Exploring Causalities between Vehicle Automation and Vehicle Sharing

by D.J. Kool
Exploring Causalities between Vehicle Automation and Vehicle Sharing

The Netherlands as a Case Study

by

D.J. Kool

to obtain the degree of Master of Science at the Delft University of Technology, to be defended publicly on 24 October 2016.

Student number: 4023218
Thesis committee: Prof. dr. G.P. van Wee
Dr. J.A. Annema
Dr. M.L.C. de Bruijne
Dr. D. Milakis

TU Delft, chairman
TU Delft, first supervisor
TU Delft, second supervisor
TU Delft, third supervisor

An electronic version of this thesis is available at
http://repository.tudelft.nl/.
Ending a research project spanning almost a year – from November 2015 to September 2016 – this thesis is completed in fulfilment of the Master of Science in Systems Engineering, Policy Analysis & Management at the Faculty of Technology, Policy & Management of the Delft University of Technology. Work on the project was sometimes completed part-time, including several breaks. The total time put into this project totals approximately six months.

I found it very interesting to study the conjunction of two subjects: vehicle automation and vehicle sharing, especially because of the opportunity to do a case study and to talk to all these professionals. It presented me with a unique opportunity to learn more about state-of-the-art technology and research. Incidentally, in the Netherlands there happened to be a great deal of expertise present on both subjects. One reason for this expertise, among others, is because the national government wants to be frontrunner in both subjects. It actively supports pilot studies and experimentation on the public roads. Secondly, scholars from various Dutch institutions are now focusing on such research.

Generally speaking, the eight chapters in this report can be subdivided into three parts, each directly relating to one of the three phases of the research. Readers who are interested in the theoretical side and thus the first phase of the project can refer to chapter 2 and 3. Here you will find the concept exploration and initial conceptual framework respectively the research approach and methods. Readers who are interested in learning about expert opinions in the Netherlands are referred to chapters 4 and 5 for empirical results and discussions.

Help and suggestions, for those who want to know more about the broader implications of the research, are discussed in chapter 6, and may be particularly relevant for scholars of one of the two research subjects.

Traditionally, I conclude this preface with a wish and an invitation. I hope that all readers find the thesis useful in some way and worth the read, and I welcome all comments and discussions about the work done.

D.J. Kool
Rotterdam, October 2016
First and foremost, I thank the graduation committee – prof. Bert van Wee, Jan Anne Annema, Mark de Bruijne and Dimitris Milakis – for guiding me through this unfamiliar process. You all helped me in a particular way. Jan Anne did not only help me with fine-tuning the contents, but he also helped me to stay pragmatic and humble throughout the project. Mark was kind enough to make extra time to discuss methods and techniques. This was very insightful, especially in the beginning of the project. Dimitris was always there for the necessary substantive talks. Finally, prof. Van Wee chaired the committee efficiently and effectively. Above all, I thank you all for the enlightening meetings!

This thesis would not have been possible without the twenty-six professionals who agreed to be interviewed. They took the requested time and often even more to prepare, sit down for the interview, and follow up in many ways.

Last but not least, I am grateful to my family and friends who were able to see it through—most of them all the way to the end. Finally, special thanks to Amy, who was and is always there for me. Thank you all for making this research project possible!
Executive Summary

Our car-based society causes a lot of undesirable effects, such as car accidents, traffic congestion, and air pollution. According to experts and the media, vehicle automation and vehicle sharing are two developments that could reduce—or even completely mitigate—these negative effects. For example: vehicle automation could improve the safety of both passengers and other road users by reducing human errors. Sharing vehicles also requires fewer vehicles on the road, resulting in less congestion and air pollution. A combination of both developments could also be realised, but research into the long-term effects of vehicle automation on vehicle sharing (and vice versa) is currently scarce. This thesis aims to fill this gap in knowledge and thereby facilitate societal benefits that might arise from a more informed policy discourse.

The main research question of this thesis is: ‘What could be the impact of vehicle automation on vehicle ownership, vehicle sharing and vice versa?’ and this research project consists of three phases. Phase (1) is a concept exploration and scoping by means of literature research and unstructured interviews, Phase (2) is a case study by means of semi-structured interviews, and Phase (3) consists of interpretation and discussion through the comparison of literature. The explorative nature of the research question is secured throughout the whole project by applying assumptions from the Grounded Theory (GT), such as keeping an open-mind as researcher, comparing theories, and iterating between and within project phases.

An initial result of the unstructured interviews is that experts mentioned that driving AVs in mixed traffic presents technological challenges; they think that fully AVs could be further away from commercialisation than originally thought. The potential of SVs might also be overestimated: they point to the hype of SV versus their relatively small numbers on the roads today. SVs are still unpopular compared to privately used or owned vehicles. However, in future, several different vehicle mobility propositions might become available. This means that a traveller might not be limited to choosing either a private vehicle, a shared vehicle, or public transport, but an individual could use combinations thereof within the same subscription, depending on the individual’s needs.

The topic list for the semi-structured interviews was designed based on the analytical distinction between three dimensions: (1) socio-technical systems, (2) actors and (3) institutions/rules by (Geels, 2004). Socio-technical systems include both the supply side (innovations) and the demand side (user environment). Considering the existence of the three dimensions above offered a number of benefits such as a priori ensuring a holistic approach to the interviews and literature research and facilitating the fitting of interview data with the three dimensions a posteriori. This process revealed the focus of the experts and identified existing knowledge gaps.

The Netherlands as a case study, comprising 19 expert semi-structured interviews, was central to this project. The participating experts were selected based on their expertise in the field and, to ensure the explorative character of the search, the variety in their backgrounds.

From these semi-structured interviews, eight key factors determining the future development of vehicle automation and eight key factors determining the future
development of vehicle sharing were distilled. According to Dutch experts, the future development of vehicle automation is determined by: (1) legislation, (2) liability, (3) consumer acceptance, (4) safety, (5) technological development, (6) legacy, (7) mixed traffic, and (8) purchase costs. Interestingly, three key factors that were mentioned in earlier studies were not mentioned by the experts in this project: AV ownership structure (public vs private), transition steps, energy and emissions. According to Dutch experts, the future development of vehicle sharing is determined by: the (1) accessibility of shared vehicles (SVs), (2) availability of SVs, (3) status of a private vehicles, (4) urbanisation, (5) SV fleet size, (6) consumers’ willingness to consume by sharing, (7) parking costs and parking space, and (8) total cost of vehicle ownership. Where political and administrative support from the municipality and coordination and integration of the vehicle sharing to public transport were mentioned in a previous study, these factors were not identified in this project. Emphasis on vehicle ownership has also lead to two key factors (7 & 8) that have only emerged in this study: parking costs and parking space and total cost of vehicle ownership. These factors clearly emphasise the attractiveness of an alternative to vehicle sharing: in this case, the ease of use and costs related to private vehicle ownership. Thus, despite the possibility of both developments materialising, Dutch experts in this project did not mention AV ownership structure (public vs private) as a key factor for the development of vehicle automation.

The insights into potential impact of each of the developments took shape through eight narratives, describing the relationship between vehicle automation and vehicle ownership. Broadly speaking, in most narratives, the highest level of vehicle automation is conditional for the potential impact to appear. Most of the experts think that personal mobility will evolve with gradually improving technology—assisting and eventually replacing the driver. Despite the gradual path of vehicle automation, the interviews also suggest that the potential interactions between automation and sharing are difficult to envision. Potential interactions were projected in the short term, and on a longer timeline when we reach full vehicle automation. There seems to be very little projected in between.

The aim of this research project was to increase the knowledge about the potential impact of vehicle automation on vehicle sharing and vice versa. Next to filling this scientific gap, this study is also relevant from a societal standpoint. Increasing the understanding of the impact of vehicle automation on vehicle sharing and the other way around could be relevant for policy-making to address the undesired effects caused by non-automated and non-shared vehicles. Given that vehicle automation and vehicle sharing are still emerging, literature in the area of synergy between the two remains sparse. Therefore, the research question central to this thesis that was answered is explorative: “What could be the impact of vehicle automation on vehicle sharing and vice versa?”

Based on expert interviews, this study concludes that vehicle automation could have impact on vehicle sharing. Moreover, the opposite seems also possible: vehicle sharing having impact on vehicle automation.

Methodologically speaking, one cannot simply generalise the findings from this study based on the Netherlands. However, the results of this study do not indicate any “uniqueness”. The initial focus of the research is on the Netherlands. Apart from one,
all interviewees were working in the Netherlands at the time of the interviews and the interview questions were aimed at the Netherlands. However, the interview findings as listed in this chapter are not unique for the Netherlands. That means that the possible causalities between vehicle automation and vehicle sharing might not be unique for the Netherlands, and perhaps also apply for other countries.

