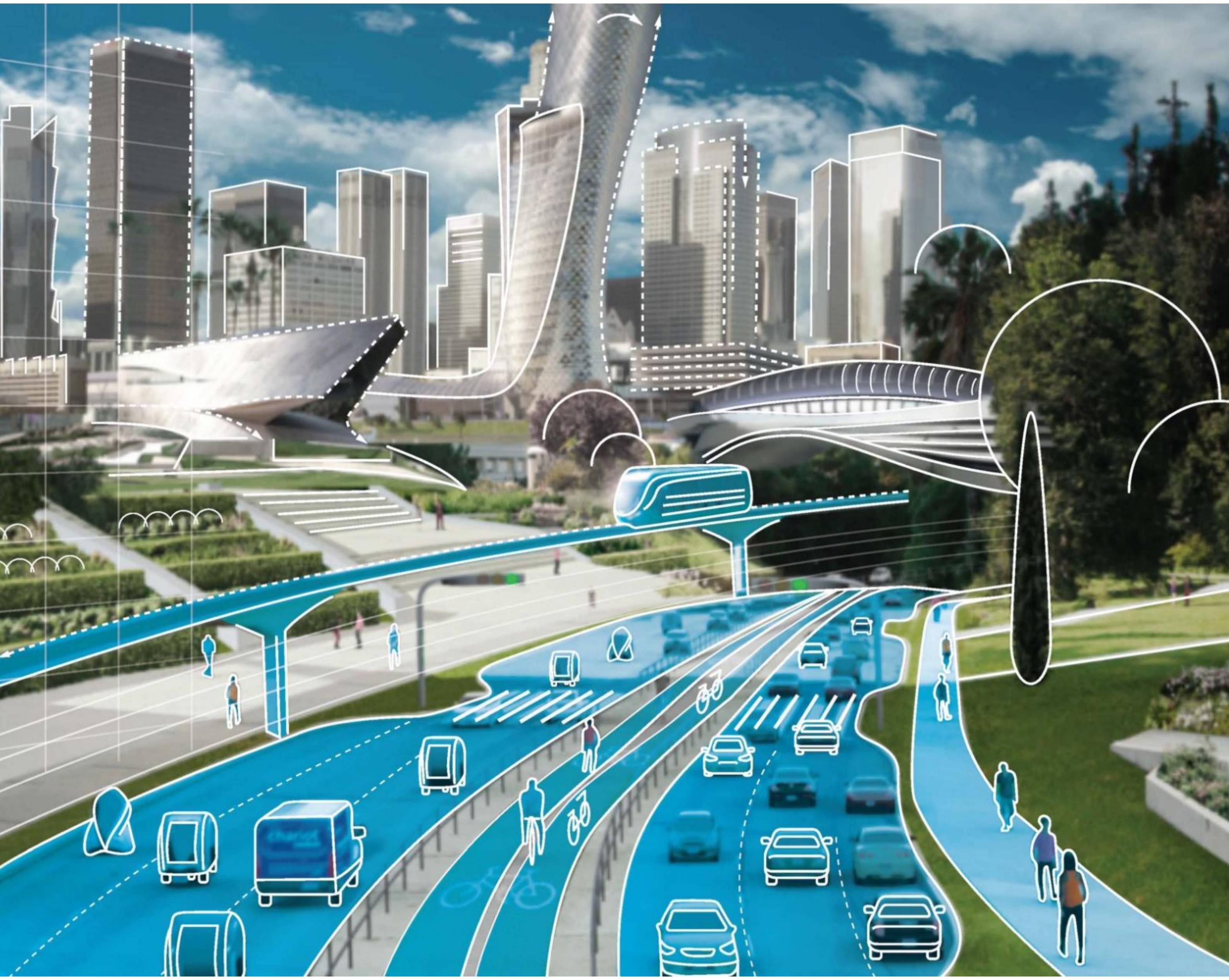
MSc Thesis in Management in the Built Environment

Paving the way for autonomous cars

Current projects and challenges in the Netherlands



TU Delft

Iris Ruysch

June, 2019

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‘Stories are the building blocks we use to make the future ‘

- Ed Finn - Founding director of the Center for Science and the Imagination at Arizona State University –

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Current projects and challenges in the Netherlands

A thesis submitted to the Delft University of Technology in partial fulfilment of the requirements for the degree of Master of Science in Architecture and the Built Environment
Master track: Management in the Built Environment

By

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Preface

This master's thesis is the result of eight months of research on the introduction and integration of autonomous vehicles in the Netherlands. The study is the final step before concluding the master's program in Management in the Built Environment with the Faculty of Architecture at the Delft University of Technology.

The first thing I learned during my master's program was the fundamental rule of real estate. Even if you do not know the first thing about it, you have probably heard the answer: Location, location, location. For instance, when I followed the elective course Valuation, location was crucial in determining the property value.

Currently, cities are growing, and the available space is decreasing. Congestion and parking are fundamental problems that tend to decrease the liveability of urban areas. Engineers and manufacturers suggest that autonomous cars can reduce these problems. As I am convinced that this technology will change the way people live in cities, I wanted to combine this subject with urban area development. During the study, I found that the technology is not there yet. As such, this study investigates five pilot projects of autonomous vehicles in the Netherlands to detect the main challenges.

On a more personal level, I express my utmost gratitude to all the people who helped me throughout these two years of study. I could not have achieved this important milestone in life without the backing and trust of a strong support group. First of all, I want to thank my mentors. I thank Aksel Ersoy and Javier Espinosa Oviedo for their guidance. Their advice and feedback were always motivating and supportive to my research. Moreover, their enthusiasm and constructive criticism helped me to stay positive and confident throughout the whole process.

Furthermore, I give my gratitude to my parents for supporting me throughout all my decisions. My parents have been by my side throughout all the great and bad moments I have faced the past two years. I also thank my boyfriend Stefan, who has supported my decisions no matter the situation.

I hope you enjoy reading this thesis as much as I enjoyed writing it.

Iris Ruysch

June 2019

Abstract

Currently, cities are in the midst of a transportation transition, namely, from human-driven to driverless vehicles. Because of the rapid development of technology, many systems are being automated or even becoming autonomous. Autonomous means that the system is able to perform each task automatically without any human intervention. Much research has been conducted to find answers to the way autonomous vehicles might impact cities. However, the results of this research are limited in practical application, because the integration of autonomous systems is still in an early stage and there have not been many integration projects in the world yet. In the Netherlands, more and more pilot projects are being established to explore the impact and applicability of driverless vehicles. As such, this exploratory study analyses how autonomous vehicles have been integrated during the autonomous vehicle transition in the Netherlands. Alongside qualitative research methods including desk research and semi-structured interviews, an analysis framework is designed and used as a means to measure the technical, social, environmental, and regulatory challenges represented in five case studies. The results show that the main challenges are, among others, road obstacles, intersections, weather implications, communication between the shuttle and other traffic flows, communication between the project team and the inhabitants of the area, and restrictions from the Dutch Vehicle Authority. Challenges such as weather implications, road obstacles, and intersections occur in each project. Looking at the current technological developments, there are autonomous vehicles that can pass intersections and obstacles already. The inability to deal with these challenges could be explained by the high costs of the technology.

Keywords: Autonomous cars, artificial intelligence, connected vehicles, intelligent transport systems.

Summary

PROBLEM STATEMENT

Congestion, parking problems, and traffic accidents tend to increase because of population growth. As a result, engineers, manufacturers, and other parties are spending their time and effort on the development of autonomous vehicles, as these vehicles may promise to be safer, more efficient, and more sustainable. The rapid development of the automotive industry might have an enormous impact on the built environment and the way people commute to their destinations. Consequently, policymakers, planners, and other parties of interest are debating this impact on future cities. This might show that the impact is still quite uncertain, but it does not mean we 'know virtually nothing' about how autonomous vehicles will have an impact on the built environment. Much research has been conducted to determine the impact on the built environment (Donaghy, Rudinger, and Poppelreuter, 2004; Site, Persia, Alessandrini, Campagna, and Filippi, 2015; Ratti and Biderman, 2017; Prieto, Baltas, and Stan, 2017; Dias et al., 2017; Ratti, 2018; Duarte, F., & Ratti, 2018; Fitt et al., 2018). However, these outcomes are mostly still based on computer programs, algorithms, or scenario analyses, merely because there are not many 'real-life' autonomous car implementation projects. Nowadays, the number of implementation pilot projects are rising to examine the impact on the built environment. However, as the technology is still not fully developed and because there is currently much unknown, there are still significant challenges. These challenges are not published in the literature yet, which might result in a knowledge gap between the manufacturers and engineers and the parties who manage the implementation projects.

RESEARCH GOAL AND QUESTION

According to the literature review, there is yet little knowledge about the practical implications when integrating autonomous cars. Thus, the primary goal of this research is to contribute to the field of knowledge concerning the management of the implementation of autonomous cars in the built environment. The research aims to provide a better understanding of the policies concerning the implementation of autonomous vehicles in the Netherlands and the technical, environmental, social, and regulatory challenges before, during, and after the implementation of autonomous vehicles. The following main research question was formulated:

'How have autonomous cars been integrated during the autonomous vehicle transition in the Netherlands?'

From this main research question, the following sub-questions can be derived:

- what is meant by the term autonomous cars?
- Who are the critical stakeholders in autonomous car projects in the Netherlands?
- What are the existing policies in the Netherlands relating to the implementation of autonomous cars in the built environment?
- What are the estimated effects of autonomous car integration on the built environment?
- What are the current technical, environmental, social, and regulatory challenges of autonomous car integration looking at the autonomous shuttle case studies in the Netherlands?

METHODOLOGY AND APPROACH

An exploratory research approach is applied to derive an answer to the formulated research questions. The limited available knowledge resulted in a descriptive, qualitative research approach. Figure A illustrates the five distinctive phases of this research. This figure proves that several observations were made prior to the research to formulate the final conclusions. Because of the exploratory research and the need to do observations, the research lacks a predefined hypothesis. This research investigates five case studies in which autonomous cars are integrated in the Netherlands. The cases, Appelscha, Scheemda, Haga, Esa Estec, and Bourtange, are selected based on the type of urban area, the time span, and the project phase. For the data collection, different qualitative research techniques are applied, including a literature review, an extensive stakeholder analysis, and qualitative interviews. Figure A illustrates how these different techniques are applied throughout the research.

First, a literature review is conducted to obtain background information about the history of autonomous cars, the architecture of autonomous cars, and the relation to the Dutch context. Furthermore, the literature review forms the basis of the synthesis of the analysis framework. This framework is applied in the case analysis part to comprehensively analyse all cases. Second, a stakeholder analysis is performed to obtain an understanding of the critical and non-critical stakeholders. Both the literature review and the stakeholder analysis are used for formulating a case description per project. Finally, the analysis framework is applied in the cross-case analysis to compare the different sub-themes of each case with the sub-themes of the other cases.

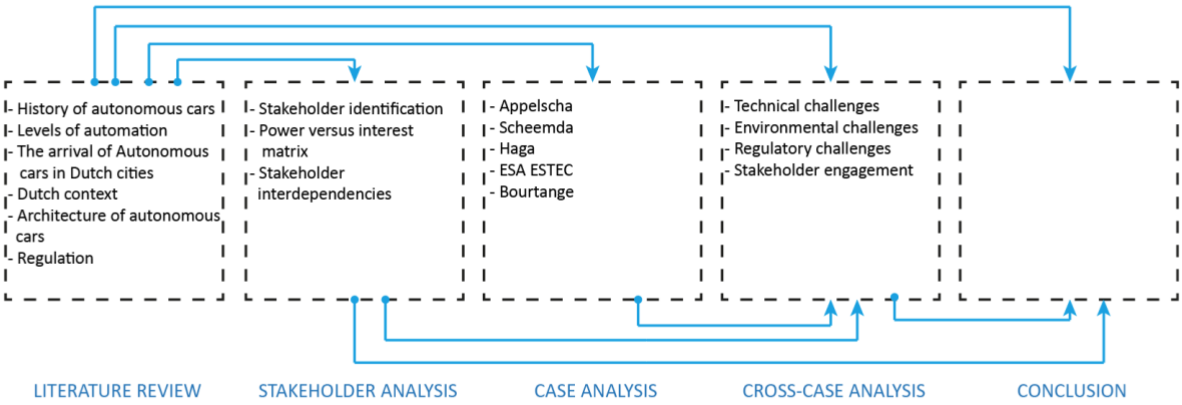

Figure A: The five distinctive phases of the research (own illustration)

ANALYSIS FRAMEWORK

The results of both the literature review and the stakeholder analysis are applied to synthesise the analysis framework. During the analyses of the case studies, the analysis framework was adjusted, which resulted in the analysis framework as illustrated in Figure B. The analysis framework summarises the case description and illustrates the current challenges of the implementation projects Appelscha, Scheemda, Haga, Esa Estec, and Bourtange. The analysis framework consists of five rows that present the five categories: context, technical, environmental, social, and regulatory. These categories are divided into sub-categories that can be filled in when analysing the projects. The analysis framework also forms the basis of the cross-case analysis. In this analysis, the results of the case analysis are compared using all categories separately to find the differences, similarities, and interrelations between the cases. The subsequent description of each case is too detailed to include in this management summary. However, the main findings are presented in the next paragraph.

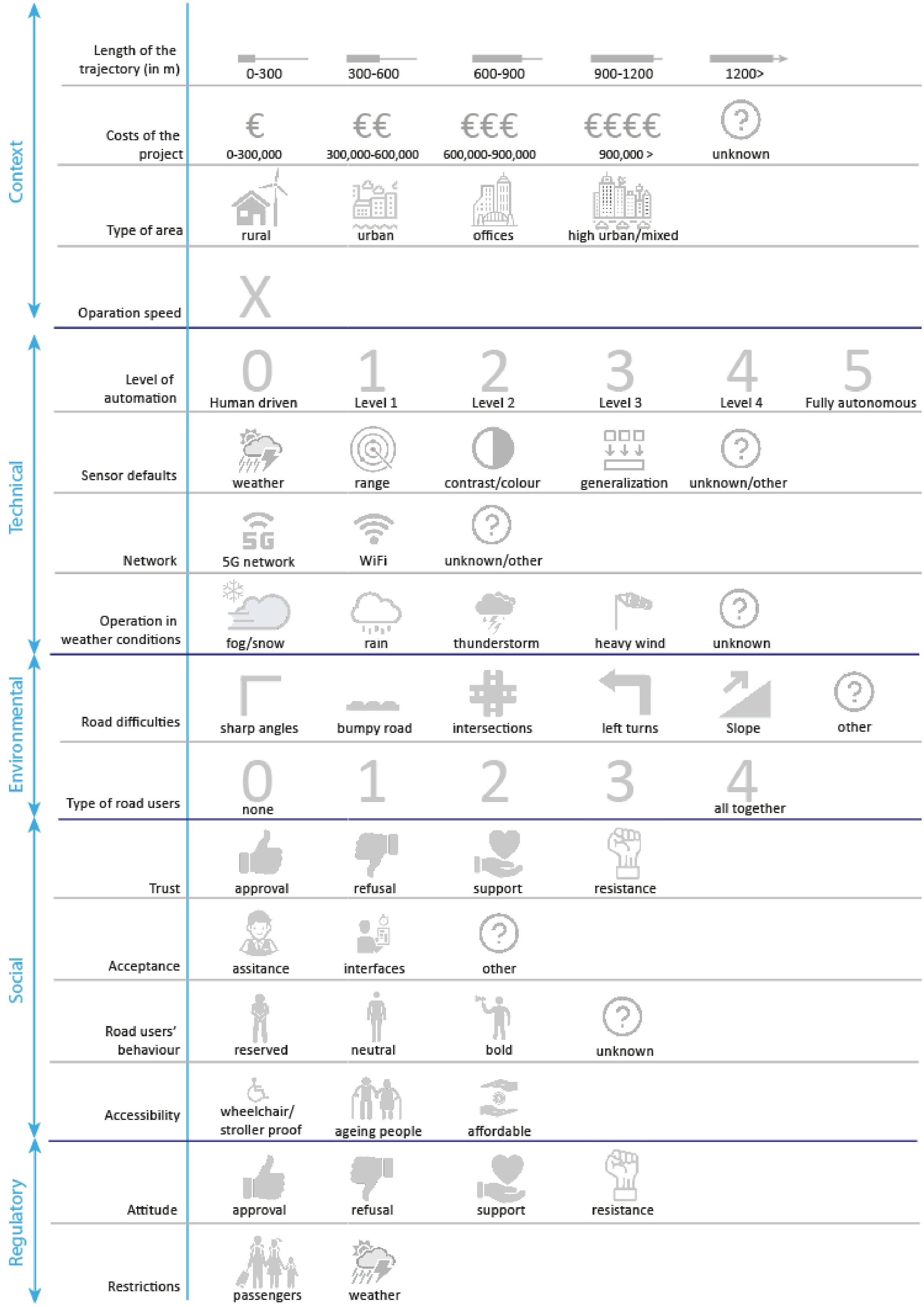

Figure B: Analysis framework (own illustration)

RESULTS AND CONCLUSION

The results of the research will be summarised through answering the sub-questions. Subsequently, an answer to the main question will be provided.

1. *What is meant by the term autonomous cars?*

An autonomous car is able to perform all driving tasks automatically, which means that there is no driver needed. The automation level in each project is level three. Level three means that a driver is still necessary but the vehicle is able to perform nearly all driving tasks automatically. When referring to autonomous vehicles or autonomous shuttles in this thesis, the author is referring to automation level three.

2. *Who are the critical stakeholders in autonomous car projects in the Netherlands?*

Both the literature and the case studies show that the critical actors are the European Commission, the Ministry of Infrastructure and Water Management, regional and local government, vehicle authorities, research institutes, service providers and suppliers, consultants, and manufacturers.

3. *What are the existing policies in the Netherlands relating to the implementation of autonomous cars in the built environment?*

Since 2015, autonomous vehicle testing has been legally permitted on the Dutch roads with a driver or steward inside the vehicle. To do this, the initiators of the project need to obtain an exemption from the Road Traffic Act 1994 by following an application procedure. This application procedure takes on average 12 months. When the exemption is granted, the project team needs to comply with several restrictions; otherwise, there is a risk of losing the exemption.

4. *What are the estimated effects of autonomous car integration on the built environment?*

The academic literature illustrates that the possible effects are a decrease or increase in private car ownership, fewer parking spaces needed in cities, an increase or decrease in urban sprawl, and probably a decrease in road infrastructure.

5. *What are the current technical, environmental, social, and regulatory challenges of autonomous car integration looking at the autonomous shuttle case studies in the Netherlands?*

The main overlapping technical challenges, which repeat in every project, are the inability of the autonomous shuttle to pass road obstacles and establish secure vehicle-to-vehicle communication. The main environmental challenge is crossroad obstacles such as unsignalised intersections, left turns, and roundabouts. The social challenges are keeping the trust level high when the automation level goes up, establishing clear communication between the autonomous shuttle and other road users, and securing proper communication between the project team and the affected people or companies. The main regulatory challenge is over-regulating, which can prevent the creation of new knowledge.

By combining the findings used to answer the five sub-questions of this research, the main research question can be addressed:

'How have autonomous cars been integrated during the autonomous vehicle transition in the Netherlands?'

As previously described, the current level of automation in all Dutch integration projects is level three. With this level of automation, there is still a driver needed to perform some driving tasks to drive safely, for instance, when passing road obstacles. The stakeholder analysis shows that the critical actors need to be either managed closely, kept informed, or kept satisfied before, during, and after the implementation projects. Policy documents show the facilitating role of the government during the transition to autonomous vehicles. However, the exemption application procedure of the Dutch Vehicle Authority is crucial in getting legal permission to operate an autonomous vehicle on public roads in the Netherlands. Moreover, driving without a steward is not yet legally permitted on public roads. One of the case studies, the Esa Estec project, shows that the implementation of an autonomous vehicle without a steward is possible on private grounds. The technical, environmental, social, and regulatory challenges in all case studies might be clarified by the level of automation. The autonomous vehicles in all projects are still in automation level three, which results in passing obstacles, operating in different road conditions, establishing secure vehicle to vehicle communication, and operating in heavy weather conditions being related to the current development of the software of the shuttles. The social challenges of keeping the trust level high and establishing clear communication between the autonomous shuttle and other road users can be improved in future projects. Lastly, the regulatory challenge of over-regulating should not harm the generation of new knowledge during the integration projects.

DISCUSSION

This research mainly focused on the implementation of autonomous vehicles in the Netherlands. The reason for this was the the lack of access to up-to-date online information and the time span of the thesis. Furthermore, the research merely focused on 'how' autonomous vehicle have been integrated instead of 'why' autonomous vehicles are being integrated in the Netherlands. The research touches on the 'why' side of the implementation in the section about the main players in the autonomous vehicle industry, but the question why different actors such as the European Commission and the national, regional, and local government are stimulating the implementation of autonomous vehicles remains unanswered. Finally, it should be noted that not all cases in the Netherlands were addressed, as the research focused on only five projects out of 20. The reason for this is the availability of information and the fact that most cases are only in the initiation phase. Because of this limited number of studied projects, all of which focused on the Dutch regulatory and market system, the results of this research cannot be generalised and projected to international projects. Moreover, it must be stated that the applied method of qualitative research might be seen as subjective to sensitivity. Several measures were taken to overcome this.

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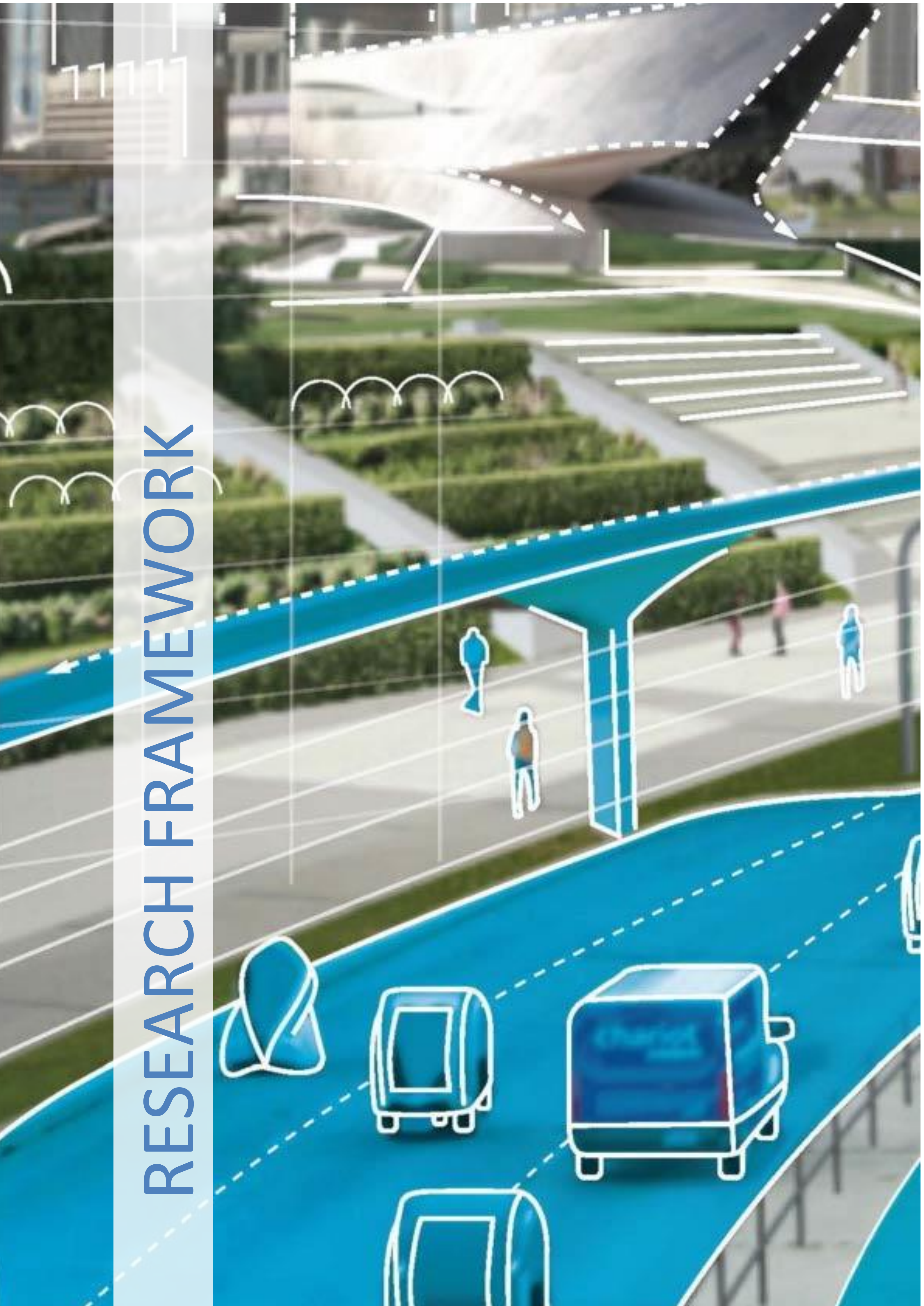
RESEARCH FRAMEWORK



1.1 Introduction

Over time, the way people travel has changed. At first, people travelled by horse and carriage, but in 1913 when the automobile became accessible to almost everyone, people began travelling by car (Eckermann, 2001). This transition from horse-powered to motor-powered transport had an enormous impact on the way cities were built and the way people lived in cities. Unfortunately, people did not estimate the future implications of the motor vehicle and, for example, the enormous contribution this mode of transportation would have regarding traffic accidents.

Right now, nearly 1.25 million people in the world die in traffic accidents each year. This is on average 3,287 people a day (Association for safe international road travel (2018). Engineers and other private companies are developing autonomous systems to contribute to the decrease in the number of car accidents. Currently, we are at the start of a second transport transition, namely, from human-driven to driverless cars. This means that there is a large opportunity to manage this transition closely.

According to the KPMG readiness index, which measures 25 countries' level of preparedness, the Netherlands is the world's most-prepared country to welcome self-driving cars (KPMG International, 2019). Moreover, across the Netherlands, more and more projects regarding the implementation of autonomous cars have been initiated. However, how should one manage the process of something that is still in technological development? To answer this question, early implementation projects could be reflected on. Exploratory research is performed into the implementation of autonomous cars during the second transport transition by analysing five autonomous car implementation projects in the Netherlands.

1.1.1 PROBLEM STATEMENT

The thoughts of the Dutch government towards autonomous cars were not quite positive, as it introduced a law only allowing conditionally automated cars on motorways until at least 2025 (Milakis, Snelder, Van Arem, Van Wee, & De Almeida Correia, 2017). This attitude has not deterred the demand for these autonomous cars, so companies kept developing the product. Autonomous cars are almost ready to go on the roads. However, these vehicles need to be tested properly. In 2015, the Dutch government changed the Road Traffic Act 1994 by allowing companies to test autonomous cars on public roads. However, the companies have to request an exemption for this, and during the tests, the vehicle cannot be tested without a driver inside. When applying for exemption, both the autonomous car and the chosen trajectory need to comply with various restrictions. Subsequently, there are restrictions that need to be complied with during operation of the autonomous car.

Likewise, in other countries, there are restrictions and guidelines that should be met when implementing autonomous cars. For example, in the United States, the U.S. Department of Transportation published the Federal Automated Vehicles Policy in 2016, which includes instructions for manufacturing, experimenting, and proposing autonomous cars, together with policy proposals for states and some ethical guidelines (U.S. Department of Transportation, 2016). The department of transport in England released a similar document in 2015 (Department for Transport, 2015). The policy documents describe clear policies on the implementation of autonomous cars. However, there is not one clear method for how parties can deal with this implementation and the involved stakeholders in a practical way.

Nowadays, the number of implementation pilot projects are rising to help answer several questions, for instance, about the impact on the built environment. However, as the technology is still not fully developed and because there is currently much unknown, there are still significant challenges when implementing these autonomous cars. These challenges are not published in the literature yet, which might result in a knowledge gap between the manufacturers and engineers and the parties who manage the implementation projects. This research aims to learn from five autonomous vehicle integration projects to inform both public and private parties of the main challenges involved actors might face during the implementation.

1.1.2 RELEVANCE

This intended contribution to the field of knowledge concerning the integration of autonomous cars aims to serve a scientific as well as a practical purpose.

SCIENTIFIC RELEVANCE

Despite the rapid development of literature on the technical aspects and the future impacts of autonomous cars, very little theory is known about the practical implementation of autonomous cars in urban areas. This study aims to contribute to the knowledge field and identify the limited research on challenges stakeholders face before, during, and after an autonomous car integration project. Little is known about the critical and external stakeholders involved and their power/interest in the projects. Thus, this study aims to contribute to the field of knowledge concerning the implementation of autonomous cars in cities and by this, to the development of autonomous cars. The finalised thesis can support students and scientists in the fields of process and project management and transportation who intend to investigate related subjects within their studies.

PRACTICAL RELEVANCE

This research aims to contribute to societal goals at different levels. First, successful integration of autonomous cars might offer a durable alternative to traditional mobility means like traveling by car. Moreover, autonomous vehicle projects might offer chances for new mobility, for example, the last mile between a public-transport stop and the final destination. Accessibility of the projects for everyone will be key. The accessibility might depend on people's social values and ability to pay a certain fee. Thus, ensuring accessibility and providing equal opportunities to make use of this new transport means should be somehow implemented in the projects. Second, to create acceptance and understanding from people during the second transport transition, the generation of trust is essential, at least in the first autonomous vehicle integration projects. The level of trust might be affected by different factors during the implementation of autonomous cars. Third, learning more about autonomous car integration projects could offer opportunities in urban area development to change parking spaces into living spaces. These changes can also result in a mind-set change to more appreciation of the built environment.

1.1.3 DOCUMENT STRUCTURE

The thesis is structured as follows: The methodology section (Chapter 2) describes how the data are collected and managed safely. The conceptual model shows the main boundaries of the research framework. The theoretical framework (Chapter 3) then provides definitions of the relevant concepts and the relationships among them. Subsequently, the stakeholder analysis section (Chapter 4) outlines the critical actors in autonomous vehicle implementation projects. The synthesis analysis framework section (Chapter 5) provides the synthesis of both the preliminary analysis framework and the analysis framework. Furthermore, the case-study analysis section (Chapter 6) describes the analysis of the Dutch implementation projects and the cross-case analysis section (Chapter 7) provides a comparison of all implementation projects. The conclusion section answers the sub-questions posed at the beginning of the thesis, followed by the main research question in the section. Finally, the discussion (Chapter 8) describes the limitations of this research and makes recommendations for future research.

1.2 Research question

Because this research is mostly exploratory, the main research question has been formulated as an open question. This question reads as follows: 'How have autonomous cars been integrated during the autonomous vehicle transition in the Netherlands?' The research is divided into two phases to answer the research question, namely, the systematic literature review and the semi-structured interviews together with the case studies. Figure 1.1 shows the division and the main subjects within this research.

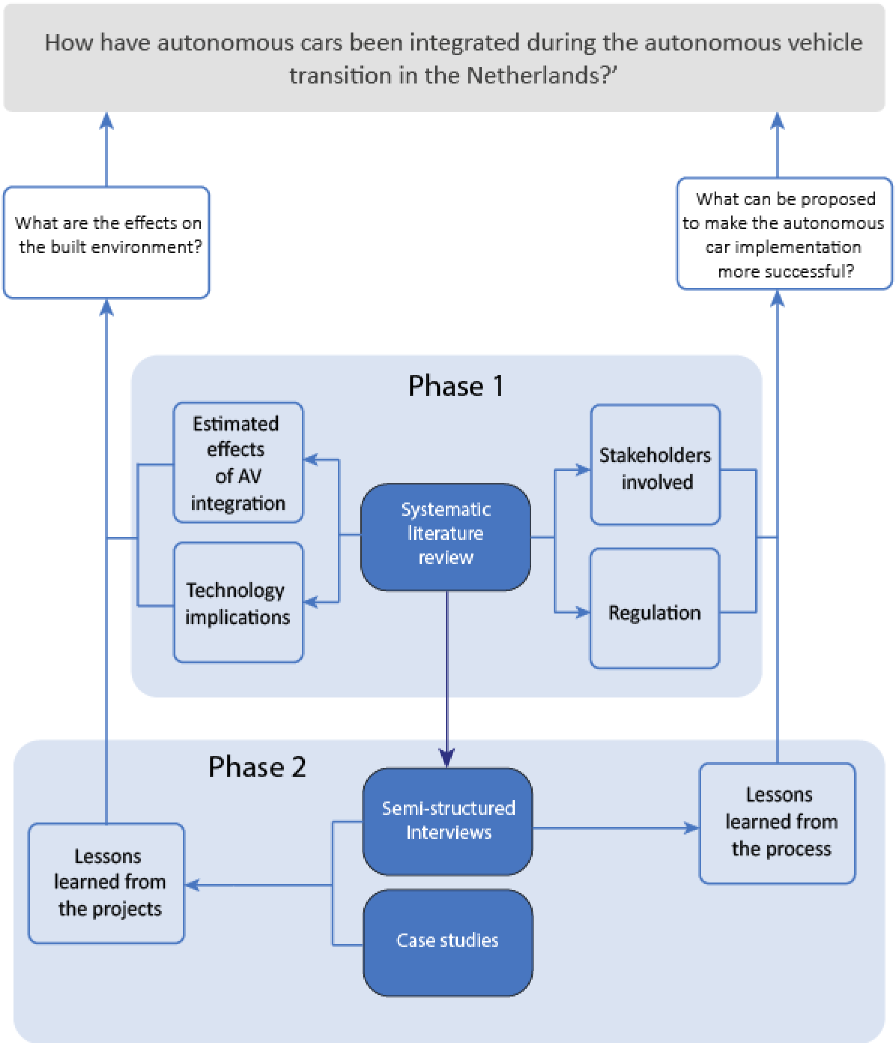


Figure 1.1. Addressing the research question (own illustration)

To answer the main question, the following sub-questions are formulated.

- What is meant by the term autonomous cars?
- Who are the critical stakeholders in autonomous car projects in the Netherlands?
- What are the existing policies in the Netherlands relating to the implementation of autonomous cars in the built environment?
- What are the estimated effects of autonomous car integration on the built environment?
- What are the current technical, environmental, social, and regulatory challenges of autonomous cars integration looking at the autonomous shuttle case studies in the Netherlands?

METHODOLOGY

2.1. Research approach

2.1.1 RESEARCH PHASES

The research consists of five distinctive phases: a literature review, a stakeholder analysis, a case analysis, a cross-case analysis, and a conclusion phase (Figure 2.1). In the first research phase, a literature review is performed into the technical concepts of autonomous cars, their history, and their impact on cities. The integration of autonomous cars is placed within the Dutch context; thus, a literature review is performed into the European and Dutch regulation regarding autonomous car implementation. Section 3 Theoretical background contains the results of the literature review. In the second research phase, a stakeholder analysis is conducted to get insight into the critical actors when implementing autonomous cars in the Netherlands. Section 4 Stakeholder analysis contains the results thereof. The results from the literature review and those from the stakeholder analysis combined lead to the synthesis of an analysis framework. Section 5 Analysis framework contains the results thereof. In the third research phase, the case analysis, both data from conducted interviews and data from the literature are used to describe the characteristics of the autonomous shuttle pilot projects Appelscha, Scheemda, Haga, Esa Estec, and Bourtange. All cases are analysed using the synthesised framework. Section 6 Synthesis case analysis contains the results thereof. In the fourth research phase, a cross-case analysis is performed, covering the technical, social, environmental, and regulatory challenges of all the cases to identify lessons learned. Section 7 Cross-case analysis contains the results thereof. Finally, in the last research phase, the findings of all previous research phases are substituted into a conclusion. Section 8 Conclusions and afterthoughts contains the results thereof.

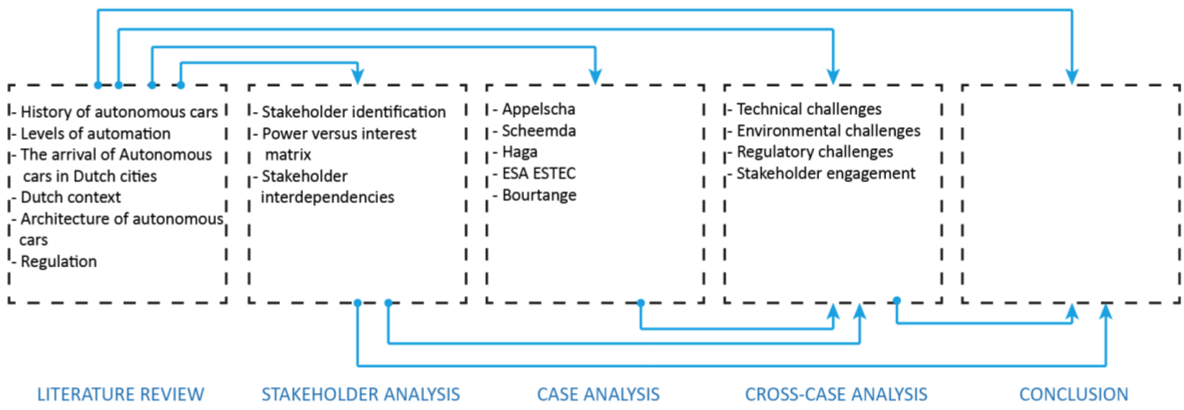


Figure 2.1 The five distinctive phases of the research (own illustration)

2.1.2 CONCEPTUAL MODEL

The conceptual model presents the relationships among the theories that are the foundation of this study. According to Milakis, Snelder, Van Arem, Van Wee, & Correia (2015), the two drivers, technology and policy, are significant in defining the future development of autonomous cars. The two drivers have an influence on each other, for example, policies can be restrictive, which can make it harder to adopt the newly created technologies in practice. If it were the other way around, where technology develops very fast and policies are supportive, the implementation of autonomous cars could occur by 2025. In addition, many people in society are concerned with this mobility transition, which means there should be engagement between these people during the implementation. Moreover, the way autonomous cars are implemented depends on the urban environment. For instance, in crowded city centres, it might be more complicated to implement autonomous cars compared to rural areas. The drivers of policy, technology, stakeholder engagement, and urban environment all have an influence on the autonomous car implementation. This study explores the impact of these drivers in five autonomous shuttle projects in the Netherlands. The proposals illustrate the main findings in combination with recommendations for future projects. The conceptual model is illustrated in Figure 2.2.

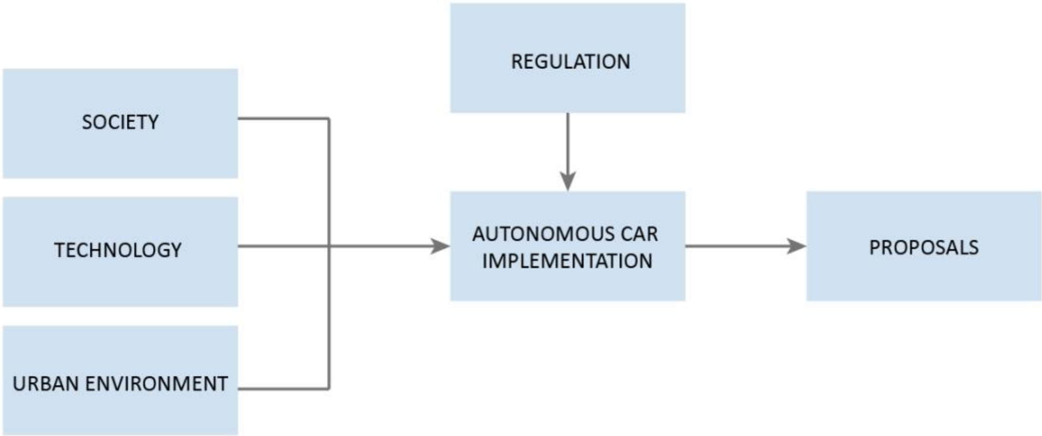


Figure 2.2: Conceptual model (own illustration)

2.1.3 TYPE OF STUDY

The scarcity in both theoretical and practical knowledge justifies the exploratory qualitative approach. Qualitative research includes in-depth analysis that focusses on quality instead of quantity. Qualitative research usually involves a causative approach based on theory building instead of theory testing (Bryman, 2016). The order of typical qualitative research is as follows: first electing the cases and second analysing the cases while connecting them to existing theory (Bryman, 2016, p.384).

Thus, an interpretive approach with notable use of qualitative research methods, such as desk research and semi-structured interviews, will be used to achieve an in-depth comprehension of the autonomous car implementation process. This research method ‘allows an understanding of the social world through an examination of the interpretation of that world by its participants’ (Bryman, 2016, p.266). Figure 2.3 illustrates the research sub-questions and matching research methods.

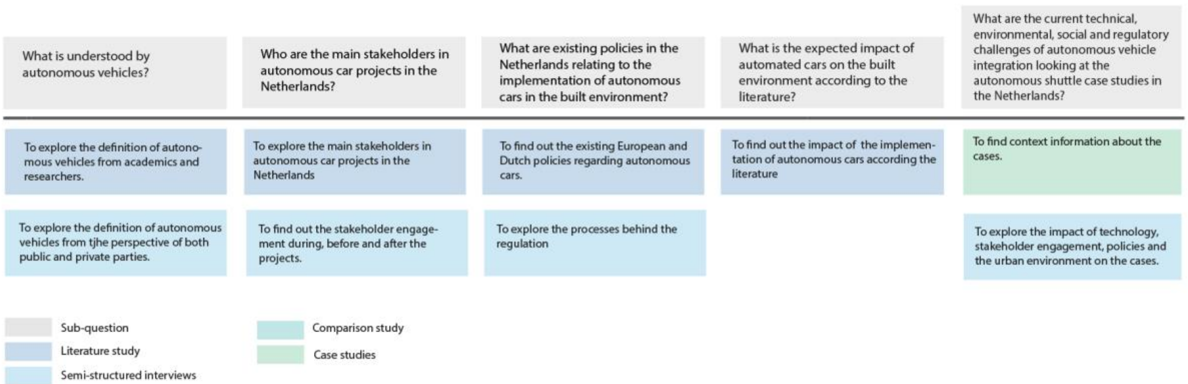


Figure 2.3: Main questions divided into sub-questions and interview questions (own illustration)

2.1.4 METHODS AND TECHNIQUES TO BE USED

DESK RESEARCH

Desk research is conducted to find theoretical knowledge about autonomous cars, the main players in the autonomous car industry, and the expected impact autonomous cars have on the built environment. The first part of the desk research gives an answer on the first sub-question: *What is meant by the term autonomous cars?* In this section, the boundaries of the research are determined. The second part of the desk research determines the main players in the autonomous car market. This section introduces a measurement method to determine the technology development in the field of autonomous driving. Also, the manufacturers of the autonomous vehicle used in the case studies are described, as these manufacturers developed autonomous shuttles, which are slightly different than autonomous cars. The third part of the desk research determines the impact of the integration of autonomous cars in the built environment according to researchers. As there is a scarcity in practice projects, the theory is mostly based on simulations and calculations.

External desk research is conducted to determine the policies to regulate the integration of autonomous cars. Most policies can be found in Government published data or policy documents made by local or regional governments. Also, regulation and legislation from the European Union can be found on the web page of the Dutch government. Moreover, the Dutch Vehicle Authority made a document about the procedure to test autonomous cars on the public road, and this document will be analysed in this section.

INTERVIEWS

A stakeholder analysis was carried out to obtain knowledge about the market status of the various actors involved in the transition to autonomous cars. The stakeholder analysis identifies both critical and external stakeholders. Some of these vital stakeholders are interviewed to give input for the case-study analyses.

Rubin and Rubin (2005) developed a typology to determine the dimensions behind the interview type. The interview scope in this research is broad, as the cases are analysed on various subthemes, for instance, the themes technology, environment, and regulation. The focus during the interviews is linked to events and processes, as the questions are related to both the project and the process of the pilot projects. The framework of Rubin and Rubin (2015) is illustrated in the table below.

FOCUS SCOPE	NARROW	IN-BETWEEN	BROAD
MEANINGS AND FRAMEWORKS	Concept clarification interview	Theory elaboration interview	Ethnographic interview
IN-BETWEEN	Exit interview	Oral histories organisational structure	Life history interview
EVENTS AND PROCESSES	Investigative interview	Action research evaluation research	Elaborate case studies

Table 2.1: The dimensions behind the interview type (own illustration, based on Rubin and Rubin, 2015)

The focus of this study is on events and processes before, during and after the integration of autonomous cars. Moreover, the interviews are used to elaborate on the case studies. This, in combination with the exploratory research, makes the scope of this research quite broad.

After determining the interviewees, semi-structured interviews were carried out to obtain more knowledge about the subject and to find out ongoing and/or already executed pilot projects in the Netherlands. With the unstructured interviews, it was essential to focus on other contact persons crucial for this study. Also, the interviewer focussed on the (expected) impact of the pilot projects on the built environment and the implications/improvements for future projects.

The interviews were pre-formulated and can be found in Appendices B and C. All interviews had the same structure; however, there was some space for having a natural conversation. The structure is important when comparing the interviews in the results section. Topic bridges were prepared to make sure all questions were answered.

CASE STUDIES

The main research question in this study concentrates principally on ‘how‘ autonomous cars are integrated. Thus, the following research approaches should be used: case studies, experiments, or shared histories (Yin, 1984). After the semi-structured interviews were conducted, five pilot projects were chosen as case studies, which were analysed using a framework. This framework is divided into five different subjects essential for the implementation of autonomous cars, such as the context information and the technical, environmental, social, and regulatory challenges. This framework may be helpful to draw lessons learned from the already-executed plans and thus serve as a feedback loop for future projects.

There are different challenges in doing case-study research. First, in the case selection, choosing the case that matches the issue best might be challenge. Second, after each case has been chosen, it might be challenging to determine the boundaries of each case (Eisenhardt, 1989). Finally, the number of cases to be studied determines the depth of the research. The challenge is to determine a certain number of cases that give a good overview of the issue studied and at the same time provide evidence for slightly different cases (Yin, 1984). Thus, multiple cases in the Netherlands are determined to analyse the same issue in a different context.

2.1.5 CASE SELECTION

Bloomberg Philanthrophies (2018) released a Global Atlas of Autonomous Vehicles in Cities that shows all pilot projects in the world in one map. However, the map is not up to date, as many projects are left off. Therefore, a map was created to show all autonomous vehicle pilots in the Netherlands.

Figure 2.4: The different phases of the pilot projects in the Netherlands (own illustration, based on autonoomvervoernoord, n.d.)

Figure 2.5: The red pin points illustrate the cases to be studied in this research (own illustration)

Figure 2.4 illustrates all pilot projects in the Netherlands where the different colours represent the different phases the projects are in. As can be seen in the illustrations, the case studies used for this research are all in different phases. The Appelscha project is already finished, whereas the Scheemda hospital project is still active. The Haga shuttle project and the Esa Estec project are now in execution and the Bourtange project is planned for the future.

The case studies are selected based on the differences in phase of the project, type of urban area of the project, and available information. The selected pilot projects are Appelscha, Scheemda, Haga, Esa Estec, and Bourtange. All cases are shown in Appendix A, and the chosen cases are highlighted in blue. Figure 2.5 illustrates the pilot projects (in red) that have been analysed in this study.

2.1.6 DATA COLLECTION

For the desk research, data were collected both from online databases such as TU Delft Repository and Google Scholar and from government published data to find information about the existing policies. The data are structured into an excel file to keep track of all sources. Prior to this research, four interviews were conducted to specify this research topic and to obtain more contact information for further research. These interviewees were contacted through an online question form from different municipalities. Table 2 shows the data of the four interviewees.

NAME	PROFESSION	DATE OF THE INTERVIEW
J. Boelhouwers	Senior advisor infrastructure at the municipality of Rotterdam	October 29th, 2018
J. Goddijn	CEO of HR groep	November 7, 2018
M. Bolt	Projectmanager automated vehicles at the municipality of Amsterdam	November 14th, 2018
D. Labots	Traffic planner at the municipality of The Hague	November 19th, 2018

Table 2.2: Interviewees prior to the research (own table)

After these interviews, it became clear that there is an overarching organisation that is responsible for six ongoing pilot projects in the region of The Hague and Rotterdam. This organisation, Metropoolregio Rotterdam Den Haag (MRDH), published a document with some information about those pilot projects; however, as it was not detailed enough for this study, two interviews were scheduled to obtain more information about one specific project. After one interview, it became clear that there were more pilot projects in the Netherlands. In the northern part of the Netherlands, three provinces, Groningen, Drenthe, and Friesland, signed a cooperation agreement to test autonomous cars.

Because the projects of the MRDH were not that developed yet—except for the Capelle aan den Ijssel project, but this autonomous shuttle operates on a separate lane, which is not relevant for this research—two projects situated in the northern region of the Netherlands were used as case studies. The profession of the interviewees and the corresponding case study is illustrated in the following table.

