrijk aspect werd niet benoemd, niet alleen kostenreductie, brandstofreductie of reistijdreductie maar vooral de reductie van de 'belastendheid' van de rit zou voor mij een belangrijk criterium zijn: in hoeverre helpt het om de rit ontspannen te maken / te houden.
- Ik ben van mening dat een bestuurder altijd zelf in moet kunnen grijpen en dat een volledig automatisch systeem zelfs gevaarlijk kan zijn bij uitval of falen. Een vliegtuig heeft een automatische piloot en de moderne vliegtuigen kunnen zelf landen maar bij bijvoorbeeld harde wind of uitval van functies zullen piloten zelf ingrijpen. In een auto zal dat mijn inziens nooit anders zijn.