The main recommendation for future research relates to an expansion of the scope. Both definitions of the research subjects were narrower than how other scholars tend to define the subjects. Expanding the scope by explicitly widening the demarcation of the aforementioned dimensions allows for more key factors for future development and causalities to be discovered. It should be noted that one increases the complexity of the research by expanding the scope. This could require different methods or adaptations to the used methods in this study.

**Keywords:** vehicle automation, vehicle sharing, vehicle ownership, the Netherlands
List of Figures

Figure 1–The basic elements and resources of socio-technical systems according to Geels (2004).................................................................................................................. 10
Figure 2–Research framework .................................................................................................................. 10
Figure 3–Steps between data and explanation (adopted from Gläser & Laudel (2013)).................................................................................................................. 16
Figure 4–Scheme for car use in the tension between private and commercial use by Lenz & Fraedrich (2016).................................................................................................. 23
Figure 5–Absolute number of interviewees who opted for specific scenarios .......... 32
Figure 6–Key Factors determining AV utilisation .................................................................................. 36
Figure 7–Key Factors determining SV utilisation .................................................................................. 37
Figure 8–N1: The legacy delay ............................................................................................................. 39
Figure 9–N2: AV technology increases appeal of using vehicles in general .......... 39
Figure 10–N3: High utilisation of SVs speeds up adoption of vehicle automation technology .................................................................................................................. 40
Figure 11–N4: SAVs as automated taxies ............................................................................................. 41
Figure 12–N5: A ‘last mile’ solution ..................................................................................................... 42
Figure 13–N6: SAVs as solution for imbalanced sharing systems ............................................. 42
Figure 14–N8: AV technology makes driving safer and could thereby lower insurance costs .................................................................................................................. 43
Figure 15–Six notions relating to the extended ST-system perspective (Geels, 2004) ........................................................................................................................................ 64

List of Tables

Table 1–Literature study: keywords ......................................................................................................... 12
Table 2–Interviewees Grouping and Location .......................................................................................... 14
Table 3–Alignment among BASt, NHTSA and SAE levels of automation (Kyriakidis et al., 2015) .................................................................................................................................. 22
Table 4–Key Factors for future development of vehicle automation by Milakis, Snelder, et al., (2015) .................................................................................................................................. 25
Table 5–Key Factors determining future development of vehicle automation .......... 30
Table 6–Key Factors determining future development of vehicle sharing ................. 30
Table 7–Interpretation of Key Factors for vehicle automation ............................................. 36
Table 8–Interpretation of Key Factors for vehicle sharing ....................................................... 37
Table 9–Causalities: an overview ...................................................................................................... 45
Table 10–Literature comparison: case study vs. Milakis, Snelder, et al. (2015) ...... 47
Table 11–Literature comparison: case study vs. KiM Netherlands Institute for Transport Policy Analysis (2015b).................................................................................................. 48
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV</td>
<td>Automated vehicle</td>
</tr>
<tr>
<td>AVs</td>
<td>AVs (plural)</td>
</tr>
<tr>
<td>GT</td>
<td>Grounded Theory</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OEMs</td>
<td>Original Equipment Manufacturers (plural)</td>
</tr>
<tr>
<td>SAV</td>
<td>Shared automated vehicle</td>
</tr>
<tr>
<td>SAVs</td>
<td>Shared AVs (plural)</td>
</tr>
<tr>
<td>ST-system</td>
<td>Socio-technical system</td>
</tr>
<tr>
<td>SV</td>
<td>Shared vehicle</td>
</tr>
<tr>
<td>SVs</td>
<td>Shared vehicles (plural)</td>
</tr>
<tr>
<td>VA</td>
<td>Vehicle automation</td>
</tr>
<tr>
<td>VS</td>
<td>Vehicle sharing</td>
</tr>
</tbody>
</table>
1. Thesis Introduction

1.1. Research Subject: Vehicle Automation and Vehicle Sharing

Automated vehicles (AVs) have been at the centre of growing hype for quite some time.¹ Mounting expectations for this new technology have prevailed not only in popular media, but also in the academic world.² Predictions of when the technology will be ready—and what ‘ready’ even means in this case—are highly debatable.³ Buying into the buzz is tempting given some of the promises that have been made: for example, AVs will supposedly increase safety on public roads while decreasing traffic congestion, gas emissions, and fuel consumption (Anderson et al., 2014). Vehicle sharing is another phenomenon that is expected to transform personal mobility. It promises various benefits for society in general and for end users in particular. Firstly, it makes better use of idle vehicles and thereby lowers vehicle demand in general. Secondly, payments by vehicle sharing users are closely tied to actual vehicle usage because vehicle sharing transforms fixed costs of vehicle ownership into variable costs (Shaheen, Sperling, & Wagner, 1998). Thirdly, vehicle sharing addresses some of the classic problems of car ownership, such as ‘arranging permanent parking, vehicle inspection, maintaining insurance coverage and repair costs that can be both uncertain and large’ (Le Vine, Zolfaghari, & Polak, 2014).

Before getting carried away by the potential positive consequences of the two phenomena, let us first decide on correct and consistent terminology. Technological capabilities and human involvement are the main factors that determine the ‘level of automation’ for automated driving. Despite some variation, all definitions consist of a range from the manual driving mode to fully automated driving, which involves no manual interaction whatsoever (Kyriakidis, Happee, & De Winter, 2015).⁴ For consistency’s sake, in this report ‘automated driving technology’ refers to vehicle automation, and ‘AVs’ refers to vehicles with one or more automated functions. Contrary, the terminology of vehicle sharing—other than ‘automated driving’—has not been ‘standardised’. Terms even prove to be an ‘ongoing source of confusion for both industry professionals and end users’ (Le Vine et al., 2014). For consistency’s sake, ‘car sharing’ refers to vehicle sharing in the context of this thesis.⁵

At first sight, except for the dependency on a motorized vehicle, the two phenomena do not have that much in common. Vehicle automation is a technological novelty that many have been dreaming of for decades. In a decade or two, vehicle automation might actually become true. Vehicle sharing on the other hand, has actually


² See chapter 1 of (Milakis, Snelder, et al., 2015) for an overview of recent literature covering when automated vehicles will reach the market, how penetration rates will evolve and to what extent this new transport technology will affect transport demand and planning.

³ For a brief summarized overview of different expectations, see: http://www.driverless-future.com/?page_id=384.

⁴ Kyriakidis, Happee and de Winter (2015) list the most well-known definitions by: BASi, National Highway Traffic Safety Administration and SAE.

⁵ Replacing ‘car’ with ‘vehicle’ is an arbitrary choice.
been around for decades. In fact, its first emergence can be traced back to Switzerland in 1948 (Shaheen et al., 1998). The public perception of shared goods has changed over the past few decades. This change has mainly been driven by the global economic recession of 2008, a growing environmental consciousness, and the ubiquity of the Internet, which brings with it the associated information and communication technologies that make sharing possible at this scale (Cohen & Kietzmann, 2014).

Interestingly, recent strategic partnerships between car manufactures, car sharing companies and tech companies suggest that the two topics—vehicle automation and vehicle sharing—are not developing independently. Examples include but are not limited to: General Motors investing $500M in Lyft\(^6\), Toyota and Uber announcing a partnership\(^7\), and Volvo and Uber spending $300M to develop a fully automated vehicle that will be ready for the road by 2021\(^8\). Next, examples of companies explicitly combining vehicle automation and vehicle sharing can also be found.\(^9\) Academic research is starting to catch up. For example, replacing privately owned SVs with AVs could affect the traffic delays and parking demand in a city (Correia & van Arem, 2016). Simulation studies demonstrate that shared AVs (SAVs) have the potential to reduce generalised transport costs, satisfy more trips and result in overall beneficial emissions impact (see: D. Fagnant, Hall, & Kockelman (2014), Correia & van Arem (2016) and Greenblatt & Saxena (2015)). Aside from simulation studies, numerous separate studies on vehicle automation and vehicle automation have led to recommendations for policy makers (see: Anderson et al. (2014), D. J. Fagnant & Kockelman (2013) and Timmer, Pel, Kool, van Est, & Brom (2015)). Unfortunately, little effort has been made to conduct research into the long-term impact of vehicle automation on vehicle sharing and vice versa. Given that vehicle automation and vehicle sharing are still emergent industries, literature in the area of synergy between the two remains sparse (Greenblatt & Shaheen, 2015). Thus, I aim to contribute to a better understanding of the impact of vehicle automation on vehicle sharing and vice versa.