PROFESSION	CASE STUDY	DATE OF THE INTERVIEW
Initiator, external advisor	Appelscha, Scheemda	March, 11th, 2019
Policy officer at the Province of Groningen	Appelscha, Scheemda, Bourtange	March 11th, 2019
Founder of The Future Mobility Network	Haga	March 8th, 2019
Project manager of the Haga shuttle project from HTM	Haga	February, 18th, 2019
Policy officer at the Province of Zuid-Holland	Esa Estec	April, 9th, 2019

Table 2.3: Second round interviews (own table)

2.1.7 DATA ANALYSIS

The collection and analysis of data occurs in several continuous steps, as illustrated in Figure 2.6. The literature review forms the basis of the synthesis of the analysis framework. Also, the literature review is used to find information about the case studies. Because not every case was broadly analysed in the literature, interviews were conducted with the municipalities of Amsterdam, Rotterdam, and The Hague. An interview was also conducted with a private company responsible for all traffic signs in the Netherlands, HRgroup, to obtain more insight into the technology. Literature from both policy documents and previous research is used as input for the stakeholder analysis. The results from the stakeholder analysis are used as input for both the case-study analysis and the conclusion. Finally, a cross-case analysis is performed in which the results of all case analyses are compared to each other to find differences and similarities in the technical, social, environmental, and regulatory challenges.

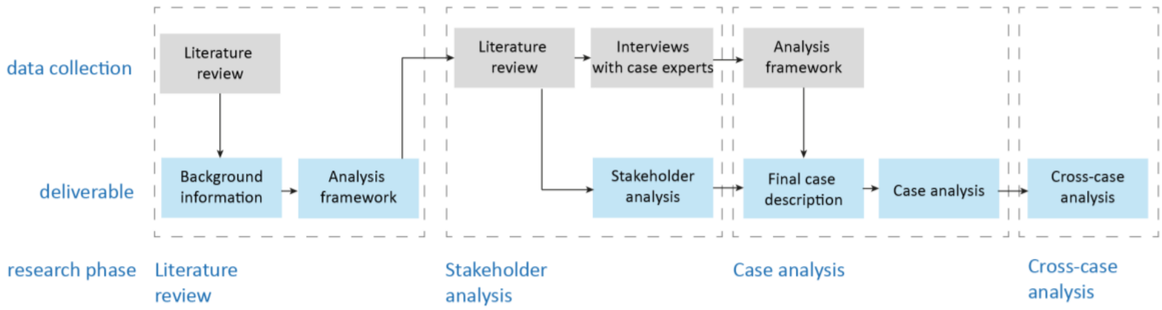


Figure 2.6. The steps of data collection, analysis, and processing (own illustration)

2.1.8 DATA PLAN

The FAIR guiding principles are established to manage data during and after completion of a scientific study. There is an urgent need to do this as there is often a considerable barrier to humans and machines effectively reusing data (Wilkinson et al., 2016). Wilkinson et al. (2016) describe four fundamental principles, findability, accessibility, interoperability, and reusability, to maximise the added-value gained through digital publishing.

The use of exact keywords that define the subject accurately can help increase the findability of the thesis. Examples of keywords that help find this thesis are autonomous, cars, pilot projects, decision making, and impact. A clear table of contents also helps the reader see the data he or she is searching. Another way of improving the findability is to use metadata, for example, by referring to the appendices for more specific data.

All data used for or generated by this thesis will be accessible for re-use because this thesis will be published on the TU Delft Repository. For people who cannot reach the repository, this thesis will be uploaded to ResearchGate, where the public can request the thesis.

To make the research interoperable and reusable, all data are written in formal English or translated from Dutch to English. Data should be useful to be reusable. Thus, all data will richly describe the context under which they were created. When data will be reused, it is essential the searcher uses the correct citation or reference. The APA 6th style of referencing is used throughout the thesis to honour the work of other researchers. The sources used for the formulation of the thesis include literature, annual reports, newspaper articles, and the audio files of the interviews.

2.1.9 ETHICAL CONSIDERATIONS

When the research with accompanying research subject, research methodology, and handling of data sets are considered from an ethical perspective, some aspects can be set under discussion.

To counter the risk of individuals being personally assessed on the statements they make within the interviews conducted for the research, the decision could be made to manage these interviews privately and never publish the names of the interviewees. However, the suppressing of such information affects the accountability of the research and its conclusions: the reader cannot verify whether the data used for the formulation of the findings originate from a trustworthy source. Therefore, in the research, this information is made publicly. However, this only occurs after proper consultation with the interviewees and a signature on the letter of consent. The letters of consent are attached to Appendix E.

2.2 Research output

2.2.1 GOALS AND OBJECTIVES

According to the literature review, there is yet little knowledge about the practical implications when integrating autonomous cars. Therefore, the primary goal of this research is to contribute to the field of knowledge concerning the management of the implementation of autonomous cars in the built environment. The research aims to provide a better understanding of the policies concerning the implementation of autonomous cars in the Netherlands and the technical, environmental, social, and regulatory challenges before, during, and after the implementation of autonomous cars. This contribution to knowledge is intended for the disciplines of urban infrastructure management, consultancy, and policy making. This study explores the critical actors in the transportation transition to driverless cars and what these actors can learn from the current implementation projects. This study will do so by first analysing the theoretical challenges in the field of autonomous vehicle implementation. Second, it will divide and map all involved actors into critical and non-critical actors. Third, it will describe and analyse five case studies with the analysis framework. Moreover, it is crucial to obtain further understanding about this topic and its impact. Nowadays, both public and private parties tend to be more reactive to this topic because there is not that much information about the implementation in the public space available yet. Thus, the last goal of this research is to stimulate and inspire future researchers to dive deeper into this topic.

2.2.2 DELIVERABLES

The aimed result of this study is a completed thesis report that determines the current challenges in the practical implementation of autonomous cars. The research provides data and conclusions about the implementation of autonomous cars, which can be useful to both public and private parties, such as regional and local governments, but also project developers and autonomous vehicle manufacturers. The challenges can determine decisions, for example, about the design or structure of the built environment or the software of the vehicles. The data and conclusions are mainly based on the experiences of both regional and local governments and private organisations, such as local public-transport companies and consultants.

2.2.3 DISSEMINATION AND AUDIENCES

This research is directed at researchers, consultants, and policymakers concerned with the management of the transportation transition from human-driven to driverless car infrastructure within the built environment. Thus, the thesis is meant for both theory and practice.

The research aims to fill a theoretical gap of knowledge for the disciplines of infrastructural management and policy making within the built environment and to bring these two concepts together. This reflects the value of this study for researchers. The research can form the basis for further research and a reference work for relevant research to this topic. Furthermore, the research aims to fill a practical gap of knowledge for policymakers concerned with the management of infrastructure within the built environment. The study provides insights into the challenges and performance of autonomous vehicle integration in the built environment. This could help policymakers make better decisions regarding their investments and the structure of the built environment.

THEORETICAL FRAMEWORK

3.1 Automobiles and cities through history

In 1926, the first science fiction journal called *Amazing Stories* was published by Hugo Gernsback. Science fiction journals like these were full of visions and illustrations about the future city (Parrender, 1980). This fascination about the future city is illustrated in many articles, books, and videos. However, the perspective on future cities has changed over time. For example, around 1920, people were convinced that cities of the future were full of tall buildings where infrastructure, mostly cars, played a big role ('1920's - What the Future Will Look Like', 2010), whereas around 1960, when the first futuristic cartoon *The Jetsons*, produced by Hanna-Barbera, was broadcast, the perspective of the future city was much more based on technical inventions. This cartoon illustrated the life of a family in a city above the clouds full of new technologies, for example, jetpacks, flying cars, smart watches, touch screens, and robots. This cartoon helped Americans, and probably people from other countries in the world, define thoughts about the future (Novak, 2012).

Fishman (1982) shows that visions and ideas about the future city fascinate people. Between 1890 and 1930, three planners, Ebenezer Howard, Frank Lloyd Wright, and Le Corbusier, tried to answer the question of what the ideal city was for the twentieth century because they believed that their societies were in need of new kinds of cities (Fishman, 1982). Howard, Wright, and Le Corbusier designed literally hundreds of models to establish this ideal city. According to Fishman (1982), the three planners all had differing ideas on how an ideal city in the twentieth century should look.

The visions of Wright and Le Corbusier showed how powerful motorcars would be in changing the way cities operated and the way individuals travelled (Duarte & Ratti, 2018). Wright created the concept of 'Broadacre city', a suburb where the automobile was king, and Le Corbusier came up with the concept of 'Ville Radieuse', where motorcars would reverse 'all our old ideas of town planning' (Le Corbusier, 1987, p.123). These 'car-oriented' visions could have been a reaction to the current transition period from horses and carriages to horseless carriages, in other words, cars.

Nowadays, visions for cities of the future are not only shaped by urban planners, architects, and social planners; multinational computing giants such as IBM, HP, Uber, Apple, etc., are using new technologies and tools to be the frontrunner in building the city of tomorrow (Ratti & Claudel, 2017). When Google searching on the terms 'future city', 'future city technology', and 'city of tomorrow', many images show up that illustrate high rise buildings, information or data streams, WiFi in every object or location, and even driverless cars.

3.1.1 THE FIRST TRANSPORT TRANSITION IN HISTORY

When the first steam-powered automobile was invented in 1769, the production costs were exorbitant, which made it almost impossible for people to own a car. The main transport means in that period of time was by horses and carriages (Eckermann, 2001). However, the horse poop had a negative impact on the liveability and air quality in cities. Therefore, several engineers were looking for solutions to make the carriages automatically driven. These engineers developed various sorts of motor-powered carriages, or as they later called them, the automobile. In 1913, Henry Ford developed the first mass-produced car, which opened transport by car to the middle-class American (Eckermann, 2001). The acceptance of the car in Europe and other parts of the world took some time. By 1927, Ford had manufactured more than 15,000,000 automobiles. By the middle of the 20th century, the American industry had become international. Different car manufacturers—Daimler, Chrysler, Hudson, General Motors, and more—began assembly in many countries in Europe and many other countries across the globe (Purdy and Foster, n.d.).

Figures 3.1 and 3.2 illustrate the transition from transport by horses and carriages to transport by the automobile. It can be observed from these illustrations that there was less space for pedestrians and the automobile was the king of the road.

Figure 3.1: An American street around 1800 (Eckermann, 2001)

Figure 3.2: An American street around 1950 (Eckermann, 2001)

Although the ownership of motor vehicles increased around the world and cities were growing, Geoffrey Jellicoe emphasised the need for new conceptualisations of the city because of the rapid industrialism and consumerism. Jellicoe created the concept of 'Motopia', a city where infrastructure was separated through elevated ramps (Jellicoe, 1963). The vision of Jellicoe referred to the serious need for transport planning with the arrival of the motorcar. Not every vision during this period was based on the motorcar; for example, the vision of Ron Heron was based on the pedestrian. He created the concept of the 'Walking City'. This illustrates that the visions of both concepts were quite subjective, namely, Jellicoe wanted to stimulate the use of motorcars, whereas Heron wanted to stimulate pedestrians in a city (Dunn, Cureton & Pollastri, 2014).

The different visions about the design of the city illustrate that the invention of the automobile resulted in a large transition, not only in the way people travelled from A to B but also the way they lived. The commuting time to work became shorter and people were able to live a further distance from their work. This phenomenon is called urban sprawl. As this research focuses on the Netherlands, the result of both the growth of the population and urban sprawl in the metropolitan region of the Netherlands is illustrated in Figure 3.3.

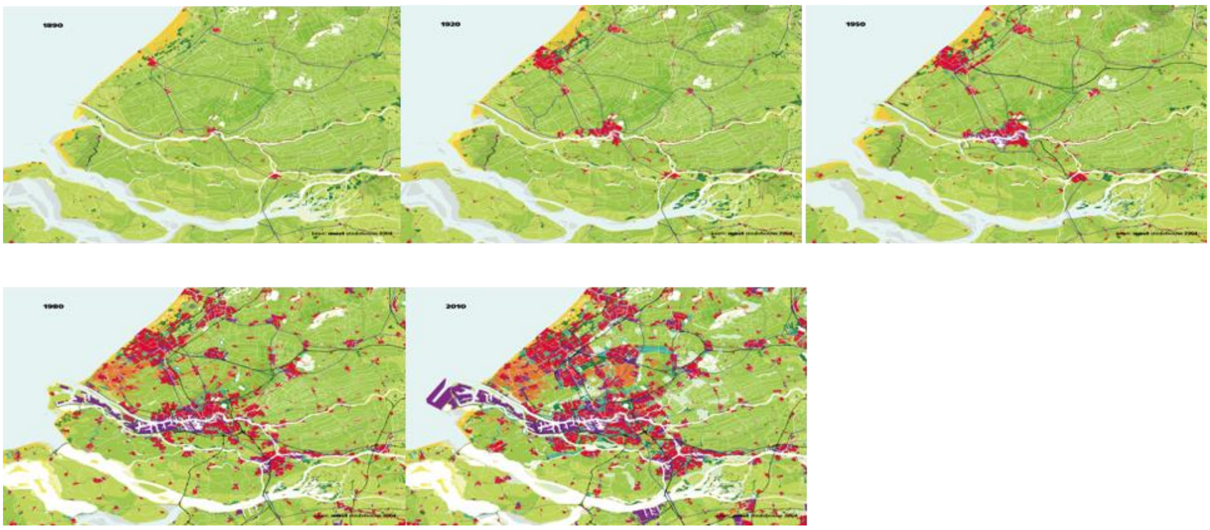


Figure 3.3. Urban sprawl in the metropolitan area of the Netherlands (PBL, 2015)

3.1.2 THE SECOND TRANSPORT TRANSITION

The thoughts in 1920 that air quality would improve with the invention of the automobile were wrong, because the automobile is gasoline-powered and produces CO_2, which harms the air quality. The population growth, urban sprawl, and the accessibility of cars and other motor-powered cars resulted in more and more cars on the public road. One of the consequences of the increase in cars is that the number of car accidents has risen. Around the world, nearly 1.25 million people die in road accidents each year. This is on average 3,287 people a day (ASIRT, n.d.). Almost 95% of these road accidents are caused by human error, which means if you exclude human intervention from driving, there will be significantly fewer accidents. Therefore, car manufacturers, engineers, and knowledge institutions are exploring the possibilities of autonomous cars.

The rapid technological and physical development of driverless cars raises many questions about the impact and effects on future cities. Research has been conducted and is summarised in section 3.2. The expectations for the development of future cities show a significant growth of inhabitants in large cities such as Amsterdam, London, and Bangkok, whereas the available space for transport stays the same (Vidal, 2018). The growing number of cars in cities will not only decrease the accessibility and traffic flow but also affect the air quality (Brown, 2017). Moreover, in rural areas, the number of inhabitants will shrink (Rijksoverheid, 2018), which means public-transport services will not be profitable anymore. For both reasons, public and private parties are exploring sustainable and smart forms of transport, for instance, shared systems and autonomous cars. Currently, we are ahead of a second mobility transition where the *ownership of a vehicle* shifts to the *use of a vehicle*. Moreover, we are ahead of a shift from *human-driven vehicles* to *driverless vehicles*.

The Dutch knowledge institute for mobility policy (Ministry of Infrastructure and the Environment, 2015) conducted a scenario analysis in which they predicted the possible impact of driverless cars. The scenario analysis is based on five levels of automation going from 0 (human driven) to 4 (fully autonomous). In Figure 3.4, four scenarios are projected in a matrix with of the horizontal axis the level of automation and the vertical axis willingness to share.

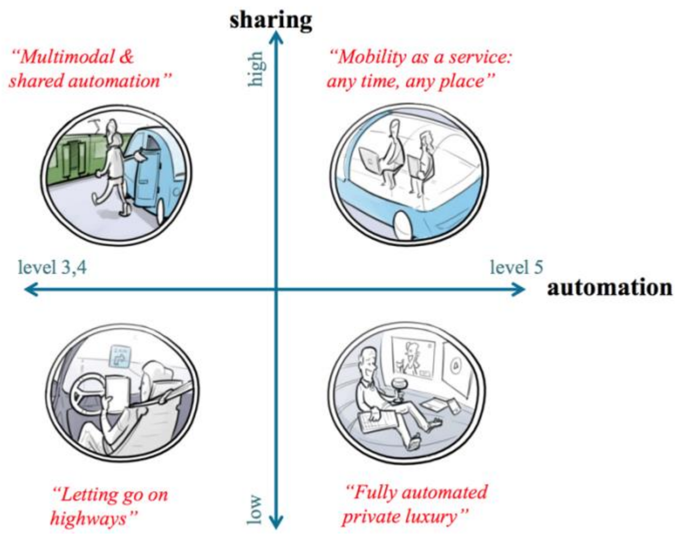


Figure 3.4. Four scenarios based on the level of automation and the willingness to share (Ministry of Infrastructure and the Environment, 2015)

Based on the four scenarios, the Knowledge Institute for Mobility Policy translated these scenarios into five transition paths that illustrate the transition from man and machine to the self-driving city.

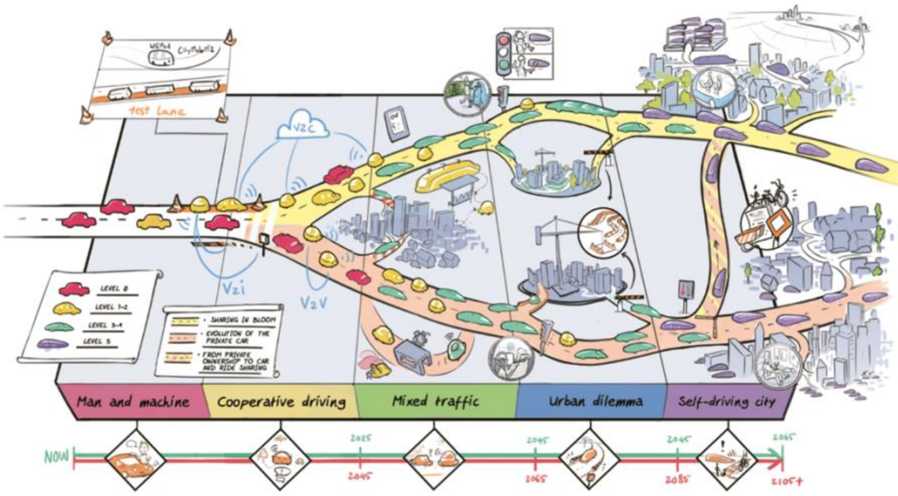


Figure 3.5. Five transition paths from man and machine to self-driving city (Ministry of Infrastructure and the Environment, 2015)

The transition from man and machine to self-driving city might have a huge impact on the way cities are organised and the way people live in cities, for instance, there might be less infrastructure needed and many automated systems might be connected to each other. The first transition—from horse power to engine power—was unexpected, which resulted in unforeseen events. For instance, congestion, air pollution, and the heat island effect. Therefore, it is essential to steer into the second transition—from human-driven to driverless—as much as possible to anticipate or even avoid unforeseen events.

3.1.3 THE HISTORY OF AUTONOMOUS CARS

When thinking about the first arrival of driverless cars, most people associate this technology with companies such as Uber, Tesla, and Google. However, this technology wasn't born in Silicon Valley or even Detroit. According to H.R. Everett, author of *Unmanned Systems of World Wars I and II*, the first unmanned ground vehicle was a radio-controlled tricycle designed by Spanish inventor Leonardo Torres-Quevedo in 1904 (Goldhill, 2016). From 1939 until 1991, General Motors (GM), one of the largest car companies in the world, was the first and only private company sponsoring the development of a self-driving car.

In the early 2000s, Congress decided to invest in driverless vehicles. Not so that people could commute easily to work while checking Facebook but to keep soldiers safer on the battlefield. The Department of Defense of the United States started the Defense Advanced Research Projects Agency (DARPA), which was an institute for the development of new technologies for the military (Loughlin, 2018).

The idea of a driverless car became real in 2004 when a group of engineers and robotics gathered for an unprecedented competition hosted by the U.S. government called the DARPA grand challenge. The DARPA challenge, which was open to anyone, was the first race to kick start the self-driving industry. Unfortunately, not one vehicle passed the finish line. However, when the challenge was held again in 2005, a car succeeded in passing the finish line, which proved to the world the possibility of technology (Loughlin, 2018). From that moment, the belief that self-driving cars were something that could only be possible in science fiction was over.

3.1.4 LEVELS OF AUTOMATION

In scientific papers, the terms autonomous, automated, driverless, and robotic cars are all used with the same meaning. However, according to a paper presented at the conference of the Heidelberg Laureate Forum by

Sifakis (2018), there is a significant difference between the definitions of autonomous and automated. He explains that an autonomous system needs the following functions: perception, reflection, goal management, planning, and self-adaptation. In some systems, it is possible that some parts are ensured by automated systems and some by humans. However, it is also possible that the whole system is ensured by automated systems. In this case, you can call the system or design an autonomous system (Sifakis, 2018).

In 2013, the United States Department of Transportation together with the Society of Automotive Engineers (SAE) provided a table with five levels of automation going from no automation (level 0) to full self-driving automation (level 5) (National Highway Traffic Safety Administration, 2013; SAE, 2018). The table below shows the levels of automation together with the functions by automation or driver. Daily-life examples of each level, mentioned by Sifakis (2018), are also added to the table. Only two examples, the shuttle and the robocar, are from a mobility perspective. However, the other three examples can give a better insight into the functions by automation.

	Level of automation	**Function by automation or driver (operator)?**	**Example**
Level 0	No automation	The driver is responsible for all actions in and around the vehicle, for example, steering, using the brake and more.	Thermostat
Level 1	Function-specific automation	Includes one or more specific control functions like stability control or adaptive cruise control.	Self-parking car
Level 2	Combined function automation	Includes at least two primary control functions,for example, adaptive cruise control together with pre-charged brakes.	Chess robot
Level 3	Environment detection	Includes at least more than two control functions, for example, stability control, adaptive cruise control, and pre-charged brakes.	Shuttle-service
Level 4	No human interaction required	Enables the driver to rely on all safety functions, however, the vehicle is limited to those functions in some conditions.	Soccer robot
Level 5	Human driver is eliminated	Designed to perform all driving functions on all roadway conditions. The driver will provide the destination but is not expected to be aware at any time during the trip.	Robocar

Table 3.1: Level of automation together with the functions by automation (Interpretation of National Highway Traffic Safety Administration (2013) and Sifakis (2018))

According to daily newspapers, we are currently at the end of level 3 and the beginning of level 4 (Van Gompel, 2018). Also, according to the Gartner hype cycle for connected vehicles and smart mobility (2018), which describes different emerging technologies, level 3 is now in a 'trough of disillusionment' (Figure 3.6). This means that the producers of the technology failed or started to work on another (more developed) technology. Level 4, full self-driving automation, is an innovation trigger. According to the scheme (Gartner, 2018), the plateau will be reached in more than 10 years. However, at the moment, the technology on paper moves much faster compared to the technology in practice, as there is a scarcity of practice projects regarding autonomous cars.

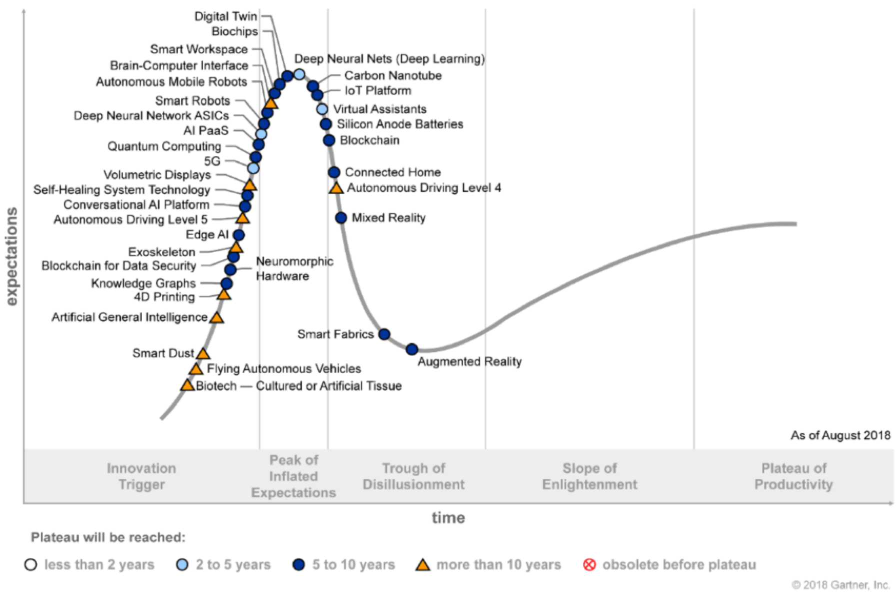


Figure 3.6: Hype cycle for emerging technologies 2018 (Gartner, 2018)

Although the focus in this research is on highly automated shuttle services (automation level 3), the term *autonomous vehicles* is applied because the final goal is to implement fully automated (autonomous) shuttles. Automation level 3 shuttles are being implemented because the technology is still in development. Policymakers want to implement autonomous shuttles because these parties mainly focus on the public perspective of autonomous cars, for example, as a replacement for or in addition to public transport.

3.1.5 THE ARRIVAL OF AUTONOMOUS CARS IN DUTCH CITIES

In summer 2014, the first self-driving pilot project with an autonomous shuttle, called WEPod, was initiated in the Netherlands. The initiator of the project was the province of Gelderland, which did so with the idea to explore sustainable forms of mobility of the future. In February 2015, the project received approval from the Provincial Council. The Parliament wanted the Netherlands to become a 'testing field' for autonomous cars.

According to the Dutch government, the country has a good infrastructure to play a pioneering role in the development of autonomous cars (Rijksoverheid, n.d.b). In addition, the Netherlands is the world's most prepared country to welcome self-driving cars, according to the KPMG autonomous vehicle readiness list of 2018 and 2019, which measures 25 countries' levels of preparedness (KPMG International, 2019). The index assesses countries on different measures spread across four themes: consumer acceptance, policy and legislation, infrastructure, and technology and innovation.

Currently, the Dutch government is stimulating self-driving vehicle pilot projects by granting subsidies and providing testing areas. In most of these pilot projects, autonomous shuttles serve the first or last mile as an addition to public transport. The Netherlands is also collaborating with neighbouring countries to create a platoon of autonomous trucks to transport flowers from the Netherlands to Antwerp, Belgium, and the Ruhr in Germany (KPMG International, n.d.). The main challenge of the integration of autonomous cars will be the number of cyclists in urban areas. The expectations are that the first large-scale application of autonomous cars in the Netherlands will be on the highways. Stijn de Groen, automotive expert at KPMG international, stated that it would be best for the Dutch government to focus on motorways rather than city streets.

3.1.6 THE RELATION BETWEEN AUTONOMOUS CARS AND URBAN AND TRANSPORT PLANNING IN THE NETHERLANDS

According to the climate agreements from Paris, CO_2 emissions need to decrease 30% by 2030 (European Commission, 2017). Consequently, the future urban planning system might be affected, because the development of urban areas focused on car-usage may increase congestion. Moreover, the focus on car usage could result in an increase in urban sprawl and a decrease in the use of public transport (Wilson and Chakraborty, 2013).

According to statistics from Statista (2019) and ACEA (2017), private car ownership around the world grew between the years 1990 and 2019. The estimations show that the number of cars will continue growing in the coming 30 years. However, the use of shared systems such as mobility as a service is excluded from this estimation. The actual question is whether the implementation of autonomous cars would further increase ca usage or result in less car usage. The answer might depend on the decision actors make regarding the integration of autonomous cars in cities (Thomopoulos & Givoni, 2015). For example, urban and transport planners could stimulate the use of either autonomous cars or also include sustainable forms of transport such as public transport, cycling, and walking. Scenario analyses could be made to estimate the effects.

3.2. Autonomous car: Definition and main players

The main aim of this chapter is to answer the first sub research question *'What is understood by autonomous cars?'* Section 6.1 gives some basic information about autonomous cars, section 6.2 explains the difference between the architecture of autonomous car and the architecture of an autonomous shuttle. In section 6.3, the main players in the manufacturing field of autonomous cars and shuttles are described.

3.2.1 THE ARCHITECTURE OF AN AUTONOMOUS CAR

To determine which routes and movements autonomous cars should take, the vehicles have cameras and sensors based on radar, LiDAR, and image technology to communicate with other vehicles and objects (Rudolph & Voelzke, 2017). The long-range radar sensor, which is located at the front side of the car, sends radio waves to sense surrounding objects nearby and at a certain distance. This long-range sensor also prevents vehicles from colliding with each other. Moreover, this sensor gives cars long-range sensing abilities because the sensor is able to see through dust, fog, rain, and snow (Wendt and Cook, 2018). Six short-/medium-range radar sensors, which are located on each corner and on the front and rear of the autonomous car, detect objects in front of or surrounding the vehicle. Six LiDAR sensors are situated on each corner and on the front and the rear of the autonomous car. These LiDAR—short for 'light detection and ranging'—sensors scan in 360° and measure the reflection of light off of objects. Lidar sensors enables an autonomous vehicle to distinguish different types of road users and objects like pedestrians, cyclists, children, animals, and so on. Four cameras are positioned on each side of the autonomous car to enable depth perception of the surrounding area and to provide information on aspects including the position, distance, and speed of objects. Thus, a combination of 17 sensors is needed to understand the environment and simulate the complex brain of the human, which only has two sensors—the eyes. The cameras and sensors are visualised in Figure 3.7.

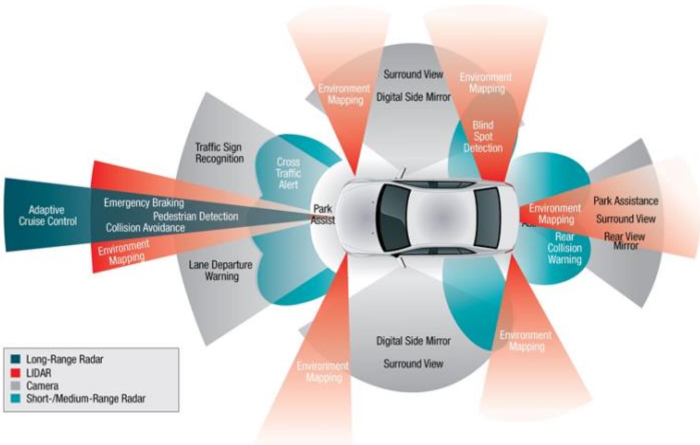


Figure 3.7: The cameras and sensors of an autonomous car (Wendt and Cook, 2018)

To guarantee the safety of autonomous cars to drive on public roads, it is crucial to test or train these vehicles. According to an estimation of ANSYS, autonomous cars should travel around 9 billion kilometres to travel safely on public roads. Unfortunately, this is can almost be called impossible because it is very time-consuming and costly. A solution to this is to train and test the sensors with simulations before testing on public roads. In a simulation programme, an autonomous vehicle can make mistakes to learn from without having any crashes or risks. Despite this innovative idea of simulating the behaviour of autonomous cars in urban areas, there are still situations that are unpredictable, for example, someone suddenly crossing the road. Even in this case, car manufacturers need to guarantee that their product is fully safe. This is where artificial intelligence comes in.

3.2.2 THE DIFFERENCE BETWEEN THE ARCHITECTURE OF AN AUTONOMOUS CAR AND THE ARCHITECTURE OF AN AUTONOMOUS SHUTTLE

Since the implementation of autonomous cars in the Netherlands is more or less focused on autonomous shuttles (public) instead of privately owned cars, it is crucial to determine the differences between these two autonomous vehicles. First, there is a difference in the appearance of both vehicles. The appearance of an autonomous car is comparable to that of a regular car, whereas the appearance of an autonomous shuttle can be compared to that of a small bus. The difference can be explained because of the use case of an autonomous shuttle. Currently in the Netherlands, autonomous shuttles are used to serve as the first or last mile in a public-transport service. To serve many people sitting down or standing up, the height of the shuttle is much larger, 2.65 metres. The length of the autonomous shuttle, 4–4.75 metres, is more than twice as large as the average car (Navya, 2017; Starlake, n.d.). According to a study on the impact of vehicle appearance on pedestrian interaction with autonomous vehicles (Dey, Martens, Eggen and Terke, 2017), the user acceptance is dependent on the appearance and looks of the vehicle. A larger and outstanding vehicle catches more attention and some people found the larger vehicle intimidating, which means people are more aware of the fact that the vehicle is different. Illustrations of an autonomous car and an autonomous shuttle are visualised in Figures 3.8 and 3.9.

Figure 3.8. Autonomous car (Waymo, 2018)

Figure 3.9. Autonomous shuttle (NAVYA, 2017).

Not only is the appearance of both vehicles different but the number and type of sensors are also slightly different. Both vehicles make use of Lidar, GPS, and cameras, but the autonomous shuttles are not manufactured with radar sensors (Navya, 2017; Starlake, n.d.). This difference could be clarified by the fact that autonomous shuttles operate on fixed roadmaps that are set in combination with a GSP antenna. However, the radar sensors might be crucial to determine the distance between the shuttle and another road object, for instance another vehicle. But the manufacturers might not expect that these shuttles would communicate with each other.

Another difference between the vehicles is their maximum speed. Practically, the maximum speed of an average autonomous car is the same as a regular car, which can be around 230–270 kilometres per hour. However, the testing speed for autonomous cars—at least in the US—is currently around 50 kilometres per hour. The maximum speed of an autonomous shuttle is 45 kilometres per hour, whereas the testing speed in the Netherlands is 15 kilometres per hour (Appendices D3 and D4). The last difference is the number of people that can be transported by the vehicle. An autonomous car can transport 4–6 persons, whereas the autonomous shuttle can transport around 15 persons (Navya, 2017; Starlake, n.d.). The differences between an autonomous car and an autonomous shuttle regarding the different uses cases is illustrated in Figure 3.10.

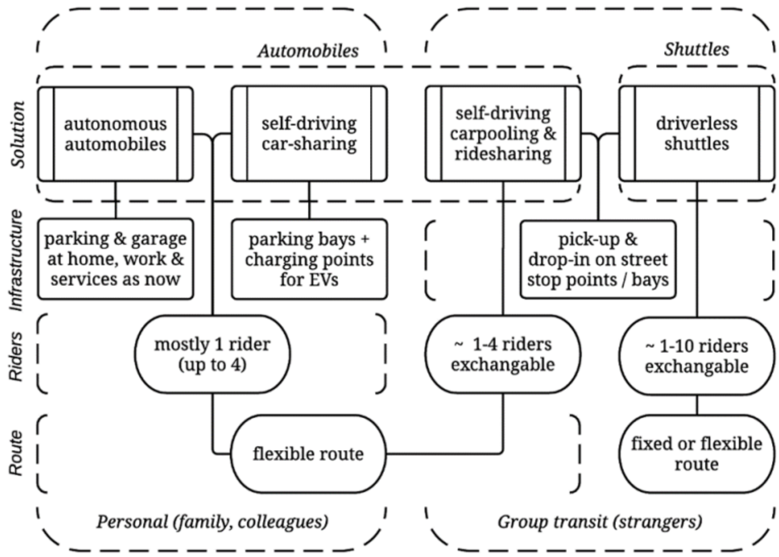


Figure 3.10. The differences between an autonomous car and an autonomous shuttle regarding the infrastructure, number of riders, and route (Ainsalu et al., 2018)

3.2.3 MAIN PLAYERS IN THE MANUFACTURER INDUSTRY

Car manufacturers such as Uber, Waymo (Google), BMW, Nissan, Ford, and Tesla have started investing in the technology to become the first company to succeed at safe integration of self-driving cars. The question is *why are these companies spending that much money and time in the development of self-driving cars?* The main reason might be the power the companies obtain by collecting data about people's journeys. When data from 1% of all vehicles in the world is collected, the company doing so, will know everything (Stikker, 2019).

Several companies are already in the testing phase. Car manufacturers can obtain data from vehicles in three different ways: from autonomous cars that operate on the public roads with a safety driver, through computer simulation, or via customers driving a car equipped with autopilot technology (O'Kane, 2018). Looking at the following table (Table 3.2), it can be said that Waymo is the leader in testing autonomous cars because of the travelled distance and the relatively small number of disengagements. The number of disengagements refers to the moments when car needed to be disengaged from driving autonomously.

COMPANY	DISENGAGEMENTS PER 1000 KILOMETRES	KILOMETRES PER DISENGAGEMENTS	NUMBER OF KILOMETRES DRIVEN IN TOTAL
Waymo	0.07	14,414.1	2,551,291
General Motors	0.21	4,864.97	929,211
Zoox	0.42	2,357.7	53,121
Nuro	0.97	1,028.3	39,718
Tesla	-	-	-
Nissan	3.0	338.7	8,807

Table 3.2: Miles per disengagements (own table based on Department of Motor Vehicles, 2018).

Table 3.2 applies only to autonomous driving in the U.S state of California. From the table, it can be observed that Tesla is not testing autonomous cars in California. In addition, Tesla is not testing autonomous cars in other states or countries. Cars manufactured by Tesla are equipped with an autopilot function. The autopilot function can be seen as semi-autonomous driving because the technology is not fully able to drive on its own without a passenger behind the wheel who is aware of the situation. However, the CEO of Tesla is completely certain that Tesla will be the first company that will achieve fully autonomous cars in 2019 (Su, 2018)

.

The disengagements and the number of kilometres driven is a measurement of the development of artificial intelligence and the safety of the autonomous cars on the public roads. According to the Department of Motor Vehicles (2018), Waymo is the frontrunner in self-driving vehicle testing. In addition, the table shows only the number of kilometres driven in the state of California, whereas Waymo started testing autonomous taxis in the state of Arizona. Moreover, many companies test the self-driving technology through simulation, which is also measured with the number of kilometres driven. When combining the kilometres driven in all states and in simulation programs, Waymo is still the frontrunner regarding the number of kilometres driven. In October 2018, Waymo reached 10,000,000 miles, which is 16,093,440 kilometres, which is more than every other company testing autonomous cars *combined* (Hu, 2018).

The amount of data is a second measurement to measure the development of self-driving technology. According to O'Kane (2018), the companies with the highest amount of data are Waymo and Tesla. However, there is a discussion about the reliability of the data both companies gather. On the one hand, it is not certain how much data from Tesla is gathered from the autopilot function of its customers, and the autopilot is only a semi-autonomous feature. On the other hand, Waymo relies heavily on data from its simulations, and computers cannot always come up with real-world scenarios. According to Tasha Keeney, an innovation strategy analyst at ARK-invest, the dataset from Tesla should not be underestimated (O'Kane, 2018).

In addition to car manufacturers investing in the development of autonomous cars, shuttle manufacturers are developing autonomous vehicles. However, the use case for autonomous shuttles is different compared to the use case of self-driving cars. The main players in the autonomous car industry by definition are not main players in the autonomous shuttle industry.

Currently, there are five autonomous shuttle manufacturers: 2GetThere, Easymile, Local Motors, Navya, Bosch, and the Belgian-Dutch VDL Bus and Coach. The two main players are Navya and Easymile, which is determined on the basis of the abilities of the shuttles. The characteristics of autonomous shuttles have not significantly improved over the last three years when compared to a newer model. The main difference between the Navya ARMA and the Easymile EZ10 is the ability of the ARMA to navigate using only satellites, which means there is no need for fixed objects along the trajectory (Starlake. n.d.; Navya, 2017). However, it should be noted that the mentioned criteria are based on constantly changing technology (Ainsalu et al., 2018). There are also some differences in the dimensions of both shuttles. In some projects, the dimensions determine the applicability of the shuttle. The dimensions of both vehicles are illustrated in Table 3.3.

DIMENSIONS	EASYMILE EZ10	NAVYA ARMA
Length	3.928	4.75
Width	1.986	2.11
Height	2.80	2.65

Table 3.3: Dimensions of the Navya shuttle compared to the dimensions of the Easymile shuttle (Starlake, n.d.; Navya, 2017)

In addition to the physical dimensions of the vehicle, the shuttle has virtual dimensions that are called the safety zone. There is a difference in the safety zone of the Easymile and the safety zone of the Navya shuttle. The safety zone of the Easymile is static, which means that the boundaries cannot be changed, whereas the safety zone of the Navya is dynamic, which means that the boundaries can be changed. The virtual dimensions of the Easymile are illustrated in Figure 3.11.

Figure 3.11. The static dimensions of the Easymile (Boersma, Van Arem, Rieck, 2018)

3.3 The impact of autonomous cars on the built environment

As a result of the rapid development of autonomous cars, policymakers feel the need to respond to this development. This is a major policy task that implies the collaboration of many stakeholders. The debate on how to steer upon this development is urgent, but at the same time, the solution does not need to be there the next day. After all, the policy area needs to take into account three levels of development: technological, market, and policy development (Zwijnenberg, 2018). The technological development goes quite fast since many car manufacturers and other companies are testing highly automated cars on American public roads already. However, full implementation of having only autonomous cars in our current mobility system will take a few decades because the market development runs at another speed (Zwijnenberg, 2018).

Every year in the Netherlands, 400,000 cars are sold and only a small percentage feature an SAE automated system. It will take a while before the market share of SAE level 2 cars is significant. If we take the current market development as a starting point, it will take years before cars with a higher level of automation are dominant on Dutch roads (Rijkswaterstaat in Zwijnenberg, 2018, p. 2). As a result, traffic in the Netherlands will be mixed for an unknown period of time. On the one hand, it is plausible that given the current economic lifetime of investments in physical infrastructure, no major (policy) changes are currently necessary. On the other hand, the government can already anticipate this development and make provisions to facilitate autonomous cars, to be able to reap the rewards of the potential social benefits faster (Zwijnenberg, 2018). Consequently, policymakers, planners, and other parties of interest are debating the impact on future cities. This might show that the impact is still quite uncertain, but this does not mean we 'know virtually nothing' about how autonomous cars will impact the built environment. Much research has been conducted to get an answer to this question (Donaghy, Rudinger, and Poppelreuter, 2004; Site, Persia, Alessandrini, Campagna, and Filippi, 2015; Ratti and Biderman, 2017; Prieto, Baltas, and Stan, 2017; Dias et al., 2017; Ratti, 2018; Duarte, F., & Ratti, 2018; Fitt et al., 2018).

According to Duarte and Ratti (2018: 8), 'automated vehicles have to reshape the way we live and design cities since the form of current cars is a constraint for realizing the full potential'. It is still not entirely clear how the design of autonomous cars will turn out in the future, but some assumptions can be made about the impact of these vehicles.

3.3.1 THE NUMBER OF CARS ON THE PUBLIC ROADS

Demographic changes and lifestyle changes have created an increase in personal transportation. The average population age has increased and individual mobility has become crucial because of distances between homes, jobs, and leisure activities and more spread-out social networks (Donaghy, Rudinger, and Poppelreuter, 2004). 'On one hand, young people have started driving later than in earlier generations, and multiple of them decided not to get a driver's license' (Duarte & Ratti, 2018: 8), but on the other hand, daily life has become more hectic as jobs are not always tied to one particular location and working hours could vary (Site, Persia, Alessandrini, Campagna, and Filippi, 2015). Autonomous cars might attract other demographic segments that currently rely on public or private transportation or even remain immobile, such as the elderly, children, and disabled people. The latter arguments refer to an increase in cars on the public roads; however, it could be argued that autonomous cars can reduce the number of cars on the public roads. Aside from the transition to autonomous cars, there is another mobility transition that has been gaining popularity: ride sharing. Apps such as Uber, Lyft, and car2go have been quite successful in many countries and the impact on private car usage might be large. Scholars estimated that every shared vehicle removes nine to 13 privately owned cars from the roads (Ratti and Biderman, 2017). However, the latter estimation is based on data from Zipcar, operates only in the United States. The adaptation to car-sharing systems might depend on the social aspects of potential users. People who live in low-density neighbourhoods, in households with multiple cars, are less likely to use car-sharing concepts, whereas inhabitants who live in cities and people with a graduate degree more often use car-sharing concepts (Duarte and Ratti, 2018; Prieto, Baltas, and Stan, 2017; Dias et al., 2017). To conclude, the answer to whether implementation of autonomous cars will result in more or fewer cars on the roads is far from determined, as it likely depends on cultural aspects that can impact the situation.

3.3.2 THE NUMBER OF PARKING SPACES

Cars are parked 96% of their lifespan, whereas autonomous cars tend to have a utilisation rate of 75% ('If Autonomous Vehicles Rule the World', 2015). Currently, a large number of square metres in cities is dedicated to cars in the form of parking places both visible in street view and invisible in underground parking garages. One of the many positive effects of autonomous cars is that they could decrease the demand for parking places (Duarte, F., & Ratti, 2018). This is because autonomous cars can serve multiple users during the day considering they are part of a shared system and therefore remain parked much less of the time. When assuming autonomous cars would be used as private vehicles in the future, the vehicles could be parked outside of cities. This does not mean that the total number of parking places decreases but that the number of parking places within cities can decrease. This all depends upon future policies, as policymakers can prevent cars from being parked in cities to improve the liveability. Moreover, the parking demand might reduce in since the size of autonomous cars may be smaller (Fitt et al., 2018). This means that parking places needed for autonomous cars might be much smaller. In conclusion, the answer to whether there will be more or fewer parking places needed might not be that there are more parking places needed in the future. One of the reasons is that shared autonomous cars will be driving around 75% of the time or will be parked outside of the city because of the costs of parking. Another reason is that privately owned autonomous cars might replace current privately owned cars, which means that the number of parking places needed remains the same. Whether or not there will be fewer parking spaces needed in the future again depends on the social aspects and future policies.

3.3.3 AN INCREASE OR DECREASE IN URBAN SPRAWL?

Changes in infrastructure, transport technologies, and behaviours have implications for the urban form. Urban sprawl is an example that results in problems of inaccessibility for those who are not able to travel by motorised transport (Fitt et al., 2018). Figure 3.12 illustrates a pattern of development from the traditional walking city to the automobile city. The traditional walking city is characterised by a compact distribution of services and facilities, whereas the automobile city is characterised by low density areas due to significant urban expansion (Newman and Kenworthy, 1996).

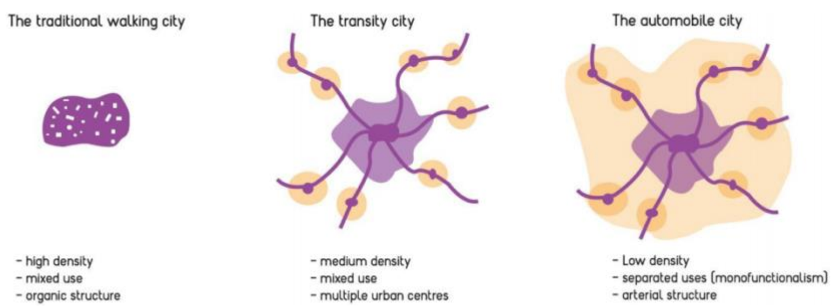


Figure 3.12: Transport and development of urban form (adapted from Newman and Kenworthy, 1996).

Urban expansion requires the extension of roads as well as other infrastructure, for instance, waste removal and water supply. Generally, urban sprawl tends to have negative environmental effects (Wilson and Chakraborty, 2013). According to research (Berg and Verhoef, 2016; Fagnant and Kockelman, 2015), autonomous cars tend to increase sprawl, because these vehicles will allow users to perform other activities while traveling to their destinations. This way, commuting time will be less time consuming and more attractive. On the contrary, because autonomous cars tend to reduce the quantity of accidents in urban areas, cities might become safer and more liveable, which might reduce urban sprawl (Duarte, F., & Ratti, 2018). Moreover, it is probable that compact urban areas will increase the attractiveness of using shared systems, which might lead to more attractive urban areas. In the Netherlands as well as worldwide, there is a trend of people tending to move to city centres. In addition, the quality and attractiveness of cities has clearly improved. After a decline between 1960 and 1990, there is now a population increase in cities (PBL, 2015). The regional forecast of PBL (2016) also foresees a strong concentration of population growth in urban municipalities for the future. An increase is expected in and around large cities in particular.

In the rural areas in the Netherlands, people are moving to the larger cities because amenities are disappearing in the outlying areas. Autonomous cars might be a solution to this, as people who are immobile can travel to the local supermarket or pharmacy again. According to a study about the implementation of autonomous cars in the public-transport system, the change in urban structure depends on the type of driverless transport systems (Ainsalu et al., 2018). The figure below illustrates two scenarios of the implementation of driverless mobility. In scenario one, the implementation is pedestrian friendly and will lead to urbanisation and re-urbanisation, whereas scenario two, which is rider friendly, will lead to de-urbanisation, suburbanisation, and urban sprawl.

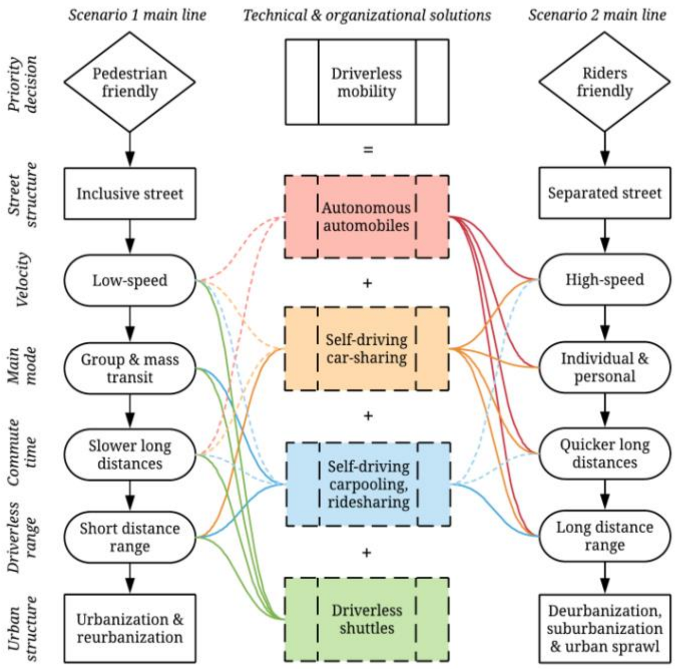


Figure 3.13. Two scenarios for the use of driverless mobility and spatial changes (Ainsalu et al., 2018)

To conclude, autonomous cars might increase the urban sprawl somewhat because travelling will become less time-consuming. However, as a result of the trend to live in larger cities, the expectation is that the population will still increase in those larger cities.