**1.2. Case study: The Netherlands**

Vehicle automation and vehicle sharing, as introduced above, are arguably relevant developments in respect of personal mobility. Here, I focus on the Netherlands as a case study, because the country offers rich examples for evaluation. Vehicle automation and vehicle sharing are at the centre of attention for the Dutch government, Dutch academics, and Dutch businesses. Below, I illustrate the attention from the two areas with examples.

The Dutch government aims to lead the pack in both fields. The government’s ambition in the case of vehicle automation is demonstrated by the Amsterdam Declaration, which was signed by all 28 EU member states on 14 April 2016.\(^10\) With this declaration, the Dutch government, the European Commission, and the EU

---


\(^9\) Tesla CEO Elon Musk announced ‘In cities where demand exceeds the supply of customer-owned cars, Tesla will operate its own fleet, ensuring you can always hail a ride from us no matter where you are’. Such a service would put Tesla in competition with ride hailing services such as Uber or Lyft. See: [http://www.reuters.com/article/us-tesla-masterplan-idUSKCN1002Q4](http://www.reuters.com/article/us-tesla-masterplan-idUSKCN1002Q4).

member states and transport industry pledged to draw up rules and regulations that would allow AVs—and even autonomous vehicles—to be used on the roads. Vehicle sharing is also high on the agenda for the Dutch government. The aim for 2018 is to have 100,000 SVs on Dutch roads.\footnote{11 See (in Dutch): https://www.rijksoverheid.nl/actueel/nieuws/2015/06/03/over-drie-jaar-honderdduizend-deelauto-s-in-nederland}

There is also a great deal of academic interest in both topics. Several Dutch research institutes have studied vehicle automation and vehicle sharing in recent years. The Delft University of Technology and KiM Netherlands Institute for Transport Policy Analysis have both conducted scenario studies on the topic.\footnote{12 See Milakis, Snelder, et al. (2015) for a scenario study of the Delft University of Technology and see KiM Netherlands Institute for Transport Policy Analysis (2015a) for a scenario study of the KiM Netherlands Institute for Transport Policy Analysis.}

The Netherlands does not house any of the big OEMs, apart from some manufacturing facilities for Tesla and Mini. However, several OEM suppliers are based in the Netherlands. As vehicle automation demands highly detailed maps, the Dutch company TomTom has partnered with several OEMs to ensure that their maps are used in future AVs.\footnote{13 See: https://www.wired.com/2015/07/tomtom-alive-getting-self-driving-cars/} Another Dutch supplier, NXP Semiconductor, has developed the computational resources needed to tie together all of the sensors found in an AV such as radar, cameras, and LiDAR.\footnote{14 See: http://fortune.com/2016/05/16/nxp-self-driving-car-bluebox/}

Focusing on the Netherlands for the purposes of this study is relevant and timely. Moreover, it is likely to result in state-of-the-art findings.

1.3. Research objective and deliverables

A knowledge gap can be drawn from the introduction above. The two research subjects are well grounded in literature, but research on the overlap of the fields is scarce. This suggest the need for greater understanding of vehicle automation and vehicle sharing, and their possible interdependencies. The objective of the research project is:

\textit{to gain insight into the potential impact of vehicle automation and vehicle sharing and vice versa, by critically reflecting on suggestions by experts.}

The primarily deliverable is one or more causal models that contain relevant factors and relationships that bridge vehicle automation and vehicle ownership. Depending on what is observed, conflicting models might also be possible. The aim of bringing together these relationships is to help shape future research in this developing area.

1.4. Relevance

Academic research into the impact of vehicle automation on vehicle sharing and vice versa is currently scarce.\footnote{15 See Milakis, van Arem, et al. (2015) for an elaborate literature study on the topic of vehicle automation.} The majority of the studies that have been carried out are quantitative in nature; a qualitative approach has not been applied in this conjunction of fields. Several scholars have simulated transport systems to explore
the possibility of automated vehicles to substitute conventional vehicles’ (Milakis, van Arem, & van Wee, 2015). Simulation models used in these studies are based on very specific assumptions, such as a constant for Vehicle Miles Travelled (VMT) (see, for example, Greenblatt & Saxena (2015)).

From a societal standpoint, there are numerous undesirable effects that can be observed in a largely car-based society. Together with aviation, the motor vehicle is the most damaging source of CO₂ emissions (Chapman, 2007). Next to the environmental effects, the sheer volume of vehicles in use also leads to loss of urban land. In order to facilitate the growing number of vehicles, we have drastically reshaped the urban environment, with large portions of city landscapes being devoted to highways and parking, as well as the service facilities that vehicle usage demands (Katzev, 2003). Traffic congestion is also an increasingly serious problem in many cities. Therefore, reducing the reducing the number of vehicles that society needs (by sharing vehicles) could be beneficial from both an environmental and a land-use perspective. Empirical studies demonstrate that individuals who make use of vehicle sharing systems tend to sell one or more or their cars (Cervero & Tsai, 2004); a ‘substantial’ shift (Martin, Shaheen, & Lidicker, 2010). In general, it can be said that ‘a reduction in vehicle ownership […] is likely to result in fewer vehicle miles travelled [VMT], reduced traffic congestion and parking demand, and an increase in the use of public transportation and other transport modes (such as cycling and walking) in lieu of car travel’ (Shaheen, 2006). Because of the potential societal benefits of an increase in vehicle sharing, the potentially positive relationship with vehicle automation renders exploration of this matter worthwhile.

1.5. Research questions

In line with my research goals, the identified knowledge gaps, and the exploratory nature of the study, the research question is formulated as follows:

RQ: What could be the impact of vehicle automation on vehicle sharing and vice versa?

(I) What definitions and factors are relevant when describing the impact of vehicle automation on vehicle sharing?

(II) According to literature and Dutch experts, what factors and concepts link vehicle automation and vehicle sharing?

A third question was added that relates to a plausible conceptual model; it combines both vehicle automation as vehicle sharing while remaining open to a changing context.

(III) In what way can the information gathered from the experts be combined into conceptual models of the impact of vehicle automation on vehicle sharing and vice versa?
1.6. Reading guide

The applied research approach and methods are described in chapter 2. Broadly, chapter 2 elaborates on the way in which the research questions are answered. The remainder of this thesis reports on the answers to the questions. Chapter 3 answers the first question: What definitions and factors are relevant when describing the impact of vehicle automation on vehicle sharing and vice versa? Chapter 4 answers the second question: According to literature and Dutch experts, what factors and concepts link vehicle automation and vehicle sharing? The third research question, regarding the interpretation and the discussion of the results, is considered in chapter 5 respectively 6. Chapter 7 and 8 answer the main research question and reflect on the chosen research approach. The blue text boxes found throughout this report highlight explicit choices made within the thought process that went in the research project.
2. Research approach & methods

This chapter is structured as follows: first, I list research requirements that translate from the research questions and literature study (2.1). Second, I explain my motivation for the underlying principles behind Grounded Theory as a starting point for a general methodology (2.2). From there, I elaborate on adopted theoretical perspective (2.3). The research requirements, the research methodology, and theoretical perspective are tied together in the research framework (2.4). The research framework consists of three phases: Phase 1: Concept exploration and (2.5), Phase 2: Case study (2.6), and
Phase 3: Description, interpretation and discussion (2.7). After outlining the phases and the applied methods, I return to the research methodology and explain in detail how the Grounded Theory was adapted for this project (2.8).

2.1. Research requirements

Based on the nature of the research question, research goal, and scope of the study, several requirements for the research approach were considered *a priori*:

- First and foremost, the purpose of this study is exploratory. As Milakis, van Arem, et al. (2015) point out: ‘the technology (especially higher levels of automation) is still in its infancy’. In contrast to established and widely used technology, I cannot test this hypothesis. Some of the technology discussed is not even available today. The novelty of the field calls for an explorative research approach rather than a descriptive or explanatory research approach.
- This second consideration is closely linked to the previous one. Within the research approach, qualitative research methods are used. As AVs are not widely used on public roads—hence the novelty of the field—quantitative data is scarce. Moreover, the research question also demands a qualitative approach.
- The third and final requirement relates to the uncertainty of both research subjects, and the research design must be able to cope with this uncertainty. As scenario studies point out, the possibilities seem endless. With regard to AVs, much information remains unknown, including when they will hit the market, how penetration rates will evolve, and to what extent these new transportation technologies will affect transportation demand and planning (Milakis, Snelder, Arem, Wee, & Correia, 2015). A similar observation might also apply to vehicle sharing. Existing research suggests that the embodiment of alternative consumption patterns—such as vehicle sharing—in everyday routines depends on institutional arrangements (regulatory and normative), on how the product–service systems are designed and applied in practice, and on the socio-cultural background of the society in which the systems are implemented in (Mont, 2004).