3.3.4 THE NUMBER OF ROAD INFRASTRUCTURE

Road conditions might not be sufficient for autonomous cars in every country in the world, assuming that an autonomous vehicle is not able to drive safely on roads with bad conditions, for example, large holes or oily asphalt. This means that the investment might differ for each country. Moreover, because autonomous cars are able to communicate with the infrastructure, the current infrastructure, for instance, traffic lights, should also be able to communicate with autonomous cars. Therefore, infrastructure may need to be renewed or adapted to the technology. However, this does not explicitly mean that there is more infrastructure needed. Additionally, when assuming autonomous cars will completely replace non-autonomous cars in the future, there will be less infrastructure needed (Sohrweide, 2018). Autonomous cars are equipped with many sensors that increase efficiency and decrease deviations. Figures 3.14 and 3.15 illustrate the infrastructural differences according to Sohrweide (2018).

Figure 3.14: A four-lane and six-lane divided urban highway (Sohrweide, 2018)

Figure 3.15: Estimation of future road infrastructure (Sohrweide, 2018)

The discussion about urban sprawl is also applicable to the question of whether there is more or less road infrastructure needed. Increase urban sprawl because of the autonomous vehicle transition might lead to more road infrastructure being required, whereas otherwise the road infrastructure would remain the same or decrease. Looking at the near future, it can be assumed there will be both autonomous cars and non-autonomous cars on the road. This means that the infrastructure changes might be less notable. In conclusion, there are two arguments that road infrastructure tends to decrease in the future. First, autonomous cars will be more efficient because of the vehicle sensors, which means that equal traffic volumes could operate on fewer and narrower lanes (Sohrweide, 2018). Second, it is expected that urban sprawl would decrease, and therefore there might be less road infrastructure needed.

All changes explained above might have an influence on the liveability of cities. It is recommended to incorporate the possible future changes into the decision-making processes of the implementation of autonomous cars.

3.4 European and Dutch regulation

3.4.1 THE EUROPEAN GOVERNANCE OF AUTONOMOUS CARS IN THE NETHERLANDS

The deployment of driverless mobility contributes to several societal objectives such as a reduction in the number of road fatalities, bringing down emissions, and reducing congestion. The ambition of the European Commission is to make Europe a world leader in the development of connected and automated mobility (European Commission, 2018).

The European Parliament (EP) set up a legally binding report directed to the European Commission, the European Committees, and member states about autonomous driving in European transport (European Parliament, 2019). In this section, the relevant resolutions to this study are described. The resolutions are divided into three subsections: road transport, consumer rights and competitive conditions, and research and educational needs.

ROAD TRANSPORT

The EP highlights the importance of standardising and verifying market surveillance procedures related to autonomous cars. Also, clear regulation is crucial to improving accident investigation procedures. The regulation needs to be harmonised and updated when necessary. To prevent road accidents, the EP underlines the necessity of including safeguard systems as a step toward autonomous driving (European Parliament, 2019). Moreover, the EP calls on Member States to provide safe, high-quality road infrastructure—which includes interoperable digital communication—that facilitates the use of automated and autonomous cars. In addition, the EP underlines the importance of clarifying the definition of requirements of vehicles with advanced driver-assistance (SAE levels 1–3) and autonomous vehicles (SAE levels 4–5) in road safety legislation. Lastly, ethical aspects should be resolved by the legislature before the vehicles can be fully accepted (European Parliament, 2019).

CONSUMER RIGHTS AND COMPETITIVE CONDITIONS

The Commission need to clarify the responsibilities and right of manufacturers, drivers, and operators at every level of automation in all modes of transport. Moreover, these rules need to be communicated to all actors properly to ensure the safety of the cars and to enable fair market access to in-vehicle data and resources. In addition, all systems in autonomous cars need to be designed in such a way that it enables potential owners or users to choose freely between service providers (European Parliament, 2019).

RESEARCH AND EDUCATIONAL NEEDS

The EP highlights the importance of knowledge sharing and collaborative research to ensure a smooth and integrated development of automation. A way to obtain knowledge about the development of autonomous cars is to facilitate real-life testing. As such, the EP urges member states to designate, by 2020, urban areas for real-life testing. Lastly, legislators must address the ethical dimension to improve public acceptance, therefore, extensive research on artificial intelligence and other aspects is essential (European Parliament, 2019).

In April 2016, the Declaration of Amsterdam was signed. With this document, member states, the European Commission, and the private sector agreed on joint goals and joint actions to facilitate the introduction of connected and autonomous driving on European roads (Rijksoverheid. n.d.a).

3.4.2 THE GOVERNANCE OF AUTONOMOUS CARS IN THE NETHERLANDS

At the moment, there are already cars on the road with automated functions, such as adaptive cruise control and automatic brake systems. Before 2015, it was forbidden to test autonomous cars on public roads in the Netherlands according to the Road Traffic Act 1994. However, since June 2015, it has been possible to test self-driving cars on public roads but only with a driver in the vehicle.

At the end of 2017, the House of Representatives received the Experimenteerwet zelfrijdende auto' (draft bill governing the experimental use of autonomous cars) from Minister Cora van Nieuwenhuizen (Ministry of Infrastructure and Water Management). In April 2018, the bill was rejected, which means that it is still not possible to issue permits for conducting tests on public roads using remote drivers. An example of remote driving is an autopilot function on the highway that completely takes over the steering wheel during that period. At the EU level, it has been agreed that all member states must be ready to introduce autonomous cars on their roads in 2019 (Ministry of Infrastructure and Water Management, 2017).

According to Dutch law, article 36 paragraph 1 of the Road Traffic Act, all motor vehicles must have a licence plate, even autonomous cars. Every motor vehicle can request approval from the Dutch Vehicle Authority to receive a licence plate. However, permission is still not possible for autonomous cars, as these vehicles do not meet the European requirements. For example, art. 5.2.29 lid 1 BW states that all motor vehicles must have a steering wheel, whereas some autonomous cars are not designed with a steering wheel. The Dutch Vehicle Authority (DVA, in Dutch: RDW) has the authority to give exemption on the regulation that enables autonomous cars to be tested on public roads. This jurisdiction is stated in Art. 48 lid 3 of the Road Traffic Act, which states that the Dutch Vehicle Authority is authorised to give exemption to register a licence plate even when the vehicle does not match with the European requirements.

The first self-driving vehicle application at the Dutch Vehicle Authority was the WEpod project. The project was initiated in 2014 by the Province of Gelderland with the idea of establishing a self-driving shuttle service between the Campus of Wageningen and the train station Wageningen/Ede (Boersma, Van Arem & Rieck, 2018). During the application period, the question was raised as to whether the self-driving shuttle should be categorised as a regular motor vehicle or as a motor vehicle with a speed limit because the WEpod would not be driving faster than 25 kilometres per hour. The advantage of a motor vehicle with a speed limit is that the vehicle is not obliged to have a licence plate. However, Art 1.1 Lid 1 states that motor vehicles with a speed limit are not allowed to transport persons. Thus, the decision was made to qualify the WEpod as a passenger car (Stoep, 2017 in Boersma, Van Arem & Rieck, 2018). Still, the self-driving vehicle did not meet the European qualifications of the Road Traffic Act 1994 Art 48, because the vehicle was not equipped with a steering wheel. However, in combination with Art 4 lid 4, autonomous cars can be equipped with a particular licence plate that shows the exemption of the DVA (Boersma, Van Arem & Rieck, 2018).

The application at the DVA was a learning process for both the project team and the DVA (Stoep, 2017 in Boersma, Van Arem & Rieck, 2018). During this application, the project team of WEpod delivered a safety plan that included the safety standards of the ISO 26262: 2011, which is an international standard for functional safety of electrical systems in the production of automobiles. At the end of 2018, the ISO 26262: 2011 is revised by the ISO 26262-1: 2018. This international standard encounters many safety procedures, for example, hazard analyses, risk assessments, management for safety requirements, and situation analyses (NEN, 2019.).

3.4.3 THE AUTONOMOUS VEHICLE APPLICATION PROCEDURE

The Dutch Vehicle Authority (RDW) developed a procedure to regulate the licensing and exemption procedure for tests with connected and/or automated driving (CAD) on public roads. The vehicle authority developed a framework to provide insight into the safety assessment and the way the applicant proves the project to be safe (RDW, 2017). The whole procedure can be divided into five steps as shown in Figure 3.16.

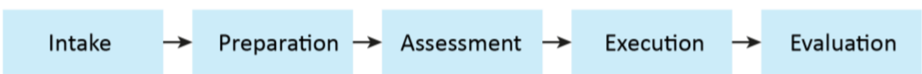


Figure 3.16. The five steps of the RDW application procedure (RDW, 2017)

The intake focuses on the pre-assessment of the test application. During this phase, the applicant is obliged to deliver an information document about the project, declare cooperation in the research, and communicate properly (RDW, 2017).

The preparation phase focuses on the preparation for the assessment of the test application. During this phase, the applicant is obliged to submit information about the primary and secondary parties, which will then be approached by the RDW and a first meeting will be initiated by the RDW with all relevant parties (RDW, 2017).

During the assessment phase, together with the advisory partners, a decision about the safety is made and whether the tests can and may be carried out. Each of the advisory partners have their own expertise. The SWOV, a Dutch independent research institute specialised in traffic safety, advises the RDW and the road authority grants permission to use of the road (RDW, 2017).

During the execution phase, the test is carried out on public roads. Feedback plays a crucial part in this phase. The applicant of the project is obliged to submit logbooks every week that will be monitored by the RDW.
The evaluation phase focuses on the development of knowledge. During this phase, the knowledge questions from the initiative phase are answered.

The application procedure takes around 12 weeks; however, this depends on the type of vehicle, completeness and quality of the documents submitted by the applicant, experience from other tests, and the cooperation of all parties. The policies are regularly adjusted based on the experience from former projects. Because the technology develops very quickly, the application procedure is a learning process for all stakeholders.

The whole process from application to evaluation is illustrated in Figure 3.17.

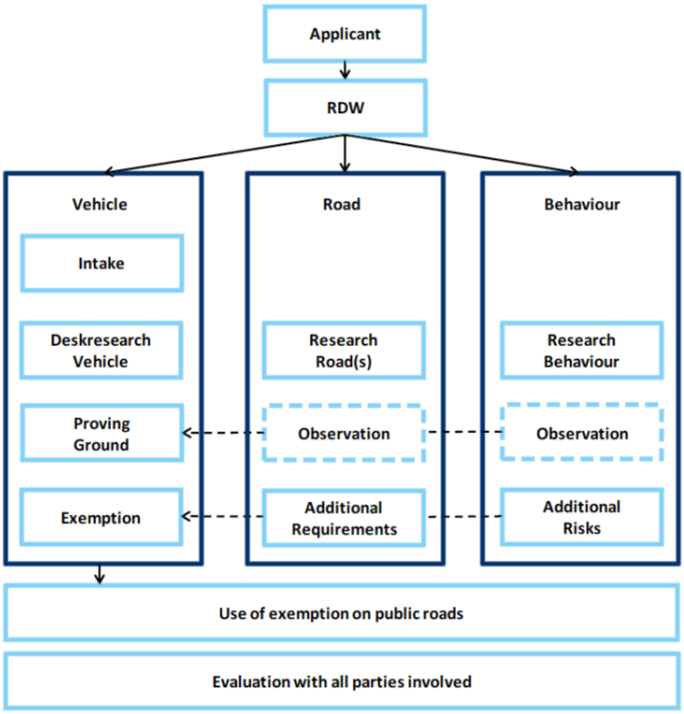


Figure 3.17. The application procedure from initiation to evaluation (RDW, 2017)

STAKEHOLDER ANALYSIS

4.1 Stakeholder analysis

This chapter introduces the main actors committed in the autonomous car transition within the Dutch context. The stakeholder analysis results in a precise overview of all stakeholders' interests. This overview can be helpful when determining strategies to engage all stakeholders.

4.1.1 THE PURPOSE OF DOING A STAKEHOLDER ANALYSIS

The ‘success’ for a public organisation depends on the satisfaction of crucial stakeholders in the project. Therefore, a stakeholder analysis is crucial in solving a dilemma that comprises or concerns various persons, organisations, and institutions (Bryson, 2004; Bryson, 1994; Moore, 1995). When key stakeholders are not or are only minimally satisfied, the expectation should be that things will change, for instance, by cutting costs, the rise of unemployment and new initiatives will be threatened (Bryson, 2004).

To research the impact of autonomous cars on the built environment, first, technical abilities and disabilities of these vehicles need to be collected from researchers or manufacturers. Second, to assess the practical feasibility of those abilities, more stakeholders need to be involved. Third, during the testing period on the public roads, as a federal agency, the road authority should satisfy the stakeholders by putting forward measures. Finally, regional and local policymakers should keep all stakeholders informed about regulation by making clear policies.

This research involves only stakeholder from Dutch organisations. This means that this study represents the regulatory system of the Netherlands. In the Netherlands, the national government governs some public highways, whereas the provincial governments govern most public roads. To guarantee the reference value of this study, both the national and provincial road operators are defined as road authorities.

4.1.2 PROCESS OF THE STAKEHOLDER ANALYSIS

The process of doing a stakeholder analysis consists of three steps. First, the stakeholders are identified, which means that all stakeholders are analysed for their interests, goals, and position within the Dutch context. Second, a power versus interest matrix is applied to determine the stakeholder’s status and influence. Third, the relations and interdependencies between all stakeholders are given.

4.1.3 STAKEHOLDER IDENTIFICATION

Ten main stakeholders might have an effect upon or might be affected by the implementation of autonomous cars included in the stakeholder identification. Together with the stakeholder analysis of Lu (2018), interviews from other research, government publications concerning the impact of autonomous driving, and comparable studies on stakeholder analysis are applied as a source to determine the stakeholders (Anderson et al., 2016; European Commission, 2010; Krabbendam, 2018; Ministry of Infrastructure and the Environment, 2016). The stakeholders are as shown in Table 4.1.

STAKEHOLDER	RESPONSIBILITY
The European Commission	The European Commission is the EU's politically independent executive arm, which is responsible for drawing up proposals for new European legislation and implementing the decisions of the European Parliament and the Council of the EU.
The Ministry of Infrastructure and Water Management	The ministry is responsible for all infrastructure projects in the Netherlands, which consists of three sections: policy, implementation, and inspection (Lu, 2018).
Regional and local government	Public organizations which execute national, regional and local policies. Provinces are responsible for the design of the rural area and the accessibility and economic policies of a region. Municipalities are responsible for the execution of policy tasks which are relevant to its residents, for example, collecting household waste and creating zoning plans.
Vehicle authorities	In the Netherlands, the road authority is called Rijksdienst voor wegverkeer (RDW) and its main responsibility is to supervise, register, and manage vehicles. Moreover, the RDW is responsible for the testing procedures.
Manufacturers	The manufacturers design, produce, and sell autonomous cars or shuttles.
Service providers and suppliers	The material producers, telecom companies, and other suppliers can make profits during the process of implementing autonomous vehicles in the built environment. Moreover, their services or products will either limit or facilitate the implementation of autonomous cars (Lu, 2018).
Consultants	The consultants are specialized in different fields in the autonomous vehicle industry, for instance, the regulation procedures or the abilities of the sensors.
Research institutes	The research institutes do research on autonomous driving from different aspects and they deliver innovative or technical solutions to both manufacturers and public agencies (Lu, 2018).
End-users (Car drivers)	The end users might have an effect on or might be affected by the implementation of autonomous cars. The driving habits of the car drivers might have an influence on the impact.
Insurance companies	Newly designed or changed insurance policies are needed for automated vehicles. Accidents that might happen in different road segments may have different imputation of responsibility (Lu, 2018).
Residents in an urban area	The residents in an urban area might have an effect on or might be affected (positively or negatively) by the implementation of autonomous cars.

Table 4.1: Stakeholders and their responsibilities—Dutch context— (own table).

The result of the stakeholder identification is listed in Table 4.2

STAKEHOLDER	INTERESTS	PROBLEM PERCEPTION	GOALS
The European Commission	Aims to promote the peace, its values, and the well-being of its citizens.	What is the impact of self-driving vehicles and what are the societal and economic consequences.	To take the lead in the development of fully self-driving systems and ensure that the legislative and EU policy frameworks are ready.
The Ministry of Infrastructure and Water Management	Provide citizens with a livable, accessible, and secure Netherlands.	Autonomous cars have an impact on the built environment and the built environment might have an impact on autonomous cars.	Be certain of a safe and optimal implementation of autonomous cars.
Regional and local governments	Improve the accessibility and the livability in the rural areas and get more knowledge about the technology.	The impact of autonomous vehicles on the built environment is unclear.	To regulate and stimulate autonomous driving projects to increase the accessibility and to get more knowledge.
Vehicle authorities	Provide public services for the mobility industry.	New rules and regulations to allow autonomous cars on the roads.	To regulate the testing and future projects and make sure they will be executed safely.
Manufacturers	Design, develop, manufacture, and sell autonomous vehicles.	The development of autonomous cars takes time and costs money. The impact may influence the ability of AC's to be implemented.	To Improve the technology of autonomous cars, promote them, and make profit.
Service providers and suppliers	Offer services or products to the autonomous vehicle industry (public and/or private companies)	Autonomous cars need innovative services and products, for instance, 5G network or good sensors.	To Improve the services and product and make profit.
Consultants	Offer advise to initiators of autonomous vehicle integration.	Autonomous vehicles should be implemented to gain knowledge	To fasten the implementation process and learn by doing.
Research institutes	Be part of the technology supply chain.	Provide new solutions and innovate ideas to make the implementation more successful.	To fasten the implementation of autonomous cars and be ahead of the future.
End-users (Car drivers)	Safe, comfortable, and affordable driving experience.	High costs, uncertainty of safety on the road, and in the car.	Benefit from safe and affordable driving.
Insurance companies	Develop insurance services	It is complicated to judge the responsible party of an accident caused by autonomous driving.	Make new insurance clauses for autonomous cars.
Residents in an urban area	Live in a safe and accessible environment.	What are the implications of autonomous cars on the urban environment? Is it safe?	Benefit from the advantages of autonomous cars.

Table 4.2: Stakeholder identification—Dutch context— (own table)

4.1.4 POWER INTEREST MATRIX

The power versus interest matrix is described in detail by Eden and Ackermann (1998: p. 121 – 5, 344 – 6). The matrix is applied as a tool to take into account the power and interests of each stakeholder. The result of this analysis determines whether collaboration between actors should be supported or not (Eden and Ackermann, 1998). The matrix is split into two axes, namely the actors' interests in the matter and the actors' power, which might affect the performance of the future matter (Bryson, 2004 in Lu, 2018). The creation of two axes results in four classes of activities: keep satisfied (high power and low interest), manage closely (high power and high interest), monitor (low power and low interest), and keep informed (low power and high interest) (Johnson and Scholes, 1999; Olander, 2007). The power versus interest matrix is shown in Figure 4.1.

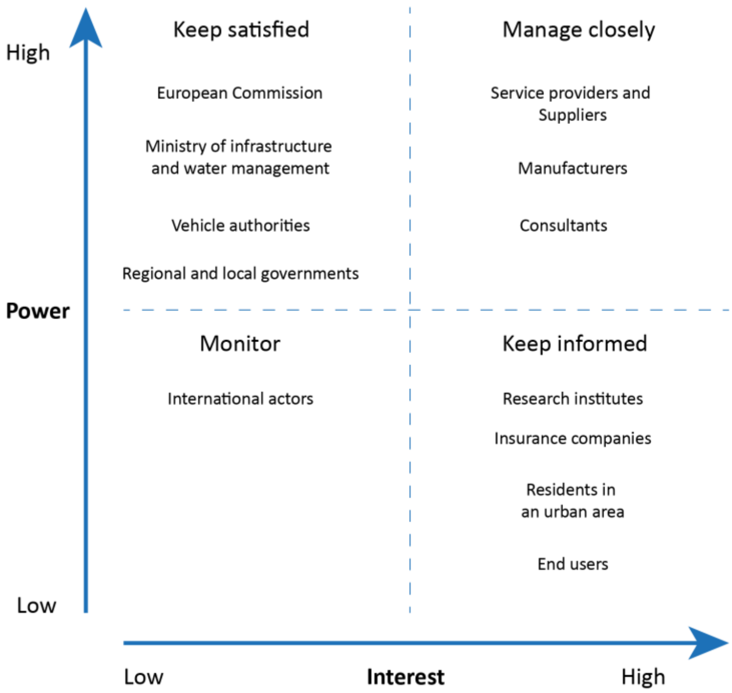


Figure 4.1: The power versus interest matrix with the key stakeholder of autonomous car implementation in the Netherlands (Based on Bryson, 2004)

The European Commission, the Ministry of Water Management and Infrastructure, the regional and local governments, and the vehicle authority are public agencies that are context setters in the transition to autonomous cars, as these governmental agencies are responsible for the regulation. To be able to test autonomous cars on public roads it is crucial to get permission for both the project and the vehicle. Also, their willingness to subsidise projects will define which and how many projects can be executed. Therefore, it is essential to keep these actors satisfied.

The research institutes, end users, insurance companies, and residents living in the 'affected' urban area are stakeholders with low power and high interest, as they might be affected by the implementation of autonomous cars. Despite that, these stakeholders do have limited power in the decisions about this mobility transition. Therefore, these actors should be kept informed.

The service providers and suppliers, manufacturers, and consultants have high power because these actors either own the software of the autonomous cars and the network, or have knowledge about the process of implementing autonomous cars, for instance, knowledge about the exemption procedure. The development speed of these services has an influence on the implementation of autonomous cars. This makes collaboration with these actors crucial. Therefore, these stakeholders should be managed closely in the process.

4.1.5 STAKEHOLDER INTERDEPENDENCIES

To comprehend the interdependencies between the actors and to work out necessary actions to manage their goals successfully, the resources of the stakeholders must be considered. The analysis of the resources and interdependencies are illustrated in Table 9.3 and Figure 4.2.

STAKEHOLDER	IMPORTANT RESOURCES	DEPENDENCY RELATIONSHIP	CRITICAL ACTOR
The European Commission	Authority on investment and policies	The Ministry of Infrastructure and Water Management	Yes
The Ministry of Infrastructure and Water Management	Authority on investment and policies	Road authorities; vehicle authorities	Yes
Regional and local governments	Knowledge and authority on road infrastructure and land use. Able to grant subsidies.	Research institutes; service providers and suppliers; manufacturers	Yes
Vehicle authorities	Knowledge and authority on vehicle supervision, registration, and test application.	Manufacturers	Yes
Manufacturers	Knowledge on autonomous cars technology and software and experience with road testing.	Service providers and suppliers; vehicle authorities	Yes
Service providers and suppliers	Knowledge about their services and products, for example, 5G network and sensors.	Vehicle authorities; manufacturers	Yes
Consultants	Knowledge and experience about the exemption procedure, infrastructure.	Vehicle authorities; manufacturers; regional and local governments; service providers and suppliers	Yes
Research institutes	Knowledge on both autonomous driving technology and the environmental impact; help manufacturers to do vehicle tests; collaboration with organizations.	Vehicle authorities; manufacturers; service providers and suppliers	Yes
End-users (Car drivers)	Driving experience; willingness to possess services or products.	Insurance companies; manufacturers	No
Insurance companies	Knowledge on the responsibility in a traffic accident.		No
Residents in an urban area	Knowledge on the transportation options in the urban environment.	Regional and local government	No

Table 4.3: Resource dependency and critical actors —Dutch context (own table)

The interdependencies of those stakeholders are visualised in Figure 4.2.

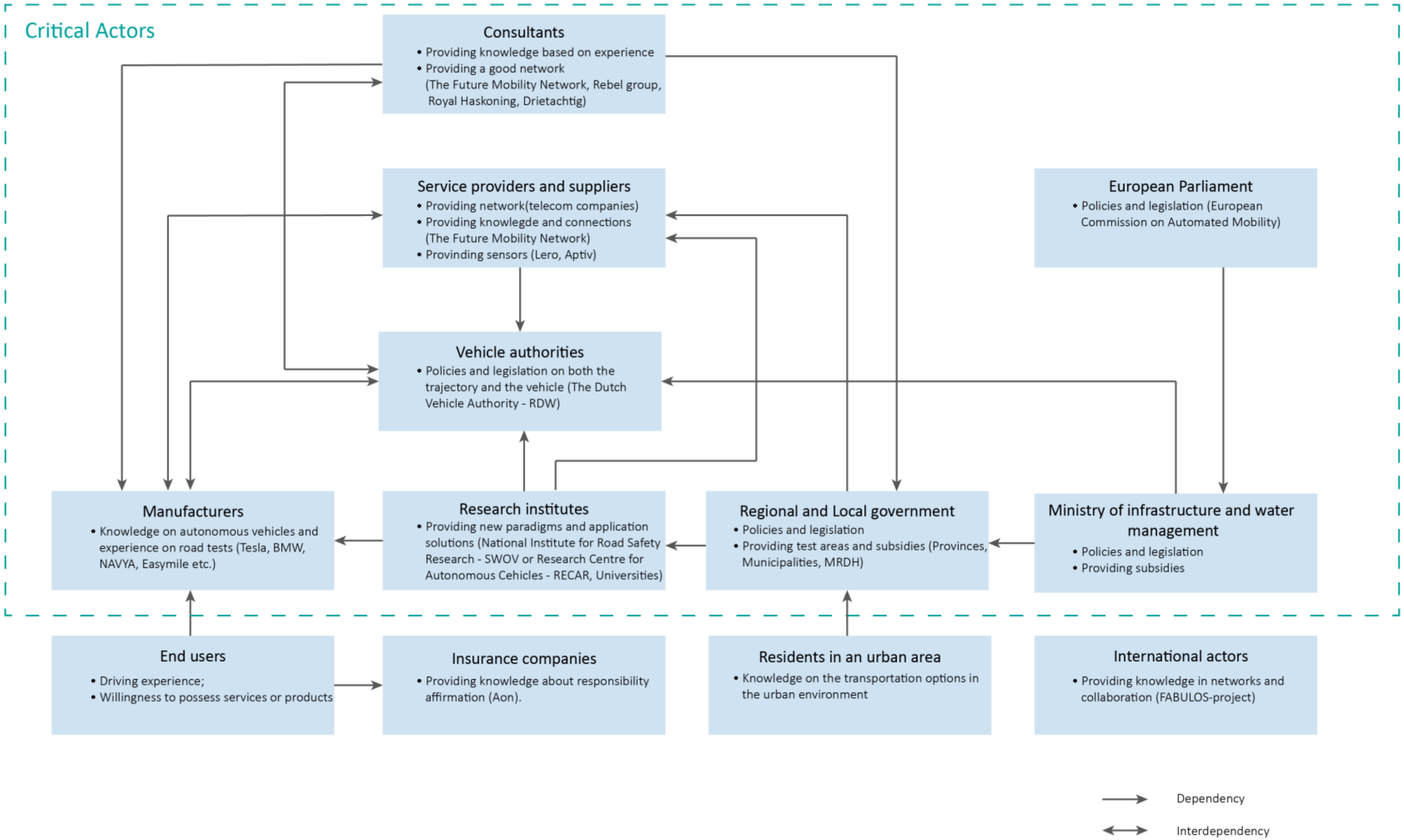


Figure 4.2: Stakeholder Interdependencies (Own illustration)

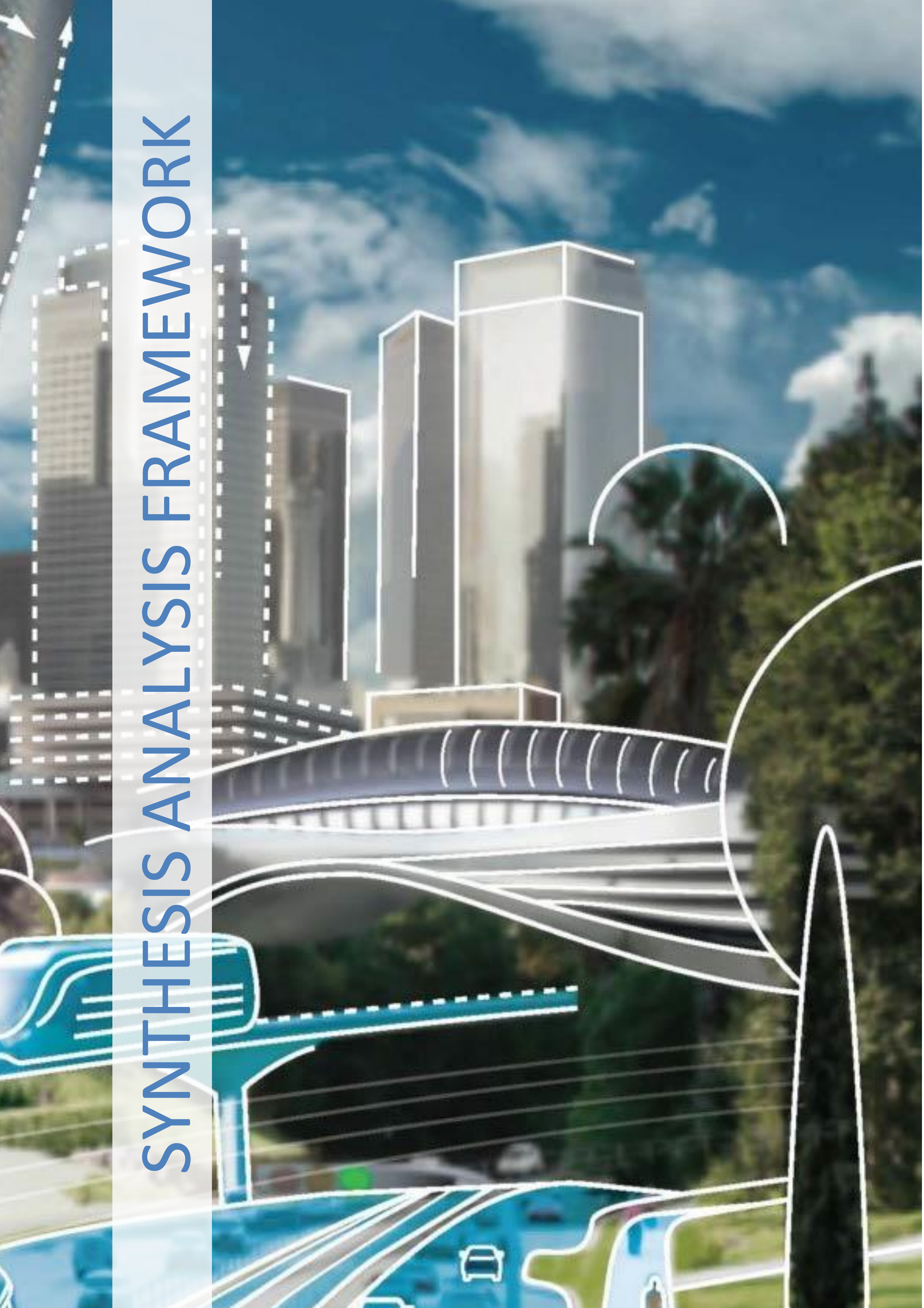
4.1.6 CONCLUSION STAKEHOLDER ANALYSIS

When comparing both the power versus interest matrix and the stakeholder interdependencies, the critical actors in the implementation of autonomous cars are the European Commission, the Ministry of Infrastructure and Water Management, regional and local government, vehicle authorities, research institutes, service providers, and suppliers and manufacturers. Consequently, the engagement levels of these particular actors are more significant compared to the other three non-critical stakeholders.

Amongst the critical stakeholders, research institutes and service providers and suppliers are the proper interviewees to examine the requirements for the autonomous vehicle implementation, as they have experience in testing autonomous cars. Also, regional and local governments, for instance, municipalities and provinces, are suitable interviewees to examine their experience and lessons learned with autonomous vehicle tests, as they are actively involved in such projects.

From the stakeholder analysis, it can be concluded that every stakeholder has its own core values. Therefore, the process of integrating autonomous cars in the urban area must be open and flexible to satisfy the different core values. Only in this way can the process proceed smoothly and all goals be more easily achieved. The stakeholder engagement plan has a large influence on the successful integration of autonomous cars.

SYNTHESIS ANALYSIS FRAMEWORK



5.1. Technical challenges

There are still many challenges in technology that can have an influence on the integration of autonomous cars in the urban area. In some cases, there are solutions or other ways to deal with these challenges; in other cases, the challenges might be underestimated. In this section, three main challenges, sensor defaults, generalisation in artificial intelligence, and the trolley problem, are described.

5.1.1 SENSOR DEFAULTS

Sensors in autonomous cars have to be extremely reliable, because road safety will be dependent on these sensors. This means that it crucial to be aware of the defaults. Every sensor of an autonomous vehicle collects data that will be merged with the data of all other sensors. An autonomous vehicle has many different sensor types, because every sensor has its own abilities and disabilities. In Figure 5.1, the abilities of all sensors combined are visualised in a scheme (Barnard, 2016).

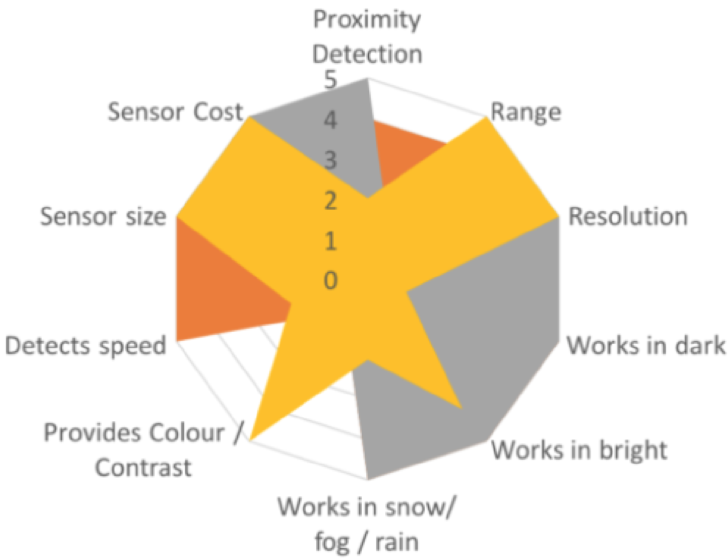


Figure 5.1: The abilities and disabilities of all sensors—LiDAR, short-range and long-range radar, cameras—combined (Barnard, 2016)

From the figure, it can be concluded that there are still some defaults or disabilities when combining all sensors. For instance, the sensors are not completely able to collect data during snow/fog/rain situations and there are difficulties in observing colours and contrasts. The range and performance of the sensors degrades as light levels dim, for instance, because of the headlights of other cars. In some conditions, the sensors are not able to detect objects against bright skies (Barnard, 2016). This means that the sensors are still not completely reliable in every situation. However, it is important to note that this article was written in July 2016. As technology develops very quickly, it might be possible that the sensors have improved. During real-time tests, it is crucial to find out the shortcomings in the performance in different situations. For instance, differences in road situations, such as an uneven road, or differences in weather situations such fog, rain, or snow.

5.1.2 GENERALISATION PROBLEM IN ARTIFICIAL INTELLIGENCE

In 1956, the term artificial intelligence (AI) was invented. AI gives the possibility to machines to learn an experience, to adapt to new information, and to perform human-based tasks (SAS, 2019). Computers can learn to easily accomplish particular jobs by processing considerable numbers of data. Moreover, the machines can be trained to recognise patterns in the data using deep learning technologies. Currently, because of the increase in data, AI is becoming more and more advanced (SAS, 2019).

Figure 5.2: The development of artificial intelligence visualised (SAS, 2019)

As artificial intelligence seems to solve a big challenge regarding the technology of self-driving cars, there are still some challenges that technologists face. Technologists should be aware of the dangers of bias of artificial intelligence. The experiences the intelligence is built upon can be different in other countries, as the objects and the road infrastructure might be different in the urban areas. Huang (2018) discovered a sort of racism in the intelligence of a self-driving car when she was a passenger in an autonomous car, wherein the car only recognised white people as pedestrians. In fact, this issue occurs because the system has a generalisation problem. Researchers were certain that they could improve this problem with the right algorithms; however, recent research has shown that conventional deep learning is even worse at generalising than previously thought (Azulay & Weiss, 2018). Thus, different types of infrastructure and objects may harm the integration of autonomous cars.

5.1.3 TROLLEY PROBLEM

A second technical issue that also presents an ethical challenge is dealing with the trolley problem. The trolley problem is a thought experiment in ethics about the impossible decision: to do nothing and allow the trolley to run over a bunch of people, or to drive off the adjacent cliff and kill one person (Rechtin, 2018). On the one hand, the trolley problem has been seen as a challenge that should be embraced by the car manufacturers; on the other hand, the trolley problem has not to be seen as an issue standing between autonomous cars and deployment. According to Silver (2018), incorporating this issue into the development of autonomous cars seems incorrect. He argues that millions of human drivers have been licensed to operate motor vehicles without receiving instruction on how to approach the trolley problem.

5.1.4 CYBER SECURITY

Parallel to the technical developments of autonomous cars, the rapid advance in cybercrime and techniques targeting infrastructure can be a major threat for the safety of autonomous cars. Accordingly, it is crucial to understand the two boundaries of cybercrime: the operation of autonomous cars as ad hoc cars and the injection of fake messages that could cause dangerous situations. As the main focus in the development of autonomous cars has been on the safety aspects, the threats of cybersecurity have been overlooked (Bagloee, Tavana, Asadi, and Oliver, 2016). It is crucial to incorporate cybersecurity as an essential part of safety engineering.

5.1.5 AVAILABILITY OF 5G NETWORK

Another technical challenge is the unavailability of the 5G network. This high-speed network is crucial in the decision-making process of autonomous cars. The importance of a 5G network is confirmed by the UK national mapping agency Ordnance Survey: 'When you switch a light on, it turns on immediately. That's what you need with autonomous cars– if something happens, the car needs to stop immediately. That's why the high frequency

5G signals are required‘ (Russon, 2018). According to the European Commission, universal access to a 5G network is needed to establish autonomous mobility technologies. They also state that there are still regions —especially in rural areas—where the current 4G network is lagging behind (European Parliament, 2018). To overcome or deal with the mentioned technical challenges, private parties work with pilot projects to train the cars in different environments.

5.2 Environmental challenges

5.2.1 ROAD CONDITIONS

Autonomous cars are designed to operate in the world as it exists; the quality of the road is not that important according to Silver (2018). However, it could be argued that there is a high difference between the condition of roads in developing countries and the condition of roads in the United States or the Netherlands. The fact that autonomous cars are being tested in Phoenix, Arizona, a state with some of the best roads in America, shows the importance of qualitative roads in autonomous car testing (Wiles, 2017). It is not stated in the literature what private companies are doing to overcome possible difficulties regarding road conditions.

5.2.2 UNSIGNALISED INTERSECTIONS AND LEFT TURNS

Crossing unsignalised intersections seems to be a difficult manoeuvre for autonomous cars. Different studies tried to minimise the total delay time of all vehicles crossing the intersection in a simulation programme (Zohdy and Rakha, 2012; Fajardo, Waller, Stone, and Yang, 2011). However, there is still improvement needed in the development of the software, as the delays can lead to traffic jams or unsafe situations in traffic. Moreover, it is crucial that autonomous cars operate safely at intersections because the difference in speed compared to other vehicles can be quite significant. This difference in speed can lead to unsafe situations.

Unprotected left turns—when the traffic light misses the green arrow or when there is no traffic light at all—are seen as a significant challenge when testing Waymo’s autonomous cars. Even for human drivers, making left turns is seen as a dangerous manoeuvre (Efrati, 2018). According to the National Highway Traffic Safety Administration (NHTSA), close to half of the 5.8 million car crashes in the U.S. are intersection-related and the majority of those are the result of making a left turn (NHTSA, 2010).

However, Waymo received a favourable report on autonomous-vehicle disengagements from California earlier this year. According to Dmitri Dolgov, head of Waymo, ‘Our report shows a marked improvement in our fully self-driving technology. Since 2015, our rate of safety-related disengages has fallen from 0.8 disengages per thousand miles to 0.2 per thousand miles in 2016‘ (Dolgov, 2018). In addition, Waymo has already driven more miles than a human would drive in 600 years and with the arrival of artificial intelligence, the algorithms will become better and better with practice.

If left turns still cause problems, there is another solution: do not turn left. The delivery service UPS designed alternative routes to avoid left turns because they have seen that doing so is less time-consuming and more cost-efficient (Efrati, 2018).

5.2.3 WEATHER IMPLICATIONS

Most autonomous car testing in the United States take place in parts of the country that provide excellent weather conditions. In other countries, for example, the Netherlands and Denmark, where there is more rainfall or snow, it can be a challenge for autonomous cars to drive safely. However, again because of artificial intelligence, autonomous cars are getting smarter every day, which means that the cars are able to take alternative routes and decisions (Rechtin, 2018). To overcome this challenge, it is crucial to perform enough testing in various weather conditions to increase the experience of the vehicle.

5.2.4 OTHER ROAD USERS

Within the urban environment, many types of road users might interact with autonomous cars. It is crucial to test the interaction with all types of road users traveling via both private and public forms of transport. The common private forms of road users are car drivers, cyclists, and pedestrians, and the common public forms of road users are busses, trams, and trains.

5.3 Social challenges

5.3.1 TRUST ISSUES

According to a survey of the Pew Research Center about Americans' attitudes toward driverless cars, 56% of the public would not want to be a passenger of an autonomous vehicle. Among those 56%, 42% are worried about giving up control or have trust issues (Smith & Anderson, 2018). Intel undertook research on the trust issue and came up with four key capabilities that are crucial to building trust. The first capability is comprehensive sensing. Autonomous cars should show the passengers both *that* the car is sensing and also *what* it is sensing. This gives the passengers confidence that the autonomous cars is aware of its surroundings. The second capability is clear, bidirectional communication. There should be simple and clear communication between the vehicle and the passengers. The third capability is the response to changes. When autonomous cars show that the response is accurate and quick, the level of trust is proven to increase. Last, there should be multiple modes of interaction between the autonomous cars and the passengers. Voice interactions, touchscreens, and mobile devices can help to create more interaction between the vehicle and the passenger (Weast, Yurdana & Jordan, 2016).

Firms such as Uber and Waymo, who are developing autonomous vehicles, have already developed a user interface that shows the vehicles, objects, and pedestrians in the area nearby and the decisions the vehicle takes. According to the Self-Driving Cars Teach-Out, an online course of the University of Michigan about various topics regarding autonomous cars, another way to increase trust is to enhance communication between the pedestrians outside the vehicles and the vehicle itself. A way to do this is to make use of LED lights on the exterior of the autonomous car (University of Michigan, 2019).

5.3.2 ACCEPTANCE

According to Overakker (2017), the social acceptance of autonomous driving systems depends on the level of automation. When only allowing automation level 3 cars on the highway, 63% of all citizens accepted the system. However, when testing the acceptance with automation level 4, most citizens do not seem ready to completely rely on level 4 autonomous systems (De Winter, Happee, Martens & Stanton, 2014).

According to the literature, it is crucial to include values and norms within the social acceptance of autonomous cars. Dethloff (2004) identified two dimensions of acceptance that are described and summarised in Figure 5.3. The dimension attitude includes mindsets, social values, and judgements and the dimension action includes observable behaviour, for instance, purchasing, using, supporting, or spreading activities. The figure can be used to measure the acceptance (Dethloff in Fraedrich and Lenz 2016).

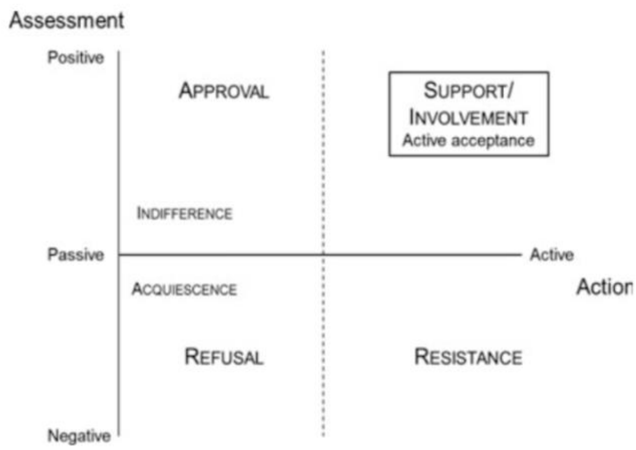


Figure 5.3: Two dimensions of social acceptance (Fraedrich, and Lenz 2016)

On the one hand, Frost and Sullivan (2006) describe that the majority of car users resist the ideas of giving up control of their vehicle to a robot or machine. On the other hand, young drivers —between 19 and 31— do not perceive the need to drive a car since they can also do other more interesting or meaningful activities: 'Regulation keeps trying to say texting is distracting to driving but for the consumer it is really the driving that is distracting to texting ' (Deloitte, 2011, p. 2).

5.3.3 BEHAVIOUR OF (ROAD) USERS

The way people behave when interacting with an autonomous vehicle is still in an early stage. People can be unpredictable because they do not know how the vehicle operates. This could result either in a reserved or neutral attitude or in a bold attitude, for example, people who want to test how close they can get to stop the vehicle. This reserved attitude of the public is also described in the case study of an autonomous shuttle in Sion, Switzerland, where more than a half of the interviewees described they either avoid or were extremely careful walking or driving near the shuttle. People were unable to interpret the movements of the shuttle or were afraid that the technology might fail (Eden, Nanchen, Ramseyer, & Evéquoz, 2017). It is thus crucial to communicate properly with both road users and the users of the vehicle. As the authors in the case study description state: 'communicating the intentions of an autonomous car's forthcoming actions has been identified as a priority for improving Human–AV interaction' (p.1573). The challenge here is to what extent the vehicle should be able to communicate and how an autonomous vehicle is able to communicate with human beings?

5.3.4 ACCESSIBILITY

Another social challenge is ensuring accessibility to all potential users. The accessibility can be divided into financial accessibility and practical accessibility. At first, it is essential that the costs to travel by an autonomous vehicle is in proportion to the costs of a comparable transport means. For example, when an autonomous vehicle serves as public transport, the costs for taking this service should be similar to the costs for taking another line in public transport. When the autonomous shuttle serves as a private transport means comparable to a private taxi cab, the costs should be in proportion to the costs of hiring a taxi. Financial accessibility can be a challenge because the technology is quite new. It is still difficult to gain financial profit instead of a loss. Second, the autonomous vehicle should be accessible to everyone. This means the vehicle should be able to transport baby strollers, wheelchairs, rollators, etc. Practical accessibility is something that should not be forgotten; however, during the development of a new technology, the object will be improved over time.

5.4 Regulatory challenges

Regulation is a big challenge facing the mobility industry. According to Mike Ramsey, research director at Gartner, autonomous cars are entering the trough of disillusionment phase of the Gartner hype cycle, and regulation is probably one of the reasons why this is happening (Ramsey, 2018). Uncertainty in regulations prevented the car manufacturer Audi from selling the Audi A8 equipped with traffic jam assist in the U.S. (Paukert, 2018). According to a survey of more than 260 leaders from the automotive and technology industries, 54% of the respondents preferred that autonomous-car-related regulations come from the U.S. Department of Transportation. To cope with this challenge, governors have worked closely together with autonomous car firms to issue guidelines instead of strict rules that might hamstring the industry (The Economist, 2018).

Because this research is merely focused on autonomous shuttle projects in the Netherlands, the regulatory challenges regarding Dutch regulation are described. However, the challenges can also be applicable to other countries. The main challenges the government faces regarding the future implementation of autonomous cars are over-regulation, rethinking education, steering employment, and liability. All challenges are mainly caused by the uncertainty of the future of autonomous cars.

5.4.1 OVER-REGULATION

As described by Mike Ramsey and other research, over-regulation might hinder the implementation of autonomous cars (Ramsey, 2018; Brodsky, 2016). The challenge for the government and policymakers is to facilitate and at the same time regulate the implementation of autonomous cars. Because the uncertainty of the impact and effects of autonomous cars is quite unclear, it is complicated and challenging to anticipate. This might result in exploratory and lengthy procedures to integrate autonomous cars, which makes it more complicated to initiate such projects. Because of a complicated procedure, the number of pilot projects might decrease, which can hinder the development of knowledge. It is crucial to prevent this downward spiral.