2.2. Grounded Theory: a general methodology

This research project aims to provide knowledge that contributes to closing the presented knowledge gap: exploring the potential impact of vehicle automation on vehicle sharing and vice versa. A research methodology that meets the requirements must be structured for this project. The principles from Grounded Theory (GT) form the starting point for meeting the above-mentioned requirements as GT fits the requirements in respect of qualitative research methodology. Adopted principles for this thesis are: keeping an open-mind as researcher, comparison of theories, and iteration between and within project phases.

These three principles of the GT approach are elaborated below.

- **Open-minded researcher**: this is also referred to as ‘theoretical sensitivity’. According to (Verschuren & Doorewaard, 2015), it implies that ‘the researcher is constantly alert and is not carried away by fantasy and creativity. Instead he or she must maintain a critical and sceptical attitude towards the development
of the theory at hand'. However, it should be noted that since there is great deal of theory available on the two research subjects separately, I do not assume that theory only materialises slowly during the course of this research. This assumption has implications for the applied methods for extracting information from data. Please refer to section 2.6 for a discussion on the matter.

- **Comparison of theories**: ‘the research technique associated with the GT approach is often referred to as the method of continuous comparison’ (Verschuren & Doorewaard, 2015). For this study, theories from the three research objects and adjoining fields were continuously compared. In addition to these theories, expert views from different fields were also compared: this resulted in a much richer comparison of theories.

- **Iterative nature**: when using such comparative methods, I am not limited to one method. Should I come across a theoretical explanation halfway through the research project, then I could return to interview reports or documents that were analysed earlier and take a fresh look at these, based on the explanation found, and new data can be acquired.

**Grounded Theory: methodology or method?**

Grounded Theory is a ‘general methodology’, according to (Strauss & Corbin, 1994). A methodology is about the principles that guide our research practice. The aim of GT is to develop *theory* that is *grounded* in data by systematically gathering and analysing data. For the purpose of this thesis, several principles from GT are applied. Methods refer the tools used in this project, for example: literature study and interviews.

The conception of GT dates back to 1965 and was developed by two sociologists: Barney Gläser and Anselm Strauss. Emphasis on theory development instead of theory validation differentiates GT from other qualitative research methodologies (Strauss & Corbin, 1994). The objective of GT, according to Gläser, is to let the theory ‘emerge’ from the data. Therefore, the researcher needs ‘theoretical sensitivity’; ‘he must have a perspective that will help him see relevant data and abstract significant categories from his scrutiny of the data’ (Kelle, 2007). A difference in opinion on this topic caused the two founders, Gläser and Strauss, to split and each start conducting research individually (Ralph, Birks, & Chapman, 2015).

---

16 See also chapter 3 in this respect.
17 Verschuren & Doorewaard (2015) list several examples of comparison techniques, such as: primary empirical comparison, secondary empirical comparison, primary theoretical comparison, secondary theoretical comparison, comparison of theories, deductive comparison, and indicative comparison.
Grounded Theory application: Gläser or Strauss?

Gläser emphasises emergence in GT, while Strauss is more interested in validation criteria and a systematic approach. I opt for Strauss’s approach because I cannot assume that theory only materialises slowly over the course of the research. Hence, a lot of theory is present at the start of this research (see chapter 3). For consistency’s sake, in this thesis, the GT methodology used by Strauss is referred to as simply ‘GT’.

2.3. Theoretical perspective

I use the extended socio-technical system perspective by (Geels, 2004) to relate the two research subjects to each other, while a theoretical perspective on the car mobility system allows for a more systematic assessment and proposal of recommendations for future research.

Geels (2004), among others, advocates the need for a systems approach that focuses on both the so-called production and user sides of innovation: socio-technical systems (ST-systems). Such systems encompass production, diffusion, and use of technology. According to Geels (2004), ST-systems consist of artefacts, knowledge, capital, labour, cultural meaning, etc. This ST-system view was deemed fit to integrate the two subjects because it forces us to look at vehicle automation and vehicle sharing as part of the same system. This focus on an ST-system forms a bridge between separate bodies of literature, in this case, the two research subjects. The conceptual model of that system consists of a production and application (i.e. technology-in-use) side, respectively, the production of artefacts and the use of artefacts in user practice. The ST-system frame is later used to interpret the findings of this first research phase. Secondly, I must form a perspective on how the subjects could be related. This perspective should enable us to integrate the three (rather different) research subjects into one cohesive system of causalities.

In addition to the ‘regular’ ST-system perspective, two analytical dimensions were added: rules and institutions on one hand, and human actors, organisations, and social groups on the other. Both are based on Geels (2004). Simply put, Geels (2004) distinguishes between three analytical dimensions: systems, actors and rules. I refer to this as the extended ST-system perspective. The extended ST-system perspective was selected for the following reasons. At first glance, automated driving could be viewed merely as a new technology. As Fraedrich, Beiker, & Lenz (2015) point out, a holistic approach is needed to be able to identify aspects that enable or constrain the implementation and adoption of full AVs in the future. Additionally, I pose two arguments that also call for a holistic approach: 1) considering AVs as merely a new technology that replaces the old one is rather simplistic, for two reasons: i) vehicle automation technology is not a single technology but a term that relates to a large group of new technologies and possibilities; ii) describing a technology becomes meaningful when considering its context. Hence: ‘artefacts only fulfil functions in

---

18 Applying the socio-technical system view in the context of vehicle automation is not a novelty. Based on the works of (Geels, 2005) a paper – discussing different scenarios of fully automated driving – adopts the ST-system approach for similar reasons: ‘(...) it is never technology alone [e.g. vehicle automation technology] that is able to induce a change in a sociotechnical system but rather the many complex interactions between societal groups, different actors as well as the alignment of specific factors’ (Fraedrich et al., 2015).

19 ‘Full’ meaning level 5 vehicle automation.
association with human agency and social structures’ (Geels, 2005); 2) the way in which I define vehicle automation also determines and limits the way in which the impact of the technology on vehicle sharing can be described. For these reasons, it is important to consider different formal models for describing car mobility and the context in which it exists.

![Figure 1–The basic elements and resources of socio-technical systems according to Geels (2004)](image)

2.4. Research framework

The intended result of this research project is to describe possible links between vehicle automation, vehicle ownership, and vehicle sharing. Formally, the goal of this research project is to find leads for future theory development based on the previously presented knowledge gap.

Therefore, I constructed a three-phased research framework based on the aforementioned characteristics (open-mined researcher, comparison of theories, and iterative nature).

![Figure 2–Research framework](image)
Although the research framework is presented as a process that flows like a waterfall, the simultaneous involvement in data collection and analysis is essential to GT (Charmaz, 1995). The emerging analysis shaped my data collection procedures, i.e. desk research and interviews.

**Combining GT and the extended ST-system perspective: a contradiction?**

The combination of using the Grounded Theory assumptions and selecting and applying the extended ST-system perspective *a priori*, might seem contradictory. After all, Grounded Theory assumes little to no knowledge when starting the research. The researcher should let the data speak for itself; results should ‘emerge’, whereas the adopted theoretical perspective frames the interview questions and the interview results. In other words: squeezing the interviews into a frame might result in fitting the data to a frame instead of letting frames arise from the data.

### 2.5. Phase 1: Concept exploration and demarcation

In order to determine definitions, I first broadened my scope by delving into the context and background of the subjects. Therefore, I conducted unstructured interviews and performed literature research in parallel. I elaborate on the way in which this was done, i.e. what was observed in this phase, which experts were consulted and exactly what documents and literature were studied. I steer my efforts by searching for an answer to sub-question (I):

(I) **What definitions and factors are relevant when describing the impact of vehicle automation on vehicle sharing?**

#### 2.5.1. Literature study

The output of the literature study consists of two types of information: formulating definitions of the research subjects and finding key factors for the future development of the subjects.

- **Formulating definitions of research subjects**: definitions and key factors are both essential to finding possible causalities between the subjects. Key factors drive or hinder the future development of the research subjects, which must first be defined. Definitions in turn determine the scope of the research project. The way in which the research subjects are defined (too precise, adequate, or too abstract), determines the number of key factors that are discoverable. For example: a very precise definition of vehicle automation leaves us with a very limited set of positive and negative factors that might influence this very specific form of vehicle automation. Thus, an overly precise definition leaves us with very few opportunities to link key factors and binds the research scope *a priori*.

- **Finding key factors for future development of research subject**: the search for key factors adds a layer to the search for causalities between the research subjects. Vehicle automation and vehicle sharing might not be related directly, but rather via several (key) factors.

The first part of the literature study began with the references in the study by (Milakis, van Arem, et al., 2015). Several online search engines were then used to find more relevant research articles. These search engines include: Scopus, JSTOR, and
Google Scholar. Keywords that were used as input for the searches include a combination of the following (see Table 1).

<table>
<thead>
<tr>
<th>Object of study</th>
<th>Vehicle automation</th>
<th>Vehicle ownership</th>
<th>Vehicle sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Keywords</strong></td>
<td>Automated driving</td>
<td>Car use</td>
<td>Car use</td>
</tr>
<tr>
<td>Autonomous driving</td>
<td>Travel behaviour</td>
<td>Sharing economy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peak car</td>
<td></td>
<td>Car sharing schemes</td>
</tr>
<tr>
<td>Self-driving vehicles</td>
<td></td>
<td></td>
<td>Business models</td>
</tr>
<tr>
<td>Driverless vehicles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robocars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drivers for growth</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criteria for selecting relevant articles out of the search query results were based on the specific relevance to the subject. In addition to regularly checking news websites, I enabled a ‘Google Alert’ in order to stay informed about the state of all three research objects throughout the study.20

The second part of the literature study was specifically based on three Dutch studies, including two scenario studies.21

### 2.5.2 Unstructured interviews

In addition to studying literature, I conducted interviews with experts in the field. The interviews in this first phase were unstructured. Interview contacts for an academic angle were first obtained from existing collaborators at Delft University of Technology (TU Delft). Additionally, the Netherlands Institute for Transport Policy Analysis (KiM) and Utrecht University were contacted to increase the diversity of the interviewees. Furthermore, interviewees in this phase were selected based on their predetermined willingness to participate and provide feedback. These interviewees were presumed to have more time and availability for additional questions outside of the original interview setting. These interviews were used to broaden the scope of the research, to see whether anything was missing from the literature study (see chapter 3), and to validate the concept topic list used for the case study. This first round also identified the first candidates for the second phase of interviews.

Phase 1 unstructured interviews were conducted with familiar participants that have similar interests to those who participated in Phase 2 interviews. This helped the interviewer to practice conducting interviews in general. A pilot test was conducted for the Phase 2 interview. This determined if there were any flaws, limitations, or other weaknesses in the interview design, and further allowed me to make the necessary revisions prior to the implementation of the study (Kvale, 2008).

---

20 See [https://support.google.com/alerts/answer/4815780?hl=en](https://support.google.com/alerts/answer/4815780?hl=en) for an explanation of the workings of Google Alerts. The same keywords as in the literature study were input for the Google Alert.

21 See (Milakis, Snelder, et al., 2015), (KiM Netherlands Institute for Transport Policy Analysis, 2015a), and (Steg, 2005).
2.6. Phase 2: Case study

Building on literature and expert knowledge, the objective of this study is to explore and to map the mental models of experts on vehicle automation and vehicle sharing. By conducting semi-structured expert interviews, I searched for the answer to sub-question II:

(II) According to literature and Dutch experts, what factors and concepts link vehicle automation and vehicle sharing?

What makes Phase 2 interviews a ‘case study’?
A case study is a ‘detailed examination of a single example’ (Flyvbjerg, 2006). For the purpose of this research project, the single example refers to the Phase 2 expert interviews. First, this series is geographically limited to experts based in the Netherlands. The interviews are all conducted within the timeframe of the research project—approximately six months. According to (Flyvbjerg, 2006) ‘a case study can be used in the preliminary stages of an investigation to generate hypotheses’; in this case, possible causalities between vehicle automation and vehicle sharing were explored. Second, the adopted theoretical perspective is both technical and social in nature. Hence, socio-technical system. As (Flyvbjerg, 2006) concludes: ‘social science has not succeeded in producing general, context-independent theory’. The knowledge generated in this research project thus depends on the Dutch context of the interviewees. By referring to the interviews as a case study, I emphasise this context-dependency.

2.6.1. Semi-structured interviews

In Phase 2, I conducted semi-structured interviews. This type of interview allowed me to encourage an informal conversation covering certain themes and questions. Semi-structured interviews allow for variation of questions from one interview to the other. In such interviews, the order in which questions are asked may vary also and is highly dependent on the flow of the conversation. My experience with conducting interviews for this research project confirmed the necessity of flexibility in conversation. See Appendix B: Topic list semi-structured interviews for the interview questions and themes.

Semi-structured interviews: balancing structure and exploration
For the case study, the semi-structured interview was chosen over the unstructured interview. A topic list served as a general guide which sought to cover the central theme: the potential impact of vehicle automation on vehicle sharing and vice versa. As a researcher, I was led by the major concerns or point of view of the interviewee. The combination of both matters is considered to be ‘the best means of securing the […] concerns of respondents’ (Wimpenny & Gass, 2000).

2.6.2. Selection of interviewees

The selection of interviewees was based on two criteria:
1. Interviewees should have expertise in field(s) of vehicle automation, vehicle sharing and/or car ownership, in various capacities;  
2. The interviewees should represent a variety of backgrounds. A variety of backgrounds is crucial for obtaining an understanding the different research objects and their interconnections. In other words, the emergence of a new technology—such as vehicle automation—‘is embedded in an existing sociotechnical system’ (Fraedrich et al., 2015).
Nineteen experts from planning, technology, research, insurance, and sales organisations in the Netherlands were interviewed (e.g., I&M—Ministry of Infrastructure and the Environment, RWS—Ministry of Transport, Public Works, and Water Management, KiM—Netherlands Institute for Transport Policy Analysis, RDW—National road traffic agency, Eindhoven University of Technology, Mercedes-Benz Netherlands, BMW Netherlands, Athlon Carlease).

The data, as presented in Chapter 4, are based on nineteen interviews. These interviews were conducted between 3 May 2016 and 17 June 2016. In this period, I travelled to each interviewee’s workplace to conduct interviews (Table 2).

Table 2–Interviewees Grouping and Location

<table>
<thead>
<tr>
<th>Background</th>
<th>Number of Interviews</th>
<th>Location</th>
<th>Notes</th>
<th>Audio recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>5</td>
<td>Berlin, Delft, Eindhoven, Utrecht</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Automotive</td>
<td>4</td>
<td>Amsterdam, Utrecht, Raamsdonksveer, Rijswijk</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Public policy</td>
<td>3</td>
<td>The Hague, Utrecht</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Insurance</td>
<td>2</td>
<td>Rotterdam</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Car lease</td>
<td>1</td>
<td>Utrecht</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Independent research organisation</td>
<td>1</td>
<td>Delft</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Implementing public body</td>
<td>1</td>
<td>Zoetermeer</td>
<td>Via Skype call on TU Delft Campus</td>
<td>1</td>
</tr>
<tr>
<td>Automotive supplier/tech</td>
<td>1</td>
<td>Delft</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Vehicle sharing</td>
<td>1</td>
<td>Rotterdam</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

2.6.3. Interview design

The topic list for the semi-structured interviews was designed based on the analytical distinction between three dimensions: (1) socio-technical systems, (2) actors and (3) institutions/rules. This is the theoretical perspective: the extended ST-system perspective. Socio-technical systems include both the supply side (innovations) and the demand side (user environment). Adoption of this theoretical framework, consisting of these three dimensions, offered a number of benefits:

- Considering the different dimensions a priori ensured a holistic approach to the interviews and desktop research.
- The framework facilitated fitting the interview data with the three dimensions a posteriori. This helped reveal the focus of the experts and the existing knowledge gaps in the field. Thus, frontloading the interview topic list with this perspective allowed for better analysis of the interviews.

Content-wise, the topic list that was used for the semi-structured interviews of Phase 2 consisted of three main topics. The topics basically boiled down to the
research subjects: automated vehicles, vehicle sharing, and the conjunction of both fields. The topic list was limited to one pager. Iteration and improvement on the concept original topic list was achieved by letting interviewees in Phase 1 review the topic list. Next, the interview notes and literature study (as presented in Chapter 3) helped improve the topic list.²²

Because vehicle sharing and ownership are the focal options for consumers within the scope of this thesis, they were grouped together. Topic A relates the left hand side of the ST-systems perspective; topic B relates to the right hand side of the ST-systems perspective.

2.6.4. Interview execution

Each interview started similarly: I kept very close to the topic list. As the interview progressed, the expert could freely elaborate on topics he or she deemed relevant. At the end of each interview, I reviewed the list to determine whether all of the topics were covered during the interview. At the close of every interview, the interviewee was asked to summarise his or her view on the possible relationship between vehicle automation, vehicle sharing, and vehicle ownership.