5.4.2 RETHINKING EDUCATION

The challenge that comes with the development of a new technology is the available number of experts on the particular field. Currently, few people know how to program autonomous cars (Silver, 2018). The problem arises because of supply and demand: there is a high demand for engineers with specific skills such as machine learning, software expertise, automotive engineering, and more, but the supply of these experts is low. Schools and universities might struggle to keep up with fast-growing technology and thus the fast-growing demand. Therefore, it might be necessary to rethink the approach to education or to offer a new form of education, for example, institutions that support employees throughout their careers (Silver, 2018). This also matches the current workforce in the Netherlands, since Dutch people often switch careers during lifetime.

5.4.3 STEERING EMPLOYMENT

The availability of autonomous cars could result in a lower demand for other transport services such as public transport, Ubers, and taxi cabs. This might result in job loss and increased unemployment (Litman, 2014). However, when rethinking education, other jobs could be created again. Still, the implementation of autonomous cars would threaten many large industries, including health care, insurance companies, construction, transportation, and energy. As an example, the annual revenue of health insurance premiums, energy, car sales, car insurance premiums, and car crashes, of around US$2 trillion, could disappear in the United States alone (Poczter and Jankovic, 2013).

5.5 Analysis framework

From Chapter 2 and the theory, it was concluded that the implementation of autonomous cars in urban areas might be influenced by many factors. Furthermore, the theory provided in the previous section of this chapter describe the main challenges actors should take into account during, before, or after the implementation of autonomous cars. In Chapter 4, it was concluded that there are eight critical actors in the implementation process: the European Commission, the Ministry of Infrastructure and Water Management, regional and local governments, vehicle authorities, research institutes, service providers, consultants, and suppliers and manufacturers. The main challenges divided into the subthemes of technical, environmental, social, and regulatory challenges form the basis of the synthesis of the analysis framework (Figure 5.4).

5.5.1 PRELIMENARY VERSION OF THE ANALYSIS FRAMEWORK

This analysis framework is of value for the research in two distinctive ways. First, the framework provides a useful scope of research in the case analysis, as the analysis framework's dimensions form the focal point for the literature review and qualitative interviews in the second and third phases of the research. Second, the analysis framework provides the opportunity to compare the challenges of the implementation projects in a comprehensible manner in the fourth phase of the research, the cross-case analysis. Figure 5.4 illustrates the preliminary version the analysis framework. With this framework, the technical, environmental, and social challenges could be assessed. The three 'dimensions' are divided into several subthemes that are helpful when analysing the five case studies.

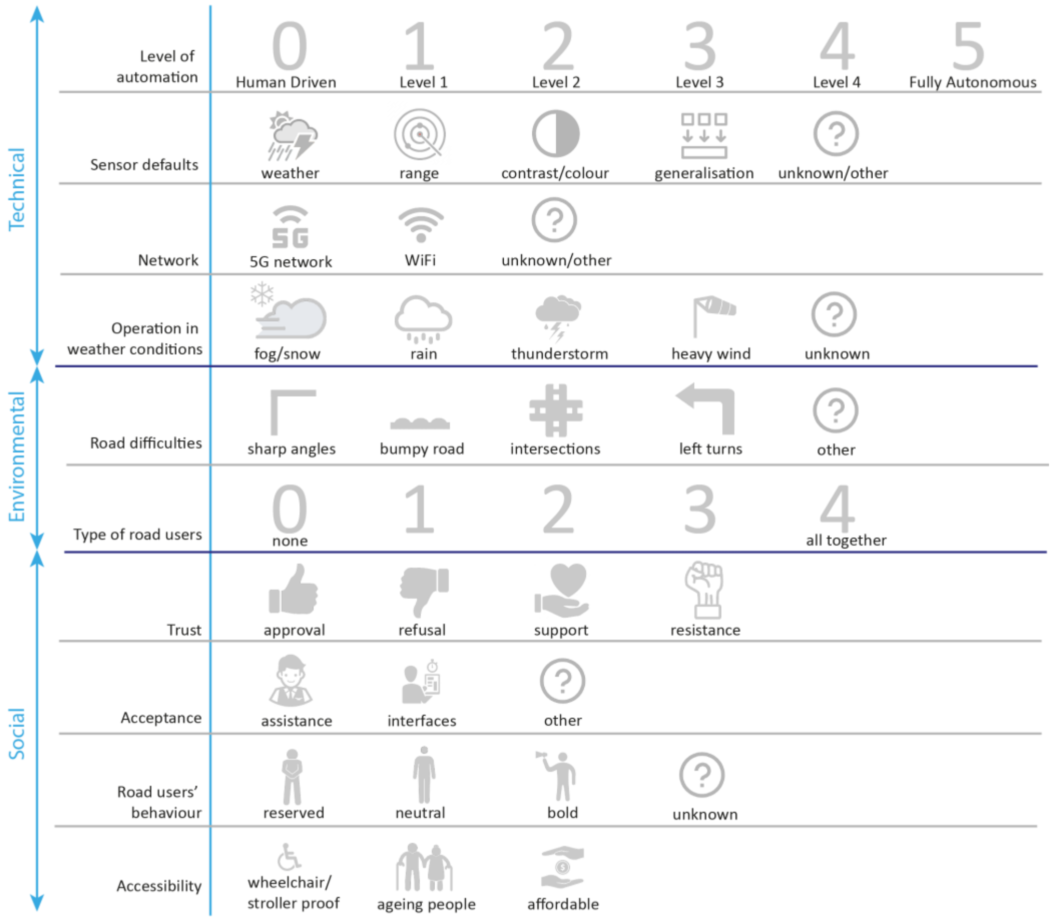


Figure 5.4. Preliminary version of the analysis framework (own illustration)

When analysing the case studies, the analysis framework has been adjusted, because the framework did not illustrate the complete overview of the cases. Moreover, during this study, it was made clear that the speed of the vehicle has a strong relationship with the challenges and restrictions by the vehicle authority. As such, the context and regulatory boundaries have been added to the framework. Additionally, some environmental challenges, such as a slope and roundabouts, were discovered. The analysis framework is illustrated in Figure 5.5

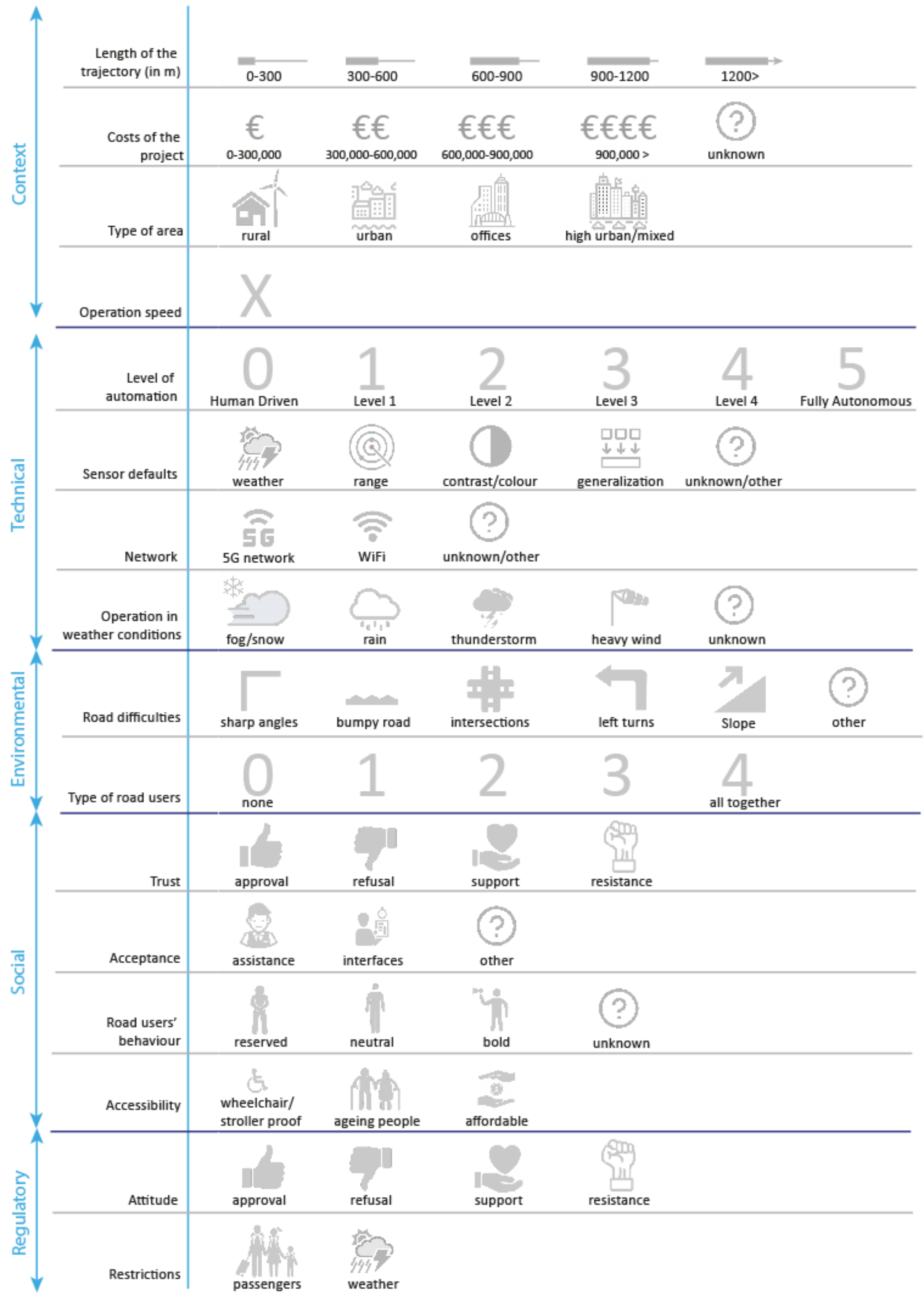
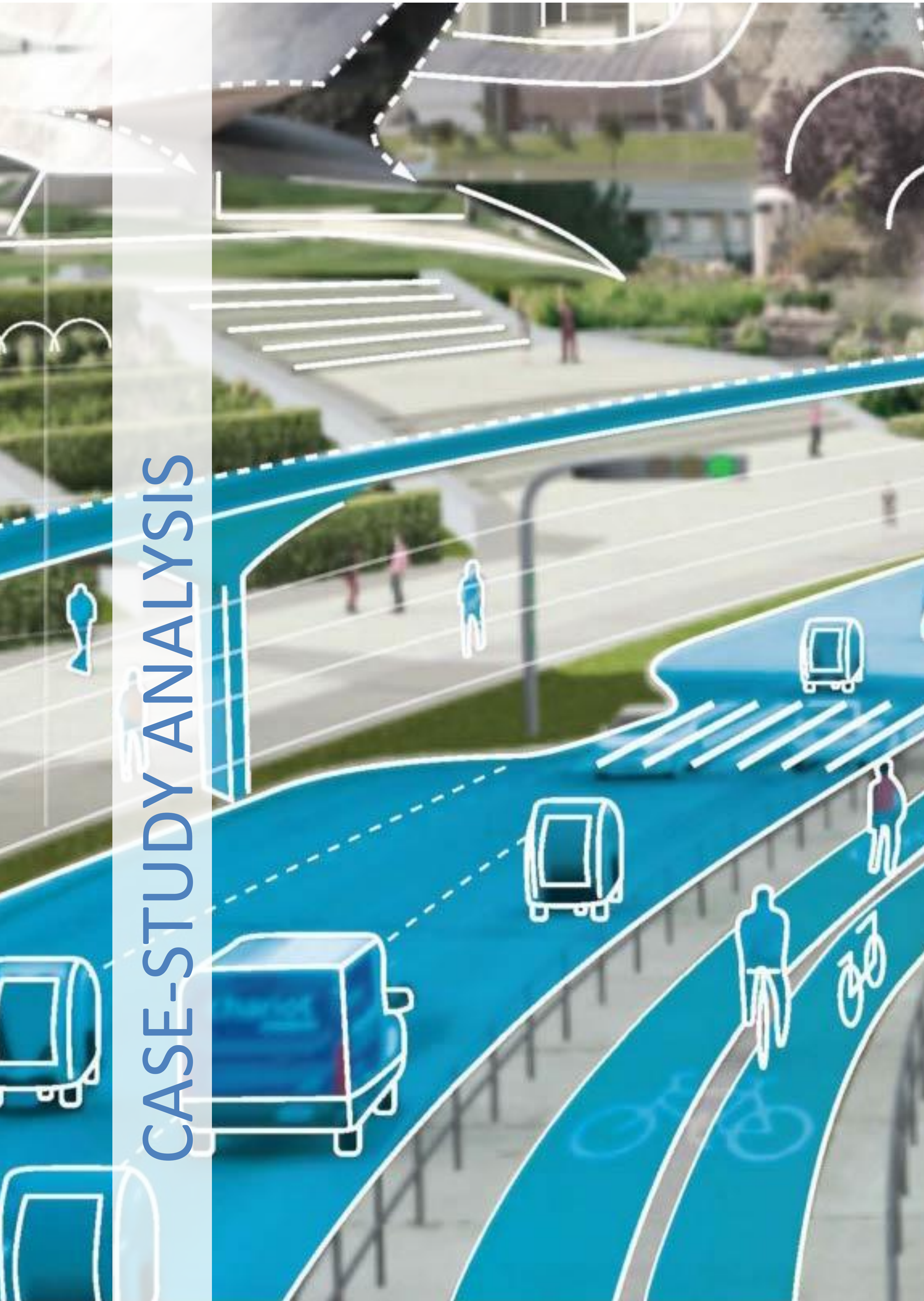


Figure 5.5. The analysis framework (own illustration)

CASE-STUDY ANALYSIS



6. Case-study analyses

The first aim of this chapter is to describe all case studies in depth. In the first sections of each paragraph, all case studies are described in terms of the location, the purpose of implementing the autonomous shuttle, the trajectory, the involved actors, the type of vehicle used, and the costs of the project. With this analysis, a clear view of all cases is given that makes it easier to understand the case-study analysis. The second aim of this chapter is to answer the sub-question: *What is the influence of the four drivers—technology, environment, society, and regulation—on the autonomous car integration looking at the autonomous shuttle case studies in the Netherlands?* Thus, the second section of each case consists of a case analysis with the use of the analysis framework presented in the previous chapter. In section 6.6 all case analyses are compared in a cross-case analysis.

6.1 Appelscha

—Finished project—

6.1.1 CASE DESCRIPTION

LOCATION

Appelscha is located in an open, quiet area with plenty of cultural history and a variety of landscapes, nature reserves, and national parks in the immediate vicinity. Appelscha is a village located in the municipality of Ooststellingenwerf, in the province of Friesland, and has approximately 4,000 residents (CBS, 2018a). Appelscha is situated in a rural area with a distance of 20 kilometres from the city Assen. The main challenge for the municipality Ooststellingenwerf is an estimated 4% reduction in residents (Rijksoverheid, 2018). The decline of inhabitants in a village or city is called shrinkage. This phenomenon is linked to many factors, such as the combination of birth, death, immigration, and emigration. Often, there are additional effects of the ageing population (more elderly people) and dejuvenation (fewer young people). A quarter of the inhabitants in Appelscha are over 65 years old (CBS, 2018a). The location of the Appelscha project is illustrated in Figure 6.1.

Figure 6.1 The location of the Appelscha case study (own illustration)

PURPOSE OF IMPLEMENTING THE AUTONOMOUS SHUTTLE

Because of the shrinkage, amenities are under pressure, which leads to financial losses. Amenities are available only in the larger villages and the problem arises how to keep these smaller villages liveable. An external advisor of the municipality Ooststellingenwerf (Appendix D3) stated in conversation that the municipal actions should be coherent with their policies to preserve the villages, so there has been a tendency to subsidise several amenities to make sure the villages stay liveable (Appendix D4). However, this is not a solution to the liveability problem when the predicted decline in inhabitants is taken into account. To explore the possibilities with autonomous cars, which can increase accessibility for elderly and disabled people, the external advisor suggested doing an autonomous shuttle test project in Appelscha (Appendix D3).

Another goal of the project was to explore autonomous transport as a future mode of transportation, without any infrastructural changes, in rural regions of the Netherlands (Boersma, van Arem, and Rieck, 2018). The pilot

ASs conducted to explore how people react to an autonomous shuttle. During the pilot project, the goal was to formulate an answer to the following questions:

- ‘What are the legal challenges in regard to setting up a pilot project with an autonomous shuttle?
- What technical aspects need to be taken care of before starting a pilot or demonstration?
- What part of the road is most suitable to facilitate such a vehicle?
- How can the vehicle be integrated into its surroundings?‘

(Boersma, van Arem, and Rieck, 2018: 2)

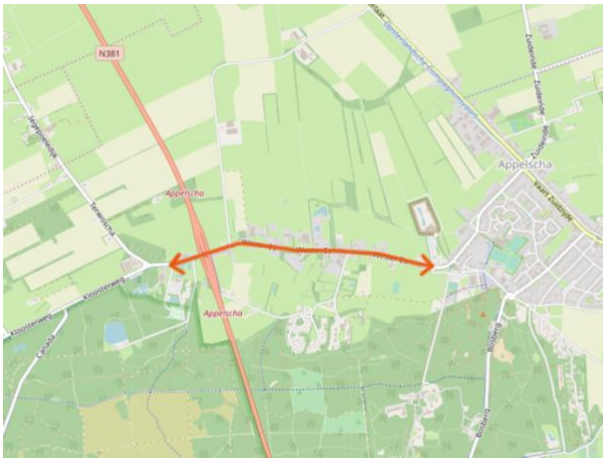


Figure 6.2: Trajectory of the Appelscha shuttle project (own illustration)

TRAJECTORY OF THE SHUTTLE PROJECT

The autonomous shuttle operated from the visitor centre of the Forestry Commission to the roundabout, on the access road of Appelscha (Boersma, van Arem, and Rieck, 2018). The distance of the trajectory was around 2.5 kilometres (Appendix D3). The shuttle drove on a separate cycle lane next to the main road. The bicycle lane is mostly in use for recreation; however, the lane is also used by commuters and students, as there is no nearby high school or university. Every day, around 350–500 people use the cycle lane (Boersma, van Arem, and Rieck, 2018). The trajectory is illustrated in Figure 6.2.

INVOLVED STAKEHOLDERS

The actors in this project were as follows:

- The national government: head department Traffic Safety and Road Transport of the Ministry of Infrastructure and Water Management.
- The regional governments: Province of Groningen, Province of Friesland, and Province of Drenthe.
- The local government: the municipality of Ooststellingenwerf
- Dutch Vehicle Authority: RDW
- Shuttle supplier: Easymile
- Insurance company: Allianz, Aon
- Initiator: Drietachtig
- Consultant: Taxi company Kort
- Road users: cyclists
- Residents of the village

TYPE OF VEHICLE

The shuttle manufacturer Easymile delivered a prototype of the EZ10 shuttle. This SAE level 3 vehicle was able to drive on roads that were mapped into the software of the vehicle, because the vehicle was not (yet) able to drive autonomously on every road (Boersma, van Arem, and Rieck, 2018). The shuttle is equipped with several sensors and cameras, a GPS tracking system, a collision detection system, and a LiDAR sensor. The maximum speed of the vehicle is 40 km/h, but the vehicle was allowed to drive only up to 15 km/h during the pilot. The shuttle supplier needed to make sure the vehicle met the requirements set by the Dutch Vehicle Authority (Boersma, van Arem, and Rieck, 2018). For example, the exterior of the shuttle could not have sharp edges and the doors had to be able to open at all times. The shuttle is able to transport up to 12 passengers at a time. However, during the Appelscha pilot, it was only allowed to transport six passengers. The vehicle used is shown in Figure 6.3.

Figure 6.3: The Easymile EZ10 shuttle used in the Appelscha project (Boersma, van Arem, and Rieck, 2018)

COSTS

The project is financed by the municipality Ooststellingenwerf and the adjustments for the vehicle are financed by the shuttle supplier Easymile. The municipality rented the vehicle from the shuttle supplier to lower the risks and because this was the first autonomous shuttle project. The municipality did get financial support from the province of Friesland and the taxi company Kort supported the municipality by providing the schedules. The budget of the municipality was 135,000 (Weehuizen in Boersma, van Arem, and Rieck, 2018) and the total costs of the project were around 150,000 (Appendix D3).

6.1.2 ANALYSIS FRAMEWORK APPELSCHA

In this section, the analysis framework is used as a tool to measure the technical, environmental, social, and regulatory challenges within the Appelscha project. The context information has been described in the former section. First, the technical, environmental, and social challenges before, during, and after the project are described. After this description, the framework serves as a summary of all challenges in one figure (Figure 6.4).

TECHNICAL CHALLENGES

The automation level of the vehicle used in the project was level 3. The challenge of this automation level is that there is theoretically no driver needed anymore to intervene during operation. However, the vehicle is technically not able to operate fully autonomously in all road conditions, which means the driver or steward cannot be excluded from this project. For instance, the vehicle was not able to overtake or pass other vehicles or obstacles on the road and the steward needed to intervene and manually pass the obstacle. Also, the traffic situation was changed whereby the priority was given to the shuttles. Moreover, traffic wardens were brought in to steer the interaction between cars and the shuttle on the large crossing of the trajectory (Arbouw, 2017).

There were no reported or communicated difficulties of the sensors with varying contrast, range, colours, or generalisation. The explanations for this could be that the pilot project lasted for only 6 weeks from mid-august to the end of September (summer) and that the vehicle was not permitted to operate during rainfall because the shuttle did not have wipers.

Moreover, during the project, the project team discovered that the Easymile shuttle had a programmed safety zone that resulted in less space being available for interacting traffic, mostly cyclists. This an important feature to take into account in future projects, as the safety zone resulted in a less-safe situation.

ENVIRONMENTAL CHALLENGES

The road on which the vehicle operated was an asphalted bicycle lane. The first physical road difficulty of the trajectory was the width of the bicycle lane (Appendix D3). According to the technical analysis, the Easymile shuttle had a programmed static safety zone that resulted in a virtually wider vehicle. The consequence of this was the reduction of the total available space for cyclists. This resulted in confusion, because the cyclists found it hard to predict the movement of the shuttle, especially with the low speed level of 15 kilometres per hour (Appendix D3; Arbouw, 2017).

The second physical road difficulty was the unsignalised intersection with provincial road N381. As the difference in speed between the shuttle and the cars on N381 was 85 kilometres per hour, the traffic situation needed to change to create a less-risky situation (Appendix D3).

A third physical road challenge was the greenery around the road, for instance, grass and trees and their falling leaves. The length of the grass needed to be shortened because of the sensibility of the sensors. Moreover, the sensors and cameras were sensitive to falling leaves (Arbouw, 2017).

Another environmental challenge is the number of road users. In this project, there are two main road users, the first are the cyclists. This type of road user can be divided into two groups: high-speed cyclists such as people on e-bikes or racing cyclists, and the slow-speed cyclists. The average speed of a high-speed cyclist is around 25 kilometres per hour, whereas the average speed of a low-speed cyclist is 17 kilometres per hour (Bicycling, 2018). With the speed of 17 kilometres per hour, people have enough time to oversee the situation and speed up when passing the shuttle. In the case of the high-speed cyclists, passing the shuttle can become a frustrating situation, because the high-speed cyclists have to slow down when there is an oncoming cyclist. Also, because of the height of the shuttle (2.75 m), it may be more difficult to observe the road situation (Appendix D3).

The other group of road users are the cars and motorcycles on the provincial road. The main challenge here is communicating properly about the change in the road situation. During the project, five traffic wardens were appointed to stop car drivers and motorcyclists when the autonomous shuttle needed to pass the road. It is unclear if there was any form of communication a certain distance away from the crossing.

SOCIAL CHALLENGES

Both the technical and the environmental disabilities led to social challenges. The first social challenge was the communication between the shuttle and the road users. Because the appearance of the front and rear of the shuttle is similar, it was complicated for cyclists to predict the movement of the shuttle (Arbouw, 2017). Thus, this resulted in either reserved or bold behaviour. There were road users who thought they could easily pass the shuttle but did not make it on time so that they ended up on the roadside. There were also road users who did not dare to pass the shuttle. This explains one of the results in the survey conducted by the municipality of Oostellingenwerf (2016), in which many respondents had a negative attitude towards the operation of the shuttle on a bicycle lane.

There were only a few people who had a resistant attitude towards the autonomous shuttle; the main reason for this resistance was the lack of trust (Arbouw, 2017). According to a survey conducted by the municipality

Oostellingenwerf (2016) about the autonomous shuttle, there were mixed opinions about the use of the shuttle. Around 65% of the respondents agreed with the statement that the vehicle did not make unpredictive movements (Gemeente Oostellingenwerf in Boersma, van Arem, and Rieck, 2018). This means that the overall attitude was that people approved of the project, and it was mainly elderly people who were not that enthusiastic about the project.

The vehicle was designed with a user interface to increase the control factor towards the shuttle passengers (Starlake, n.d.). The assistance of a steward also helped comfort people. Moreover, road signs and a matrix sign where added to the location to make people aware of the changed situation. During the project, people seemed to be more aware when the matrix sign was on (Boersma, van Arem, and Rieck, 2018). In addition, yellow signs were painted on the road to make the road users aware of the situation.

During the project, the shuttle was not accessible to people in wheelchairs, those with strollers, and other objects on wheels, as the shuttle was not equipped with a safety belt (appendix D3 and D4). After three days of operation, the Dutch Vehicle Authority decided to forbid letting the shuttle operate with passengers, as many cyclists ended up on the roadside (Arbouw, 2017). This means that the service was not accessible to people anymore.

REGULATORY CHALLENGES

The regulatory challenge in this project was to develop a procedure to receive an exemption from the Dutch Vehicle Authority. Together with the Dutch Vehicle Authority, the project team of the Appelscha project developed a procedure that was later implemented in all other projects in the Netherlands (Appendix D3). Another challenge was that the Dutch Vehicle Authority did not permit the shuttle to operate when the road was slippery, and the road was surrounded by trees with falling leaves.

CONCLUSION OF THE ANALYSIS

To conclude, the main technical defaults in this project were the technical disabilities such as obstacle crossing and vehicle-to-vehicle interaction, the safety zone of the vehicle and thereby the interaction with the other road users, and the disability to operate during rainfall. These defaults led to an untrustworthy transport service, as people could not count on a day-to-day service. The main environmental challenges in the project were the width of the lane, the crossing of the provincial road, and the ability for other road users to pass the shuttle. These difficulties led to frustrating interactions with the shuttle. The main social challenges were the communication between the vehicle and the road users, the gaining of trust, and the functional accessibility to people or objects on wheels. The results of the analysis are summarised in the analysis framework (Figure 6.4).

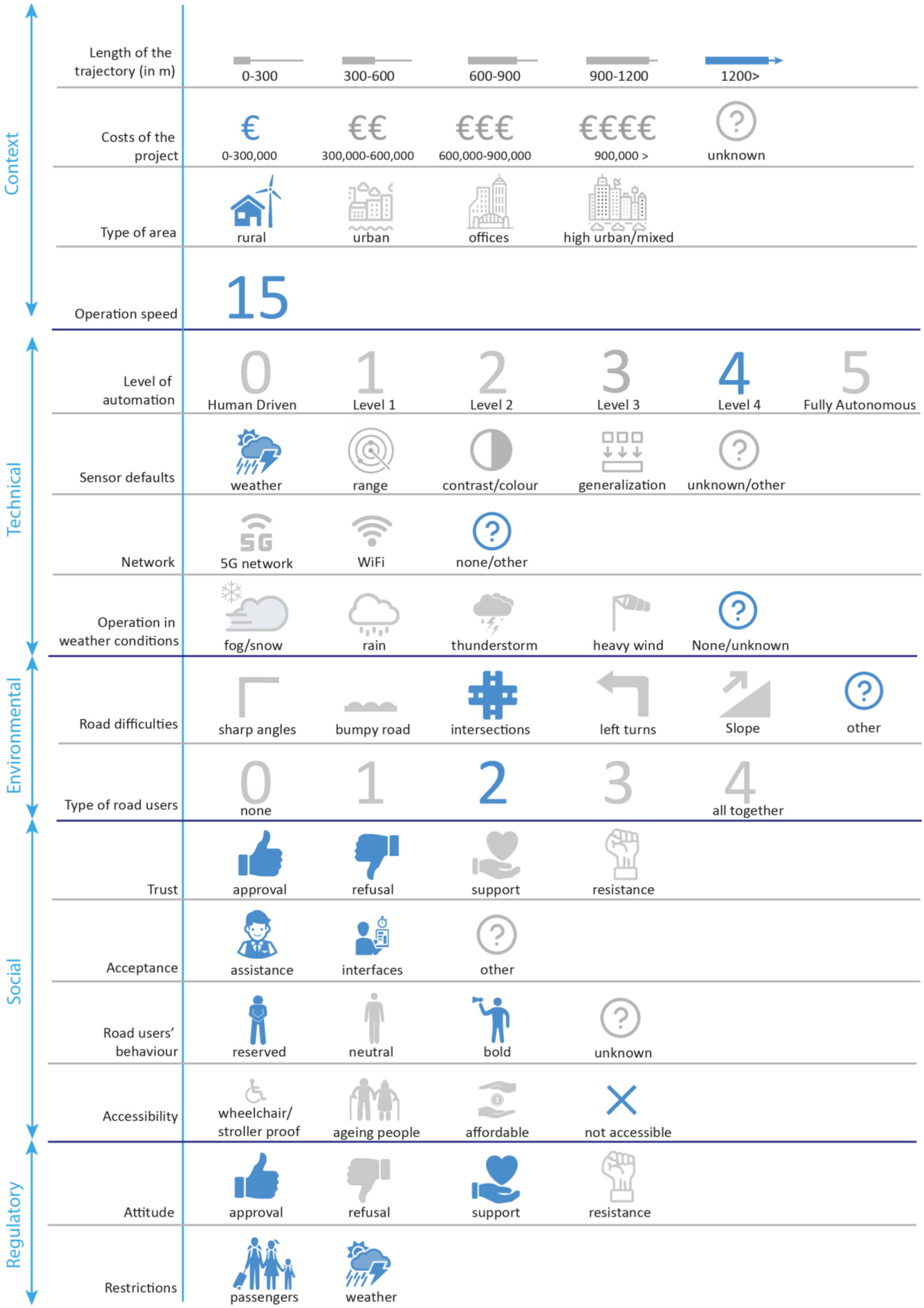


Figure 6.4: Analysis framework based on the Appelscha case (own illustration)

6.2. Scheemda

—Active project—

6.2.1 CASE DESCRIPTION

LOCATION

Scheemda is a village located in the municipality of Oldambt, which is situated in the eastern part of the Province Groningen and has approximately 2,400 residents (CBS, 2018b). Scheemda is located in a rural area with a distance of around 30 kilometres from the city of Groningen and around 20 kilometres from the border with Germany. As the municipality of Oldambt is categorised as a high-shrinkage area, there is an expected 16% decline in residents of 16% till 2040 (Rijksoverheid, 2018). The main challenge for the municipality of Oldambt is to keep the villages liveable and accessible. Almost one-third of the inhabitants (32.2%) in Scheemda are more than 65 years old (CBS, 2018b). This is approximately twice as much compared to the metropolitan cities of Amsterdam, Rotterdam, and The Hague (at 12.2, 15.1, and 14.2%, respectively) (CBS, 2019). The location of the Scheemda project is illustrated in Figure 6.5

Figure 6.5: The location of the Scheemda case study (own illustration).

PURPOSE OF IMPLEMENTING THE AUTONOMOUS SHUTTLE

In 2018, the Ommelander Hospital was built in Scheemda. The purpose of implementing an autonomous shuttle was to increase the accessibility to the main entrance of the hospital (Autonoomvervoernoord, n.d.). The distance between the main entrance of the hospital and the closest bus is around 1200 metres. This means that patients, employees, and visitors travelling by public transport need to travel around 1200 metres by foot to arrive at their destination.

Another purpose of this pilot project is to gain more knowledge about the opportunities for autonomous transport in the region. In the shrinkage areas, public transport is expensive, as there are fewer people using and paying for the services. Instead of spending a larger amount of money by subsidising public transport services, autonomous cars could offer a cheaper and more efficient public-transport service (Appendix D4). During the pilot project, the goal was to determine an answer to questions such as:

- How does the autonomous shuttle interact with other road users such as cars and ambulances?
- How to safely pass crossings?
- How to connect the shuttle time schedule with the bus schedule? (Appendix D4).

The project is divided into two phases, the testing phase and the expansion phase. The testing period is at least 6 months. When the autonomous shuttle service is successful, it will be incorporated as part of the public-transport service. In the second phase, the trajectory will be expanded to the centre of Scheemda and eventually to the train station of Scheemda. This trajectory is around 4.5 kilometres (Autonoomvervoernoord, n.d.).

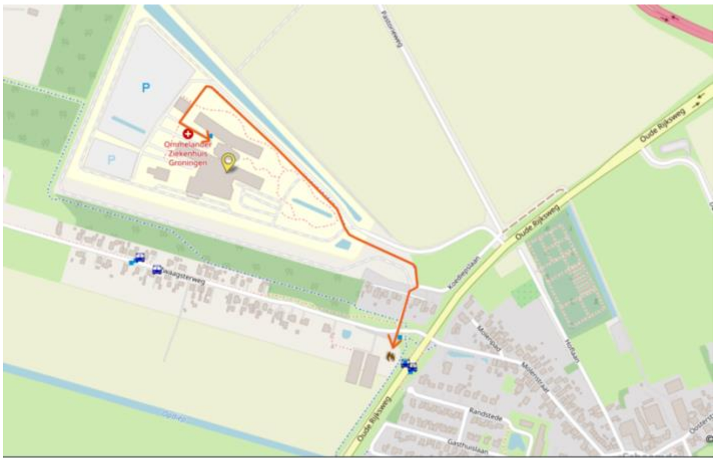


Figure 6.6: Trajectory of the Scheemda shuttle project (own illustration).

TRAJECTORY OF THE AUTONOMOUS SHUTTLE

The autonomous shuttle operates from the main entrance of the Ommelander Hospital to the closest bus stop on Molenstraat. The trajectory is around 1200 metres. The shuttle operates on both a public car lane and a separate bicycle lane. The cycle lane is mostly used by patients, employees, or visitors of the hospital. There are three important crossings in the trajectory where there is interaction with other road users such as cyclists, cars, and ambulances (Appendix D4). The trajectory is illustrated in Figure 6.6.

INVOLVED STAKEHOLDERS

The actors in this project are as follows:

- The national government: the Ministry of Infrastructure and Water Management.
- The regional government: Province of Groningen, Province of Friesland, and Province of Drenthe.
- The local government: municipality of Oldambt
- Dutch Vehicle Authority: RDW
- Shuttle supplier: Navya
- Ommelander hospital
- Local transport company: Arriva
- Product and software supplier for the simulator: Greendino, Robottuner
- Service provider for the 5G network: KPN
- Shuttle users: patients, employees, and visitors
- Road users: car drivers, cyclists, pedestrians
- Residents of the village

TYPE OF VEHICLE

After the experience with the EZ10 Easymile shuttle in the Appelscha project, the vehicle was tested at the research lab Eemshaven. The research team discovered some malfunctions in the abilities of the shuttle, for example, the distance between the ground and the bottom sensors is 30 cm. This results in a malfunction in registering movements between 0 and 30 cm from the ground (Province of Groningen, personal communication, March 11, 2019). When the research team came into contact with the Navya manufacturer and came to the conclusion that the Navya shuttle had more features at that moment, the project team chose to drive with a Navya shuttle at the Ommelander hospital (Appendix D4).

The SAE-level 3 Navya shuttle is able to drive on roads that are mapped into the software of the vehicle, as the vehicle is not (yet) able to drive autonomously on every road. The shuttle is equipped with several sensors and cameras: a GPS tracking system in combination with a GNSS antenna to determine the exact position of the vehicle at any movement, an odometry system which estimates the velocity of the vehicle and the changes in vehicle position, and multiple Lidar sensors to provide both 2D and 3D perception maps (Navya, 2017). The vehicle is not able to transport people in wheelchairs, as there is no safety belt present in the vehicle (Appendix D4). The shuttle is electric, which means that the vehicle needs to be charged. The Easymile shuttle has a static safety zone, whereas the Navya shuttle has a dynamic safety zone. This means that the safety zone can be adapted to the location (Appendix D4). The maximum speed of the vehicle is 45 km/h, but the vehicle was able to drive only up to 15 kilometres per hour during the pilot (Appendix D4 and Navya, 2017). The vehicle used is shown in Figure 6.7.

Figure 6.7. The Navya shuttle used in the Scheemda project (autonoomvervoernoord, n.d.)

COSTS

The province of Groningen invested in the rental costs of the vehicle and partly in the infrastructural change to widen the cycle lane. The rest of the investment cost was borne by the hospital (Appendix D4). The maintenance of the lane is also carried out by the Ommelander hospital, as they are its owners. Together with the municipality of Oldambt, the province of Groningen invested in the bus stop, as this is situated on municipal land. At last, the Arriva transport company is paying the stewards and they deliver the time schedules (Appendix D4). Renting an autonomous shuttle for one year costs €250,000. Everything is included in this price, the vehicle, the exemption by the Dutch Vehicle Authority, the communication, and the experts, but when there are also infrastructural changes needed, the costs will be higher (Appendix D4). This project was planned to last 6 months and some infrastructural changes were needed. Therefore, the costs for this project were around 150,000 euros.

6.1.2 ANALYSIS FRAMEWORK SCHEEMDA

In this section, the analysis framework is used as a tool to measure the technical, environmental, social, and regulatory challenges within the Scheemda project. The context information has been described in the former section. First, the technical, environmental, and social challenges before, during and after the project are described. After this description, the framework serves as a summary of all challenges in one figure (Figure 6.8).

TECHNICAL CHALLENGES

The automation level of the shuttle is level 3. The technical challenge with this automation level in this project is the inability to pass obstacles and objects on the road (Appendix D4). The shuttle partly operates on a separate road, which decreases the chance for an obstacle on the road. However, when there is an object on the road, the steward needs to guide the shuttle manually with a joystick (Appendices D3 and D4). This is because the shuttle operates on a programmed route. This means that the steward cannot be excluded from the shuttle until this technical ability has been added to the software.

Another technical challenge is the communication with other road users. There are three crossings on the trajectory with different road users (Appendix D4). One of the crossings includes the interaction with emergency ambulances. The shuttle gives priority to these vehicles. However, the stop at this crossing is set beforehand and the steward needs to push the 'GO' button after confirming the road is clear (Appendix D4).

Moreover, the shuttle serves as the last mile between a bus station and the main entrance of the hospital. The technical challenge is to connect with the public-transport service. The speed of the shuttle is 15 kilometres per hour, which means going back and forth from the bus stop to the main entrance takes around 10 minutes. The public bus passes the bus stop Molenstraat every 60 minutes, which means a proper connection between the autonomous shuttle and the bus stop is crucial.

A technical challenge discovered in the initiation phase of the project is a barrier of the laser sensors (5Ggroningen, 2016). The shuttle has a laser sensor on every corner and there is a GPS ball on the roof. The project team programmed a route in advance and specified a few location points. The shuttle knows the exact location because of the GPS and a laser sensor that recognises location points. However, when creating a barrier, for instance, with a large truck, it can lead to a deviation in the location point of 30% (5Ggroningen, 2016). No difficulties of the sensors with varying contrast, range, colours or generalisation, were reported or communicated.

ENVIRONMENTAL CHALLENGESS

The main road on which the vehicle operates is a widened bicycle lane. As a lesson learned from the Appelscha project, there is enough space for bicycles to pass the shuttle (Appendix D4). The shuttle also operates on the public road, where it has to interact with other road users such as pedestrians, cars, and agricultural traffic. The interaction with cars is still a challenge, because the difference in speed is quite high. The road situation has not changed, but the shuttle had a programmed stop in the beginning. This programmed stop was prohibited by the Dutch Vehicle Authority for safety reasons (Appendix D4). The shuttle needed conformation from the steward to pass the road. However, this programmed stop has been removed, as it confused other road users (Appendix D4).

SOCIAL CHALLENGES

The technical and the environmental disabilities led to social challenges. The first social challenge was the communication between the municipality and the local inhabitants. Before and during the project, there was a small conflict with the inhabitants who live next to the road where the shuttle operates. A resident was furious, and she stated that the municipality promised to limit the nuisance (de Veer, 2018). It could be concluded that the communication with the local residents could have been better.

Most people reacted positively to the Navya shuttle. In November 2018, the shuttle reached the 1500 passengers and currently many reviews are being shared where people express their positive and enthusiastic experience (Appendix D4). For instance:

'Walking long distances is not possible at the moment. This test allows me to take the bus. Otherwise I would have had to take a taxi or ask a family member with a car'

and

'I think this is the future and I experience it as a normal bus ride, just as I am on the bus from Delfzijl to Scheemda. I am positive!'

(word-for-word translation from Parkstadveendam, 2018).

Moreover, people were very pleased with the steward. The steward gives the passengers comfort and is able to explain the purpose and technical abilities of the shuttle (Appendix D4). Moreover, the steward can offer a hand when people have difficulties entering the shuttle. The challenge for the future will be to exclude the steward, because people who go to a hospital can be fragile and immobile. In this case, the steward might be crucial, and the question is raised whether a shuttle that operates between a hospital and, for instance, a bus stop can become driverless at all.

The overall attitude people have towards the shuttle seems to be quite positive and trustworthy. It is not clear whether everyone accepts the shuttle, but the overall acceptance is secured by the steward. Also, the user interface shows the exact route, which also increases the acceptance. Moreover, road signs and matrix sign where added to the location to make people aware of the changed situation. Nevertheless, the fact that almost one-third of the inhabitants of Scheemda are over 65 years old might result in less acceptance. This has been shown by the Appelscha project, where mostly elderly people were not that enthusiastic about the shuttle.

During this project, the shuttle was not accessible to people in wheelchairs and those with strollers and other objects on wheels, as the shuttle was not equipped with a safety belt (Appendix D4). During the pilot project, there was no fee to ride in the shuttle. It is not clear what the costs will be when the pilot project is over, but it is assumed that the costs will be comparable with the costs for public transport (Appendix D2).

REGULATORY CHALLENGES

According to the shuttle supplier, the shuttle can operate safely in every weather condition (Navya, 2017). However, when the road condition is very bad because of the weather, for instance, because of heavy snow, it might be necessary to take the shuttle off the road. It should be noted that the same consideration is made for any other vehicle. Despite the fact that the shuttle can operate safely on the public road in every road condition, it is not allowed to operate in every weather condition. The Dutch Vehicle Authority does not grant permission to drive in every road condition, as there has not been any research regarding the behaviour of the shuttle during poor weather conditions (Autonoomvervoernoord, 2018).

CONCLUSION OF THE ANALYSIS

To conclude, the main technical defaults in this project were the technical disabilities such as vehicle-to-vehicle communication and operating on a time schedule. Proper vehicle-to-vehicle communication with the use of 5G network is crucial in this project, as the shuttle needs to interact with emergency ambulances. Moreover, a proper connection with the other public-transport service is essential to increasing the accessibility of traveling by public transport. The main environmental challenge was the use of fixed stops on crossings. The programmed fixed stops, which are currently removed from the software, led to confusion of road users. The social challenges were the communication between some inhabitants of Scheemda and the municipality Oldambt and the accessibility to people or objects on wheels. Poor communication with external stakeholders such as inhabitants could result in an appeal process, which might oppose the project. The power–impact matrix in Chapter 5 illustrates the importance of informing residents of an area. Another social challenge is the exclusion of the steward, because the presence of the steward increases the trust and acceptance. The challenge regarding regulation was the operation on every road condition. When the shuttle is not able to operate every day, the service becomes untrustworthy. The result might be a decrease in public-transport travellers. The results of the analysis are summarised in the analysis framework (Figure 6.8).

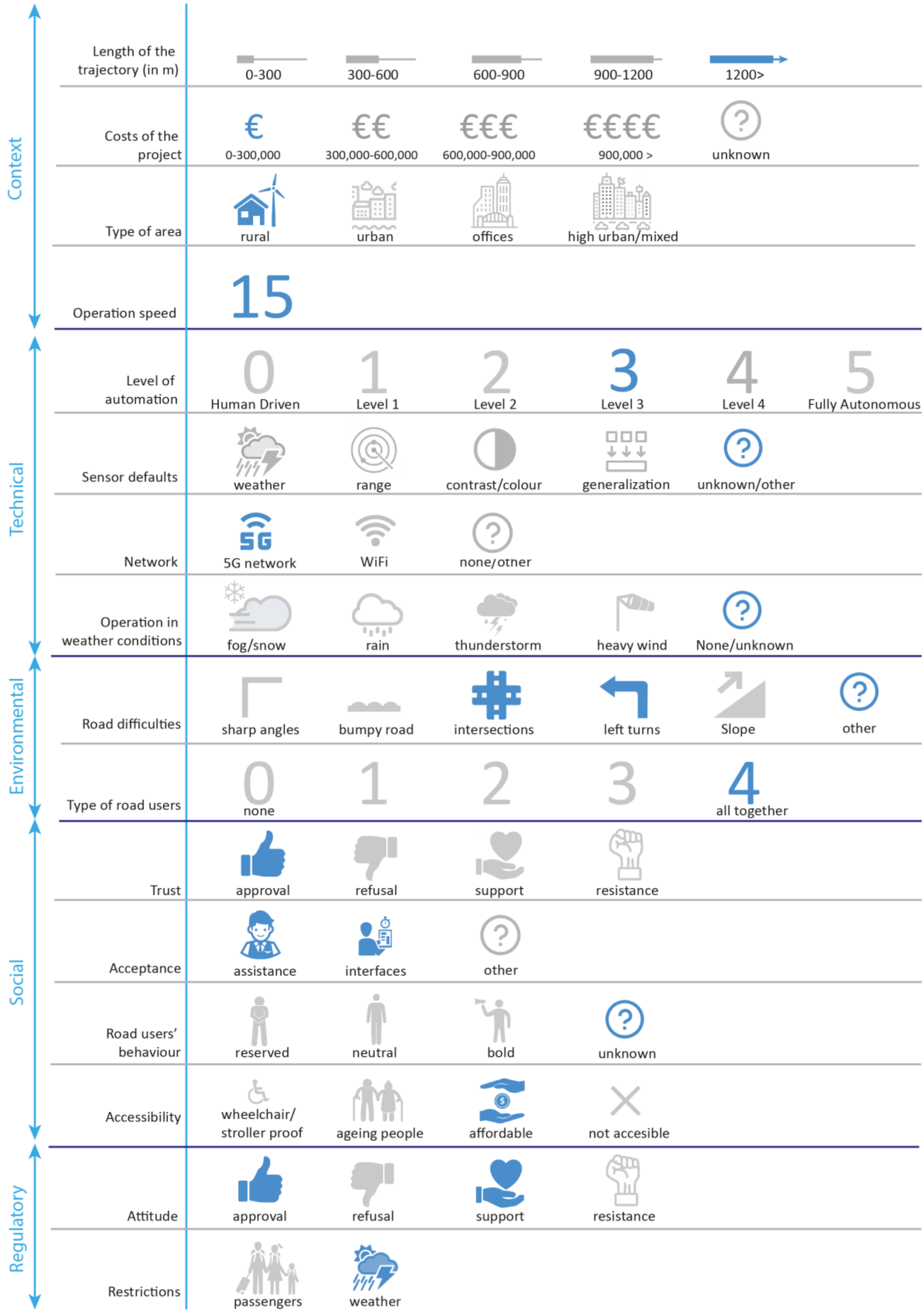


Figure 6.8: Analysis framework based on the Scheemda case (own illustration)

6.3 Haga

—Mid-execution project—

6.3.1 CASE DESCRIPTION

LOCATION

The Haga shuttle project is situated in The Hague (Figure 6.9). With almost 540,000 inhabitants, The Hague is part of the three most densely populated cities in the Netherlands. The Haga shuttle project is situated in the neighbourhood of Leyenburg, which is located in the south-western area of the municipality of The Hague (Figure 6.10). This neighbourhood has around 15,000 inhabitants and almost one-fifth are more than 65 years old (CBS, 2018c). From CBS statistics (2018), it is clear that there has been an increase in the population of the municipality of The Hague. From 1995 to 2018, the population increased by 21%. Thus, the main challenge for the municipality of The Hague is to keep the city accessible and liveable despite the population growth.

Figure 6.9 The location of the Haga shuttle case study (own illustration)

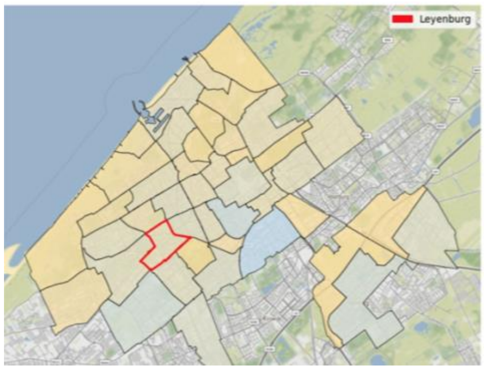


Figure 6.10 The location of the Leyenburg neighbourhood (CBS, 2018)

PURPOSE OF IMPLEMENTING THE AUTONOMOUS SHUTTLE

The main purpose of this project is to gain more knowledge about the possibilities of autonomous shuttles in a city with many inhabitants. The government's yearly costs for a regular public-transport bus are around 150,000 euros. These costs are that high mainly to pay for the salary of the bus drivers. When taking the driver out of the vehicle, it becomes an interesting business model (Appendix D5).

Another purpose for implementing the autonomous shuttle is the accessibility to the hospital. Currently, people take cars to the hospital because the first and last part of their journeys do not connect well with public transport. Offering coverage for the last mile can lead to more people choosing to travel by public transport. Patients, employees, and visitors with limited mobility will soon have comfortable transport between the public-transport stop and the main entrance (Appendix D2 and D5). During the pilot project, the goal is to determine answers on questions such as:

- How does the autonomous shuttle interact with other road users such as cars and ambulances?

- How to connect the shuttle time schedule with the public-transport time schedules? What happens when the bus gets delayed?
- How to make clear that there is an autonomous vehicle on the road and how to determine the pathway of pedestrians?
- How to communicate with the shuttle users?
- How to safely separate other vehicles from the shuttle road?
- What is a safe width of the shuttle road?

(Appendices D1 and D2).

TRAJECTORY OF THE SHUTTLE PROJECT

The autonomous shuttle operates from the main entrance of the Haga hospital to the closest bus and tram stops on Leyweg. The trajectory is around 300 metres and the shuttle started operating on this trajectory on 28 May 2019. The first phase consists only of test rides without people; during the second phase, the shuttle will be available to people as well. The shuttle drives on the public road. Thus, the shuttle interacts with other road users such as pedestrians, cyclists, and cars (Appendices D1 and D2). The trajectory is illustrated in Figure 6.11.

Figure 6.11. The trajectory of the Haga case study (own illustration)

INVOLVED STAKEHOLDERS

The actors in this project are as follows:

- The national government: The Ministry of Infrastructure and Water Management
- The regional government: the province of Zuid-Holland
- The local government: the municipality of The Hague
- Dutch Vehicle Authority: RDW
- Dutch transport authority: MRDH
- Shuttle supplier: NAVYA
- Haga Leyenburg Hospital
- Local transport company: HTM
- Consultants: The Future Mobility Network, Rebelgroup
- Research Institute: SWOV
- Shuttle users: patients, employees, and visitors
- Road users: car drivers, cyclists, pedestrians

TYPE OF VEHICLE

In this project, the consortium chose to drive with a Navya shuttle because this shuttle has the most features at the moment (Appendix D1). The details of the shuttle are already described in Section 6.7. Figure 6.12 illustrates a composite picture of the shuttle in front of the hospital.

Figure 6.12. A composite picture of the Haga shuttle (Kerssies, 2019)

COSTS

The local transport company HTM together with The Future Mobility Network and Rebelgroup set up a private company, which is called 'De Haagse Shuttle' (Appendices D1 and D2). The municipality of The Hague and the Haga hospital are also financial supporters of the private company. The Dutch transport authority MRDH subsidised half of the project (Appendix D2). The whole project cost around 1.2 million euros (Appendices D1 and D2).

6.3.2 ANALYSIS FRAMEWORK HAGA

In this section, the analysis framework is used as a tool to measure the technical, environmental, social, and regulatory challenges within the Haga project. The context information has been described in the former section. First, the technical, environmental and social challenges before, during and after the project are described. After this description, the framework serves as a summary of all challenges in one figure (Figure 18.4). It should be noted that at the time this thesis was written, this project was between the exploration phase and the execution. The autonomous shuttle has been operating on the trajectory only since the 28 May 2019. Consequently, the social challenges are not fully complete.

TECHNICAL CHALLENGES

Just as the other projects, the automation level of the shuttle is level 3. Thus, the first technical challenge is that the shuttle is not able to pass obstacles automatically. This means that the steward needs to guide the shuttle manually with a joystick. The shuttle operates on a separate road without cars or cyclists, which decreases the chance of an obstacle on the road. However, the steward still cannot be excluded from the shuttle until the technical ability to pass obstacles automatically is added to the software. This is something the shuttle developer should implement.

The second technical challenge is that the shuttle needs to make a 90° angle turn (Appendices D1 and D2). During the test, the ability to make the sharp turn will be assessed. The trajectory is situated next to a big development area and the road is only temporarily constructed; this means the costs for changing the route will be probably less high compared to the costs of changing a newly constructed road (Appendix D2). It is crucial to reflect on this challenge even when it turns out to not be a technical challenge.

The third technical challenge is that the shuttle is bidirectional (appendix D1), which means that the shuttle does not have a front or rear. The challenge with this is ensuring the direction indicators, the headlights, and the brake light switch on time when driving another direction.

ENVIRONMENTAL CHALLENGES

An environmental challenge is that there should be proper communication between the shuttle and the other road users. The trajectory will be marked with a specific colour—probably green—to create awareness of a different road situation. Moreover, traffic signs will be added to make sure the road is free of obstacles (Appendix D1). The challenge here is if these environmental changes are sufficient as a communication means.

Another challenge regarding the route is the difference in height. A part of the road has a slope of 12% (Appendix D1). This might be a challenge for the shuttle, as it is the maximum slope at which the shuttle can operate (Navya, 2017).

SOCIAL CHALLENGES

28 May 2019 was the official opening and implementation of the Haga shuttle project. Still, many social challenges are unclear for now, as there was little time to fully analyse the implementation. However, some things can be said. The first social challenge might be the behaviour of both the road users and the passengers of the shuttle. Most people are unfamiliar with the implementation of an autonomous shuttle. This could result in a reserved attitude from potential users or other road users. Communication through social media such as Twitter, Facebook, and the HTM website or via the HTM on-demand app could help create awareness and recognition of the existence of the shuttle. Moreover, flyers and posters in the hospital could increase proper behaviour of the road users and the passengers. Information about the arrival and departure times of the shuttle are available at the shuttle stop (Appendices D1 and D2).

A third probable social challenge could be to keep the service financially accessible to anyone. Currently, the shuttle service is free, as the project is still in a testing phase. However, when the service becomes trustworthy and a fixed part of the public-transport service, the service provider HTM could require paying a fee (Appendix D2). Consequently, the future technical challenge will be to make sure everyone checks-in with their public-transport chip card when there is not a steward to check this.

REGULATORY CHALLENGES

As with the previous projects, the exemption of the Dutch Vehicle Authority may not be used if the road surface is slippery and in weather conditions that limit visibility to less than 50 metres or where visibility is insufficient to be able to perform road tasks (The Future Mobility Network, personal communication, May 2019). The Dutch Vehicle Authority does not grant permission to drive in every road condition, as there has not been any research regarding the behaviour of the shuttle during heavy weather conditions (Autonoomvervoernoord, 2018). The challenge here could be how a slippery road or limited visibility should be measured.

CONCLUSION OF THE ANALYSIS

To conclude, the main technical challenges regarding the implementation of an autonomous shuttle between the public-transport stops and the main entrance of the Haga hospital probably will be the 90° angle and the shift of the direction indicators, the headlights, and the brake lights. A proper shift in direction and action indicators is crucial, as this might affect the vehicle-to-people communication. Moreover, proper communication with other road users might create less confusion and more desirable behaviour. The main environmental challenge will probably be the communication to road users to make them aware of a different road situation and the difference in height of the trajectory. Proper communication with the other traffic flows is essential to prevent obstacles and undesirable behaviour on the trajectory of the shuttle. Moreover, it is crucial to reflect on the ability of the shuttle to operate on a 12% slope. The social challenges are not completely clear, as the shuttle was just implemented at the time of writing. The main social challenges are probably the accessibility to immobile people, the financial accessibility to passengers and to steer upon the behaviour of other traffic flows. The challenge regarding regulation is the operation on every road condition. When the shuttle is not able to operate every day, the service might become untrustworthy. The results of the analysis are summarised in the analysis framework (Figure 6.13).

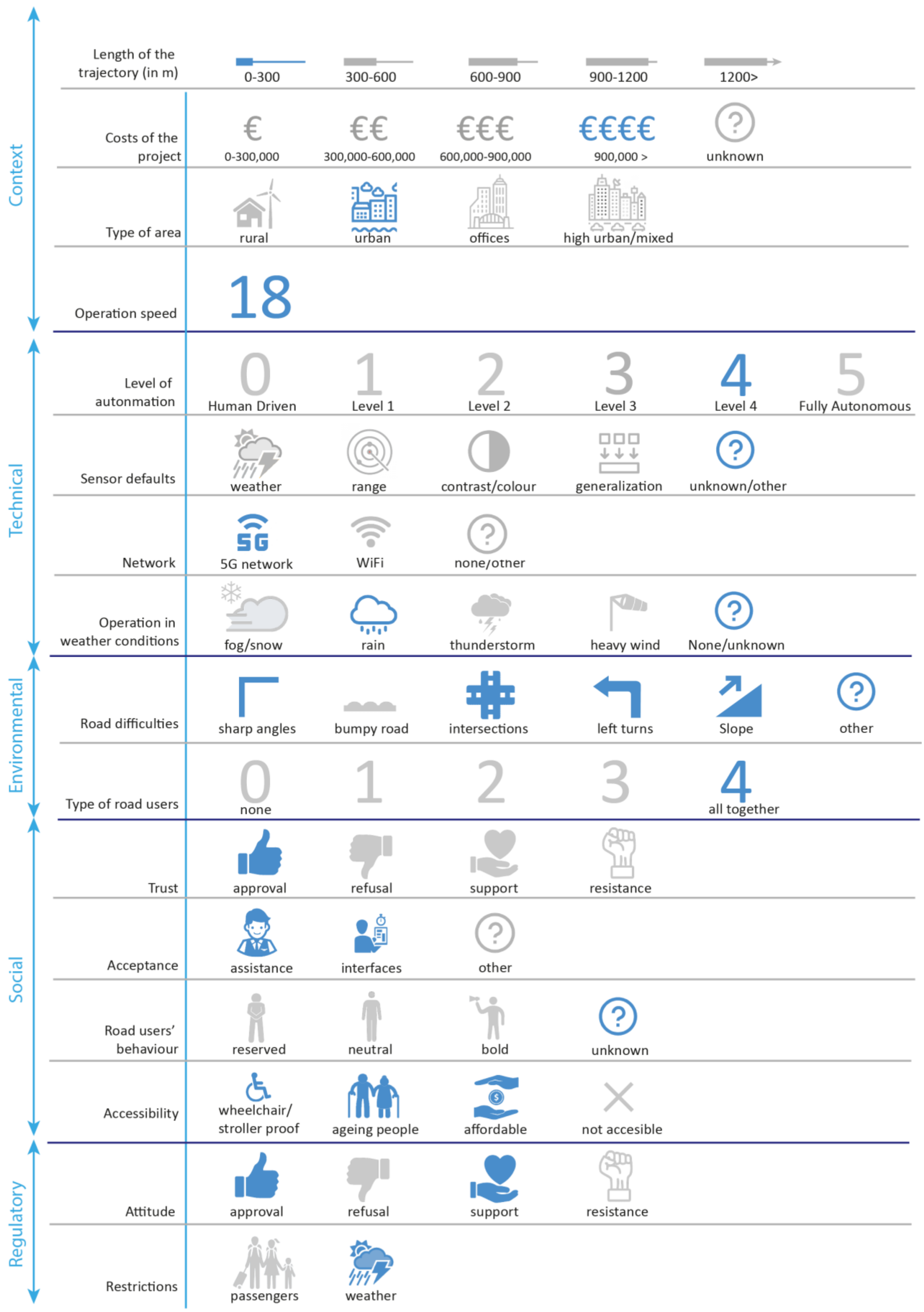


Figure 6.13: Analysis framework based on the Haga case (own illustration)

6.4 Esa Estec

—Mid-execution project—

6.4.1 CASE DESCRIPTION

LOCATION

Esa Estec (European Space and Technology Centre) is the European Space Agency's main technology development and test centre for spacecraft and space technology (ESA, 2019). The Esa Estec project is located in the Southern part of Noordwijk, a city located in the municipality of Noordwijk that has around 43,000 inhabitants (CBS, 2019). The project is located several kilometres outside the village and close to the town of Katwijk. The location is illustrated in Figure 6.14.

Figure 6.14: The location of the ESA ESTEC case study (own illustration)

PURPOSE OF IMPLEMENTING THE AUTONOMOUS SHUTTLE

The main purpose of implementing an autonomous shuttle is to gain knowledge about the opportunities of autonomous shuttles and test whether this type of technique is suitable for deployment in other places in the province (Appendix D5). The province of Zuid-Holland wants to explore the possibilities of making public transport more efficient and effective and wants to observe the technical implications autonomous shuttles have. Also, on this trajectory, the shuttle can operate without a steward as the road is owned by Esa Estec. This means that this will be the first pilot project that will gain knowledge about driving without a steward. Moreover, the province wants to increase the accessibility of Esa Estec and specific attention will be paid to the transport of people with movement disabilities or a visual impairment (Appendices D1 and D5).

This project is divided into two phases. The first phase will consist of test rides with a steward on a trajectory that is secured by a barrier. If this turns out well the steward will be removed, and the shuttle will operate with a remote control. In the second phase, the trajectory will be expanded to the public road (Appendices D1 and D5). First, there will be a steward again see if everything works safely. The steward also contributes to the trust issue by explaining the autonomous shuttle concept to the users. When everything turns out well—and when the experimental law is officially established—the shuttle will operate without a steward on the public road (Appendix D1). It will take around two years to complete these two phases. During the pilot project, the goal is to determine answers on questions such as

- Do self-driving shuttles make the use of public transport more attractive?
- Can we gain experience with self-driving shuttles (in terms of technology and operation)?
- What is the potential for expansion of the trajectory?
- How will the users accept the new form of transportation?

THE TRAJECTORY OF THE SHUTTLE

Before the shuttle drives on the Esa Estec grounds, the research team automated driving Delft (RADD) will experiment with the vehicle on the test area on de TU Delft Campus (Appendix D1). After the testing period, the autonomous shuttle is set to drive on the owned roads of the Esa Estec company. The possible trajectory is illustrated in Figure 6.15. The orange route, phase one, is on private grounds of Esa Estec, whereas the blue route, phase two, is on municipal grounds. During phase two, the route will be expended to the bus stop called Schorpioen. At that time, the shuttle will drive on the public road, which means there will be interaction with other road users. After phase two, the trajectory will probably be expanded again to the new development site that is near the Esa Estec centre (Appendix D5).

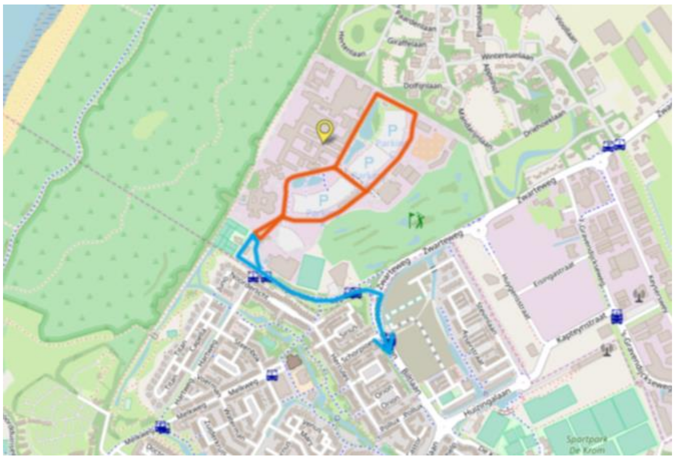


Figure 6.15. The trajectory of the ESA ESTEC case study (own illustration, map adapted from OpenStreetMap)

STAKEHOLDERS INVOLVED

The actors in this project are as follows:

- The national government: The Ministry of Infrastructure and Water Management
- The regional government: the province of Zuid-Holland
- The local government: the municipality of Noordwijk and the municipality of Katwijk
- Dutch Vehicle Authority: RDW
- Dutch transport authority: MRDH
- Shuttle supplier: Navya
- Local transport company: Arriva
- Consultants: The Future Mobility Network, Rebelgroup
- Research Institute: SWOV
- Shuttle users: employees, visitors
- Road users: car drivers, cyclists, pedestrians

THE VEHICLE USED

In this project, the project team chose to drive with a Navya shuttle because this shuttle has most features at the moment. The technical details of the shuttle are already described in Section 6.3.

COSTS

The total costs of the project will be approximately 1.5 million euros (Appendix D5). The project team wants to lease two autonomous shuttles. The lease price of one autonomous shuttle is approximately 250,000 euros for 6 months. The research programme, the consultants, and the maintenance are all included in the total costs of 1.5 million (Appendix D5). The province of Zuid-Holland subsidised around 600,000 euros. The other financial supporters are Esa Estec, Arriva, and The Future Mobility Network (Appendix D5).

6.4.2 ANALYSIS FRAMEWORK ESA ESTEC

In this section, the analysis framework is used as a tool to measure the technical, environmental, social, and regulatory challenges within the Esa Estec project. The context information has been described in the former section. First, the technical, environmental, social, and regulatory challenges are described. After this description, the framework serves as a summary of all challenges in one figure (Figure 6.16). It should be noted that this project is currently in the beginning of the execution phase, which means the autonomous shuttles have not arrived at the location yet. Consequently, not all challenges could be described yet, because the project is in an early stage. Therefore, some assumptions have been made. In addition, it should be noted that some challenges overlap, for instance, a technical challenge could also be categorised as a social challenge.

TECHNICAL CHALLENGES

The main technical challenge probably will be connecting the three autonomous shuttles to each other. On-site, two shuttles will be operating between the different buildings, the main entrance, and the parking places. Proper vehicle-to-vehicle communication should ensure that there will be a secured distance between both shuttles. When the distance between both shuttles becomes smaller, confusion could arise as to which shuttle to choose. However, when one of the shuttles gets delayed for some reason, the other shuttle should not be harmed by this.

Another technical challenge is connecting the shuttle services to the time schedule of the off-site shuttle service. The total length of one round on-side including stops will be around 10 minutes. When there are two shuttles, the maximum waiting time will be around 5 minutes. Therefore, the time is will probably not be a big challenge.

A probable technical disability will be passing road obstacles automatically. From the former case studies, it can be concluded that the Navya shuttle is not able to pass objects automatically yet. When one shuttle has a malfunction on the trajectory, it should not harm the operation of the other shuttle.

Another technical challenge will be the communication between the control rooms. In this project, three control rooms are planned, by Esa Estec, Navya, and Arriva (The Future Mobility Network, personal communication, April 2019). It is essential that the communication between all three control rooms goes smoothly and that it is clear which responsibilities are linked to each control room. Moreover, it is crucial the employees in the control room can speak proper English. The network that is needed for this vehicle to control room communication is 5G. This network should be reliable.

Both the Navya shuttles are equipped with a safety belt to secure wheelchairs, strollers, or other objects on wheels (The Future Mobility Network, personal communication, April 2019). Because the development of the autonomous shuttles is still in an early stage, the vehicle might stop abruptly. This should not harm disabled or auditory/visual impaired people. Therefore, a technical challenge lies in dealing with these abrupt stops.

Moreover, all autonomous shuttles are equipped with a ramp to make sure wheelchairs and other objects on wheels can safely enter the vehicle. The challenge here is how to deal with a small obstacle on the road that makes it unsafe for people to use the ramp.

Lastly, similar to the Haga shuttle project, the shuttles are bidirectional, which means that the shuttles do not have a front or rear (The Future Mobility Network, personal communication, April 2019). The challenge with this is that the direction indicators, the headlights, and the brake light should switch on time when driving in another direction. Possibly, by the time the shuttles are operating at Esa Estec, this challenge will have been solved during the Haga project.

ENVIRONMENTAL CHALLENGES

The main environmental challenge is dealing with other road users. On-site, the shuttles need to interact with cars and probably with trucks responsible for the logistics. The operating speed of the shuttles will be around 30 kilometres per hour (The Future Mobility Network, personal communication, April 2019). This speed will be the highest speed level ever tested in an autonomous shuttle project in the Netherlands, which means it is crucial to reflect on the added value of a higher speed level.

Off-site, the shuttle needs to cross both a bike lane and an intersection with cars and sometimes horses. The challenge can be the difference in speed. However, the operating speed of the off-site shuttle is still undetermined.

SOCIAL CHALLENGES

In this project, the focus will be partly on the transportation of disabled or auditory/visually impaired people. Communication with this vulnerable target group might be quite different compared to the communication with other people. Therefore, it might be a challenge to directly come up with other forms of communication.

Moreover, the communication might be different on-site and off-site, as on-site there could be communication with the use of a network such as Wi-Fi, which is more complicated off-site. The challenge here is to generalise both communication forms to overcome confusion.

Lastly, there should be proper communication with the inhabitants of the homes around the trajectory to overcome frustration, for instance, about their privacy.

REGULATORY CHALLENGES

Different than the other projects, the autonomous shuttles on-site can be used during rain and snow, since the vehicles will be operating on-site. It depends on coming regulation if the off-site shuttle is permitted to operate without a steward. Probably, in the beginning a steward need to be present to serve as a host and to check whether the vehicle have difficulties. However, it is still unclear when it is permitted to drive without a steward. The regulatory challenge in this project is to overcome over-regulation of the public actors. As described in Section 5.4, it is crucial to prevent ending up in a downward spiral.

CONCLUSION OF THE ANALYSIS

The main technical challenges in this project will probably be the interaction with the other autonomous shuttle, the connection between the on-site autonomous shuttles and the off-site autonomous midibus, passing road obstacles, and dealing with abrupt stops. A reliable, preferably 5G, network is crucial to establish interaction and communication between both shuttles. Moreover, to offer a trustworthy transport service, it is essential to improve the technical abilities such as smoothly braking and passing obstacles automatically. The main environmental challenge, which is different from the other projects, is the speed of the on-site shuttles of 30 kilometres per hour. A higher operating speed could result in less time to make decisions in different road situations. The main social challenge is the communication with disabled and auditory/visually impaired people. Proper communication is crucial to overcome frustrating and confusing situations. Over-regulating might be the main regulatory challenge. The main issue with over-regulating is that it will harm the learning process.

It should be noted that some challenges are based on assumptions and that the first phase of this project is mostly exploratory. This means that the challenges might be solved when the shuttles transport passengers. The main challenges of the Esa Estec project are summarised in figure 6.16.

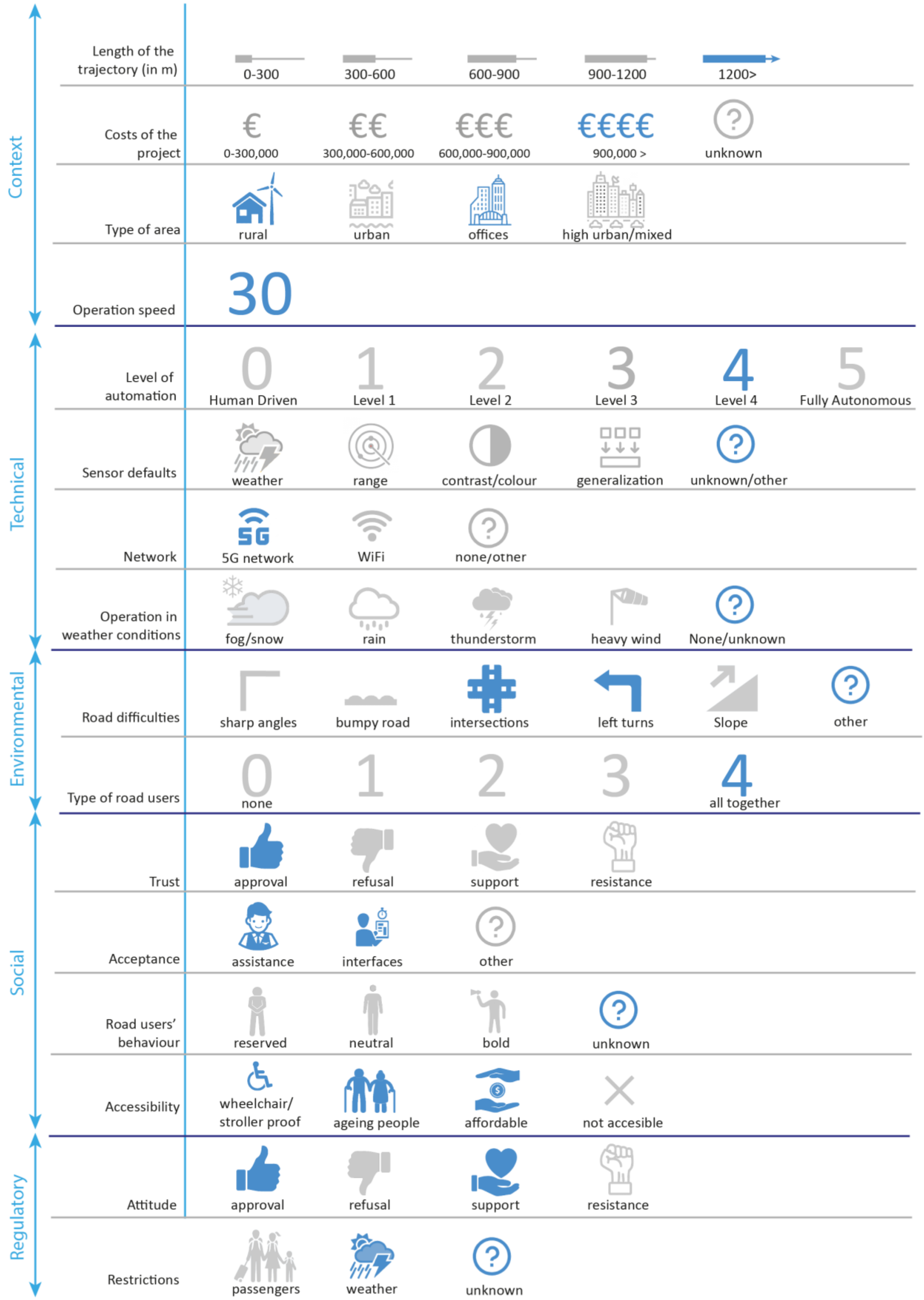


Figure 6.16: Analysis framework based on the Esa Estec case (own illustration)

6.5 Bourtange

— Future project—

6.5.1 CASE DESCRIPTION

LOCATION

Bourtange is a fortified village located in the municipality of Westerwolde that has 420 inhabitants. More than a quarter of the residents are more than 65 years old (CBS, 2018d). Bourtange is located in a rural area with a distance of around 40 kilometres from the city Emmen, around 60 kilometres from the city Groningen and 2 kilometres from the border with Germany. As the municipality of Westerwolde is categorised into the high-shrinkage region, there is expected to be a 16% decline in residents by 2040 (Rijksoverheid, 2018). Therefore, the main challenge for the municipality is keeping the villages liveable and accessible. The location is illustrated in Figure 6.17.

Figure 6.17: The location of the Bourtange case study

PURPOSE OF IMPLEMENTING THE AUTONOMOUS SHUTTLE

The main purpose of implementing an autonomous shuttle in this area is to explore the possibilities of transporting tourists and packages (Appendix D4). Nowadays, many package delivery companies drive in and out of the small village, which annoys many residents and is inefficient. Therefore, the province of Groningen wants to test if it is possible to transport the packages from a pick up point, for example, the information centre, near the shuttle stop outside the village to a drop off point inside the village (appendix D4). This can also result in the creation of private parties who want to invest in these methods of sustainable transport. In addition, how well the shuttle operates on an old, historic, less-comfortable road with a narrow pass through will be explored (appendix D4). The goal for this project is to determine answers on questions such as the following:

- How to make clear—especially for tourists—that there is an autonomous vehicle on the road and how to determine the pathway of the pedestrians?
- How to connect the shuttle time schedule with the package-delivery time schedules?
- How to get the packages in and out of the shuttle?
- How to safely store the packages within the shuttle?
- How will the residents of the village react to the autonomous shuttle?

THE TRAJECTORY OF THE SHUTTLE

The trajectory is not set yet. However, the probable trajectory will be between the closest bus stop, de Vesting, and the centre of the village (Appendix D4). The trajectory will be probably approximately 400–500 metres. The possible trajectory is illustrated in Figure 6.18.

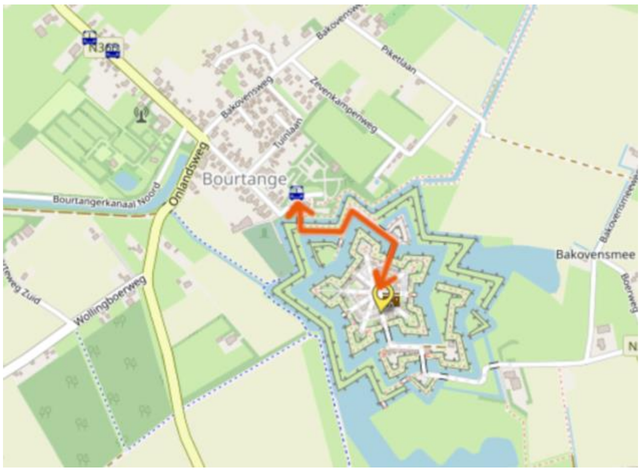


Figure 6.18. The possible trajectory of the Bourtange case study (own illustration)

STAKEHOLDERS INVOLVED

The *probable* stakeholders involved in this future project are as follows:

- The national government: the Ministry of Infrastructure and Water Management
- The regional government: Province of Groningen, Province of Friesland, and Province of Drenthe
- The local government: the municipality of Westerwolde
- Dutch Vehicle Authority: RDW
- Shuttle supplier: Navya?
- Local transport company: QBuzz, Arriva?
- Product and software supplier for the simulator: Greendino?, Robottuner?
- Delivery company: PostNL?
- Shuttle users: tourists, residents
- Road users: car drivers, cyclists, pedestrians
- Residents of the village

THE VEHICLE USED

It is quite probable that the Navya shuttle will be used in this project. The reason for this is the fixed safety zone of the Easymile shuttle and the fact that the Navya shuttle offers more features. A fixed safety zone will be difficult in the Bourtange project, as the entrance of the village is quite narrow. However, it is possible that the Easymile, or another shuttle supplier, will come with better features.

COSTS

The project is in the planning stages, so the costs are not yet determined. Currently, many autonomous shuttle projects are being executed, which can result in a lower purchase or rental price. When looking at the other projects in the Northern part of the Netherlands, the estimated costs will likely be around 150,000 euros. However, this is an estimation.

6.5.2 ANALYSIS FRAMEWORK BOURTANGE

The analysis framework serves as a tool to measure the technical, environmental, social, and regulatory challenges within the Bourtange project. In the first section, the context information is described such as the vehicle used in the project and the costs of the project. After the descriptions of all challenges subdivided into the four dimensions, all challenges are combined in the analysis framework (Figure 6.20). It is crucial to note that this project is still in the initiation phase, so it is unclear whether the project will be executed or not. This also means that most challenges are based on assumptions. Moreover, the technical challenges are based on the current technical abilities of autonomous shuttles. There is a high possibility that the technical abilities have been further developed in the period the project will be executed.

TECHNICAL CHALLENGES

Looking at the current technical development, the main technical challenge in this project will probably be obstacle passing. The lanes in this small village are narrow and the chance of an obstacle on the road might be higher. The average width of the autonomous shuttles is around two metres, whereas the average width of the roads in Bourtange is around five metres. This might cause complicated situations.

Part of the reason for implementing an autonomous shuttle at this location is to decrease the need for delivery trucks or buses to enter the village. The challenge in transporting goods is ensuring the packages are safely stored. Another challenge that might arise is the need for someone or something, for instance, a robot, to transport the goods into and out of the shuttle.

ENVIRONMENTAL CHALLENGES

Bourtange is an historic fortified village with uneven roads. The environmental challenge that might arise with these bumpy roads is the disability of the sensors to detect all surrounding objects. Another challenge that might occur because of the uneven roads is discomfort for passengers. Moreover, all roads in Bourtange are constructed of cobblestones. One of the characteristics of these stones is that they might be slippery. Therefore, the challenge might be ensuring adhesion to the road during or after rainfall.

Another environmental challenge will be the narrow pass through to enter the village. Figure 6.19 shows the narrow pass through. There is a high probability that the road situation will need to be changed, for instance, by adding traffic lights to give the shuttle priority. A consequence of a change in the road situation is that other road users need to be informed properly.

Figure 6.19 Gateway Bourtange (Daguitje, n.d.)

Lastly, Bourtange has two entrances to the village. During the day, there are peak hours of people departing from or arriving at the village. Only one of the entrances is situated near a bus station, whereas both entrances offer a connection with the public highway. This might result in more traffic pressure on the entrance near the bus station, which is the entrance where the shuttle might be operating. During these peak hours, the shuttle needs to interact with various road users such as pedestrians, cyclists, and cars. The contrast of interaction between the shuttle and many road users on peak hours, and the interaction between the shuttle and few road users during the day, might be challenging in this project.

SOCIAL CHALLENGES

Because Bourtange attracts many tourists, the challenge arises to inform people with another native language of an unusual situation. An additional challenge with tourists is that the environment is new and exciting, which can result in inattention.

Another social challenge is ensuring the privacy of the inhabitants. Conversations about sensors that are scanning objects and images in combination with ensuring people's privacy might worry or even anger people. Thus, the communication between the initiators of the project and the inhabitants of the village should be handled carefully.

Finally, the shuttle will probably be driving in two directions because of the scarcity in space. This might cause confusion, as people may find it hard to predict the direction the shuttle is driving in. Thus, good communication through both the vehicle and the environment might be essential in this project.

REGULATORY CHALLENGES

A challenge regarding regulation in this project will probably be dealing with over-regulation, as Bourtange is an historic village. As the idea of the initiators of this project is to transport goods, there may be a liability problem, as the question arises of who is liable for the goods when something gets broken? Another question that might arises is whether delivery truck still permitted to enter the village during the day or if every company is obliged to deliver the packages at a certain time.

CONCLUSION ANALYSIS FRAMEWORK

To conclude, the challenges mentioned in this chapter are based on assumptions, as the project is still in an early stage. On the one hand, it is unsure how the technology will develop over time, which means it is unclear whether the challenges will still be applicable as the technology develops. On the other hand, some challenges, for instance, the environmental challenges due to the small pass through, will remain roughly the same, as the pass through might not be easily changed. The main technical challenge in this project will probably be obstacle passing in combination with the narrow roads. Dealing with a small pass through, uneven and slippery tiles, and many other road users at the same time are the main environmental challenges. The main social challenges might be the communication between the autonomous shuttle and tourists, the communication with the inhabitants, and the communication between the shuttle and the other road users. Lastly, liability and over-regulation might become a regulatory challenge. The results of the framework analysis are summarised in the framework in Figure 6.20.

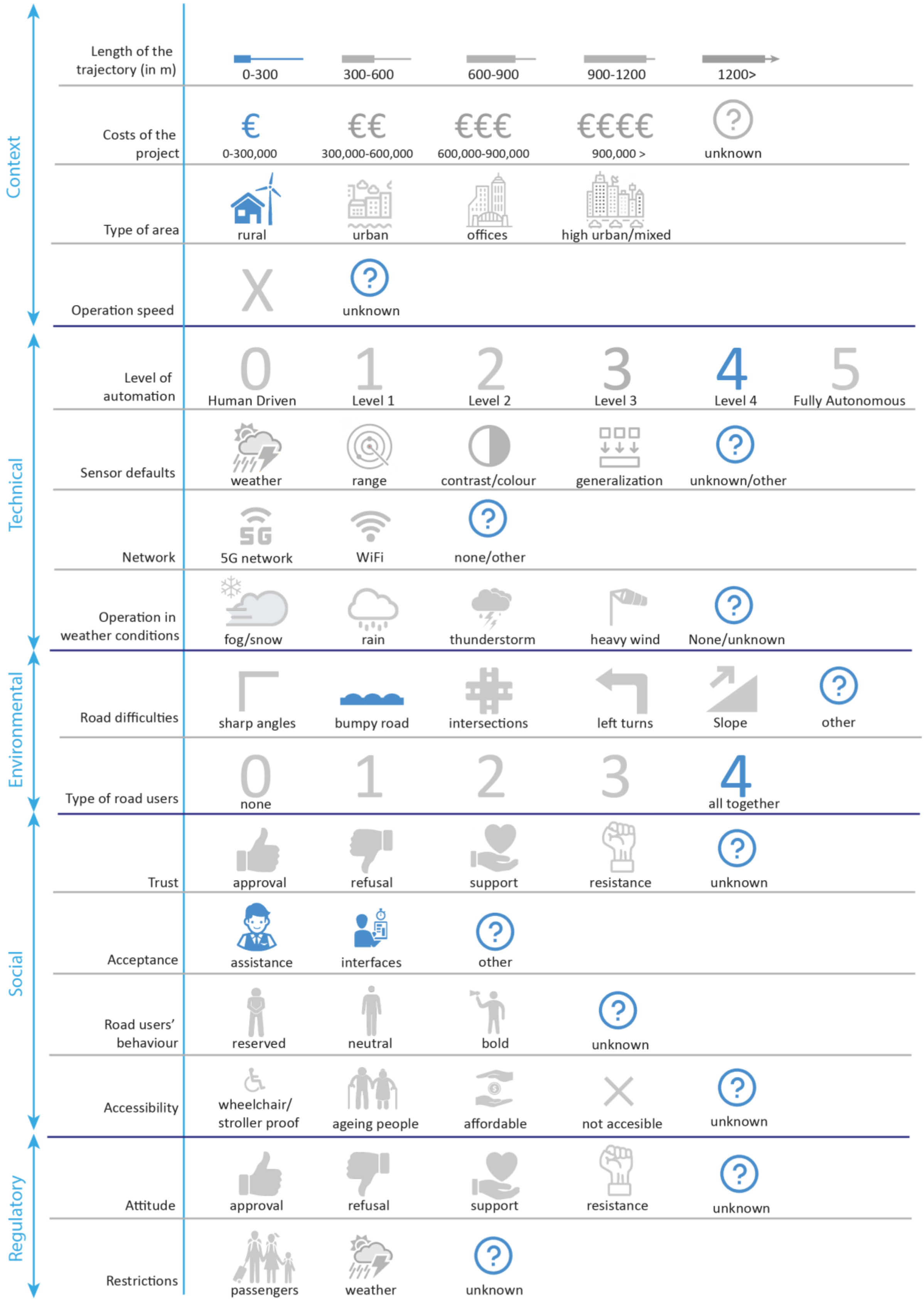


Figure 6.20: Analysis framework based on the Bourtange case (own illustration)

6.6 Cross-case analysis

6.6.1 CONTEXT

When comparing the differences concerning the context information available for each case, some remarkable differences and relations can be observed. In most cases, the context information of each case already determines the main challenges during the project. This chapter describes the differences in costs, the involved actors, the length of the trajectory, the area type, and the speed limit during operation. A visual comparison of all case studies can be found in Appendix F.

COSTS

The costs for every project are either around 150,000–300,000 euros, or more than 1.2 million euros. The large difference of around 1 million euros might be explained by the costs of buying an autonomous shuttle instead of leasing. Currently, few vehicles are being manufactured, which makes the purchasing price high. In almost every project, the shuttles are being leased, but in the Haga project, the shuttle has been bought by the Haga BV.

Another explanation of the tremendous costs of the projects may be the number of autonomous shuttles used. The higher costs of the Esa Estec project can be explained by the number of vehicles used in the project in combination with the time span. The project will last around two years and the one-year lease contract for one shuttle is approximately 1 million euros. The Appelscha and Scheemda cases, which cost approximately 150,000–300,000 euros, only lasted or in the midst of lasting for 3–6 months. This means that the price for leasing the vehicle in the Appelscha project was around 125,000 euros.

A third explanation of the difference in price might be the number of environmental changes needed. In both the Appelscha and Scheemda projects, there were hardly any infrastructural changes needed, whereas the infrastructural changes in the Haga shuttle case are a bit larger. However, large infrastructural changes are not necessary in all projects.

Lastly, some public stakeholders involved are willing to grant a subsidy, for instance, regional governments, local governments, and transport authorities. These subsidies might provide the possibility of implementing a more extensive project, which would lead to an increase in the total cost of the project. Moreover, when expanding the project or when exploring more projects, the initiators of the project hope the costs for the autonomous shuttles will decrease because of economies of scale. Thus, on the one hand, more (public) stakeholders might result in greater subsidies and a more extensive project, which means higher overall costs. More public stakeholders might lead to more research questions, and more research question could lead to more private actors, for instance, consultants. Involving private parties might increase the costs of the project. On the other hand, when the projects get more extensive and more project are being explored, the future costs of projects might decrease due to economies of scale.

INVOLVED ACTORS

When comparing the different actors involved in the project, some differences were found. In the Haga and Esa Estec projects, an additional public actor is involved in the project. The public organisation MRDH, which is a regional transport authority, is mainly a financial supporter for both projects. In addition, the Scheemda and Haga projects are comparable in the shuttle users, namely, both use cases include the transportation of clients, visitors, and employees from a public-transport stop to a hospital. This might mean that the communication between the shuttle and the passengers of the shuttle is comparable. The table below summarises all actors in each case, where the public actors are in *italics* (Table 6.1).

APPELSCHA	SCHEEMDA	HAGA	ESA ESTEC	BOURTANGE
- *The national government* - *The regional government* - *The local government* - *Dutch Vehicle Authority* - Shuttle supplier: Easymile - Insurance company: Allianz, Aon - Initiator: Drietachtig - Consultant: Taxi company Kort - Road users: cyclists - Residents of the village	- *The national government* - *The regional government* - *The local government* - *Dutch Vehicle Authority* - Shuttle supplier: NAVYA - Insurance company - Ommelander hospital - Local transport company - Product and software supplier for the simulator - Service provider for the 5G network: KPN - Shuttle users: patients, employees and visitors - Road users: car drivers, cyclists, pedestrians - Residents of the village	- *The national government* - *The regional government* - *The local government* - *Dutch Vehicle Authority* - *Dutch transport authority: MRDH* - Shuttle supplier: NAVYA - Insurance company - Haga Leyenburg hospital - Local transport company - Consultants: The Future Mobility Network, Rebelgroup - Research Institute: SWOV - Shuttle users: patients, employees, and visitors - Road users: car drivers, cyclists, pedestrians	- *The national government* - *The regional government* - *The local government* - *Dutch Vehicle Authority* - *Dutch transport authority: MRDH* - Shuttle supplier: NAVYA - Insurance company - Local transport company - Consultants: The Future Mobility Network, Royal haskoning, Rebelgroup - Research Institute: SWOV - Shuttle users: employees, visitors - Road users: car drivers, cyclists, pedestrians	- *The national government* - *The regional government* - *The local government* - *Dutch Vehicle Authority* - Shuttle supplier: NAVYA? - Insurance company - Local transport company - Product and software supplier for the simulator? - Delivery company: PostNL? - Shuttle users: tourists, residents - Road users: car drivers, cyclists, pedestrians - Residents of the village

Table 6.1. All involved actors in each project, where the public actors are in italics (own table).

LENGTH OF THE TRAJECTORY

The length of the trajectories in each project is either short, 300 metres, or quite long, 1200–2000 metres. The distance of the trajectories probably depends on two factors, namely, the distance needed to comply with use case and the complexity of the environment. In all pilot projects, a use case is determined that describes the purpose of the implementation of an autonomous shuttle. In both the Haga project and the Scheemda project, the use case is to operate between a public-transport stop and the main entrance of a hospital. This makes the distance quite short, as there is a bus stop nearby a hospital. The same statement can be made for the Bourtange project.

The complexity of the environment also determines the length of the trajectory. For instance, in the Appelscha project, there were not many environmental challenges, which made it possible to make the trajectory around 2000 metres long, whereas in the Haga project, the trajectory is as short as possible, as there are many environmental challenges. In the Esa Estec project, it is possible to experiment with the length of the trajectory, as the shuttle is going to operate on private ground.

AREA TYPE

According to the interviewees from the North of the Netherlands, the rural areas are better suited than the urban areas for implementation of autonomous cars. They stated it is less crowded and there is more space, which decreases the need for many infrastructural changes (Appendices D3 and D4). The main differences between the cases in the rural areas, Appelscha, Scheemda, and Bourtange, are the costs of the projects and the number of environmental challenges.

SPEED LIMIT

The speed limit is mostly determined by regulation. In all cases, the maximum operating speed of the shuttle is between 15 and 20 kilometres per hour. In the Esa Estec case, the speed limit will probably be 30 kilometres per hour, as the shuttle is operating on private grounds during the first phase.

6.6.2 TECHNICAL CHALLENGES

The technical challenges mentioned in the literature in Section 5.1 are slightly different from the challenges mentioned in the individual case analyses. Technical challenges such as sensor defaults and operation in heavy weather conditions were mostly undermined by regulation of the Dutch Vehicle Authority. The technical challenges regarding cyber security are the responsibility of the shuttle manufacturer. The shuttle manufacturer develops the hardware and the software, which means they need to secure a safe operation system. In this research, it is assumed the hardware and software of the operating system is secured. This chapter compares the technical challenges for each case, wherein some remarkable differences and relations can be observed. A visual comparison of all case studies can be found in Appendix F.

LEVEL OF AUTOMATION

In all projects, the repeating challenge is the inability of the autonomous shuttle to pass obstacles. This inability is caused by the level of automation. The software of the shuttle is not developed completely yet, which means that there should be someone watching the whole route in or outside the shuttle. Currently, the steward needs to guide the shuttle around the obstacle manually. In all cases, the presence of the steward is not directly a challenge. However, the costs of having a steward increases the costs for the project. In the end, one of the purposes of integrating autonomous cars is to remove the driver from the vehicle to decrease the costs for operation. Thus, this challenge indirectly influences the attractiveness of implementing autonomous shuttles.

INTERACTION BETWEEN THE SHUTTLE AND OTHER VEHICLES

In the Scheemda project, interaction between the shuttle and the emergency ambulance is essential to safe operation on the entire trajectory. Currently, the shuttle stops automatically, and the stewards needs to grant permission by hitting a 'GO' button. However, when the shuttle is able to receive a signal from the ambulance to stop, no steward will be needed on this intersection. The Esa Estec project is unique in terms of the number of autonomous shuttles, as in this project three autonomous shuttles are planned to be implemented. Therefore, during this project, is it crucial to test the communication between the shuttles to explore the reliability of vehicle-to-vehicle communication. In the other projects, it might be more difficult to implement vehicle-to-vehicle communication, as the interacting vehicles are bicycles or human-driven cars with automation level 0.

CONNECTING TO (PUBLIC) SERVICES

In the Scheemda, Haga, Esa Estec, and Bourtange projects, a proper connection between the time schedule of the shuttle and the time schedule of the public-transport service is essential. The reason for this is that the autonomous shuttle serves as a first or last mile in the public-transport service. Moreover, the Bourtange and Scheemda projects are located in shrinkage areas. Consequently, the public-transport services are not optimal, for instance, most buses arrive only twice an hour, whereas most buses in the urban area arrive four times an hour. The challenge here is to avoid delays in the time schedule. Currently, the delays can be caused by road obstacles or by additional time needed to extend the ramp for objects on wheels. In the Appelscha project, the shuttle did not operate from or towards a public-transport service, and thus this was not a challenge.

BIDIRECTIONAL SHIFTS

Apart from the Appelscha project, in all projects, the Navya shuttle was implemented, as this shuttle has the most features and abilities compared to other shuttle brands. The Navya shuttle operates in two directions, which means the shuttle does not have a front or rear. The challenge that occurs is that the brake lights need to become head lights and vice versa. Moreover, it needs to be clear to other traffic flows which direction the vehicle is moving.

ABRUPT STOPS

Especially in the Scheemda and Haga projects, it is crucial the abrupt stops are not disturbing to passengers, as the targeted passengers are, amongst others, clients from the hospital. The challenge is to mute the movement to make the trip pleasant for all passengers.

ANOTHER USE-CASE

The use case of the Bourtange project is somewhat different from the use cases of all other project, because the shuttle might transport both people and packages. Despite the Bourtange challenge still being in the initiation phase, the challenge here will likely be storing and transporting the packages safely.

6.6.3 ENVIRONMENTAL CHALLENGES

The environmental challenges mentioned in the literature in Section 5.2 are fairly comparable to the challenges mentioned in the individual case analyses. The environmental challenge regarding the weather has been undermined by regulation, since it is not permitted to operate in heavy rainfall. The environmental challenges discussed in this chapter are unsignalised intersections, left turns, and roundabouts; road conditions; the other traffic flows; and fixed road obstacles. A visual comparison of all case studies can be found in Appendix F.

UNSIGNALISED INTERSECTIONS, LEFT TURNS AND ROUNDABOUTS

The repeating environmental challenge in all projects is to operate automatically and safely on unsignalised intersections, left turns, and roundabouts. In the Appelscha project, this was solved by assigning traffic wardens to give priority to the autonomous shuttle. However, this might not be the optimal solution, as this probably costs a large amount of money. In the Scheemda project, several stops were programmed in advance to cross over the unsignalised intersections. This solution is much more cost efficient, but there is still a steward needed to grant permission to cross over the intersection. Currently, it is still forbidden to drive without a steward, but when it is legally permitted to operate without a steward, the unsignalised intersections, left turns, and roundabouts will still be a challenge. The other projects are currently in the execution phase or in the initiation phase, which means it is not yet possible to reflect on this.