2.6.5. Handling interview data

These semi-structured interviews were transcribed. Based on prior personal experience, it seemed likely that some interviewees would elaborate on topics that were more relevant to certain questions. Information relating to a specific question could sometimes be scattered across different segments of the interview transcript. This is common practice with semi-structured interviews.²³

²² Please refer to Appendix C: Application of theoretical perspective in the topic list, for a detailed account of the application of the extended ST-system perspective in the topic list.
²³ See for example El Halabi, Doolan, & Cardew-Hall (2012).
2.7. Phase 3: Description, interpretation and discussion

The output of Phase 2 is qualitative data, consisting of interview notes and audio recordings; this is the interview data. In Phase 3, causal arguments are derived from the qualitative data. More specifically, Phase 3 can be broken down into three smaller steps: description, interpretation, and discussion. The process during which the complexity of the case study is reduced, and its relation to the other project phases, is displayed below (see Figure 3). This particular sequence of steps between interview data and answers to research questions was adopted from (Gläser & Laudel, 2013).

The primary activities of Phase 3 are elaborated on below:

- **Linking raw data to the research question**: The interview data that I worked with is directly linked to the research question because the data collection was guided by information requirements derived from the research question. More specifically, the topic list was frontloaded with the knowledge obtained in Phase 1, such as the theoretical perspective and the definitions (see section 3.1 for the latter). However, at the beginning of the analysis, the information contained in the texts was not systematically linked to the research questions or structured according to the theoretical background against which the research question was formulated. As previously mentioned, information relating to a specific question was sometimes scattered across different segments of the interview.

---

24 The cited Jochen Gläser is one of two authors of Gläser & Lauden (2013) and is not to be confused with Barney Gläser, one of the founders of Grounded Theory.
transcript. Qualitative data analysis typically begins with linking raw data in the texts to the research question, which includes identifying, locating, and structuring raw data (Gläser & Laudel, 2013). These operations are only analytically separable; in this case, the tasks were conducted simultaneously when texts were processed for the first time. The precise execution and results of this step can be found in Chapter 4’s ‘Case study: Descriptive results’.

- **Searching for patterns in the data**: this step is ‘crucially dependent on the analyst’s creativity and ability to recognize patterns in the data’ (Gläser & Laudel, 2013). I refer to this step as interpretation: I interpret the interview data in such a way that causal relationships become visible. The precise execution and results of this step can be found in chapter 5 ‘Case study: Interpretation’.

- **Integrating patterns**: ‘The first question is usually whether all patterns are in fact different or whether some of them can be merged into one’ (Gläser & Laudel, 2013). Having done this, integration means linking all of the data that had no part in the identification of patterns—such as key factors from the literature study—to these patterns. In this process, further conditions for the operation of mechanisms are added. Furthermore, it is very important that all cases and data that do not fit the patterns are fully explored. Full exploration is achieved by reflecting on literature and the theoretical perspective. Recommendations for future research are found in chapter 7.

In short, all aforementioned steps in Phase 3 work towards an answer the third sub-question (III):

(III) **In what way can the information gathered from the experts be combined into plausible conceptual models of the impact of vehicle automation on vehicle sharing and vice versa?**

### 2.8. Adaptation of GT: methodological considerations

Given that the research framework has been made explicit in the previous sections, I can now elaborate on the adaptation of GT principles in more detail. Adaptations and deviations from the Grounded Theory to a tailored research methodology are made explicit by contrasting the works by Hallberg (2006)25 with the thesis approach:

1. **Open sampling**: the aim is ‘to maximise variations in experience and descriptions by using participants from contrasting milieus and backgrounds’. This aim is reflected in the interview sample that varies from field of expertise and also domain (i.e. policy, academic or business). Because I limit my sampling to the two research subjects and three domains, I instead refer to semi-open sampling.

2. **Intensive interviewing** permits an in-depth exploration of a particular topic and goes beneath the surface of ordinary conversation. I also met this characteristic to the best of my capabilities. The topic list was designed around a few broad introductory questions that should be sufficient for an interview followed by relevant ‘probing and follow-up questions’.

---

25 The characteristics of GT as defined by Hallberg (2006) reflects his point of view. The way in which GT has been used and interpreted has changed significantly over the years (Ralph et al., 2015). The scope of the research project does not include long elaboration on the history of and changed perspectives on GT.
3. The open sampling, or in this case semi-open sampling, is later followed by theoretical sampling. The latter means that the emerging results determine the direction.

**Interviewee selection: pre-selection vs. emergence**

Nineteen experts from planning, technology, research, insurance and sales organisations in the Netherlands were interviewed in the Phase 2 of this study. A pre-selection was done based on the principle of ‘open sampling’: to maximise variations in experience and descriptions by using participants from contrasting milieus and backgrounds. The next step, according to GT, is to start ‘theoretical sampling’: emerging results start to determine the direction of inquiry and interviewee selection. This led to a more academic focussed interviewee sample. Details on the exact procedure and results can be found in chapter 4.

4. The fourth and fifth characteristic (hierarchical coding and generating categories from the data) relates to the most significant deviation from GT in this thesis. The coding characteristic was not applied; generating categories was partly applied for two reasons. First, because I have a personal interest the field of AVs and vehicle sharing, and since I am unexperienced in this type of research, it would be naïve to assume an *a priori* direction determined by my hypotheses and preconceptions. Second, the original idea of researchers who have freed their minds of any theoretical preconceptions whatsoever is impossible, regardless of experience in the field or with the research methodology. In fact, literature on vehicle automation, vehicle ownership and sharing was used as a starting point for this study. In fact, some scholars conclude that ‘the construction of theoretical categories, whether empirically grounded or not, cannot start *ab ovo* but have to draw on already existing stocks of knowledge’ (Kelle, 2007). Therefore, I deviate from the idea of omitting all prior knowledge; instead I actively search for literature in adjoining fields. Second, feeding categories into the interviews by use of a predefined topic list, coding the interview transcripts and subsequently generating categories from the data would result in a loop in which I partly ‘generate’ my own pre-conceived categories.

5. See point 4 for generating categories from data.

6. ‘Identification and verification of relations between emerging categories and between categories and their properties in the data ensure that these conceptual relationships are grounded in the data’ by (Hallberg, 2006). This is achieved by constantly comparing the interview data with prior interview data and literature data.

7. A core category determines and delimits the theoretical framework. This was achieved by choosing two categories: vehicle automation on one hand and vehicle sharing and ownership on the other. Vehicle sharing and ownership was combined into one category

8. ‘Detailed memo-writing during the entire analysis process requires writing down ideas, assumed associations, and theoretical reflections related to each of the emerging categories’. No deviations or notes are relevant here.
9. ‘Data collection proceeds until so-called theoretical saturation is achieved, which means that new data does not add new information’. This applies to the literature study and to the expert interviews.

Theory-ladenness of observations: emergence vs. theoretical sensitivity
The extent to which researchers should avoid all relevant material prior to the analysis of the data is a point of contention among grounded theorists. Given that many researchers focus their attentions in areas in which they have already accumulated some expertise, it is unrealistic to assume that they approach the phenomenon of interest as a clean slate. Instead, Goulding (1998) argues that it is more appropriate to recognise the prior knowledge of researchers, while employing an iterative process of literature review and data collection and analysis. For the purpose of this thesis, I follow Goulding and recognise the ‘theory-ladenness’ of observations and strived to be ‘theoretical sensitive’. This ‘utilization of existing theory is indirect and unsystematic’ (Gläser & Laudel, 2013). Please refer to chapter 6 for a first attempt of a systematic comparisons of pre-existing theory and interview findings.

2.9. Chapter conclusions

The research methodology—the principles that guide this research practice—borrows from Grounded Theory. These principles are secured in a research framework that consists of three phases. Additionally, over the course of the project, I collect and analyse data while ‘wearing a set of lenses’: this is my theoretical perspective. Within the mentioned phases, different methods were used to collect and analyse data; the research methods.

The way in which the research framework was designed determines the way in which research was both grounded in theory and open to unexpected findings. It ensures iteration between literature and case study and it allows for comparison between the two groups of results: literature and case findings. Unstructured interviews of Phase 1 improved the literature study in the same phase. The same literature study grounds the topic list in theory, which was used in the following Phase 2.
3. Concept exploration and demarcation

In this chapter I report and conclude the first phase of the research project; Phase 1: Concept exploration and demarcation. In this phase, I answer the first sub-question: what definitions and factors are relevant when describing the impact of vehicle automation on vehicle sharing? I started by studying the subjects independent of each other and asking two questions. First, how can vehicle automation and vehicle sharing be defined? The answers can be found in section 3.1. Second: what factors drive or constrain vehicle automation and vehicle sharing? These answers can be found in section 3.2. Insights from unstructured interviews have indirectly contributed further detail and dimensions to the definitions of the subjects. During every unstructured interview, I asked for supporting literature. Suggestions were later used to improve upon the first two sections of this chapter (see 3.1 and 3.2). This chapter concludes with findings from the unstructured interviews that are valuable for this research project, but do not directly relate to definitions or factors (3.3).