OTHER TRAFFIC FLOWS

Dealing with other traffic flows is the second repeating challenge in all projects. In every project, there are at least two, but more often four, different traffic flows that interact with the autonomous shuttle. Other traffic flows can be seen as fragile and continuously moving road obstacles that need to be taken into account.

ROAD CONDITIONS

In the Appelscha project, the road was narrow, and the grass needed to be mown, as the Easymile shuttle had a programmed safety zone. Also, the road in the Bourtange project is quite narrow. The project team will probably decide to implement the Navya shuttle instead of the Easymile in this project. In addition, the road in Bourtange is uneven and might become slippery during or after rainfall. In the Haga project, the road has a slope of 12%, which is the maximum slope the Navya shuttle can handle. This might become a challenge in this project. The situations mentioned in this section illustrate the importance of qualitative roads. This might change in the coming years, as the technology is in the midst of rapid development.

FIXED ROAD OBSTACLES

A challenge that has not been mentioned yet in the literature is dealing with fixed road obstacles. In the Bourtange project, the trajectory of the shuttle is not yet set. However, there is a possibility the shuttle will need to pass through a narrow gateway. Fixed road obstacles make the implementation of autonomous cars more difficult; however, implementation is not impossible. Other examples of fixed road obstacles could be greenery such as trees or buildings.

6.6.4. SOCIAL CHALLENGES

The social challenges differ from the technical and environmental challenges, as the technical and environmental challenges can be observed physically, whereas the social challenges need to be analysed, for instance, with the use of a survey. Despite the fact the Haga, Esa Estec, and Bourtange projects are not yet executed, assumptions can be made. Three social challenges were added as mentioned in the literature in Section 5.3, namely, the communication between the project team and the environment, the dilemma of keeping the steward as a host, and the communication between the control rooms. A visual comparison of all case studies can be found in Appendix F.

TRUST

The trust level in the Appelscha and Scheemda projects is pretty high. This high trust level is probably caused by the presence of the steward and the presence of information interfaces. This level of trust might be the same for the other projects. However, as the social values and perceptions of the people in these areas might be different, it is not completely certain. Overall, this means that the trust issue will be not a challenge as long as a steward is present. Contrarily, when the steward is removed from the shuttle, there might be a substantial decrease in the trust level. Therefore, trust is essential to include in the social challenges.

ACCEPTANCE

The acceptance of a new technology depends on the target group and the people affected by this particular technology. For instance, in the Appelscha project, 65% of the people who did not accept the autonomous shuttle were ageing people. This could be explained by the high number of elderly people in the village and the social values of these people. The expectation is that when new technologies are implemented on a university campus, the acceptance will be much higher. Still, the acceptance of all sorts of people is important, as the business case will become more feasible. Therefore, the challenge is making this new technological development acceptable to everyone.

BEHAVIOR OF ROAD USERS

Reflecting on the behaviour of the road users in both the Appelscha project and Scheemda project, people reacted differently to the autonomous shuttle. A large number of people were enthusiastic in the Scheemda project and 3,000 people have already made use of the shuttle system (Appendix D4). Despite the enthusiasm, people's behaviour is unpredictable. To illustrate this, in the Appelscha project, people's behaviour was either reserved or bold, as they were not able to fully estimate the behaviour of the autonomous shuttle. The challenge for the project team is to establish proper communication between the automated shuttle and the road users to decrease this uncertainty. Possibly, there is no one way to communicate in these projects, as the social values and interpretations differ between people.

ACCESSIBILITY

Accessibility can be divided into physical and financial accessibility. The physical accessibility is still lacking in many of the projects, including the transportation of people or objects on wheels. The main reason for this is that the Dutch Vehicle Authority does not allow objects on wheels in the autonomous shuttles. Next to the regulatory blockade, the shuttles in the Appelscha project and the Scheemda project were not equipped with a safety belt, which made it unsafe to transport objects or people on wheels. In the Haga and Esa Estec projects, there will be a safety belt. However, the shuttle might still not be accessible to objects or people on wheels because of regulations. In the Esa Estec project, transporting people or objects on wheels could be experimented with, because the shuttle will operate on private grounds.

The financial accessibility is currently not a challenge, as a ride in the shuttle is free during the testing phases. However, when the shuttle is part of the (public) transport service, there might be a fee. Expectations are that the fee will be comparable to public-transport fees. The challenge will be to create a business case that keeps the shuttle financially accessible.

COMMUNICATION WITH THE ENVIRONMENT

During the Scheemda project, news articles appeared about the privacy of the inhabitants living next to the street where the autonomous shuttle operates. This illustrates that the communication between the project team and the inhabitants of Scheemda, and especially the people who live directly next to the trajectory, was probably deficient. Negative publicity might affect the successfulness of a pilot project. Therefore, it is essential that nearby residents are properly informed. This has also been concluded in the stakeholder analysis in Chapter 4.

THE DILEMMA OF KEEPING THE STEWARD

Currently, it is not legally permitted to drive without a steward. However, expectations are that this might be possible in coming years. In the Scheemda project, the steward serves as a host who helps to comfort and inform people about what the new transport means. Moreover, the steward helps vulnerable people get into and out of the shuttle. Therefore, the thought has risen to keep the steward in the shuttle to serve as a host. The same statement might apply for the Haga project. Thus, the challenge has been raised of whether to keep the steward in the shuttle as a host or to take out the steward. Possibly, this dilemma could be answered easily in the situation of a hospital, but the dilemma might be more difficult in other use cases.

COMMUNICATION BETWEEN CONTROL ROOMS

In the Esa Estec project, three control rooms will be established to control all autonomous shuttles. Two control rooms will be located on-site, and one control room will be located in Lyon, France, at the shuttle manufacturer. The challenge will be to ensure qualitative communication between all three control rooms. This challenge is probably also applicable to the Haga shuttle project, as there will be two control rooms, one in the Netherlands, and the other in France. The control rooms of all other projects are only situated in France. Therefore, this challenge is applicable only to the Esa Estec project and the Haga project.

6.6.5 REGULATORY CHALLENGES

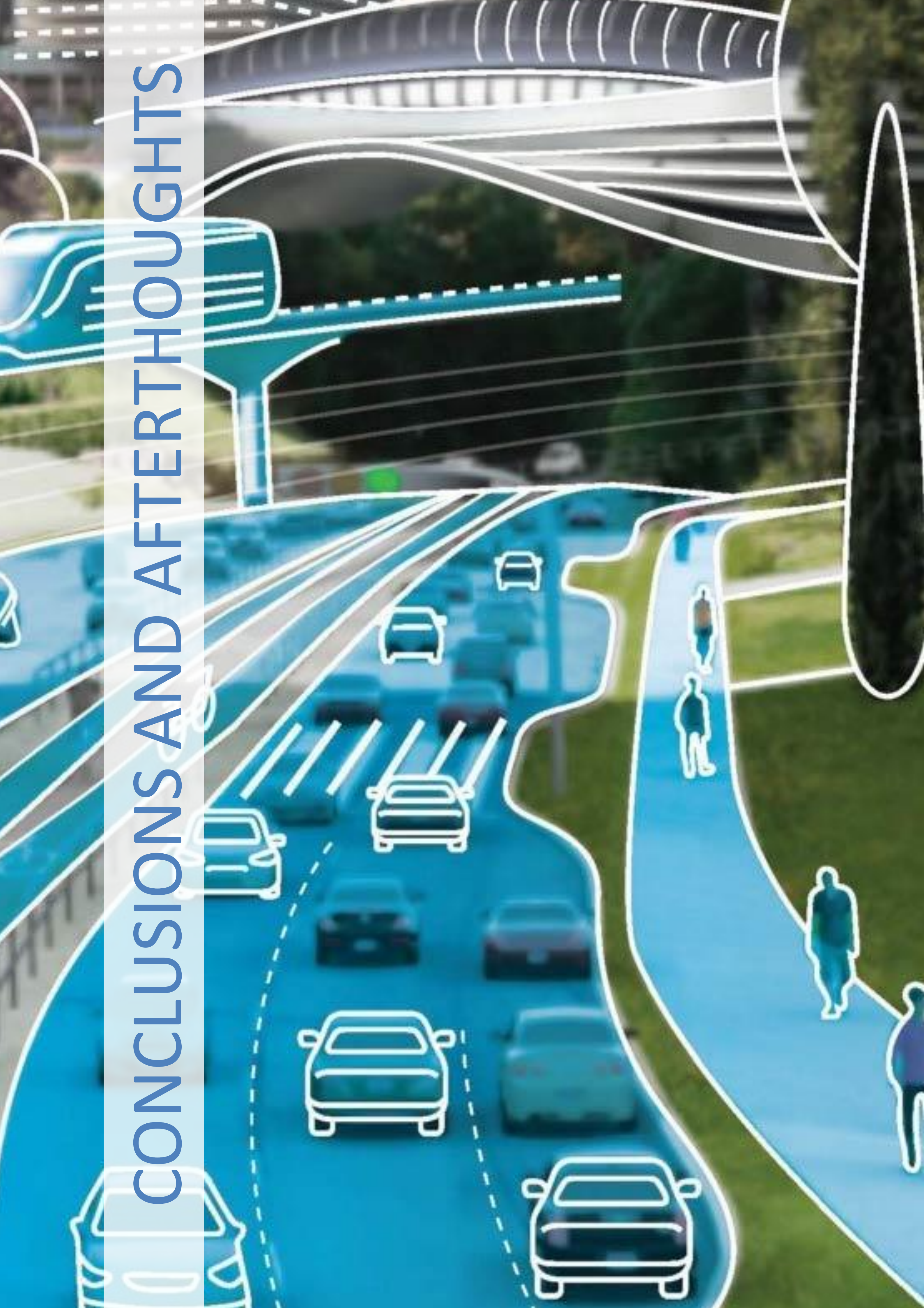
The regulatory challenges described in the literature mentioned in Section 5.4 differ from the regulatory challenges described in the cases analysis. The challenges mentioned in Section 5.4 are related to public actions, whereas the challenges described in the case analysis are related to the requirements needed to get permission for executing the project. Rethinking education, preventing unemployment, and assessing the liability do not directly affect the projects. Therefore, only the regulatory challenge of over-regulating is described.

OVER-REGULATING

In all projects, the main regulatory challenge is to deal with over-regulation from the public authorities. The exemption from the Dutch Vehicle Authority will be directly withdrawn if the vehicle operates in an unsafe manner. Moreover, the shuttle is not permitted to operate when the visibility is less than 50 metres because of weather conditions or in other conditions that might hamper the functioning of the sensors.

Another regulatory challenge it to decide when to drive without a steward after the legal permission has been officially granted.

CONCLUSIONS AND AFTERTHOUGHTS



7.1 Conclusion

This study aimed to contribute to the field of knowledge concerning the implementation of autonomous cars in cities and thus to the development of autonomous cars. Five implementation projects of autonomous shuttles in the Netherlands at various stages from the initiation phase to completion were researched. The following main question was posed: *'How have autonomous cars been integrated during the autonomous vehicle transition in the Netherlands?'* The scope of this research resulted in an exploratory approach to answer this question. The methodology section (Chapter 2) described how the data were collected and managed safely. Moreover, the conceptual model shows the main boundaries of the research framework. The theoretical framework (Chapter 3) then provided definitions of the relevant concepts and the relationships among them. Subsequently, the stakeholder analysis section (Chapter 4) outlined the critical actors in autonomous vehicle implementation projects. The synthesis analysis framework section (Chapter 5) provided the synthesis of both the preliminary analysis framework and the analysis framework. The case-study analysis section (Chapter 6) described the analysis of the Dutch implementation projects and the cross-case analysis section (Section 6.6) provided a comparison of all implementation projects. This chapter answers the sub-questions posed at the beginning of the thesis, followed by the main research question in the section. Finally, the discussion (Section 7.2) describes the limitations of this research and recommendations for future research.

To answer the main research question, five sub-questions were formulated. The first sub-question focuses on the definition of autonomous cars; the second examines the critical and external stakeholders in autonomous cars integration in the Netherlands; the third explores the existing Dutch policies relating autonomous car integration; the fourth focuses on the expected impact of autonomous car integration in cities; and the fifth examines the current technical, environmental, social, and regulatory challenges in autonomous car integration.

The first sub-question addresses the definition of autonomous cars. Literature was used to provide an understanding of the current definition of autonomous cars. Research illustrates different levels of automation, starting from level 0, no automation, to level 5, fully automated, or autonomous. To answer the sub-question, an autonomous vehicle is able to perform all driving tasks automatically, so there is no driver needed. As this thesis is written in the middle of the integration from zero automation to full automation, the automation level in each project is still level 3. Level 3 means that the driver is still necessary, but the vehicle is able to perform nearly all driving tasks automatically.

The second sub-question examines the critical and external actors in autonomous vehicle integration projects. Both the literature and the case studies show that the critical actors are the European Commission, the Ministry of Infrastructure and Water Management, regional and local government, vehicle authorities, research institutes, service providers and suppliers, consultants, and manufacturers. Without involving the critical actors, autonomous cars cannot be implemented in the Netherlands.

The third sub-question explores the existing Dutch policies relating to the implementation of autonomous cars. Policy documents from both the European Commission and the Dutch government illustrate the facilitating role of the government to implement autonomous cars. Since 2015, autonomous vehicle testing has been legally permitted on the Dutch roads with a driver or steward inside the vehicle. To do this, the initiators of the project must obtain an exemption on the Road Traffic Act 1994 by following an application procedure. This procedure takes on average 12 months. When exemption is granted, the project team should comply with several restrictions, otherwise there is a risk of losing the exemption.

The fourth sub-question focuses on the estimated effect of autonomous vehicle integration on the built environment. The academic literature illustrates that the effects of implementing autonomous cars on the built environment are far from straightforward, because the development of autonomous cars is still at an early stage.

Currently, the possible effects are a decrease or increase in private car ownership, fewer parking spaces needed in cities, an increase or decrease in urban sprawl, and probably a decrease in road infrastructure.

The fifth sub-question examines the current technical, environmental, social, and regulatory challenges in autonomous vehicle integration projects in the Netherlands. The main overlapping technical challenges, which repeat in every project, are the inability of the autonomous vehicle to pass obstacles and establishing secure vehicle-to-vehicle communication. The main environmental challenges are crossing unsignalised intersections, left turns, and roundabouts and operating in non-optimal road conditions. The social challenges are to keep the trust level high when the automation level goes up, to establish clear communication between the autonomous vehicle and the other road users, and to secure proper communication between the project team and people of companies from the environment. The main regulatory challenge is over-regulating, which can counteract creating new knowledge.

By combining the findings used to answer the five sub-questions of this research, the main research question can be addressed. As previously described, the current level of automation in all Dutch integration projects is level 3. With this level of automation, there is still a driver needed to perform some driving tasks to drive safely, for instance, passing road obstacles. The stakeholder analysis shows that the critical actors need to be either managed closely, kept informed, or kept satisfied before, during, and after the implementation projects. When not involving all critical actors, autonomous cars cannot be implemented in the Netherlands. Policy documents show the facilitating role of the government during the transition to autonomous cars. Applying for an exemption from the Dutch Vehicle Authority is crucial in getting legal permission to implement an autonomous vehicle on the public roads in the Netherlands. Despite the facilitating role of the European Commission and the Dutch government, driving without a steward is yet not legally permitted on the public roads. One of the cases, the Esa Estec project, shows that the implementation of an autonomous vehicle without a steward is possible on private grounds. The technical, environmental, social, and regulatory challenges in all case studies might be clarified by the level of automation. The autonomous vehicles in all projects are yet in automation level 3, so the ability to pass obstacles, operate in different road conditions, establish secure vehicle-to-vehicle communication, and cross unsignalised intersections may be resolved in time as the software is further developed, allowing higher levels of automation. The social challenges of keeping the trust level high and establishing clear communication between the autonomous shuttle and the other road users can be integrated in the actual process. Last, there is a regulatory challenge in that over-regulating should not harm the generation of new knowledge during the integration projects.

7.2 Discussion

This research identified several limitations as a result of the research scope, the case selection, the methodology, and the analysis framework. Subsequently, this final chapter outlines the limitations, along with academic recommendations for future research and proposals for future implementation projects.

7.2.1 LIMITATIONS OF THE RESEARCH

SCOPE

The main research aim was to contribute to the field of knowledge concerning the implementation of autonomous cars in cities. Although the transition from human-driven to autonomous cars is coming all over the world, this research mainly focused on the implementation of autonomous cars in the Netherlands. Reason for this was the accessibility of up to date online information of international cases and the time span of the thesis. Furthermore, the research was merely focused on 'how' autonomous vehicle have been integrated in instead of 'why' autonomous vehicle are being integrated in the Netherlands. The research touched the 'why' side of the implementation in the section about the main players in the autonomous vehicle industry. However, the question of why different actors such as the European Commission and the national, regional, and local government are stimulating the implementation of autonomous cars remains unanswered. Finally, it should be noted that not all cases in the Netherlands were addressed, as the research focused on only five projects out of 20. The reason for this is the availability of information and the fact that most cases are only in the initiation phase.

CASE SELECTION

For this study, five autonomous vehicle implementation projects from the Netherlands were researched. The choice of these cases was based upon both the information available from the internet and the contact persons. Because of the limited number of studied projects, all focused on the Dutch regulatory and market system, and the results of this research cannot be generalised and projected on international projects.

METHODOLOGY

Within the research, exploratory qualitative research was conducted. Qualitative research has been generally seen as a research method sensitive to subjectivity. Several measurements were taken to overcome a judgmental interpretation of the findings. First, the data obtained from the interviews were compared with data from academic literature. An overview of the academic literature and archival documents used can be found in the references section. Second, the interviews were all conducted by the same researcher, which resulted in an equal personal attitude during the interviews. Moreover, the results of the interviews were all, if necessary, revised by the interviewees to be certain of the quality of the results. During the interviews, some answers were quite positively formulated by the interviewees, probably out of pride for their project. This attitude could result in a bias that might influence the research results. Therefore, both public and private parties were interviewed to decrease the bias. The positively formulated attitude was filtered out of the results as much as possible. Additionally, more interviewees could have reduced the bias even more. Another limitation relating to the bias in the interviews it the gaining of knowledge due to former interviews. This new knowledge could be applied to the other interviews; thus, the interviews are not completely comparable. Lastly, the results from the interviews are used for both the case description and case analyses, to overcome limitations in the case descriptions. Consequently, the reader is able to interpret the case-study analyses much easier.

7.2.2 RECOMMENDATIONS

FOR FUTURE RESEARCH

One of the limitations in this study is the limited number of case studies. For future research, the number of case studies could be extended. Obviously, extending the number of cases should not be done to the detriment of the depth of the analysis. Therefore, when extending the number of case studies, the time span of the research should be probably extended as well. Moreover, future research could include international cases to broaden the scope of the research. Consequently, the results could be relevant for other countries as well. During the research there has been discovered that the implementation of autonomous cars in different countries might depend on the public involvement. For instance, in Singapore, the financial support for the implementation of various technological developments is substantial. Future research could investigate whether financial support might impact the success of the development of new technologies. This study was limited in identifying the social challenges in the implementation projects, as not every project has been executed yet. Therefore, future research could investigate the social challenges in these projects, for instance, by conducting a survey. The analysis framework used in this research might be adjusted to make every variable measurable. Moreover, future research should explore adding more variables to the analysis framework regarding the ongoing developments of the technology. In coming years, it might be legally possible to exclude the steward from the vehicle. People will not be able to rely on the steward, which will probably result in a decrease in the trust level. Therefore, future research should look into to the level of trust concerning the development of the autonomous vehicle technology. In the Scheemda project, some of the inhabitants of the village complained about their privacy. To overcome future issues regarding privacy, it is recommended the projects explore how to tackle the privacy issues relating to autonomous vehicles. Finally, according to the case analysis, the level of trust and acceptance towards the implementation of autonomous cars among ageing people might be lower compared to the level of trust and acceptance among adults and young adults. As the population is ageing, it is essential to investigate how to increase the trust level and acceptance of elderly people.

FOR FUTURE PROJECTS

Although the case studies presented in this thesis are all quite successful, some additional remarks can be made. First, the communication between all projects is lacking. During the interviews, it became clear that there are some knowledge gaps, for instance, how to communicate with the shuttle supplier. Moreover, both the interviewee from the Appelscha project and the interviewee from the Haga project stated that knowledge sharing is lacking (Appendices D1 and D3). To overcome any duplication of activities, it is crucial to share knowledge not only with the surrounding cities and villages but also with the cities and villages located at a specified further distance. Preferably, the knowledge should be shared with the neighbouring countries as well. There is already a website, Bloomberg Philanthrophies (2018), with many pilot projects in the world, but this website is not up to date anymore. Therefore, it is recommended to either keep the website up to date or to design a new database that will be checked regularly.

Second, the extremely rapid development created the need for new knowledge fields. As a result, it might be necessary to rethink the approach to education or offer a new form of education, for example, institutions that support employees throughout their careers. This also matches the current workforce members' tendency to switch careers during their lifetimes. Thus, education institutions and governments need to work together to encourage citizen to learn new skills to fill new roles in the autonomous vehicle industry. This could also partly solve one of the regulatory challenges of increasing unemployment.

Third, another regulatory challenge is over-regulating. It is essential to overcome over-regulation and to be aware of not ending up in a downward spiral. This study recommends encouraging governments and other public parties to encourage real-life testing in different circumstances. This way, the knowledge about the practical implications and challenges might increase.

Finally, in the Scheemda project, the communication between the residents living next to the trajectory of the autonomous vehicle and the project team was probably lacking, as some residents complained about their privacy. It is highly recommended to keep these actors involved during the whole process.

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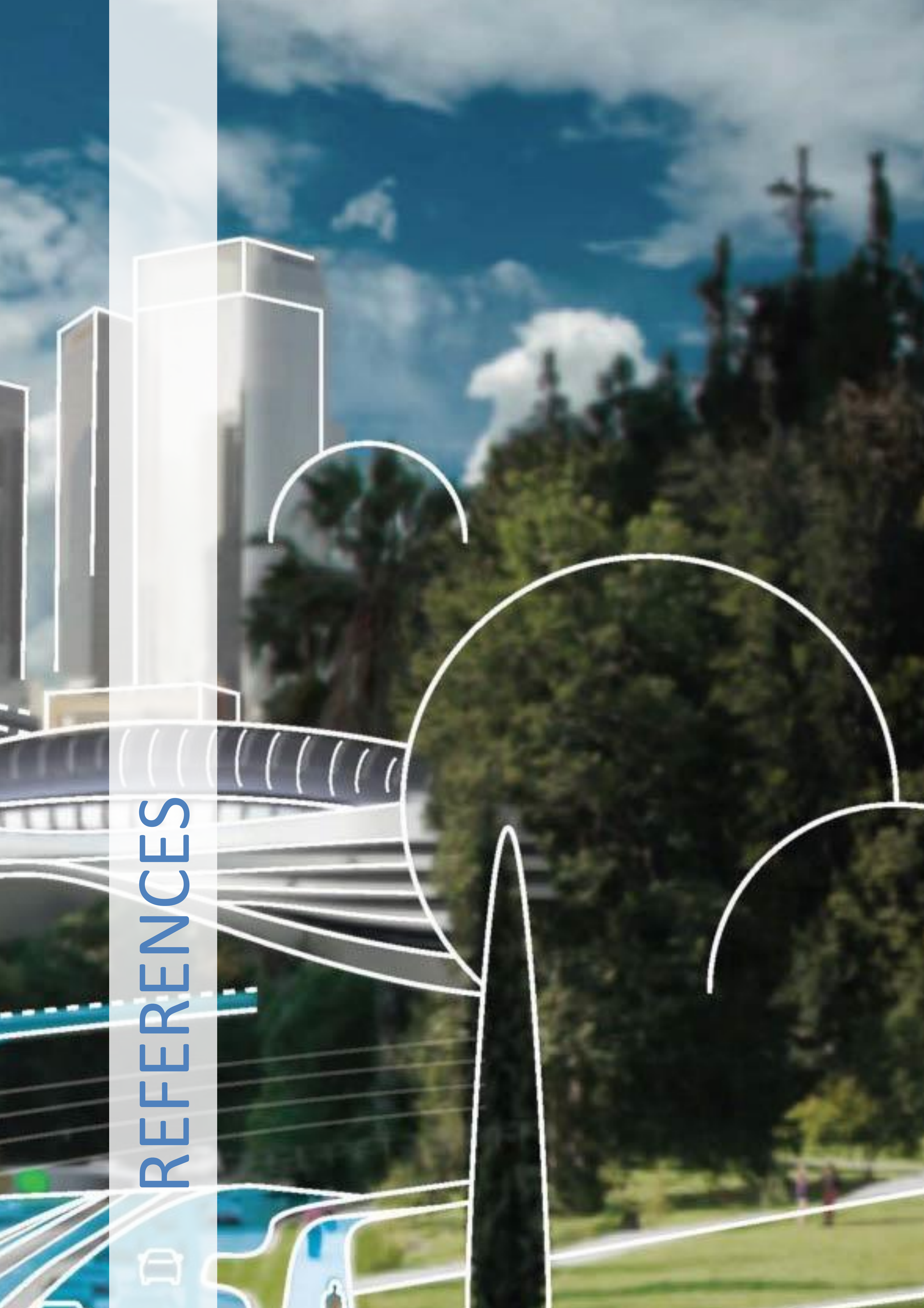

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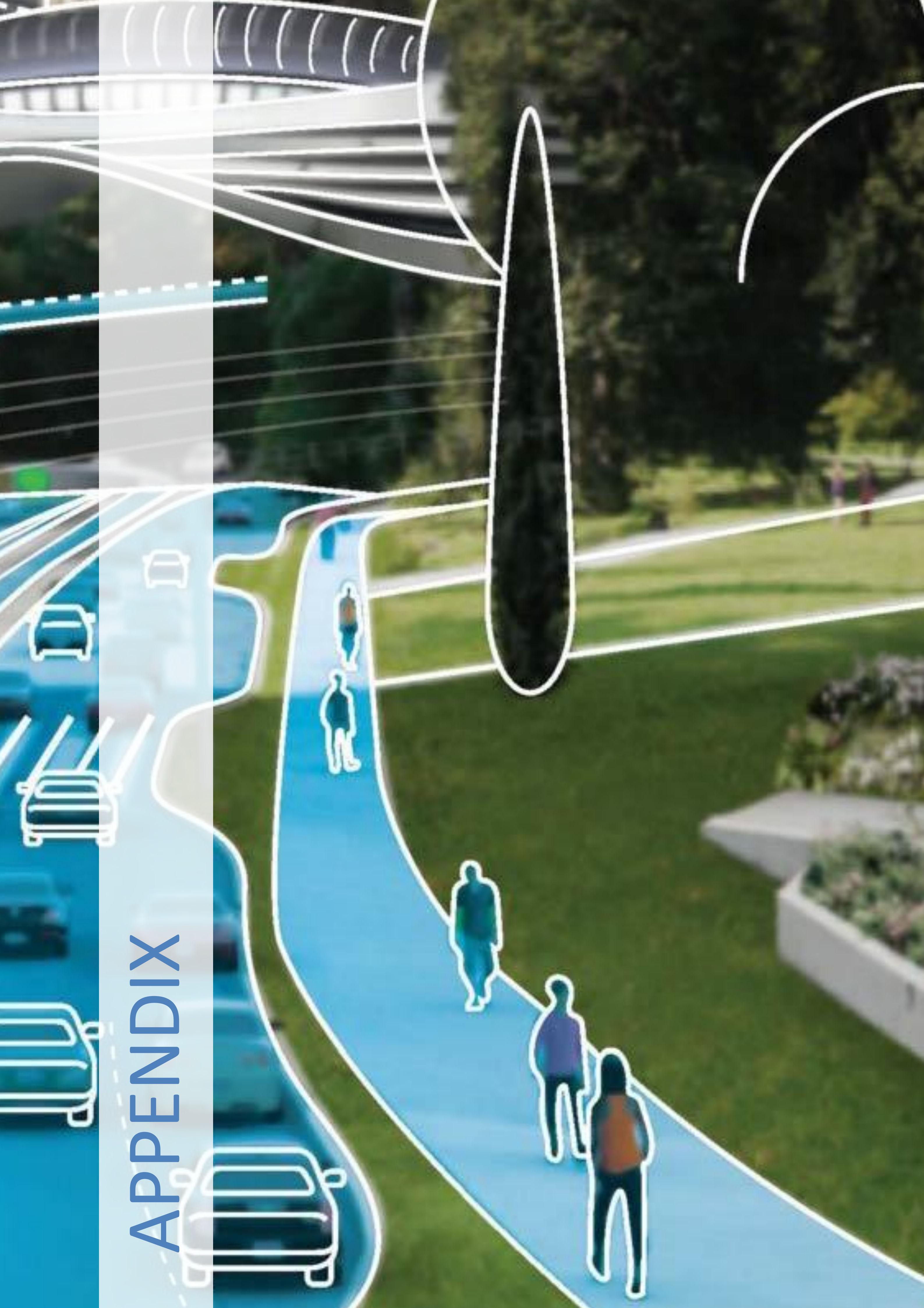


APPENDIX

APPENDIX A.

A.1 Projects

Place			Phase			Level of automation (0-5)	Type of urban area	Investment	(Expected) date of completio	Stakeholders
	Operational	Tender	Business case	Exploration	Idea					
Capelle aan den IJssel - Kralingse Zoom						3	Office(evt residential)	€4,5 mln	1999, 2018 (expansion)	Municipality of Capelle ad IJssel, MRDH, Municipality of Rotterdam, Connexxion, 2gettheres, Real estate owners and companies situated at Rivium businesspark, RET, GoBike, Waterbus.
Rotterdam The Hague Airport (RTHA)							x Airport	€7,0 mln	2018	RTHA, Schiphol Real Estate, MRDH, municipality of Rotterdam, Municipality of Schiedam, Municipality of Delft, RET
Schiedam							Office area	€8,5 mln	2017	Municipality of Rotterdam and the municipality of Schiedam, MRDH, RET, companies in the area, knowledge institutes
Delft							Campus	€3,2 mln	2017	TU Delft, Haagse Hogeschool, Hogeschool Rotterdam, TNO, companies (voertuig- en infratechnologie aanbieders, vervoerders), overheden (regio, gemeent- en, inspectie, RDW), Researchers (universities, hogescholen, (start-ups), students, potential users, Dutch Automated Vehicle Initiative (DAVI).
Rijswijk							x test area	€0,45 (+5 mln)	2018	Municipality of Rijswijk,Provincie Zuid-Holland, Businesspark Plaspoelpolder, companies with interest in Rijswijk, Industrieschap Plaspoelpolder, Impppuls
The Hague Binckhorst							Mixed-use area	€0,45 (+5 mln)	2018	Municipality of The Hague, Provincie Zuid-Holland, exterxal experts, potential project developers, local transport company,
Fieldlab TU Delft							Mixed-use area	€0,45 mln	2020	Municipality of The Hague, external experts of AVLM , potential projectdevelopers, possible collaboration with the municipality of Leiden and Rijswijk, Public transport companies, OV bedrijven, companies in the area, interested developers and residents.
Haga shuttle The Hague						3	Mixed use area			Municipality of The Hague, HTM, The Future Mobility Network, Rebel, Haga hospital, external advisors, Navya, Aon insurance company, local government, procince of zuid-holland
ESA ESTEC						4	Test area		2019	Municipality of Noordwijk, Arriva, The Future Mobility Network, Rebel, Esa Estec, external advisors, Navya, Aon insurance company, local government, procince of zuid-holland
	Done	In development	Active	Future						
Eemshaven									01-11-2017 — 01-12-2017	Province Groningen, Robottuner, Greendino, Groningen Seaport, Municipality of Eemsmond, RDW, Hanzehogeschool Groningen, Easy mile, NAVYA
Groningen Airport Eelde						3	Village/suburb		01-05-2018 — 31-10-2018	Province Drenthe, Airport Eelde
Loppersum en Zernike							Airport		01-03-2018 — 30-04-2018	Provinde Groningen, 5GGroningen, Municipality of Loppersum, Robottuner, Greendino, RDW, NAVYA, Easymile
Ommelander Ziekenhuis Scheemda						3	Village/suburb		01-07-2018 — 20-12-2018	Province Groningen, Ommelander Ziekenhuis, NAVYA, Greendino, Robottuner, Gemeente Oldambt, RDW, Arriva
Kernverbinding in Fryslan						3	National park/Museum		01-01-2018 — 31-12-2020	Province Friesland
Leerlingenvervoer rond Dokkum							Village/suburb		01-01-2018 — 31-12-2020	Dockinga college, DDFK municipality, Arriva, Platform 31, Noorsoost Frieaslsn, Municipality Dantumadiel, Municipality Dongeradeel, Municipality Ferwerdiel, Ministry of Intrastructure and waterways, municipality Kollumerland
BeMuP regio westellingwerf						3	Village/suburb		01-01-2020 — 31-12-2020	BeMuP, Municipality Westellingwerf, Prvince Friesland, Ministry of Intrastructure and waterways
Proef met passagiers bij Nationaal park Dents-Friese Wold Appelscha						3	National park			Municipality Oostellingenwerf, Province Friesland, Province Groningen, Province Drenthe
Bourtange						3	Village/suburb		13-09-2016 — 07-11-2016	Vesting Bourtagne, Municipality Westerwolde

Figure A.1: List of pilot projects in the Netherlands, with the type of urban area, the automation level, the date and the stakeholders. The projects which are marked in blue in the first row are the ones chosen for this research.

APPENDIX B. INTERVIEW QUESTIONS

B.1 Interview questions prior to the research

Introductie

1. Zelf voorstellen
    1. Wie ben ik?
    2. Waar doe ik onderzoek naar?
    3. Vragen of het goed is als het gesprek wordt opgenomen voor het onderzoek.

Interview

2. Kunt u iets vertellen over uw rol binnen de Gemeente Rotterdam?
    1. Wat zijn uw verantwoordelijkheden binnen uw afdeling?
    2. Met welke partijen bent u veel in gesprek?
    3. Is er een overkoepelende partij/manager die jullie afdeling taken oplegt of komt dit vanuit de overheid?

3. Wat doen jullie binnen de gemeente Rotterdam met betrekking tot zelfrijdende voertuigen?
    1. Voorbeelden?
    2. Leidt u dit, of zijn er meerdere mensen betrokken binnen de gemeente bij dit onderwerp?
    3. Welke partijen zijn er nog meer bij betrokken van buitenaf? evt zelfs andere landen?

4. Hoe zijn jullie in aanraking gekomen met het onderwerp zelfrijdende voertuigen?
    1. Is er bijvoorbeeld iemand of een partij die jullie heeft aangespoord, iemand vanuit de gemeente/overheid/externe partij?

5. U gaf in mailcontact al iets aan over een samenwerking met de Gemeente Capelle aan den ijssel over het project Parkshuttle.
    1. Hoe betrokken zijn jullie bij dit project?
    2. Hoe zijn jullie hier betrokken bij geraakt?
    3. Hebben jullie enige invloed op dit project?
    4. Met wie verloopt het contact hierover?
    5. Wat levert het voor jullie op? Bijvoorbeeld kennis/ervaring?

6. ik ben benieuwd in hoeverre de implementatie van zelfrijdende voertuigen invloed heeft op jullie besluitvorming.
    1. Welke partijen zijn er betrokken bij jullie besluitvormingsprocessen?
       Voorbeeld geven over de gemeente Utrecht die nieuwe busbanen aanlegt.
    2. Worden onderwerpen zoals zelfrijdende voertuigen geïmplementeerd tijdens de besluitvorming?
    3. Gebeurt dit ook binnen andere afdelingen van de Gemeente? In hoeverre dit natuurlijk bekend is bij u.

7. Ik heb ook nog een vraag over jullie visie voor de toekomst met betrekking tot zelfrijdende autos.
   Benodigdheden/obstakels
    1. In hoeverre denken jullie dat zelfrijdende autos geïmplementeerd kunnen worden?
    2. Wat is er nodig om het te kunnen implementeren?

3. Zijn er bijvoorbeeld nog obstakels die de implementatie van zelfrijdende voertuigen kunnen afremmen of zelf kunnen tegen gaan? Fysieke obstakels of bijvoorbeeld bepaalde regelingen/wetten? Conflicten met het huidige systeem?
4. Zijn jullie nu al proactief bezig met de implementatie? Voorbeeld?

Technologie

5. Is de technologie er volgens jullie al klaar voor?
6. Hebben jullie op sensoren op plekken staan? Misschien voor andere doeleinden?
7. Zo ja, hoe hebben jullie toegang tot dit soort informatie? Is er bijvoorbeeld een externe partij die hiervoor zorgt?
8. En, wat doen jullie vervolgens met dit soort informatie? Wordt dit bijvoorbeeld ook gebruikt voor andere doeleinden binnen de Gemeente?

Conflicten

9. Botst de implementatie van zelfrijdende voertuigen met het huidige systeem?

Afsluiting
Bedanken voor het interview.
Vragen of de geïnterviewde zelf nog vragen heeft aan mij.
Aanbieden om na afloop de scriptie op te sturen.

B.2 INTERVIEW QUESTIONS

The Interview is divided into five parts. First, the interviewer introduces him/herself and some general questions about the case will be asked. After the introduction questions will be asked about the four themes shaping, stimulating, regulating and capacity building.

Introduce myself

1. *Who am I?*
2. *What am I researching?*
3. *Do you mind if I record this interview for further research?*

A. Introduction

1. Who are you and what is your profession?
2. how did you get involved in this project?

B. Shaping - place promotion

1. Is there a leader in this project?
2. What are/Do you know his/her responsibilities?
3. Do you have the contact information so I can get in touch?

If the interviewee is the leader in this project ask the following questions, otherwise ask question 3 and go to question 7..

4. Did you look at other opportunities in the area, for example, private parties who are interesting in collaborating?
5. Are there external drivers which can make the development of the AV integration more successful or integrated?
6. Do you encounter other developments in the region? For example other pilot projects?

Continue with the following questions if the interviewee is not the leader of the project..

7. How often are there meetings with the stakeholders?
8. Are all the stakeholders present during these meetings?
9. What do you do during the meetings?
10. Who are the financial supportera within this project?
11. Are there other supporters or professionals within this project? (could also be designers)

B. Shaping - Place preparation

1. Is the project designed as a single project or integrated?
2. Is there thought about the connection between the trajectory and the physical/social barriers? (physical= roads, trees etc; social= schools, hospitals).
    a. Are these also part of the financial plan?
3. Do you know who owns the area?
    a. How is this managed?
4. Were there any quality standards or functional standards set for the trajectory? or for the vehicle?
    b. Or, Is there any design code?
5. DId you need any regulatory approvals for the project?
   How was this handled?

6. Is there a demand for this project? Do you have the numbers somewhere?
    a. Where does this demand come from?
    b. Does this project completely match with the demand?
7. What are the risks in this project?
    a. Can you reduce these risks in a way? How?
8. Who is the leading investor?
    c. What is their interest in the project?
9. Which investment is the largest?
10. Are there investments in the area around the trajectory?
11. What does the financial planning look like?

B. Shaping - Strategic implementation

1. Will the project be developed in phases?
    a. How many phases are there?
    b. Can you name them?
2. Did you select a developer for this project?
   Where was this choice based on?
3. How will the project be maintained?
   Is there a maintenance plan?
    a. Who will be responsible for the maintenance?

C. Regulating

1. What regulation was stated for this project?
2. Is there any mandatory regulation in order to steer the end-users?
3. Does the driver need to have any knowledge of the vehicle(according to policies)?
    a. Are there any policies within HTM which say so?

D. Stimulating

1. Are there any subsidies available to establish the project?
2. Are there any tax incentives provided by the state?
3. Are there any actions by the state which reduces the risks?
    a. What is the reason the project only can last for 4 years?
4. Are there any other environmental improvements in the area around? For example from the public sector.
5. Is there a business area around the trajectory? Or maybe other developments? (zelf opzoeken)

E. Capacity Building

1. What happens if some policies change? For example, you did not get any subsidy, or the development only can last for 1 year?
2. Do you rather see the development as an opportunity or just a transportation means?
3. Is there any data available by the government? For example, information about the users? Or information from the hospital?
    a. Is there any information available from other projects?
4. Are there any professionals concerned with the project?
   . What knowledge is needed from the experts?
5. What tools does the leader use to manage the process? Stakeholder management? Financial management? Evaluation decision-making? giving constraints?

Extra questions:

1. Why is there chosen for the automation level 3?
2. Is there any resistance in the idea of going autonomous? Competition? Safety?
3. What are the lessons learned of the previous projects?
4. What is the difference? How do you start? Is there already a starting point?
5. What are the biggest challenges? Technological? Sociological?

Closing

Thank you for the interview.

Ask whether the interviewee has any questions.

Do you have any recommendations for my research?

Offer to send the thesis afterwards.

APPENDIX C: SUMMARIES INTERVIEWS PRIOR TO RESEARCH

C.1 Municipality of Amsterdam

Interview November 14th

1. What is your role within the municipality of Amsterdam regarding self-driving vehicles?

00:20 - 01:49

I work for the CTO service at the municipality of Amsterdam, which is the innovation team, Chief Technology Office. And my job title is project leader self-driving transport in which we have a smart mobility action program. This program was determined by the city council in 2016 and it actually encounters that we (The Netherlands) must gain insight into the potential consequences of smart mobility. Almost every local/regional governing authority has a similar programme which means that in every region or city it is stimulated to get more insight. We have this approach where we want to test a lot outside/ in real-life. We have the opinion that you could hold a lot of sessions internally with all self-appointed experts and another could roll out computer models, but we also think you should just try to find out if it works or not.

And of course under conditions and frameworks that it is acceptable and safe, etc. But that is, I think, a very important starting point for us to experiment the following because you get insight into the consequences more quickly. Are you familiar with smart mobility?

Yes.

01:50 - 03:10

So you have the 4 usual frameworks that almost every governing authority in the Netherlands uses to identify the themes. There is mobility as a service, self-driving transport, data and digital infrastructure. All programs are the same in the province of North Holland and also in the region. And if I am right also in the province of South Holland. Mobility as a Service is primarily intended to find out what the influence is of a smartphone. And how the use of the smartphone going to change the way people move through cities? And how will new services and platforms be created like Uber? In the end, there are expectations that a larger overarching company will manage these service companies.

We also do things with data and digital infrastructure and privacy, because it can have huge consequences. And I am responsible for self-driving transport. And within self-driving transport, we are especially focused on how self-driving transportation will impact the city? And yes we can only determine this for Amsterdam, we cannot do this for other cities or provinces since the impact can be different for every city.

We want to find answers on questions like what kind of consequences can it have for Amsterdam and how should we prepare for it and should we think about it, but that is of course very difficult because it is not there yet. It is already there in other places in the Netherlands and we are in contact with all those other locations and all those other governments and places and companies which are working on self-driving transport. Therefore we can see the lessons they have learned and how can we learn from it? We should not do the things that they have done again 30 times, because then we will learn nothing.

2. Yes. And In the end everyone wants to be the frontrunner, right?

03:20 - 03:40

Exactly, it is wonderful to be the frontrunner, however, in the end, what do you achieve?

3. And it probably will cost a lot of money and time?

03:52

Yes, it can cost a lot of money, energy and time but I think we have sorted everything out since we have good communication to overcome something like this will happen.

4. Are you in contact with the big municipalities like Rotterdam?

04:20 - 11:17

Yes and I've been there as well. I've been in Groningen, Rotterdam, The Hague (Leidschenhage) to discuss things. We have contact with the 5 big cities, also with Eindhoven and Utrecht. We found out that every city has the same problems. In the three northern provinces in the Netherlands, they are using smart mobility to make cities and villages more liveable. In the municipality of Amsterdam, we doing some experiments. We try to do projects with self-driving vehicles, however, that is difficult in the municipality of Amsterdam. We have three projects. The first project, which is the most difficult project is a shuttle for disabled children. We are looking for other parties to involve who also have some interest in the project. Without investing parties the project will not be financially feasible. The second project is Kerpolder where we analysed the last mile solution since there is no public transport and there are too little residents in this neighbourhood to offer this. The companies located in this neighbourhood want to be accessible therefore they bought permission from the GVB (municipal transport company) to serve public transport. However, this costs a lot of money, therefore, they thought to have elektrical self-driving transport since the rule of thumb is that the driver is 70% of all the costs. So we looked if it was possible to have self-driving vehicles and we found out that it is technically not feasible right now.

The conclusion of his story is that the second project is possible (with an extra traffic light etc) however, it costs around €500.000 extra and it will take a lot of time to establish everything because of the complexity and regulation. On the long term, when the area is redeveloped —there are already plans for this — we want to implement multiple forms of smart mobility. We want to stimulate using public transport instead of the car.

Next to these two projects, we are also working with multiple small scale projects. We try to focus on the outer areas of Amsterdam since I don't know if the inner city is suited for automation level 5. Maybe when it works out in the outer areas we can also do projects in the inner city.

5. How do you interpret self-driving vehicles? Do you want to focus on level 5 for example?

11:27 - 16:53

Well, we use an instrument which is called de toekomstrader (In English: The Future Radar), where we sketch different scenarios of possible future changes. The Toekomstradar shows three trends: the first trend is a sharing society vs a society where people appreciate their own goods and the other trend is a society where the government want to develop its own infrastructure vs a society where the government takes it hands off of infrastructure. Based on these two trends four scenarios are developed. Based on these scenarios we made possible solutions. If this happens, or when we are moving to this society, how can we react to this? It is crucial to be objective when seeing different news articles about self-driving vehicles. According to Bart van Arem, we have a digital environment where everything is possible. According to these articles we are running behind the implementation of self-driving vehicles but at the same time, there is already a place where self-driving vehicles are driving. (Rivium - Capelle) We interpret self-driving vehicles as vehicles without a driver.

6. And only with self-driving shuttle and cars or also with drones, bicycles?

17:07 - 18:37

We think everything is possible. The EMS Institute, sort of the “third” university of amsterdam collaborates with the TU Delft and researches the Roboat. For now, we are more focusses on public transport forms. I have the opinion that self-driving vehicles is something for car suppliers and manufacturers. We are not a fan of cars and we are stimulating to have fewer cars in Amsterdam. So we only stimulate self-driving vehicles as a form of public transport since we can not steer on private self-driving cars.

7. Do you have the opinion that self-driving cars can replace private cars and in combination with Mobility as a service can reduce the capacity of cars in the city?

18:48 - 19:46

Yes. We think that is possible but then we should steer on sharing systems. The impact analysis of the Province North Holland performed by the TU Delft and Arcadis concluded that with self-driving vehicles the number of cars in the city would increase even more because it will compete with the bicycles and pedestrians as well.

8. What if the car suppliers made it happen to have safe self-driving cars on the market in 5 years? Do you have policies which counteract with this?

19:51 - 21:54

Well, that’s why we have the toekomstradar. I do not assume that those vehicles will be on the market in 5 years. I think car suppliers are also going to steer on shared systems and we think this is a good idea if it is not going to compete with other transport means. And if it doesn’t make the city more crowded. If self-driving taxies are going to make Amsterdam more crowded I am not sure if we are going to support this or not.

21:59- 26:18

This part is about the involvement of the national government and in what way these policies influence the decisionmaking processes of the municipality of Amsterdam. Also Marten explains about the collaboration with Europe. However Amsterdam is not (really) working together with european countries, so I don’t think this is relevant.

9. What are the biggest obstacles to implement self-driving vehicles?

26:20 - 35:02

The regulation is difficult, which is logical. However, this takes some time. Another obstacle is financial feasibility since it is still expensive. When it become financially more attractive than I think many companies appear and the obstacle is gone. Another obstacle is the technology. I think the problem is with the actual state of technology and not with the government/policymakers. I think the ministry and government with the new regulation etc are working ahead of the car suppliers. You have many shuttle and car suppliers now and at a certain moment in time, they need to have revenue as well. I am curious about what is going to happen. For those companies it is not just an experiment, it is a huge investment. Another obstacle is the infrastructure. Also historical cities, I don’t see it happen. Maybe it is easier on the national highway. So, for example, you just drive to the highway manually and when you arrive at the highway you push a button and the car becomes self-driving. I think the technology will arrive at the highway first and maybe after this self-driving vehicles will *go to other parts of the city after this. Another obstacle is cyslists. In Amsterdam, the cyclists are very active and dominant. Many persons in Amsterdam ignore red traffic lights so when there is a self-driving vehicle on a crossing the vehicle will stay on the same place for years. Another barrier could be the complexity of infrastructure. When you have a road of 70 km/h and the vehicle should cross this road with 30 km/h it is still not safe. But this has also to do with the technology.*

10. Where do you stand when looking at other countries?

35:10 - 39:25

I think countrywide there are three trends. So you have Asia, where the government is steering and investing tons of money in the development (Singapore, Tokyo, Korea), those countries are also not hindered by politics and elections. Then you have countries like Australia, North Amerika where the car suppliers boost the technology and the government is only facilitating to test the technology. You also see the difference that in Asia there is collective transport and in America and Australia is it more focussed on private transport. And at last in Europe and the Western countries, we are sort of in between these two trends. I think in the Netherlands we have the disadvantage that we don;t have a big car manufacturer/supplier. Mostly the car manufacturers have a good connection with the institutions end policymakers in their home country and therefore they mostly test their technology there. You can also see this as an adventage since we are a neutral country. The RDW steers upon a good regulation and procedure which can be applied in other countries in Europe as well.

10. And if we look at the Netherlands, how do you position Amsterdam?

39:38 - 41:20

That is a hard question. I think there are locations where it is easier to implement self-driving vehicles. For example in Rotterdam, they already have a trajectory which is succesful. I am not sure if there are parties who are more experienced in the development. I think it is good to make progress with the Netherlands and not separately some cities or municipality.

C.2 Municipality of The Hague

1. What is your role within the municipality of The Hague?

1:58 - 03:36

I work within the Department of Mobility. I am mainly concerned with parking policies, shared car systems and self-driving transport. Self-driving transport is a theme I am responsible for since we don't have someone special for this function in our department. I think this function will be filled soon since we are going to start with two pilots in The Hague. I think it is a pity that this function is not appointed to someone since the municipality does a lot and there are many meetings, unfortunately, I have not enough time and knowledge to be responsible for this theme as well. Last years I have been working on shared systems and self-driving transport but this was very minimal.

2. how do you interpret the term self-driving vehicle?

03:50 - 05:50

For now, we are focussing on public transport. I think the development of self-driving cars will come, so we could adapt our infrastructure to this. We are part of the SURFstad research. I work at the dienst stedelijke ontwikkeling (city development department) and I am working on the self-driving vehicle theme together with the department of stadsbeheer bereikbaarheid en verkeersmanagement (city management accessibility and traffic management). Together (with 2 other colleagues) we decided to collaborate with the SURFstad research. With the SURFstad research, we are exploring how we should handle the implementation of private self-driving cars in the future. I think the municipality is responsible to invest in self-driving vehicles as a means for public transport. So we should develop knowledge and do pilot projects. We see self-driving vehicles for public transport as a solution to transport issues. We are exploring to develop a metro-like system which connects Scheveningen with the region. The idea is to enlarge the distance between stops, but we can assume that walking distances can be big and therefore we can use self-driving shuttle services.

3. So it would not be a replacement of the bus but just an extra service?

05:59 - 06:36

It could also be a replacement for the bus. For example on bus trajectories which are cost inefficient at the moment. The costs of the bus chauffeur are quite high (70%) and by removing the driver from a bus the costs for the trajectory goes down.

4. Online I saw the pilot project of the Binckhorst, how far are you with this project?

06:40 - 08:56

We did a feasibility study since there will be developed 10.000 dwellings and the public transport service is not that good. We want to establish this development (hoogstedelijk/metropolitan) with fewer cars and therefore we think self-driving vehicles/public transport could be a solution. We want to stimulate public transport by developing less parking places for example.

5. You said you want to stimulate fewer cars by developing less parking places. Should this come from your policies?

09:03 - 09:28

Yes. Our policies. We are thinking of centralized parking amenities and thereby we want to stimulate shared systems.

6. And those shared systems, could this be also done with self-driving vehicles?

09:32 - 10:05

Yes. And we are also looking at bicycles and shared systems. A company wants to do a pilot with a hub with shared cars, bicycles, scooters etc. And when we stimulate and offer these options it is realistic to steer on fewer parking places.

7. Do you obtain knowledge from other municipalities?
10:09 - 11:18

The University of Paris made an inventory of all projects in big cities both in the Netherlands and in other countries. Last week she presented what all projects do in terms of parking norms and alternatives for the car. So the Merweede Kanaalzone is an example with a low parking norm, shared hubs. This location is comparable with the Binckhorst so you should look at it.

8. Ok, and does the project also offer self-driving transport?
11:22 - 11:50

No. But it is comparable with the Binckhorst project. Also, Amsterdam is working on the Harbourcity project which is a development project. The only can adopt a very low parking norm (0,2) because of the accessibility so they are exploring the alternatives.

9. Ok. And do you collaborate with other municipalities?
11:50 - 13:30

Yes. We have G4 and G5 meetings. We are joining forces within the smart mobility team (Krachtenbundeling) where we share knowledge. We also agreed on not doing the same pilot in order to learn as much as possible. This also happens within the region → MRDH. Thanks to the research of the metropolitan region we did feasibility studies.

The interviewee showed all the initiatives on a map from the MRDH. The metropolitan region also got money to subsidize the initiatives. Around 15 million euros since the projects are quite expansive because of the vehicles and the control rooms. This probably will change in the future because of the economies of scale.

10. How is every project different? In terms of the vehicle/level of automation or in terms of the environment? Or both?
15:30 - 15:59

MRDH is making sure the use cases are unique. I think there are differences.

11. How did you get involved with the theme self-driving vehicles?
16:20 - 16:55

Actually because of the research of the MRDH. So we did some research on which places it would be possible and an opportunity at the same time.

12. Does self-driving transport have an influence on the decision-making processes of the municipality of The Hague?
17:02 - 19:49

No, not yet. But in the Binckhorst project, we are having conversations with the government since we tend to construct a tram line over there which is very expansive and this will be partly paid by the state since it is a long-term investment. For the Binckhorst, we divided into short-term/ long-term and self-driving transport good be a good solution. So between 2025 and 2030, we are thinking of a ALV trajectory in combination with self-driving vehicles. So we are not taking into account self-driving transport in our infrastructural decision *making, except for the Binckhorst project. In this project, the intrastructural network should be developed and therefore we want to steer on self-driving transport as well. But we are not doing this for other areas.*

13. Could this be because of the pilot which make you more focused on the Binckhorst area?
19:45 - 19:52

Yes. But maybe there is the idea that the vehicles should adapt to the current infrastructure. So maybe we only need to steer on the networks like 5G etc.

14. Are there any decisions coming from the national government regarding automated vehicles?
19:58 - 20:52

The government is actively steering on automated transport and they are also working interntionally. But they are also curious about the lessons learned from the pilot projects. But there are no infrastructural restrictions from the state.

15. What is the impact of self-driving transport?
20:55 - 21:24

That's is the story of SURFstad. They a having eight research pathways and one is the impact of automated transport on urban planning. I find it very difficult to determine. We think it will take while when self-driving vehicles will be implemented in cities.

16. What is the reason for this?
21:33 - 23:28

The complexity and than in particular the interaction with cyclists. When you are cycling around you will explore the complexity and the automated shuttle will not be able to move. An automated shuttle will wait till it is safe to make a turn and then infrastructural changes might be needed in order to solve this problem. And that's interesting with the pilot project. We want to use communication forms to make people aware of this self-driving shuttle, so maybe with a different colour asphalt or particular signs. The project manager calls it a robotstraat (Robotstreet).

According to a figure the interviewee showed the integration of automated vehicles in cities will be around 2030.

17. Are there any necessities to implement the pilot projects?
23:30 - 27:03

At first, money. But also the regulation is something. For now, it is only possible to test with a steward but in the end, we also want to test without a steward. probably this experimental law will come in 2020. So the purpose of the pilot is to drive without a steward. And financially, we get 50% subsidy from the MRDH and it is possible to get 60% support of the state. This means that we can subsidize another 10% from the municipality. And then we should look at other parties which want to invest in a pilot project. But the problem is that most companies and residents don't see the value of such a project since it is still in the pilot/experimental phase. So the research for a grondgebonden investor (Ground-bound investor) is difficult.

18. Is the municipality able to get an exemption for particular areas to get the experimental law earlier?
I don't think so. I think this needs to be set by the national government.

19.	Last week, I had an interview with the municipality of Amsterdam. They are also doing pilot projects and are progressive in the implementation of self-driving vehicles. Do you have an idea where the municipality of The Hague is positioned relative to other municipalities?
27:08 - 28:07

There are not many pilots in the public space in the Netherlands. And since as we are going to do the pilots with the Haga Shuttle and the Binckhorst project I think we are quite progressive as well.

30:07 - 31:08

I want to add something that you probably already have heard. Many people say that In the future there is no need for parking places anymore since you can order your automated vehicle. I think this is something for 2040 or later. There are many things to learn regarding technology, safety and acceptance but I assume you've read this many times already.

C.3 Municipality of Rotterdam

October 29th

1. What is your role within the municipality of Rotterdam?

1:33 - 02:20

This is the Department of Traffic and Transport, which is part of the department of city development. Traffic and transport is a very broad department since we do things with cyclists, safety, national roads, parking places, infrastructural design, air quality, everything which can be linked with traffic and transport. I am a senior Smart Mobility and self-driving transport is part of this.

2. Are there any specific parties you are in contact with?

02:23 - 05:15

Yes. We are working together with the region. So you have the MRDH which is an assembly of 23 municipalities in the region. So we are working together with Capelle a/d IJssel, Schiedam, Rijswijk, etc.. Municipalities who are actively working on this topic. And we sit down together to discuss what we are doing and to share knowledge. And the MRDH also gives subsidies to the project. We also collaborate with big cities like Utrecht, Amsterdam, Eindhoven. We also work together on a national scale, so with the cities, provinces, The Dutch ministry of infrastructure and Water Management (Rijkswaterstaat). We also collaborate with European countries/cities to share knowledge. So all these collaboration forms are public collaborations. We also collaborate with knowledge institutes like the TU Delft (Bart van Arem), but also private parties, car manufacturers and shuttle suppliers. We also collaborate with the RDW (Dutch Vehicle Authority) which gives the exemption to drive on the public roads with self-driving vehicles.

3. How do you get in contact with the external parties like the car manufacturers and shuttle suppliers?

05:34 - 07:12

Mostly, they contact us since we can assign a testing area for those parties. But also they look up partners which already is in contact with us. We are now collaborating with BMW and 2getthere and the latter is the shuttle supplier in the project of Capelle a/d IJssel at the Rivium business park.

4. What do you do regarding self-driving vehicles in the municipality of Rotterdam?

07:25 - 09:39

We tried to bundle our knowledge in a lab, however, we still find it difficult what to do since we don't know what the future will bring us. We formulated a few business questions we want to get an answer on. Sometimes we do the research ourselves and other times we work together with the TU Delft. We also try to do pilot projects to gain our knowledge. The pilot which is the most realistic now is a shuttle service between Rotterdam The Hague Airport and the metro station Meijersplein. The trajectory is around 1-2 km, however, the shuttle needs to drive on the public road which is quite new and challenging. We do not think that a separate lane for the shuttle, such as the project in Capelle, is the future. Therefore, we want to do a pilot project where the shuttle also interacts with other road users.

5. So you are doing research right now on this topic?

09:43 - 11:06

Well, we want to do the pilot over there. However, we are not doing this pilot ourselves. There is a market party who set up the project and they asked us to facilitate the project. So want to find out the technical abilities of the vehicle, how it interacts with the users and so on. It is not completely certain whether the project will take place, however, we are definitely thinking of it. We also learn things by collaborating with other municipalities.

6. Do you want to be a frontrunner in the integration of self-driving vehicles?
11:08 - 12:28

I think everyone wants to be a frontrunner, so this is difficult since you become a competitor. And this was also happening in the beginning since people want to be the first or reach the press. In the beginning of October (2018) we signed a convenant that people should collaborate instead of being each other's competitors. This convenant also led to a stronger position in the market, since we can say for example "we are the Netherlands, the test country of self-driving vehicles".

7. So you have this covenant with parties in the Netherlands, but is there also one with Europe?
12:29 - 13:10

No. It is already a big deal that we have this in the Netherlands. Maybe there is less competition with other countries compared to the competition with cities. There are some European partnerships of countries who collaborate on a project and these projects can get European subsidy as well.

8. How do you share the information with Europe?
13:21 - 14:20

We have these meetings (werkgroepen) where other European countries can join and share their experience and knowledge. Every country is different in terms of infrastructure and regulation. And the Netherlands is a country where there are a lot of cyclists, which is also very specific.

9. How did you get involved in the topic of self-driving vehicles?
14:49 - 16:10

We had the Rivium project already, which is in Capelle and also a small part of the municipality of Rotterdam. This project led to regional interest (MRDH) in smart mobility. The TU Delft also started to do research and that's how we got involved in this topic. It eventually became a hype, everyone was talking about self-driving vehicles and then Tesla came. If we develop new infrastructure we assume the road will be there for 20 years (probably longer), therefore it is good to think of changes and developments in the future. Innovation went very fast in a short period of time and at the same time, it goes very slow.

10. Are you also doing projects with self-driving trucks?
16:59 - 17:37

Yes. And in particular, around the harbour, they are doing tests with platooning, however, we are not that involved in these projects. Despite that, the platooning trucks need traffic light which can communicate and we are also working on this within our department.

11. So, you are also working with sensors already?
17:44 - 18:49

Yes, our first step is to make our traffic light intelligent in order to communicate with the vehicles. This is through WiFi or 4G/5G. We are converting the 'old' traffic lights into intelligent traffic lights at the moment. These traffic light also can give information to the current vehicles and it also receives and stores the information it gets from the traffic as data. And in the end, the traffic lights should communicate with the self-driving vehicles. We are now testing these traffic lights with the truck project. I am not sure if it works completely right now.

12. Do you extract and analyse the data from the intelligent traffic lights?
18:55 - 19:44

We already have a lot of data from the 'old' traffic lights. This data will be better, however, in the end, we have so much data that it is difficult to see what can be done with all this data. The question is how can the data be used?

13. Did you have any influence in the Capelle a/d Ijssel project?
20:01 - 21:18

The trajectory which is already there is constructed in 1999, so I am not sure about that. The first stop at the metro station Rotterdam - Kralingse zoom is on our land so I am quite sure we were involved in this. They are now working on an extension of the trajectory and they want to start driving on the public road as well. We are involved in this sideways, however, it is mainly the municipality of Capelle who has the responsibility. Probably, we are going to help with intelligent traffic lights since we have a lot more experts in this field.

14. Do self-driving vehicles already have an influence on the decisionmaking processes?
21:32 - 23:28

No. Not that I know. It is merely seen as a pilot phase, testing periods. I think this will come in the future. However, when self-driving vehicles become privately owned the car will be a larger competitor for cyclists and pedestrians. Therefore, I think we want to focus on sharing systems or regulation to overcome this. But I think it will take a will before we are going to discuss such issues.

15. Are there any obstacles which can delay the implementation of self-driving vehicles?
23:54 - 25:26

For the Shuttle the legislative part was difficult. However, this will become easier due to the experimental law. In the beginning, the largest obstacle is the costs since there are not that many shuttles yet and the technology and its sensors are still quite expansive. Having a chauffeur is still cheaper compared to the self-driving vehicle. Also, in Rotterdam, the RET has the concession for public transport in this area which means it is not easy to implement a new service because this can compete with the service of the RET. For the private self-driving cars, the obstacle is still the technology which is not fully developed. Also, when the time is there I think the self-driving cars will firstly operate on the national highways.

16. So the roads are already ready for the self-driving vehicles?
25:36 - 26:46

There is a discussion which we have with the suppliers, the ministry and Rijkswaterstaat. We say that the suppliers should deal with the roads as they are now. We are not changing the roads for those vehicles. Other cities share the same opinion about this. This is different for Rijkswaterstaat because on the national highway there are only cars on the roads and the roads are easier to change. The only thing is the WiFi connectors, however, this is the digital infrastructure.

APPENDIX D: TRANSLATED TRANSCRIPTIONS INTERVIEWS

D.1 The Future Mobility Network – Haga shuttle and Esa Estec

Introduction

At the beginning of the conversation, we talked about what is happening right now with the developing technology and how people handle this 'transition'. Alwin explains that a lot of people are saying that the technology is still not ready etc..

00:36 - 01:48

However, there are already projects in collaboration with The Future Mobility Network which proves this statement wrong. In April, the Shuttle of the Haga Shuttle project will arrive in the Netherlands which will be wrapped with the right logos. After this, the shuttle will be tested on the public road.

*At Eza Estec we are even going to test the vehicle **without** a steward inside. The shuttle will be tested on a private area which is secured by a barrier, why? because we are going to test the shuttle **without** a steward and we think it is already possible. This is going to happen already the coming year, not next year, even when the experimental law is not there yet.*

1. The experimental law means that you only can test self-driving vehicles with a driver inside **on the public road**, right? So, If you have a privately owned area then it is possible to test without a driver?

01:59 - 02:35

Yes. The experimental law is actually a remote control, for example, a joystick, which can control the vehicle from a distance. This is not that complicated. This is actually happening already, however, inside the shuttle with a steward who does the same actions. The only challenge with a remote controller with a distance from the vehicle is a good and reliable connection. This is exactly the reason why people are testing with 5G at the moment.

2. What is the added value when using the 5G network instead of the current network?

02:38 - 03:21

They call it latency. This is the reliability of the connection. So with this 5G network, the connection between the steward at a distance and the vehicle is more reliable.

3. What is the role of The Future Mobility Network in projects with self-driving vehicles? And what do you do to improve the Artificial Intelligence of the vehicles?

03:43 - 05:49

We are the intermediary between the government or the initiator of the project (The interviewee calls it: de probleem eigenaar) and the suppliers of the shuttles. We have cooperations with all shuttle suppliers and we know all their road maps. We analyse if the problem or idea of the government/initiator can be a use case and whether it can become a business case. We know the actual state of the technology which will be added to a location, so the artificial intelligence and to improve this deep learning is not our goal. We know the abilities of the system, so we add this system to a location and we look at possible changes in the location to adapt to the system or the other way around: adapt the system to the location. The latter is way more complicated since you need to increase the knowledge of the system. However, the system is not able to pass other cars or to anticipate. That is the reason why the relationship between the location and the system is of high importance. What I find interesting to add about Artificial intelligence is that also the human and the environment has artificial intelligence. Humans and the environments adapt to robots, which is very interesting since people who look to the world from a technical perspective often forget to implement this. And then people think they have *to make the robot even more intelligent since the robot needs to adapt to the environment. However, this is not completely necessary since the human being and the environment will also adapt to the robot. It is the same as the adaptation to the first motor cars. At first, people were afraid of the cars, however, later on, they learned that it was dangerous to cross the road without looking. This is the same with robots, people will go through a learning curve. This learning curve should be going slow and safely and therefore we will take a lot of mitigation measures to implement the robot on the public road. But when the robot is on the public road you will see that people will adapt to this robot as well.*

4. Will the infrastructure will adapt to these robots as well?
05:54

I hope so.

5. Do you have any idea how this is possibly going to change?
06:04 - 07:09

Well, a robot does make fewer mistakes, so they will need less space. So this means the roads can become smaller, which can result in wider sidewalks. Parking places are not needed anymore since the shuttles don't need to be stored anywhere. Then the question is how and where are the shuttles going to be charged, so that's something you really should think about. So we are working on the idea of robot arms which can be plugged in when the vehicle stops.

6. Do you think that every self-driving shuttle in the future will be electrical? Since I've read a lot of articles which stated that the coming of self-driving vehicles will have an impact on the congestion and thereby the liveability of cities..
08:03 - 9:20

Yes. We assume that. That's what I find interesting because you can approach this topic very scientifically. When you approach an innovation scientifically you can look at this topic from many different points of views. What we do is: we test all the assumptions people have in real-life on the TU Delft testing field. For example, is a shuttle able to interact with people? In this testing area, we try to find answers on these type of questions. Therefore our slogan is: learning by doing. And if self-driving vehicles will result in an increase in congestion or not, so let's not spend to much time doing research about this. But just see what happens when doing research in real-life.

7. I Agree. But on the other hand, when not doing research and have the "let's see what happens" attitude will not work out for policymakers since if the coming of self-driving vehicles will result in more congestion then they are too late. I think policymakers should govern proactively.
09:25 - 11:02

That is what I find very interesting. When the first car arrived nobody was harmed. However, during the time when there were more and more cars on the public roads people experienced that cities were becoming overcrowded or even not liveable anymore. And the government let everything happen and thus congestion in cities. So we say let's steer on innovation. And Innovation can be organised in different ways, for example, shuttles and share systems. However, it is very difficult to implement these innovative systems since the government want to know the long-term effect. But if you keep on discussing about this effect there will be no implementation of innovation. So That's why I say: accept that you don't know the effects and make sure it can be tested in field labs in cities and that's where you can find the answers. Let's not ask the question, but just figure it out while testing.

8. So you would advise policymakers to establish more test locations in order to find the answers?
11:29 - 13:15

Yes. And define your research questions. And that is what we are doing right now, the MRDH gives subsidies and they define their research questions which result in many answers. This way, there are many other questions being answered as well. A spatial planning officer has a different point of view than a traffic engineer and an economist, therefore, we try to connect these people in order to find a common goal. And this is one of the reasons why we are at the #1 of the autonomous vehicles readiness index. The Wepod was one of our projects. We were the first in the whole world which made the WEpod project happen, the first autonomous shuttle on the public road. You never achieved this when constantly asking questions about the feasibility of the shuttle.

9. From some case studies of the WEpod I found out that the RDW (Dutch vehicle Authority) did not have any procedure to give the vehicle exemption on beforehand so they developed their procedure during the WEpod project, how did this go?
13:47 - 14:54

Yes. Actually the same. During the meeting in Amsterdam (Zalmhuis overleg) we sat together with the ministry, the prosecution (OM), the RDW and the INW because the ministry wanted to be the frontrunner of self-driving vehicles and therefore we needed to discuss how to achieve this. Let's do a pilot. And based on their trust and a lot of meeting, questions and answers, analyses and documents we got the exemption. However, even after this, the questions and answered keep on going since you are in the middle of research.

10. And did the procedure developed over time or is it still the same procedure?
14:58 - 15:45

No, the procedure has changed and developed over time. But there is still a meeting at the beginning and the funny part is that the SWOV has a lot of questions because the documents we deliver are increased compared to the documents in the WEpod project. For example, we delivered a new file about the training period of the steward and then the SWOV asked a lot of questions about this, however when we did not deliver this file, there weren't any questions about this.

So for now, we got the exemption for three months from the RDW for the Haga Shuttle project. After this, it will be expanded to a year all based on trust and how the project goes.

11. How long does such a procedure take from application to exemption?
15:51 - 16:18

Around 12 weeks.

12. So, the shuttle arrives in the Netherlands before you know you will get the exemption?
16:19 - 17:00

Yes. The RDW transports the shuttle to the Netherlands and they have questions for example about how this shuttle will interact with people who will walk around the shuttle. Those things are tested at the RDW. When the RDW concludes that the vehicle operates as expected the vehicle is ready to be tested on the public road. So the shuttle gets an extra check at the RDW, after this the vehicle will be tested for one or two weeks on the public road without passengers. And after this, the vehicle is ready (by law) to serve passengers.

13. What were the biggest infrastructural challenges in the Haga Shuttle project?
17:10 - 17:50

Arc rays (in Dutch: boog stralen), which is can be corner with a radius of 90 degrees or another radius. Another challenge is the combination with pedestrians, how to make clear that there is an autonomous vehicle on the road and how to determine the pathway of the pedestrians. What does the logo of the shuttle look like? How to safely separate other vehicles from shuttle road? what is a safe width of the shuttle road?

14. I know from the project in Appelscha that the width of a cycle lane was actually not wide enough for the shuttle to operate safely. Are you in contact with people from the North of the Netherlands to get that sort of information?
18:15 - 24:02

I found that a pity because we tried to get in contact with Groningen. We experience there is a good network here with the MRDH with AVLM which are exchanging research questions. But Groningen did not collaborate. So we approached Groningen a few times to share their data but they never share their data anywhere, they don't even have a web page with specific information on it. Or for example, information on how to communicate with the Navya supplier. What are the do's and what are the don'ts. But for now, we cannot anticipate since they don't share their experience with us. The reason can be that there is no university connected to them. The essence of a university is to share knowledge since you are doing research for a particular social interest. Also evaluations, for example, the WEpod project is fully documented en open to anyone on the internet. So we have a knowledge agenda autonomous vehicles (Kennis agenda autonoom rijden) where we have all our documents and articles. And maybe it sounds a little silly but it could also be the distance since you have to travel 2/2,5 hours.

15. Do you also support the projects financially?
26:46 - 27:37

Yes. Even risk-bearing. Moreover, we are investors in the Haga Shuttle project (De Haagse Shuttle B.V.) and in this B.V. we want to have more shuttles in The Hague eventually.

16. What do you do to determine the feasibility of a project?
31:42 - 32:35

We have a plan made out of four steps:

1. *First, we define the **use case** so for example for an airport we need to transport luggage. A regular shuttle is too small for this, therefore we need a bigger shuttle.*
2. *Second, we determine which **technology** is suited for the project. So we look up all the suppliers and see which shuttle is best suited for the use case.*
3. *Third, we look at the infrastructural **changes***
4. *Fourth, make a **business case,** therefore we calculate the costs. In order to solve the use case, this shuttle is needed, with this technology and these infrastructural changes are needed and therefore the costs for the shuttle will be around … And we want to earn this back in 4 or 5 years.*
   And that's the feasibility study we do.

17. Where do you get the knowledge from? By doing research?
33:50 - 35:04

Yes. But also by collecting information in a dropbox. So, when we find an interesting document about autonomous cars/boats/drones we put it into our dropbox.

D.2 HTM – Haga Shuttle

A. Introduction

1. Who are you and what is your profession?

I am the project manager of the Haga Shuttle project of HTM. I am responsible for complimentary transport services so for example bike services near large stations and self-driving vehicles.

2. How did you get involved in this project?

Since the HTM wants to look and think ahead of the future we also wanted to do something with self-driving vehicles. In our opinion self-driving vehicles can serve as the "last mile" because it mostly serves as the last transport means to arrive at your final destination. In the case of the Haga hospital clients, employees and visitors needed to walk a couple of hundred meters to arrive at the hospital when travelling with public transport. Therefore, we thought it would be good to do the self-driving pilot project at this location. Since I am the product manager of complimentary transport services I got involved in this project.

B. Shaping - place promotion

1. Is there a leader in this project?

I am the project manager in this project, however, there are two persons (Gerard Boot and Remco Derksen) who operate on a higher level. They have the ultimate responsibility. If a big decision is going to be made, it should be discussed with Gerard Boot and Remco Derksen.

2. Did you look at other opportunities in the area, for example, private parties who are interesting in collaborating?

We are thinking of integrating self-driving vehicles also in the Binckhorst area together with the MRDH. They are redeveloping this area into an area with mixed functions like housing, offices and recreation. However, the municipality wants to decrease the number of cars and therefore a similar shuttle project can be a good alternative for cars.

Own finding: As I understand from the interview they are not doing a collaboration with other companies than the hospital in the area close to the Haga Shuttle project. The distance between the binckhorst area and the Haga shuttle project is around 7 kilometres.

3. Are there external drivers which can make the development of the AV integration more successful or integrated?

-

4. Do you encounter other developments in the region? For example other pilot projects?

Do you know the project ….? I have contact with someone who is involved in this project from the pronvince Zuid-Holland. I can give you his contact information, his name is Sebastiaan van der Vliet.

I googled. Sebastiaan van der Vliet is senior policy advisor public transport from the province of Zuid-Holland.

5. How often are there meetings with the team?

We meet every Friday with the team.

6. Are all the stakeholders present during these meetings?

No, Gerard and Remco are not present during each meeting since most of the time the decisions can be made without them, only when the decisions are very big Gerard and Remco are present.

7. Who are the financial supporters within this project?

Together with Rebel and the Future Mobility Network we have set up a BV. We also got 50% of the money from MRDH. The MRDH gets money from the State to divide this between traffic and transport projects in the

Netherlands. the whole project costs around 1.2 million euros. The municipality of the Hague and the Hospital are also financial supporters.

I did some research to find out when projects qualify to get the subsidy from the MRDH. A condition for obtaining a grant is that it must promote or serve a regional goal, as described in the Implementation Agenda on Accessibility (UAB).

8. Are there other supporters or professionals within this project? (could also be designers)
No. All professionals and experts are within our project team. We got the technical expertise from the Future Mobility Network, the infrastructural and sustainability expertise from Rebel Group, the knowledge about the vehicle from Navya, which is the company where we bought the vehicles and we have inhouse knowledge about the infrastructure and public transport.

B. Shaping - Place preparation

1. Is the project designed as a single project or integrated?

I did not ask this question since I think the interviewee would not understand the question. However, according to the information it really stands out that this project is designed as a single project.

2. Is there thought about the connection between the trajectory and the physical/social barriers? (physical= roads, trees etc; social= schools, hospitals).
Yes. The trajectory of the project has a sharp turn (90 degrees) in it. We did think about this turn beforehand. (Physical barrier) We are still struggling how to optimally adapt to this turn. However, there is a development going on next to the trajectory, so the road is going to be temporarily. Thanks to this, we can test the turn out first and therefore, the investment should not be that large. We also thought about the connection between the hospital since part of the trajectory is owned by the hospital and part of it is owned by the municipality of The Hague. The hospital is not really a barrier, but it is good to take into account the pathways and routes of the clients, employees and visitors since pedestrians are quite vulnerable. This is a thing we are still struggling with.

a. Are these also part of the financial plan?
The "turn barrier" is taken into account in the financial plan.

3. Do you know who owns the area?
Yes. The municipality owns most of the land. A small part of the land near the entrance is owned by the hospital.

a. How is this managed?
We are still in negotiation with the municipality of The Hague, that's the phase we are in now. Things like liability etc are going to be discussed now.

4. Were there any quality standards or functional standards set for the trajectory? or for the vehicle?
There are some functional standards which are necessary to implement. For example, traffic boards which seek attention from the other road users. Also, other functional standards are stated by the RDW (Rijksdienst Wegverkeer = state agency responsible for the public roads).

a. Or, Is there any design code?
Since this project is still a pilot and the area around is going to be a construction area for a while the trajectory is temporary. Therefore, we don't have to implement any design codes.

5. Did you need any regulatory approvals for the project?
Yes. we needed to hand in a fully documented report to the RDW which includes the plan and the safety measures.

a. How was this handled?

The RDW is now still busy with this document. Despite that, we are quite sure that we are going to get permission since we are an experiences public transport company with a good reputation. Also, we know a lot about the users of public transport and how to communicate in other forms with these users.

6. Is there a demand for this project? Do you have the numbers somewhere?

We don't have the exact numbers. We have numbers on how many travellers check in an out at the tram/bus stop. But we are not sure how many people are travelling to the hospital from that stop. However, we know that a lot of people travel by public transport. Therefore, we think that there is a high demand for any form of transport on this trajectory.

a. Do you also get data from the hospital about the clients/visitors etc?

I don't think it makes sense to use this data since this data is based on clients, employees and visitors. Therefore, we did not ask for data from the hospital.

b. Where does this demand come from?

From clients, employees and visitors who come and go to/from the hospital.

c. Does this project completely match with the demand?

Yes. The shuttles even are suited for people in wheel cheers.

7. What are the risks in this project?

It is hard to name all the risks since mostly you don't know them. But if I have to name the risk than the highest risk was to get the financial planning fixed. It is always hard in such a project to get enough subsidy and private parties who want to get involved. Another risk is the sharp turn in the trajectory. We are still working on this.

a. Can you reduce these risks in a way? How?

Yes. It is important to make a feasibility study on beforehand to make sure there is a demand from the users but also from a company involved (in this case the hospital). Another way to reduce the risks is to have the right experts within the team.

8. Who is the leading investor?

The leading investors are both the MRDH and the Haga Shuttle BV.

a. What is their interest in the project?

The Transport Authority of the Rotterdam The Hague Metropolitan Area (MRDH) gets its money from the state. The MRDH provides subsidies for traffic and transport projects. These are subsidies for the construction of infrastructure, influencing driving and travel behaviour, the operation of public transport and for some pilots. The MRDH wants to increase their knowledge and to improve the accessibility in different areas. The interest of Rebel and the Future Mobility Network is to gain knowledge from the pilot project.

9. Which investment is the largest?

The subsidy of the MRDH and the Haga Shuttle BV are equal.

10. Are there investments in the area around the trajectory?

No.

11. What does financial planning look like?

According to a document provided by the MRDH the Haga Shuttle BV retrieves €595.000 in 2019.

https://mrdh.nl/sites/mrdh.nl/files/files/AVLM%202019.pdf

B. Shaping - Strategic implementation

1. Will the project be developed in phases?

Yes. There are three phases. The first phase is the exploratory phase where we do impact analyses and get in contact with different parties who are interested to cooperate. In this phase, we have been to Appelscha, which is a pilot project in the North of the Netherlands. We also inform for subsidies and other regulatory approvals. The second phase is the Initiative phase. During this phase, we send the project file to the RDW to get permission. We also fill in the application to obtain the subsidy from the MRDH and we are in contact with the municipality about the project. When everything is arranged we can begin the execution phase where we first do a testing phase with people from the Haga Shuttle BV and test drives with only a operator in the vehicle. When we have enough test drives we can start to drive with real passengers.

2. Did you select a developer for this project?

No. We execute the project ourselves. However, I will be off the charge from then and someone else from HTM will take the lead to manage the execution of the project.

a. Where was this choice based on?

We have enough knowledge in-house to execute and manage this project.

3. How will the project be maintained?

The maintenance of the vehicle can be divided into 5 levels. The first three levels can be done by our own mechanics. Two of our mechanics are in France at the moment to have training about the vehicle and how to repair small things like lightning. Levels 4 and 5, which is software related, should be maintained/repaired by Navya since this is in their policy.

a. Is there a maintenance plan?

We are in discussion with the municipality of The Hague to make agreements about the maintenance of the roads etc.

b. Who will be responsible for the maintenance?

For the vehicle both HTM and Navya and for the trajectory probably the municipality of The Hague or the Province of Zuid-Holland since this is the owner of the road (Still in a discussion about this).

C. Regulating

1. What regulation was stated for this project?

The project must be approved by the RDW. Also since the experimental law is still not fully implemented the vehicle must have a driver/guard.

2. Is there any mandatory regulation in order to steer the end-users?

Yes. This is also checked by the RDW. It should be safe and clear for users what to do and what rules to follow to have a safe journey.

3. Does the driver need to have any knowledge of the vehicle(according to policies)?

Yes. The driver needs to be in training as well. HTM will provide this training.

D. Stimulating

1. Are there any subsidies available to establish the project?

Yes. 50% of the MRDH.

2. Are there any actions by the state which reduces the risks?

Not that I know.

a. What is the reason the project only can last for 4 years?

Because it is a pilot project. We want to test the technology and if the shuttle will be used enough. If we see the project is not working at all we maybe stop earlier.

4. Are there any other environmental improvements in the area around? For example from the public sector.
Not that I am aware of.

E. Capacity Building

1. What happens if some policies change? For example, you did not get any subsidy or the development only can last for 1 year?

Without the subsidy we could not do this project, so I think we should postpone or cancel the whole project.

2. Do you rather see the development as an opportunity or just a transportation means?
We rather see it as an opportunity to learn more about this new way of public transport.

3. Is there any data available by the government? For example information about the users? Or information from the hospital?
Already answered

a. Is there any information available from other projects?
Yes. We got some information while going to the Appelscha project. However, we did not use a lot from this project since the environment is totally different and in that project the control room was still in France while the control in our project is in the Netherlands. So If something in the software errors we can solve this problem probably faster. Also, the data will be easier to obtain. We still did start from scratch with this project just because the difference is quite big.

4. Are there any professionals concerned with the project?
Yes. But these professionals are our housed within our Haga Shuttle BV.

a. What knowledge is needed from the experts?
Technical knowledge, knowledge about the subsidies and regulation, knowledge about the vehicle and knowledge about infrastructural developments.

Extra questions:

1. Why is there chosen for the automation level 3?

It is still a pilot and there is still not totally agreed on the experimental law. We wanted to do something we can learn from, therefore, we chose to do the level 3.

2. Is there any resistance in the idea of going autonomous? Competition? Safety?
HTM has a good image since it always provides good transport connections and services. Therefore, we want this to be successful as well. There is a possibility that it can harm our image. However, this does not cause any resistance.

Closing

Thank you for the interview.
Ask whether the interviewee has any questions.
Do you have any recommendations for my research? Something that has yet to be investigated?
Offer to send the thesis afterwards.

D.3 Drietachtig – Appelscha and Scheemda

Introduction interviewee

1. Who are you and how did you get involved in the autonomous vehicle topic?

00:00 - 01:39

I am an external advisor at platform autonoomvervoernoord which I started together with the three provinces Groningen, Drenthe and Friesland. We are researching if autonomous transport can add to the accessibility and liveability of villages (rural areas) in the North of the Netherlands. And if autonomous transport can contribute to this, our ambition is to add autonomous transport to the mobility supply. So then autonomous transport will be part of all transport means in the North of the Netherlands. The platform is not only focused on the road, but also on the railroads, the air and the waterways. In the air we work together with drone hub and we are testing with an autonomous train, autonomous boat and autonomous shuttles on the roads. For the accessibility and liveability of the rural areas we are currently focusing on the 'last mile' solution.

2. Why is the North of the Netherlands more suitable for the combination of the four innovative means of transport?

01:39 - 02:47

I think the unique proposition is that we have a relatively low-risk profile since the North of the Netherlands is sparsely populated. We feature all forms of mobility, modality and all infrastructural solutions. However, compared to the Urban Agglomeration in the Netherlands (de Randstad) we have more space and opportunities to test autonomous transport with a lower risk profile. We also experienced this with Appelsha, Eemshaven and Scheemda. In the North of the Netherlands, it is easier to block a road and nobody harms from this, whereas in Amsterdam, Rotterdam or The Hague other connections get overcrowded which can cause problems. Therefore, In the North of the Netherlands, it is possible to test autonomous transport easier and faster with a lower risk profile.

02:47 - 03:58

With the Appelscha project, we were able to determine the application procedure to get permission to test an autonomous shuttle on the public roads. In the Eemshaven project, we tested this application procedure again together with the RDW, SWOV and all the other parties. The result of the test in Eemshaven was that the application procedure worked out as planned. In the Scheemda project we validated and applied this application process again and we also added a more extensive risk analysis of the vehicle together with the RDW so the vehicle is tested as well. At this time , we have the application process to get the exemption from the RDW to test the shuttle on the public roads and we have the risk analysis of the vehicle which is set. And now you see that in other parts of the Netherlands, for example, in The Hague and Noordwijk they can test a shuttle on the public roads due to this certification procedure of the vehicle.

3. Does the application procedure to obtain the exemption from the RDW gets faster since you get more familiar with the procedure? And how long does the application procedure take?

03:58 - 05:05

Yes. The application period has everything to do with the circumstances of the location. We are now working on new projects which are a bit more complex. The application procedure is the same: we have to deliver a project plan and a risk analysis of the location, then the kick-off meeting takes place. After this meeting, the RDW, the road owner and SWOV need to analyse several other things. When the exemption is assigned we will test for a set time, mostly 2 weeks. The official exemption is usually set for 3 months with an extension to 6 months, depending on the sitiuaton. If something significantly changes, for example, in the location or with the vehicle (the speed goes up from 15 to 25 km/h), then the vehicle and route should be tested again based on these new circumstances.

4. What were the challenges with the recent projects (Appelscha, Eemshaven)?

06:23 - 07:53

During the risk analysis of the location, everyone agreed upon the suitability of the separate cyclist lane. Of course there were some challenges, for example, the connection with the N-road (N-wegen) and access roads of dwellings, crossings, the trajectory was definitely not very simple. The vehicle supplier looks at every meter of the route and location and determines wehter or not something should be changed for a certain period in time or if mitigating measures should be taken. For example he or she could suggest switching priority situations (voorrangssituaties). Still, it is always the case that you know 80 per cent and you don't know 20 per cent. We had to find out everyting by ourselves. From the project in Wageningen (WEpod), we didn't get any information. They didn't want to share their knowledge so we just started to test the vehicle anyway.

5. What did you learn from the width of the cycle lane in the Appelscha project?

08:47 - 10:30

If you choose to let the shuttle operate on a lane with passing cyclists, make sure the width is wide enough. At the beginning of the Appelscha project, we assumed that the shuttle could drive on one side of the road whereby there would be enough space left for cyclists to pass. However, because of the safety zone of the sensors, the shuttle could not drive that close to the roadsides which resulted in less space left to safely pass the shuttle. So step by step we will learn the abilities and disabilities of the vehicle. The supplier of the vehicle can apply these evaluations into the development process of the new shuttles. During the first meeting of the Appelscha project, there were tons of questions we wanted to get answered in order to understand the vehicle a bit more. A lot of the questions were answered, some of the questions weren't. But what we learned from the project was: Was is the position of the vehicle on the road? Where do we want the vehicle on the road? What should still be developed? Are there any harsh infrastructural solutions or changes needed? How do other road users react to the vehicle? And how do the users of the vehicle experience the ride?

6. Which parties are involved in the kick-off meeting?

10:30 - 11:12

I do not guarantee that I am complete but the policy, the road owner, the RDW, the SWOV, the insurance company (Aon), the initiators of the project, the concerned knowledge institutions or educational institutions, suppliers for example from the 5G lab or sensors/cameras…

7. What happens during the meetings?

11:12 - 14:10

The initiators of the project have made a project plan. By the way, this procedure is the same procedure the RDW has for the Netherlands. Together with the RDW, we gave input for developing the procedure, but the same procedure is equal for all other projects in the Netherlands. The first step in this procedure is project plan made by the initiator of the project which includes a description of the stakeholders, the time planning, the trajectory of the vehicle, characteristics of the location (Where/how long/purpose). This plan will be sent to the RDW. The second step is that the RDW will start to have conversations with the supplier of the vehicle. After this step, if everything is approved the plan obtains a "GO". The third step is to execute a risk analysis of the location. And after this, a risk analysis of the vehicle should be conducted. Than the RDW will examine if the analysis of the location still matches the risk analysis of the vehicle.

During the first meeting, every stakeholder obtains the plan of the project and the risks analysis. The RDW is the chairman of this meeting so they will explain what is going to happen and they will invite everyone to collect research questions (people are not forced to do this). The initiator of the project is obliged to answer these questions (if possible) during the project.

8. Do you get anything in return when answering all those questions, maybe subsidies or something else? Or what happens if you refuse to answer the questions?

14:20 - 14:49

No. You get nothing in return. It has something to do with decency. We are working on a public innovative project, not a commercial project. In the end, we all want to learn something from it. We were the initiators of the whole process and trajectory with the RDW which is now used all over the Netherlands. Nevertheless, we got nothing in return from other projects.

9. Did come to a certain point where you also didn't share anything anymore with other people/institutions?

14:49 - 15:46

Yes. We have been at a certain point. I can only speak for ourselves. I don't know the reasons behind the fact that people don't want to share things. I only know the reason why we DO want to share things. We think we are a unique region where autonomous vehicles can be tested on public roads with different actors to achieve a standard for autonomous transport in the Netherlands.

10. Are the projects subsidized?

16:10 - 17:30

Together with the provinces, we decided that every province finances her own projects. And the provinces arrange their own subsidy. Besides this, we work together with arriva to involve the parties of interest. Because in the end, our projects might be interesting for them as well. We are really looking for a possible business case. During this phase, we want to figure out if people want to make use of autonomous transport and if yes, what are the numbers? And when can there be a business case if we come to the period that the steward is not obliged to be present anymore? And how much does a vehicle cost by then? The business case is currently not possible. Or you need to have a "Capelle-like" trajectory constantly filled with people, then it can be possible. But Capelle is in a enclosed area with specific circumstances which is not demanded in our projects.

11. From another interview, I heard that the costs for an autonomous shuttle project are around 1.2 million euros. Is this comparable to the costs of the projects of autonoomvervoernoord?

17:37 - 19:58

No… I know the costs of the Appelscha project and these are not even close to 1.2 million.. Probably 1/10 of it.. The difference could be that we did not buy or develop a vehicle, but we rented it. We also hired some experts. The infrastructural changes might also be included in the costs.

12. Was Appelscha the first project you have been involved in? And how did you get involved in this project?

20:04 - 25:20

Yes, it was the first project I have been involved in.

I am really good at flip-thinking (omdenken) so I got assigned by this municipality to think about the livability of villages. Many amenities in these villages, like supermarkets and healthcare, disappear and the problem arises how to keep these villages still liveable. The municipal actions should be coherent with their policies to preserve the villages, therefore there was the tendency to subsidise several amenities to make sure the villages stay liveable. However, that is not really a solution to the liveability. At that time, I read the letter to the Parliament of the minister Schultz van Heagen-Maas about autonomous vehicles. So I went to the mayor and asked with whom I should get in contact with. When I got in contact with Florien van der Windt, she told me that they actually had not thought of the chances of implementing autonomous transport in the rural areas. While particularly in the rural areas there is an urgency and need to improve the accessibility. In history, there was this steam train which was connected to all the villages. Our idea was to bring back this connection but in the form of autonomous transport. Not that we knew how far the technologies were already, but the idea was there. Via Florien, I got involved in the Task force Dutch Roads (together with Wageningen, MRDH, RDW and many other parties). After this, the idea came to do a shuttle project in the North of the Netherlands. I knew *that it was not permitted to drive on the public roads with a self-driving shuttle, however, there are more things which are not allowed in the Netherlands... So we ordered the shuttle from France which we wanted to test on an enclosed area. However, this was also not allowed… So we assigned for an event licence and we organized a sustainable mobility event called 'E-motion day'. Around 2000 people have been in the shuttle on this event which was driving a small trajectory with a bus stop on this enclosed area. At first, the RDW was not very amused. However, the day was a success and the councillor which was also present during this event asked me: Where is this vehicle going to operate? And I said: hmm.. It could be there… And the Councillor answered: Ok, well.. let's go to the trajectory and let's see what we can do. So we went to the location (Appelscha) and the Councillor said: let's do this… When we had the first ride of the Appelscha shuttle the representatives of the Provinces of Groningen, Drenthe and Friesland were invited and during (or one/two weeks before) they said they wanted to combine all the powers and they signed a declaration of intent to collaborate as autonoomvervoernoord.*

13. Were there any infrastructural changes needed?

30:10 - 32:41

On both sides of the road, we placed traffic signs to communicate that we are having this pilot project with an autonomous shuttle. Also, we placed large "stickers" on the road with the same message. Later in time, the municipality assigned a few "hosts" to explain certain things about the vehicle. We also added some small stops by making use of Stelcon plates. On one crossing we needed to add a temporary traffic light since the speed level was a lot higher here. This latter measure is something that you want to remove in the near future and replace it with sensors.

14. What if the experimental law gets approval today, would you directly drive without a steward or not and why?

32:41 - 33:29

No, I think the technology still needs some improvements to be able to drive safely. At the 5G lab in Groningen, we are testing with 5G network and cameras in order to see if the shuttle can drive with a remote control with no steward inside. We are using 5G because with 4G the latency is too high.

15. Currently, in the North of the Netherlands autonomous vehicles are fulfilling the "last mile" of a trip, however, as you may know in America autonomous taxi's like uber and Waymo are popular. Do you think autonomous transport like this could be something for the North of the netherlands?

42:30 - 45:51

If I look through the hairs of my eyelashes to the future we will have shuttles and technology. The development of the software and technology will robotize a car or vehicle and the technology might be applied on existing vehicles like a Mercedes bus, a sprinter, a VW bus or maybe even a smart. That way the vehicles don't need to be approved since everything is already present like lightning, brakes etc. The only thing that needs to be certified is technology. Then the technology will become more scalable since not every village or last mile needs a bus which is suitable for 10 persons. So I can assume that in the future the technology will be implemented on existing vehicles. Then the service could be also more efficient and less expensive. The question is if a shuttle service is the most suitable and (Cost) efficient option, I am still not convinced. I am not convinced the shuttle will be driving everywhere since this also depends on the density of the village and the number of people who want to use the shuttle. I can image in the future people can reserve a self-driving vehicle at a certain time. Maybe there will be both small self-driving vehicles and big self-driving vehicles in the future...

16. Do you think some people refuse to take a ride in a self-driving shuttle because there are scared for example? How did you experience this in the Appelscha and Scheemda projects?

45:55 - 47:22

Nobody ever did refuse to go inside of the shuttle. Not in the Appelscha project and neither in the Scheemda project. Scheemda did already serve over 3000 persons. Old people are sometimes a bit more careful when the step into the vehicle, however, when they step out of the vehicle they are very excited. Children are already enthusiastic in the beginning like: "oh a mobile robot, I know what I am going to study in the future! I can go to the soccer training myself now". The experience of going into a self-driving shuttle will become a small memory.

17. If you assume there will be more autonomous vehicles, do you think it will be forbidden to park cars or even to drive a car in the city centre? Or don't you experience the nuisance of (parked) cars in the city centres?

49:20 - 50:24
I think here is a big difference between the North of the Netherlands and the Agglomeration of Cities in Netherlands (Randstad) when answering this question. For example, in the North of the Netherlands people are happy to see some life in villages, so they are less irritated of parked cars. While in the Agglomeration of Cities in Netherlands (Randstad) or the bigger cities like Groningen I could imagine cities become more liveable when they become car free. Self-driving shuttles could be a good replacement to travel to the inner cities since these vehicles won't be parked.

18. What if the experimental law gets approval today, are there any projects within autonoomvervoernoord where you would you directly drive without a steward or not and why?

51:48 - 52:58
What I understand from the RDW is that this procedure will be very complicated. I have some ideas about this, however I will keep this for myself for now.