3.1. Definitions of research subjects and adjoining concepts

In conjunction with the thesis requirements, I formed workable definitions of the research subjects. I also included ‘vehicles’ and ‘ownership’ in the search for definitions because these concepts are inseparable from the research subjects. Defining the meaning of the research subjects was important, as the interpretation of the subjects directed the rest of the research process.

Studied definitions are first and foremost valued for their assumed usefulness in the case study. Hence, the results of Phase 1 serve as input for Phase 2. Defining and consequently understanding these subjects is the first step in designing adequate interview questions for the Phase 2 interviews. This means that, given the explorative nature of the research and the novelty of the field, definitions should allow for a certain degree of flexibility.

3.1.1. Definition of vehicles

In this research project, private automobiles or motor vehicles are the focal point. Therefore, public transport is a priori excluded from the scope. The essence of a vehicle is captured by European legislation, which is in force in the Netherlands. According to Article 3, section 11 of directive 2007/46/EC from the European Parliament and the Council, a motor vehicle is understood to be the following:

**Vehicle:** ‘means any power-driven vehicle which is moved by its own means, having at least four wheels, [...] with a maximum design speed exceeding 25 km/h’ (European Parliament & Council of the European Union, 2007).

3.1.2. Definition of vehicle automation

Vehicle automation, for the purposes of this project, relates to private transport of individuals only. Public transport and transport of goods is not included within this scope.

---

26 The removed phrase ‘being complete, completed or incomplete’ relates to stages of type approval and was not considered relevant in for the definition of a motor vehicle.
Much has been said about the definitions of autonomous and automated vehicles. Directly following the adverb ‘fully’, both adjectives ‘autonomous’ and ‘automated’ seem to be used to describe the same thing: a human driver is no longer be needed to drive a car to its destination.\(^{27}\)

Scholars use both adjectives quite often. A swift search query into the ScienceDirect online database for journal articles using the keywords ‘autonomous driving’ and ‘automated driving’ returned 295 and 188 results, respectively, since 2010. Thus, it seems that ‘autonomous’ is scholars’ preferred adjective. Some scholars simply choose ‘autonomous’ over ‘automated’ because usage of ‘autonomous’ is more widespread (Chang, Healy, & Wood, 2012). Other authors do make a clear distinction between autonomous driving and automated driving.

A distinction between ‘autonomous’ and ‘automated’ is made by Milakis, Snelder, et al. (2015)–in this case defined by technology. In their paper, they argue that the development of automated vehicles takes place along two axes. One axis is the manual to automated axis that describes ‘the extent to which the human driver monitors the driving environment and executes aspects of the dynamic driving task’. This relates to the classification by institutes that I return to shortly. The second axis encompasses the ‘autonomy’ of the vehicle. It ‘describes the extent to which vehicles can communicate and exchange information with other vehicles (V2V) or with the infrastructure (V2I)’ (Milakis, Snelder, et al., 2015).

### Automated vs. autonomous vehicles: a semantic discussion

For Maurer, Gerdes, Lenz, & Winner (2016), a ‘special perception of Kant’s concept of autonomy’ came to be of importance in understanding ‘autonomous driving’. In general, autonomy serves as a starting point and is defined as ‘self-determination within a superordinate (moral) law’. According to the authors, in case of autonomous driving, this means that ‘man lays down the moral law by programming the vehicle’s behaviour’. They conclude that an ‘autonomous’ vehicle is a vehicle that must continually make decisions about how to behave in traffic in a manner consistent with the rules and constraints within which it was programmed (Maurer et al., 2016). When they ask experts from diverse disciplines for approval of this definition, the responses they receive range from complete rejection to carefully considered approval. To my knowledge, institutes that have attempted to define autonomous or automated driving have all preferred the use of ‘automation’. As Kyriakidis et al. (2015) point out, attempts by the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt), the U.S. National Highway Traffic Safety Administration, and the privately owned SAE Institute use a similar classification system. Because of this preference and the clear connection to the level of vehicle automation, as depicted in the table below, I chose for ‘automation’ instead of ‘autonomous’.

---

\(^{27}\) I am aware that several alternative terminology is being used in scientific literature to refer to the same concept, such as: self-driving vehicles, driverless vehicles, robocars, and variations to the aforementioned. These alternatives were not omitted from the research but were used as keywords in the literature study. However, I do not think that going into detail on each of these terms and their definitions would contribute to the clarity of the scope in this part of the thesis. See for a rather fun read on this matter: [http://www.theatlantic.com/technology/archive/2016/03/what-should-we-call-self-driving-cars/471711/](http://www.theatlantic.com/technology/archive/2016/03/what-should-we-call-self-driving-cars/471711/). Furthermore, ‘driverless’ vehicle was deemed unfit because it includes all vehicles that do not require a driver at the steering wheel. For example, this also includes remote-controlled vehicles (Kröger, 2016).
Adapted from the works of Kyriakidis et al. (2015), Table 3 was generated based on these three classifications.

Table 3—Alignment among BAS, NHTSA and SAE levels of automation (Kyriakidis et al., 2015)

<table>
<thead>
<tr>
<th>Source</th>
<th>Levels of automation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 0(^{28})</td>
</tr>
<tr>
<td>BAS</td>
<td>Driver Only</td>
</tr>
<tr>
<td>NHTSA</td>
<td>No Automation</td>
</tr>
<tr>
<td>SAE</td>
<td>No Automation</td>
</tr>
</tbody>
</table>

Considering the aforementioned expert opinions, I choose to use ‘automated’ driving as defined by SAE because it is highly usable in the context of this thesis. The high usability is based on several arguments. First, I agree with (Chang et al., 2012) that the term ‘automated’ driving in and of itself is arguably ‘more accurate’ than ‘autonomous’. Since I consider all levels of automation in this thesis, using the adverb ‘autonomous’ for vehicles that are not fully automated is not adequate.\(^{29}\) Secondly, the SAE classification delineates the concept adequately: the domain is vehicle automation and the assertion consists of the degree of automation over six levels. The second axis, defined by (Milakis, Snelder, et al., 2015) as ranging from autonomous to communicative, is not included in the definition of vehicle automation. The main reason for this exclusion is to keep the definition simple in order to avoid misunderstanding during Phase 2 interviews.\(^{30}\) Apart from the delineation and the operationalisation in Phase 2, the third requirement—the definition must relate to the research objective and research questions—is met by the search for definitions themselves. Consequently, for the purposes of this research project, vehicle automation is defined as follows:

**Vehicle automation (VA):** the six levels of (private) vehicle automation, which span from no automation (Level 0) to full automation (Level 5) (SAE On-Road Automated Vehicle Standards Committee, 2014).

3.1.3. Definition of vehicle sharing

Although ‘carsharing’ or ‘car sharing’ is the term preferred by scholars, institutes and media, I choose to use ‘vehicle sharing’. A ‘vehicle’, for the purposes of this thesis, is understood to be an automobile or car that is used for private mobility. The reason

---

\(^{28}\) Phase 1 and 2 interviewees omit level 0 in their answers and talked about the five levels of automation. I can think of two explanations. One, the interview topic was vehicle automation and level 0 simply does not address any form of automation. Two, modern-day cars are almost always fitted with one or more systems that enable level 1 automation or higher (i.e. Electronic Stability Control). Thinking about cars without such systems would probably mean taking a step back in history, instead of looking forward.

\(^{29}\) From Phase 1 interviews it became clear that most interviewees refer to the levels of automation as defined by SAE.

\(^{30}\) Communication of vehicles could turn out to be a factor of relative importance in relation to the research subjects according to experts. In such case, this is included in the results of Phase 2.
for deviating from the norm is consistency in terminology: the research subjects all consist of a combination of the words ‘vehicle’ and a characterising adverb (automation, sharing, and ownership). Hence, vehicle sharing in this thesis and carsharing in general are understood to relate to the same concept, unless explicitly stated otherwise.

Carsharing: a semantic discussion
Before considering different attempts to define ‘carsharing’ by scholars and institutes, it should be noted that there has been debate about the correctness of the term ‘carsharing’. What many consider ‘carsharing’ does not actually involve sharing among peers without any profits (strictly sharing), but rather involves commercial enterprises whose businesses do not involve any sharing at all (Eckhardt & Bardhi, 2015). ‘Worldwide, individuals generally access ‘carsharing’ vehicles by joining an organisation that maintains a vehicle fleet in a network of locations’ (Shaheen & Cohen, 2013). For the purpose of this thesis, I only consider the commercial side of carsharing.

Figure 4 illustrates a distinction between commercial and private vehicle usage. In this project, both commercial applications—taxi and rental—are not considered to fit the vehicle sharing umbrella. Thus, vehicle sharing for the purpose of this research project does not cover taxi nor rental services. However, although the distinctions made in Figure 4 might be valid at present, future developments might challenge their validity.