D.4 Province of Groningen – Scheemda and Bourtange

1. Who are you and what is your role in the automated vehicle's transition?

00:00-01:26

My name is XX, from 2008 I am working at the Province of Groningen and now I have been working for one and a half year for a smart mobility team. I am the programmemanager of the team and I have eight people in my team who do everything related to smart and green mobility. With "green", we address hydrogen, electrical buses that sort of things.. everything related to charging stations and, for example, autonomous vehicles is part of the "smart" mobility.

2. How did you get involved in this topic?

01:26- 02:06

The first time I got involved in an autonomous vehicle project was with the Appelscha project. During the development of the Appelscha project, we saw chances for the rural areas in the province of Groningen. The rural areas are less accessible and it is expansive to invest in or maintain good public transport options in these areas. Therefore, we thought autonomous vehicles could be a solution for this. This resulted in enthusiasm and a collaboration with the Appelscha project. In September 2016, a Letter of Intent was signed by the Province of Friesland, the Province of Drenthe and the Province of Groningen which resulted in autonoomvervoernoord.

General questions about the project

1. Was the Province of Groningen also financially involved in the Appelscha project?

02:31- 03:13

Yes, we also contributed financially to the Appelscha project but we also helped to get the exemption to actually let the vehicle drive on the public roads. This was also something that the municipality was not able to do on its own because of both the height of the investment and the lack of position towards RDW and the ministry. . In this case, it was also helpful that we, as a province can have easier and faster communication with the ministries since we are a regional authority. As a regional authority, you are situated between the municipality and the national government, which makes it easier to get the exemption. We also contributed financially to the infrastructural changes in the Appelscha project.

2. As I understood from the interview with Frans Hamstra, there were only small infrastructural changes like small road enlargements to make sure cyclists could pass and traffic signs to make sure people are aware of the vehicle. However, the last example is more of an addition to the infrastructure instead of a change. Do you know if there were more infrastructural changes needed?

03:36- 04:07

No, most of the changes were related to attention signs and a few priority situations (In Dutch: voorrangssituaties) were changed. The small road enlargements were the 'real' changes on the infrastructure. For us, it is important to do as less as possible to change the infrastructure because we want the shuttles to be able to drive on each public road in the end. If we have to change the infrastructure a lot then these projects will become more expensive.

3. I don't know if I may ask, but how much does a project like Appelscha and Scheemda costs?

06:26- 07:06

Oh, that's a hard one. I am not so sure about Appelscha because I was indirectly involved in that project. What is generally known about projects with self-driving shuttles is that the cost of renting a vehicle for a year is around 250.000 euros. Everything is included in this price, the vehicle, the exemption by the Dutch vehicle Authority, the communication, the experts, but when there are also infrastructural changes needed than the costs will be a little higher. So it depends on what you do and how much changes are needed.

4. And were there a lot of infrastructural changes needed for Scheemda?

07:06- 09:55

The Scheemda Shuttle still drives on a bicycle lane because there are still technical implications to letting the vehicle fully interact with the cars on the public road because of the difference in speed. The bicycle lane was a bit too small. So, while thinking about the Appelscha project, we made the lane a bit wider with the use of grass boulders. We made use of this material because it is less permanent and easy to remove when it turns out it does not work. With Appelscha we experienced that the vehicle actually drives on an invisible rail, so it is not possible to make an abrupt lane change or movement to the left or right. Now we see that it is much easier for a cyclist to pass the vehicle on the lane. The difference between the Appelscha project and the Scheemda project is the interaction with other traffic participants. In the Scheemda project, the shuttle experiences interaction with cars for the first time, since the shuttle has to pass two crossings.

5. Are cyclists able to drive on those grass boulders?

09:55- 10:16

Yes. That's completely fine. I tested it myself as well.

6. What were the biggest challenges in the Scheemda project?

10:34-12:54

I think that the biggest challenge was the interaction with other traffic while driving with passengers inside the shuttle. In the Appelscha project we tested the shuttle on a bicycle lane with cyclists, but in this case, there are also pedestrians, cars and agricultural vehicles. There is also a crossing where the shuttle crosses ambulances which go to the hospital in emergency cases. Another challenge is that there is a connection with the bus service scheme. So we have to make sure the autonomous shuttle drives on a set time schedule.

7. I saw the different projects on the website of autonoomvervoernoord. Is every project different on its own, for example, do you want to experience different difficulties in every project? How do you choose the projects?

12:54- 14:46

Every time we want to take the next step. Appelscha was more of a showcase project just to get more experience with such projects and the exemption from the Dutch Road Authority etc. Now we learned things from that project. We do not want to do such a pilot showcase project anymore since it was not intended to let the shuttle drive there for more than two months. We want to focus on projects which can add to the sustainable public transport network. For example, the Scheemda project drives between a bus station and the Ommelander Hospital on a trajectory of 1.2 Kilometres. In the future, we want to expand this trajectory to the centre and train station of the village which makes it a trajectory of 4.5 kilometres. With every project we want to do something new in the pilot project so we can achieve what we want to achieve. In the end, the shuttle is part of our public transport service, therefore we need to test things. So now we are testing to drive on a time schedule with passengers. The project goes quite well, already over 3000 persons were passengers of the Scheemda shuttle. In the project for in the future, Veenkolonien - Bourtange, a fortified village, the main learning objective is the transportation of tourists with a shuttle, however, this is quite comparable with the Scheemda shuttle. Therefore, we want to add something to the learning process which is the package service. Nowadays, many package delivery companies drive in and out of the small village which annoys many residents and also is very inefficient. So we want to test if it is possible to transport the packages from a pick up (information centre) point near the shuttle stop outside the village to a drop off point inside the village. This can also result in private parties who want to invest in these ways of sustainable transport.

8. Do you experience/expect larger infrastructural changes when the challenge in each next project gets bigger or when the location is more complex?

14:46- 16:42

Yes and no. The vehicles are still not able to do everything autonomously, however, they become better because of new technology and artificial intelligence. Therefore, it mostly depends on development. Currently, we choose environments/ areas we think are challenging enough for the vehicle but still not too complicated. By doing this we can limit the infrastructural changes and risks. So in these circumstances, it is a no, however, if we want to take next steps the vehicle should be able to drive in areas where the speed is 50 km/h instead of 15. And in that case, it could be possible that the infrastructural changes will be larger, but we try to limit this.

9. When doing research I looked up different autonomous vehicle manufacturers and in each company, there are differences in sensors, artificial intelligence etc. Therefore, I can assume that each vehicle brand has other experience/knowledge or "intelligence". So how did/do you select the vehicle manufacturer?

16:43- 19:30

Yes. We choose vehicles based on their abilities. It also depends on the trajectory, for example, in Bourtange there is a narrow passthrough and we already know that the EZ10 (Easymile) has a static safety zone which is still quite broad, so, therefore, the Easymile will not be an option for this project. The Navya shuttle has a dynamic safety zone so this vehicle will be suitable for this project. We tested the Easymile on our test area, Eemshaven and we experienced this safety zone, however, the new version of the Easymile will probably not have this static safety zone anymore. This is also the reason why we invest in this right now so we can steer the manufacturers in a way that they can implement our wishes in the new software. This is also the reason why we have meetings with Navya to share our findings and ideas. We also test new technologies like 5G network and 360 degrees cameras with them. Doing this, we will have the possibility to get the steward out of the shuttle. Now they are working on the technology of autonomously passing an object on the road. We hope we can test this within four months.

10. I assume that in the case of a hospital (Scheemda project) you have to transport passengers that are more fragile like patients or people in wheelchairs. How did you implement the users in this project?

19:38 - 20:50

It is possible to take all kinds of passengers into the shuttle. However, we are not able to do so since the shuttle does not have a safety belt to secure a wheelchair. We hope the next version of the Navya shuttle does have a safety belt. if someone in a wheelchair is able to get out of the wheelchair and sit on a passenger seat than it is possible.

11. The first autonomous shuttle project in the Netherlands was the Wepod in Ede Wageningen and during this process, the project team experienced the procedure with the Dutch Road Authority. Did this project help to make the procedure easier and faster and did the project team shared their knowledge?

26:00- 26:50

We have been there a few times. The difference with our projects and the Wepod project is that the Wepod project is focused on the technological features of the autonomous shuttle. They imported an Easymile shuttle and placed their own sensors on the vehicle to test things. We choose our trajectory and based on the characteristics we choose the vehicle. We are working less on the technical aspects in detail and we are more focused on the public transport service. Of course, we find it important that we know how the sensors work so we have a technical manager on the project who knows enough of the technical aspects. For example, when there are errors or other problems that the stewards can not solve, the technical manager can solve these problems.

12. Why did you choose to drive with an Easymile vehicle instead of a Navya vehicle at the Eemshaven?

29:23 - 31:50

Well, we knew the Easymile vehicle from the Appelscha project. So we were curious about what the vehicle exactly could do. In the Appelscha project, we experienced what we had to do to get such a vehicle on the public roads and how the vehicle was able to drive back and forth on a road with not that much difficulties. During the testing periods with the Easymile at the Eemshaven, we came into contact with the Navya manufacturer and we came to the conclusion that the Navya vehicle had more features at that moment.

31:50-33:02

Greendino, which also made the simulation for us and worked together with the WEpod project, helps to keep us up to date with the new technologies and manufacturers of autonomous vehicles. They have been to London lately at Aurrigo and other companies. We also had conversations with 2getthere from the Capelle project. However, this project is different since the vehicles are driving with magnets and on a separate bus lane. They want to expend the trajectory and drive on the public road as well.

13. Do you know the difference between the Haga shuttle project and the Scheemda project? Since both projects are situated around a hospital.

34:30-35:04

I know the Haga Shuttle trajectory is much shorter, around 300m and the area is more open. It was funny to hear after they visited our project in Scheemda they started to do a project with a hospital as well.

14. Do you share knowledge with other projects for example with MRDH in the west part of the Netherlands?

35:11-35:50

The knowledge sharing is at a starting phase right now. The MRDH and GVB (from Amsterdam) visited us. I am in a national collaboration about smart mobility and part of this collaboration focuses on shuttles and pods which I am responsible for. Also, Rotterdam and Amsterdam are joining and we want to look at the possibility to share knowledge, however, this is still in a starting phase.

35:58-37:10

When we started we had contact with Helmond at the automotive campus and we had contact with the project in Wageningen, which is now partly moved to the Tu Delft. And we are conscious to not do the same sort of projects. For example, in Helmond they are testing platooning on the public road but we are not testing platooning because why do the same thing? And for the same reason, we are not fully focusing on the technical aspect, since the TU is concerned with this and it has been done with the project in Wageningen. Therefore I think it is important to have enough communication to see what everyone is doing to prevent us from doing the same projects.

15. In the Scheemda project, who are the investors?

37:15- 38:38

We as the province are investing money in the rental costs of the vehicle. We invested a small part in the infrastructural change to widen the cycle lane. The rest of the investment was carried by the hospital. They also do the maintenance of the lane. Together with the municipality, we invested in the bus stop because this is situated on municipal land. Furthermore, we have Arriva the public transport company, they are paying the stewards and they deliver the time schedules.

16. The shuttle is electrical, so where is the charging point of the vehicle?

38:38- 39:06

In the hospital, there is a depot, where the goods come in and go out. The shuttle will be parked and charged every evening in this depot. This is also financed by the hospital.

17. Frans Mentioned a control room which is now still in France. Would it be possible to have this control room in the Netherlands? And what is the idea behind that the control room is now still in the Netherlands?

39:30-42:20

Yes. This is possible. We don't have this control room in the Netherlands since we don't steer the software and because we are still renting the vehicle. In the case that we buy the vehicle, we can also, for example, buy the software and updates for 5 years and then it will be good to have a control room in the Netherlands as well. We are already developing this at the Province House. Especially when we have several projects running with or without a steward. Navya is checking all the projects all over the world in France. They mentioned the Scheemda project as the best for now because of the way we dealt with the project, the setup, communication, process and documentation, which is a great compliment.

18. If we go to the future project Veenkolonien - Bourtange, what is the next step or challenge?

42:48 - 43:20

The next step will be the package delivery and the small passthrough. Another challenge will be the big stones on the road, which can make the route less comfortable, so we want to test how the shuttle will react on this.

19. Why is this a challenge?

43:20-43:33

Well, when the road is bumpy then the sensors will constantly move as well.

20. What were the biggest risks at the Scheemda project?

43:33-46:48

Beforehand?

Yes

The interaction with the other vehicles was a big risk on forehand. There are many crossings where there can be interaction with cars, cyclists and pedestrians. We did mitigate these risks to built a hard stop in the route. Together with the RDW, SWOV, insurance company (Aon) and other people involved in the first meeting we thought of these fixed stops. After the stop, the steward had to look if the road was clear and then hit the 'GO' button to give the shuttle permission to drive again. However, we saw it went quite good already and these fixed stops were mostly more confusing and dangerous for the people in and behind the shuttle. Therefore we removed most of the hard stops. But these things you only discover when you are testing. Another risk is that you don't know how people react on the shuttle since we also transport patients. To mitigate this risk we did demo's in different places so that people could experience what it is like to sit in a self-driving shuttle. During these demo's we experienced that it was more difficult for older people to get comfortable in a self-driving shuttle compared to children who found it exciting.

21. How do you gain trust with people who are less comfortable with self-driving vehicles?

46:48-47:55

The steward plays a big role in this since he/she can assist people and explain everything about the vehicle. Maybe in the future, we choose consciously to have a steward on some trajectories for a while to help people to get in and out of the vehicle.

22. What if the experimental law gets approval today, would you directly drive without a steward or not and why?

50:21- 52:05

I think we will begin to drive without a steward, however, not in the Scheemda project and definitely not directly with passengers. I think we want to test this first, for example, at the Eemshaven testing area. When something is approved by law this does not directly mean that the technology is ready for it. But we are one of the parties who informed the Dutch Upper Chamber that we are waiting for the law to be approved since we think we are ready to test it.

23. Do you find it realistic that all self-driving vehicles should be parked at the outer circle of the cities if you assume there will be privately owned self-driving vehicles as well?

53:00 - 53:30

Yes, I think it is realistic. This is also something we are taking into account. We have this project where we create hubs for public transport. But we are also taking into account the fact that in the future self-driving vehicles can be parked there as well.

24. Do you find it realistic that the government would force that every autonomous vehicle should be electrical?

53:30- 55:15

Yes. That's also a demand in our projects. We are not testing with non-electrical vehicles. In the near future, we plan to ban every vehicle which is not zero-emission. I think in a few years there will be drawn a circle where diesel vehicles are not allowed anymore.

D5. Province of Zuid-Holland – Esa Estec and Haga

1. Who are you, what are your responsibilities?

I am senior policy advisor for public transport and air transport for the province of Zuid-Holland. We offer concessions for the areas outside the metropolitan region of The Hague and Rotterdam (MRDH), for instance, Leiden, Alpen aan de Rijn, Gouda, Katwijk, Dordrecht, Geldermalsen. We also have some railroads and the waterbus. So I make policies on how the transport should be suited and what we ask from the service supplier/transport company. And when we give the concession, we should monitor or discuss the transport service in order to meet with the societal demand. At the same time, we think of new public transport stops, separate bus lines. So, in short, we think of: What kind of transport do we want? And how can we organize this? And now the question is, we want to match with the demand of the society. And for about 100 years we know how to offer qualitative public transport, for instance, look at the subway of London. It is fast, frequent, trustworthy. And actually we want every public transport means to be fast, frequent and trustworthy. We want to transport as much passengers as possible. And we need this to achieve the societal goals like accessibility. Public transport is much more efficient than the car and it gives the possibility to create a livable city where everyone can live. However, this also means that there is a transition, for instance with the bus lines. In the past, the bus lines stopped in every street. Nowadays the bus lines are more frequent and faster. However, the problem then is that the distances from and to the bus stops get larger. And then the first and last mile problem arises. So you can travel by bike, but also by autonomous shuttles. The shuttles can offer comfort for people who don't want to travel by bike. But they also can offer a service for people who are not able to travel by bike. So, we see potential in this. However, the technique is still not completely developed yet and therefore we are doing experiments to see whether these new technologies work or not.

2. Are these experiment in the public area?

Yes, for instance the Esa Estec shuttle. Somewhere these days the shuttle will be ordered. And the idea is that there are two phases. In the first phase the shuttle will operate on private grounds with a control remote (so without a steward inside the vehicle). And after this, when everything goes well, the idea is to expend the trajectory to the public roads. The advantage when you experiment within the borders of Esa Estec, you don't have to get exemption from the Dutch Vehicle Authority. The trajectory is around 1 km by 1 km. And the purpose is to create a transport service between the closest public transport stop and the main entrance of Esa Estec. There is a parking problem and Esa Estec is an important company for the economy, with around 1000 employees who all mostly travel by car. And the employees are mostly foreigners, which find it less easy and attractive to travel by bike. This way, we hope to make public transport more attractive. And at the same time you can test the interaction between the shuttle and other road users, since there are lots of pedestrians, cyclists and cars operating around the Esa Estec building. (Within the borders) Therefore, this area is interesting to experiment. If everything works out well, we expend the trajectory. This is planned in about two years.

3. Who choose the trajectory of the shuttles? For instance, the trajectory of the Haga shuttle is quite short (300) while the trajectory of the Esa Estec shuttles is much longer (2 km).

I think the Haga project was decided upon by the MRDH. As I can remember it had something to do with offering a service. And especially for people who have difficulties in walking. I think it was mainly for the HTM to gain knowledge and experience with this technology.

Intermezzo about the shuttle in Capelle aan den Ijssel (which is only level 2 and not flexible since the infrastructural changes are quite costly. We don't want to adjust the infrastructure that much when implementing new technologies.

4. What comes first, regulation or technology?

In an ideal situation, there a question from the society. And then you will look at the things needed to answer the question from the society. If you turn this around, technology is looking for solutions or something. In my opinion, a good policymaker or government first looks at what we all want. What are the main assignments? For instance, the energy transition or to build more dwellings, to improve the quality of the build environment, etc.. And after determining the assignment, then we arrive at the question how to solve the first and last mile challenge? And then, autonomous shuttle could be a wonderful solution. So, from my perspective you first look at the problem and then you look at the solutions, instead of the other way around. So then technology fits within the broader societal development.

5. Are there any barriers to implement autonomous shuttles?

Yes. They are very costly. But the idea is that the costs to implement these shuttles decrease as there are more and more implementation projects. And currently, we need to pay the stewards still. However, when the steward can be removed, we can make a business model. Because imagine, currently we have to pay 150.000 euros for each bus on the public roads. A chauffeur costs €50.000 each year, and every bus has three chauffeurs because of holidays, schedule changes etc. But these costs of 150.000 are only to pay the chauffeurs. But I can assume that an autonomous shuttle can serve as a pendel. Which makes the busses more efficient. So, when implementing autonomous shuttles, the other busses can operate more frequently. And the savings can be used to implement the shuttles. This also creates the solution to increase the accessibility to the rural areas. In Esa Estec we can experience the acceptance of people towards these shuttles. And since the employees of Esa Estec are working in the technology/engineering sector we expect these people will accept the shuttle very fast.

6. I am aware of the projects in the Nothern part of the Netherlands. How is the contact between The province of Zuid-Holland and the northern region?

Yes, we frequently dicuss things. And for instance, Arriva which is doing the Esa Estec shuttle, also serves transport in the northern region. So the result is that Arriva can implement the knowledge they gain from the Esa Estec project in the northern region. And we also involve a consulting company who have the experience with implementing autonomous shuttles. This consultancy firm, The Future Mobility Network works closely together with the TU Delft.

7. So, you mentioned you don't want to adjust the infrastructure in order to implement autonomous shuttles?

Well, preferably not. But sometimes I can understand some changes are needed. But preferably as less as possible.

8. And are there anay infrastructural difficulties you've noticed already?

Yes. We see this as the Esa Estec project. For instance, traffic signs, small changes in the pavements (stoepjes), a different angle in the road. We've made a document to see what we needed to do in order to implement the shuttle. If everything works out, the shuttle is going to operate on the road around coming summer. We had conversations with Esa Estec and they were complaining that many of their employees travel by car. And for that reason, we are doing this project now. So, on the one hand we have the transport demand from Esa Estec and on the other hand we have this large experimental area to test in.

9. When is the shuttle ready to travel on the public roads in the Esa Estec project?

Well, if everything is stable the shuttle can go on public roads, however, the steward still needs to be present in the vehicle. And this is also dependent on the Dutch Vehicle Authority (RDW). This authority should also give permission to drive without a steward. During the project you experience many difficulties you never thought of, *for instance, what about the insurance, what about safety, what about social safety? How does the vehicle have contact with the control room? How does the vehicle connect with the other public transport services? And we try to answer these questions with the pilot project. Do people want to pay for this service? Are disables people able to enter the vehicle by themselves?*

10. Which parties are involved in the Esa Estec project?

- The province of Zuid-Holland
- Esa Estec
- Insurance company
- Arriva
- Municipality Noordwijk
- The Future Mobility Network

11. Is the ministry of waterways and infrastructure involved in this project?

We had some conversations with the ministry, however, their role is to observe everything. We organize some meetings to get everyone around the table. However, the ministry does not really participate in these meetings. The contact with the Dutch Vehicle Authority goes via the project itself. We as the Province gave subsidy to do the project and we stated some guidelines and rules which needed to be followed. The technical specifications and the execution of the project were handled by the consortium, so arriva, future mobility network etc.

12. Do the consortium lease or buy the autonomous shuttle?

They lease the vehicle.

13. And why is that?

As I can remember leasing the vehicle for two years was more expensive than buying the vehicle. And when you buy the vehicle you can sell it afterwards or you can re-use the vehicle in other projects/experiments. The vehicle contributes to the transport problem in this area. So if the test is successful, the shuttle can stay in operation there. Arriva is responsible for the exploitation and maintenance of the vehicle.

14. Is the control room located in France or will there also be a control room in the Netherlands?

Our idea is to have a control room near the project area.

15. Is it an option to combine the control room of the Esa Estec shuttle with the control room needed for the Haga shuttle?

No, because the Esa Estec will be exploited by Arriva and the Haga shuttle is exploited by HTM. These projects also adds to the knowledge of these service providors. Another question we, as a province, would like to be answered is how fast these projects could be executed. And to what extend? Currently, we see that the inner cities are way to complex to integrate these shuttles.

16. Are the end users (the employees and visitors of Esa Estec) involved in the project?

The stewards are going to welcome the passengers the first few months. When visitors want to enter the Esa Estec area they have to check in at a reception. Thus, the person working at the reception can inform the visitor of the shuttle. When the shuttle is going to operate on the public road this story is different. However, this will be around 2020.

17. What are the reasons you give subsidy? Or when do you give subsidy?

Currently, I call it ad hoc policymaking. The subsidy is called: improvements of the public transport chain. And there are several requirements that state how to comply to get subsidy.

If we look at the future. Cities can become less livable because of the increase in cars. So my question is, can you create a policy to exclude regular cars out of the city and to only allow autonomous cars? Well I think this is something for the municipalities. We are making policies for the provincial roads and public transport. Currently we are trying to stimulate building houses around important public transport stations or hubs. In order to stimulate public transport uses.

18. What are the costs for the shuttle project?

The shuttle is around 250.000 each. Essa Estec is around 1.5 million. Two vehicles, the stewards, maintenance, research. And we subsidise around 600.000 euros. Esa Estec, Future Mobility Network, and Arriva contribute financially.

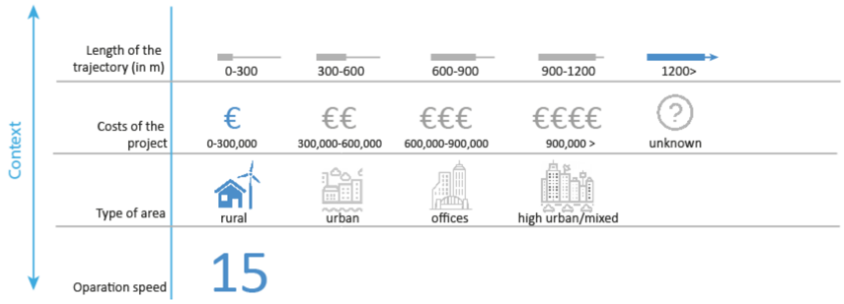
Closing

Thank you for the interview.
Ask whether the interviewee has any questions.
Do you have any recommendations for my research? Something that has yet to be investigated?
Offer to send the thesis afterwards.

APPENDIX E: ANALYSIS FRAMEWORK COMPARISON

E.1 Context

Appelscha



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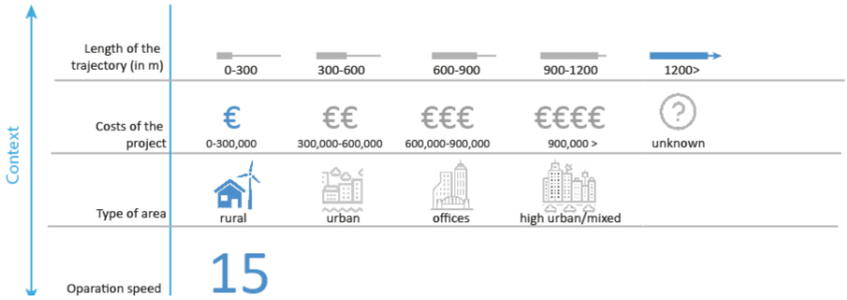
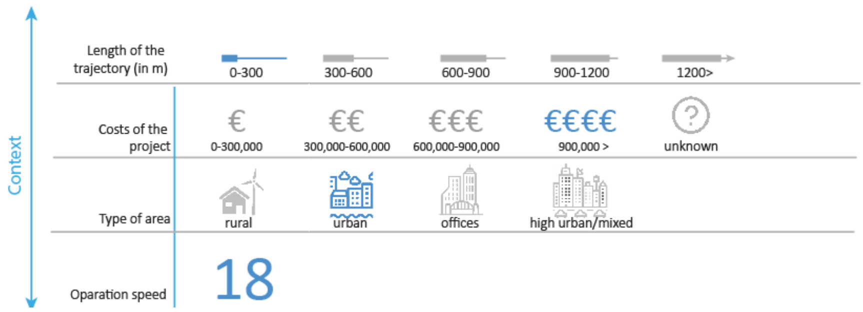
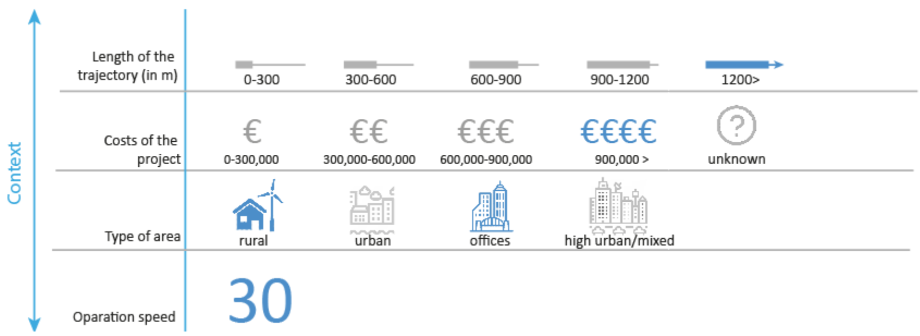


Haga



Esa Estec



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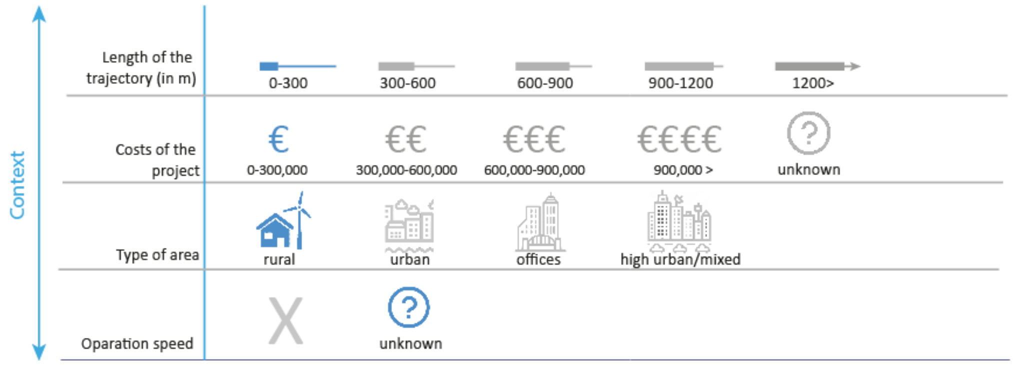
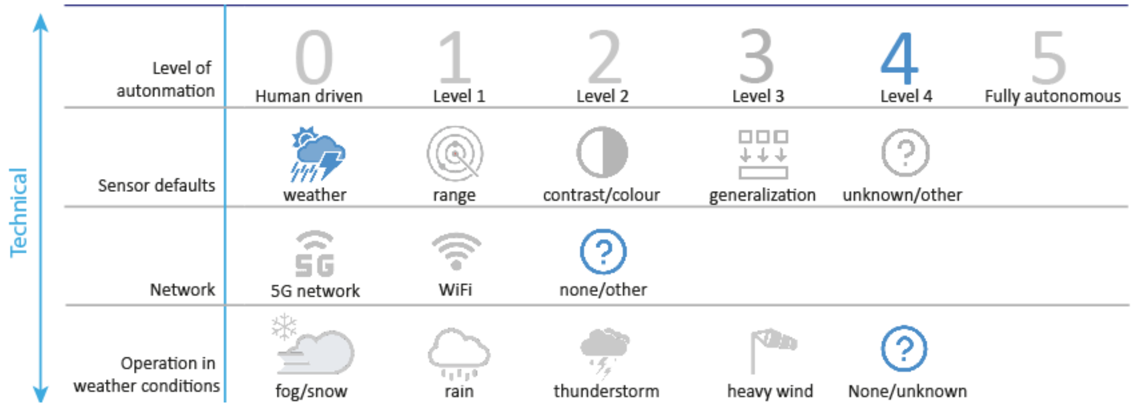

Context
Length of the trajectory (in m)
0-300
300-600
600-900
900-1200
1200>
Costs of the project
€
0-300,000
€€
300,000-600,000
€€€
600,000-900,000
€€€€
900,000 >
unknown
Type of area
rural
urban
offices
high urban/mixed
Oparation speed
X
unknown

E.2. Technical challenges

Appelscha



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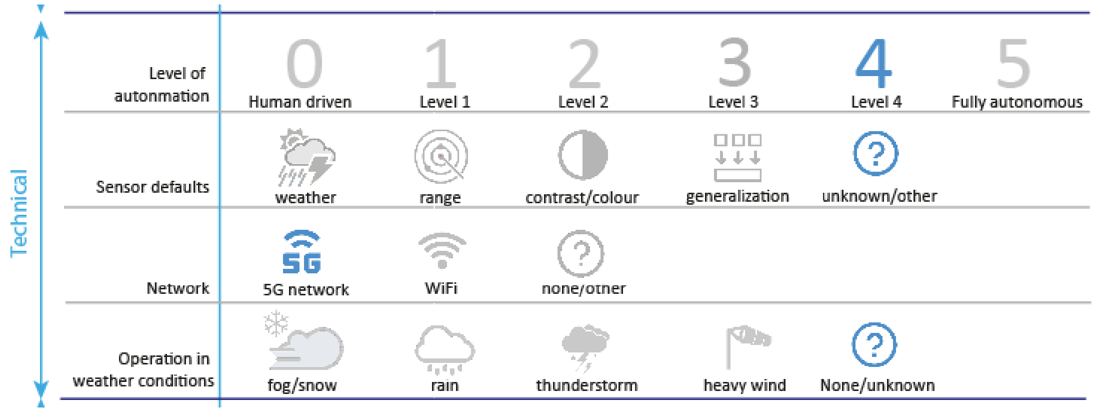

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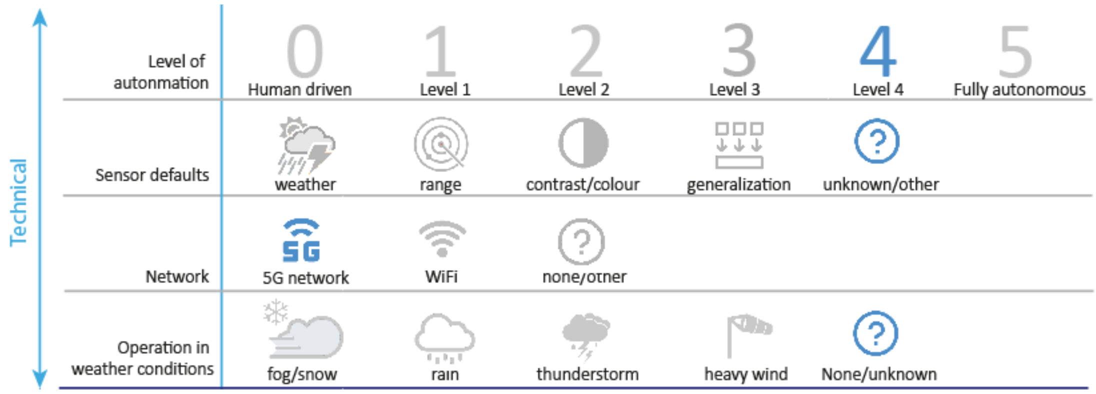
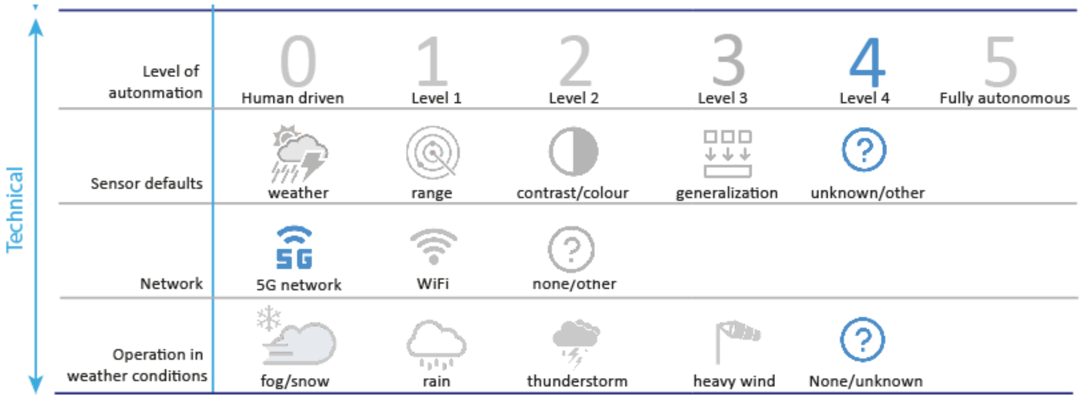


Esa Estec



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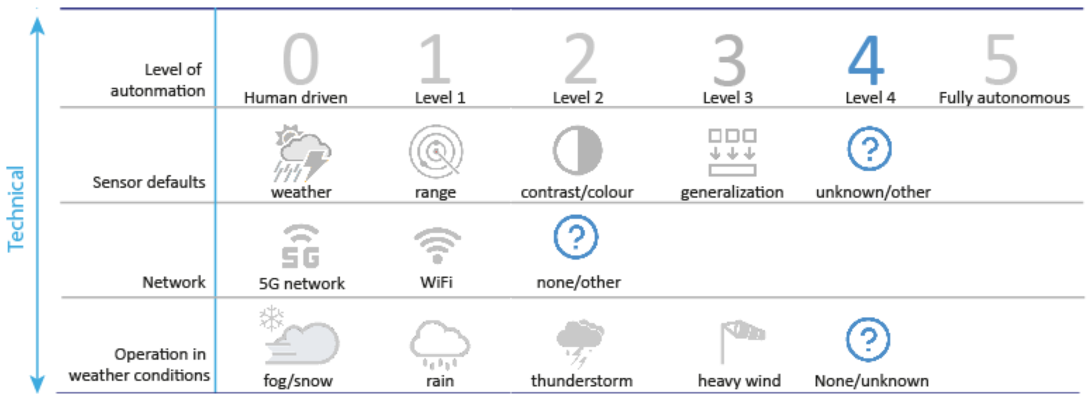
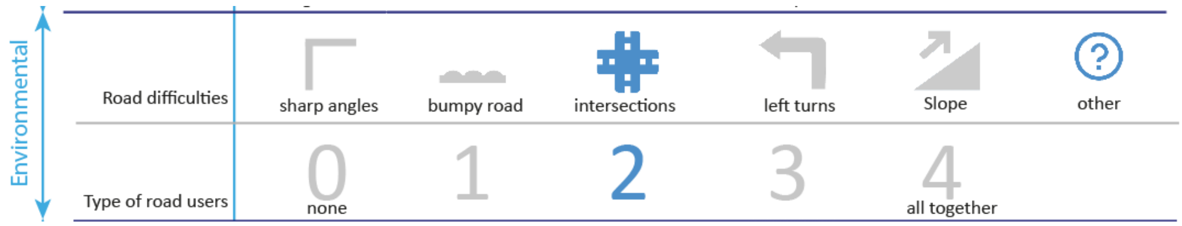


E.3 Environmental challenges

Appelscha



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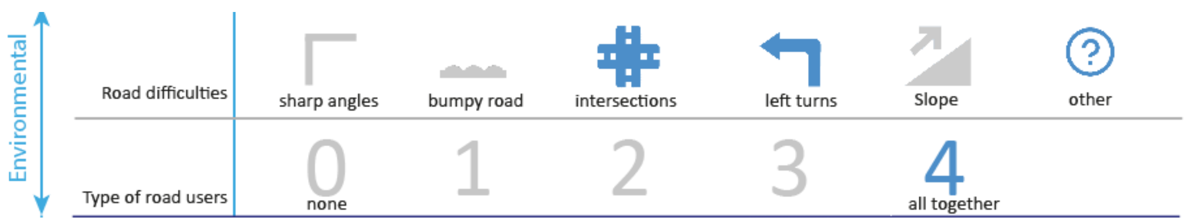

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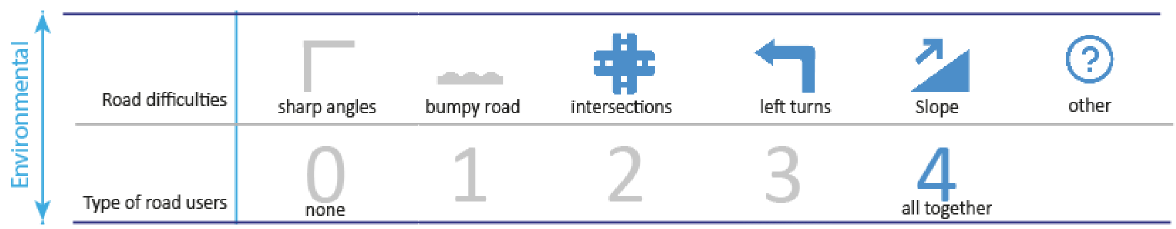
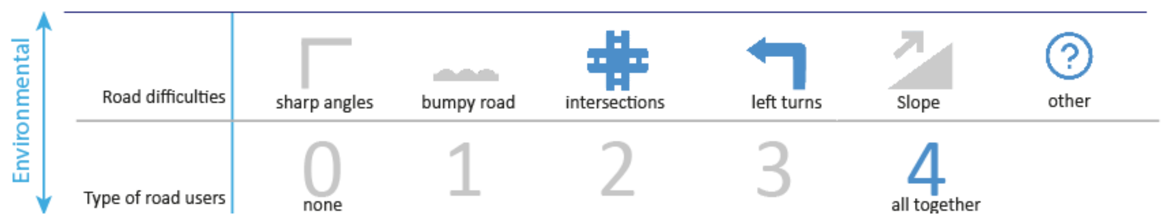


Esa Estec



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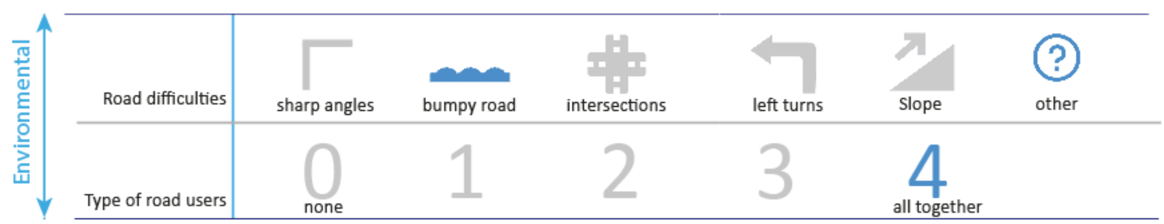
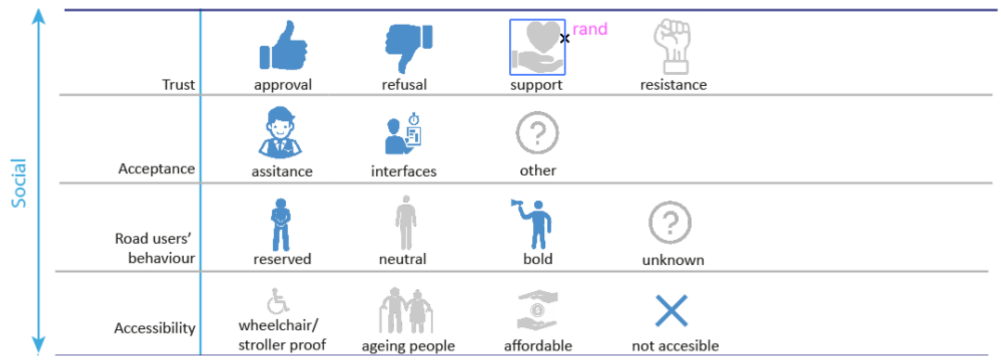


E.4 Social Challenges

Appelscha



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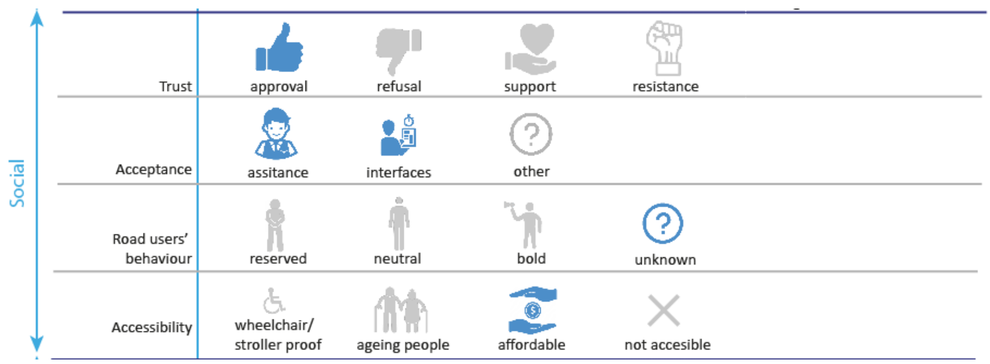

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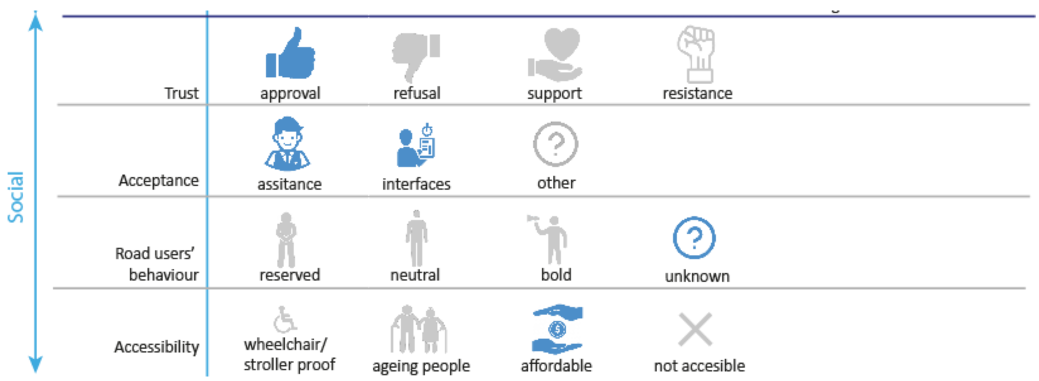
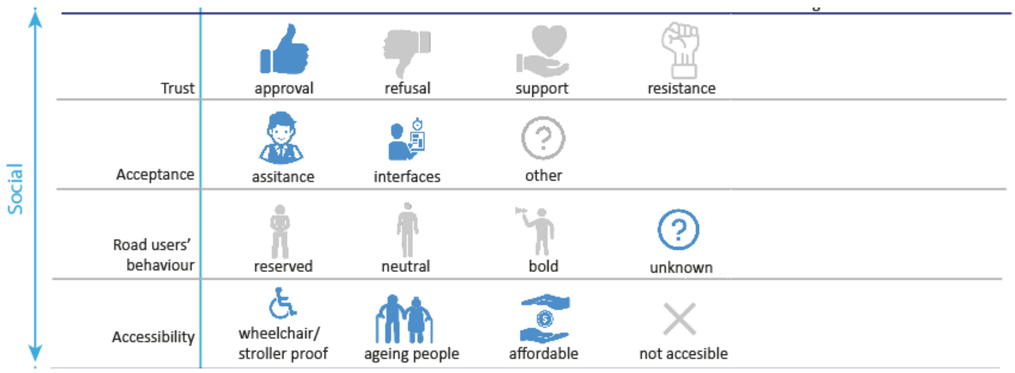


Esa Estec



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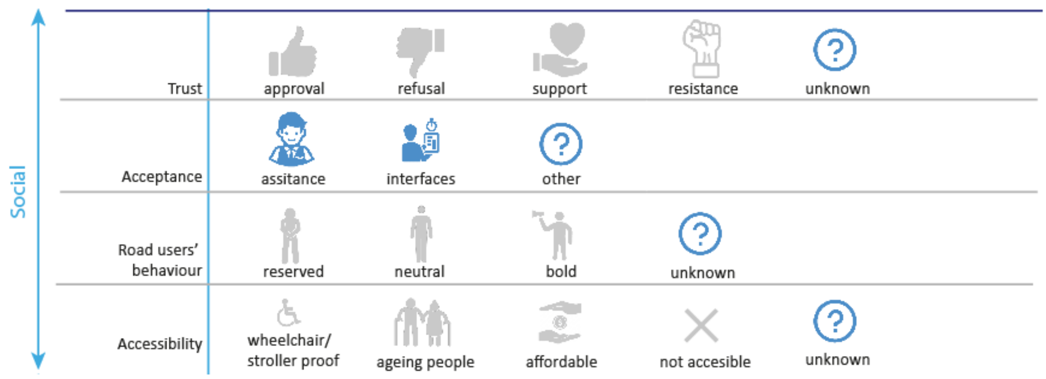
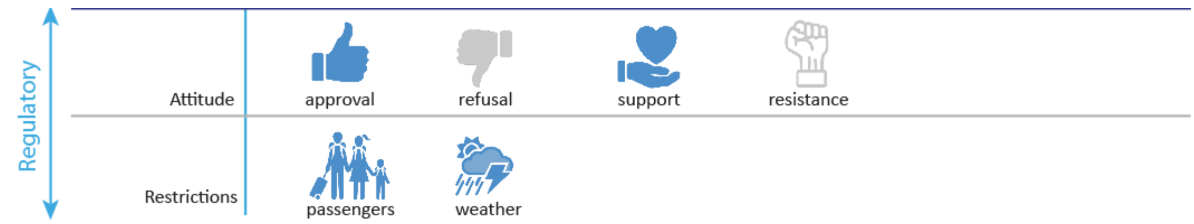


E.5 Regulatory challenges

Appelscha



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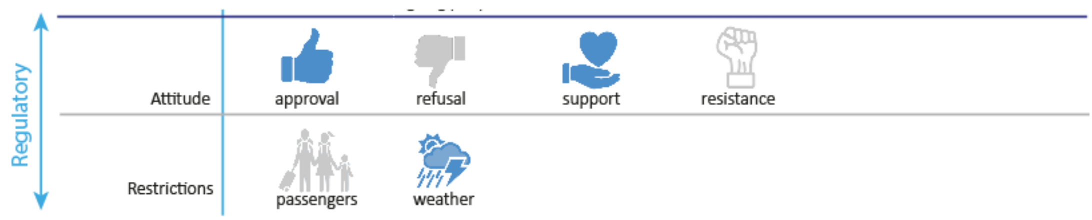

Esa Estec

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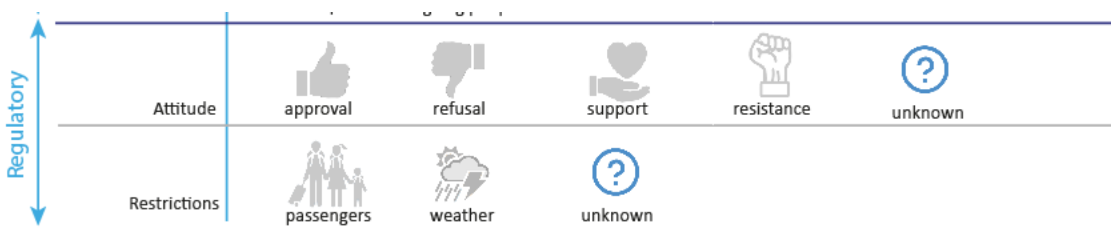

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