Figure 4–Scheme for car use in the tension between private and commercial use by Lenz & Fraedrich (2016)

The principle of ‘carsharing’ seems simple: ‘individuals gain the benefits of a private vehicle without the costs and responsibilities of ownership’ (Shaheen & Cohen, 2007). In the case of a family car, this principle would only apply to the non-owners like teenage kids, not to the parents who oftentimes actually own the car. 31 I begin by considering some definitions used by scholars, followed by attempts at definition by institutes.

According to (Le Vine et al., 2014), the terminology of ‘carsharing’ has never been standardised. The study does, however, provide a list of several general

---

31 In the case of a family car, this principle would only apply to the non-owners like teenage kids, not to the parents who oftentimes actually own the car.
characteristics, from which I draw to indicate what is and what is not considered carsharing for the purpose of this thesis.

• ‘The vehicle is driven by the end user as in traditional car hire (i.e. not a paid chauffeur, as in a taxi)’. This characteristic distinguishes carsharing clearly from services that include a driver, such as Uber (Meelen & Frenken, 2014).
• ‘Usage is billed in time increments of minutes or hours, and sometimes also on the basis of distance travelled’. Variable factors, especially, are commonly used to charge users. This exemplifies the pay-per-use principle.
• ‘There may be a one-time sign-up fee or an annual subscription fee, in addition to time-based and/or distance-based charges’.
• ‘Usage is in some cases spontaneous and in others reserved in advance’.
• ‘The vehicles are typically available from distributed locations across a service area, in contrast to traditional car hire in which vehicles are accessible only from a small number of storefront or airport locations’. This characteristic is refined by (Ferrero, Perboli, Vesco, Caiati, & Gobbato, 2015) in their efforts to categorise research works, and is divided into three categories: two-way (station-based), one-way (station-based), and free-floating. Two-way means that the available cars are parked in defined spaces and that the journey must start and finish in the same parking lot. The set of parking lots is predefined. One-way is similar, but the parking lot in which the journey finishes can be different from the parking lot in which it began. Again, the set of parking lots is predefined. The last category, free-floating, means that the cars are freely parked in public spaces within the operational area. The journey can start and finish in any point within this area.

So, for the purpose of this thesis, I conclude that vehicle sharing is understood to be some kind of service in which the end user drives the vehicle, usage is billed based mainly on variable costs, there might be a periodic subscription fee, usage can be spontaneous or planned and reserved, and vehicles are typically available from distributed locations.

Similar to AVs, institutes have also attempted to define vehicle sharing. The CarsSharing Association defined ‘carsharing’ back in 2011:

‘Carsharing is a membership based service available to all qualified drivers in a community’ (Car Sharing Association, 2011).

This definition does not add any detail to the aforementioned thesis definition of vehicle sharing, except for a ‘membership’. Vehicle sharing is thus defined as an umbrella concept that can take various shapes and forms—especially from a business model perspective—and is defined by a set of specific characteristics that are not considered vehicle sharing in this project. Its success may be defined as the its ratio of shared vehicle users to vehicle ownership.

Delineation for ‘vehicle sharing’ proves to be much more difficult than ‘vehicle automation’. Its domain could be defined by its business models (Cohen & Kietzmann, 2014) and by its environmental and social purpose (Car Sharing Association, 2011). Given the explorative nature of the study, defining a very narrow concept of vehicle
sharing *a priori*, by, for example, limiting the scope to only one specific business model, is not desirable. However, a usable initial definition was formulated:

**Vehicle sharing:** some kind of service in which the end-user drives the vehicle, usage is billed predominantly based on variable costs, there might be a periodic subscription fee, usage can be spontaneous or planned and reserved, and finally vehicles are typically available from distributed locations, specifically excluding ride sharing and carpooling.

### 3.1.4. Definition of vehicle ownership

For the purpose of this thesis, vehicle ownership is defined as the opposite of vehicle sharing.

**Vehicle ownership:** a vehicle owner has the exclusive right to use a private vehicle. This user is mainly responsible for paying the total costs of ownership, including fixed and variable costs such as purchase price, tax, insurance and fuel.

### 3.2. Key factors for future development

This section reports to the second part of the literature study: the search for key factors for future development of the two research subjects. Hence, vehicle automation and vehicle sharing might not be related directly, but rather via several (key) factors. The future development of vehicle automation and vehicle sharing does not happen overnight; rather, it depends on several factors. Such key factors have been well documented by scholars, as delineated below.

#### 3.2.1. Vehicle automation


**Table 4—Key Factors for future development of vehicle automation by Milakis, Snelder, et al., (2015)**

<table>
<thead>
<tr>
<th>#</th>
<th>Key factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AV technology trials</td>
</tr>
<tr>
<td>2</td>
<td>Interoperability among AV technologies</td>
</tr>
<tr>
<td>3</td>
<td>Costs/benefits of AV technology</td>
</tr>
<tr>
<td>4</td>
<td>Development of AV in EU</td>
</tr>
<tr>
<td>5</td>
<td>AV ownership structure (public vs private)</td>
</tr>
<tr>
<td>6</td>
<td>Transition steps</td>
</tr>
<tr>
<td>7</td>
<td>Incidences</td>
</tr>
<tr>
<td>8</td>
<td>Energy, emissions</td>
</tr>
<tr>
<td>9</td>
<td>Legal/institutional context (national and European)</td>
</tr>
<tr>
<td>10</td>
<td>Public/private expenditures on infrastructure</td>
</tr>
<tr>
<td>11</td>
<td>Stability of policies</td>
</tr>
<tr>
<td>12</td>
<td>Accessibility, social equity</td>
</tr>
<tr>
<td>13</td>
<td>Psychological barriers (Citizens and customers)</td>
</tr>
<tr>
<td>14</td>
<td>Marketing/image of AV</td>
</tr>
<tr>
<td>15</td>
<td>Attitudes towards AV</td>
</tr>
<tr>
<td>16</td>
<td>Income</td>
</tr>
</tbody>
</table>
Additionally, the study by (Milakis, Snelder, et al., 2015) identifies five ‘driving forces’. The study identifies technology and policies as the most influential driving forces. Since the study selects these driving forces to build their scenario matrix, I assume that these driving forces are external to their perceived system.

In a similar exercise, the KiM–Netherlands Institute for Transport Policy Analysis selected technology and the degree of sharing car ownership and car trips as the most influential driving forces. The KiM emphasis the high impact and uncertainty of both factors. The KiM is a governmental research body and may not consider policies less unpredictable than the study by (Milakis, Snelder, et al., 2015).③

Nonetheless, it can be concluded that technology will have a high impact and that its development is highly uncertain, according to both studies. Moreover, the degree to which policies support AVs and the amount of shared car ownership and car trips is both influential and uncertain, though possibly to a lesser extent than the technology itself.

### 3.2.2. Vehicle sharing

Development of vehicle sharing has been extensively studied and summarised by the KiM–Netherlands Institute for Transport Policy Analysis.

<table>
<thead>
<tr>
<th>Key factors for vehicle sharing (KiM Netherlands Institute for Transport Policy Analysis, 2015b):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Political and administrative support from the municipality.</td>
</tr>
<tr>
<td>2. Big fleet size and variety of vehicles and providers, oftentimes in combination with highly urbanised development.</td>
</tr>
<tr>
<td>3. Ease of use. This is increased by quick access to the shared vehicles via apps and automatic payment of parking fees, among other things.</td>
</tr>
<tr>
<td>4. Coordination and integration of the vehicle sharing to public transport.</td>
</tr>
<tr>
<td>5. Marketing and profiling.</td>
</tr>
</tbody>
</table>

### 3.2.3. Vehicle use

Determinants for vehicle ownership have been very thoroughly investigated. For example, vehicle ownership can be determined by the following factors: income, the costs of vehicle ownership and use, and the sociodemographic characteristics of households (Dargay, 2002). In this case, we derive initial determinant factors from the works of Steg (2005) since her study is based on two questionnaire studies conducted in the Netherlands. The motives for care use, which relates to the right hand side of the ST-system perspective, were based on the idea of material possessions, such as vehicles. Three main categories of factors were used: instrumental, symbolic, and affective factors determining vehicle use (Steg, 2005). These categories are summarised below:

③ Neither one of the studies explicitly states why ‘driving forces’ or ‘uncertainties’ were not selected, but only the ones that did.
3.3. Unstructured interviews: findings

In this first series of interviews, I interviewed seven experts (see Appendix A: List of Participants in explorative interviews). These interviews were used to: broaden the scope of the research, see whether anything was missing from the literature study, and validate the concept topic list used for the case study in the second phase. This first round also assisted in the identification of the first candidates for the second phase of interviews.

Except for one interview, all interviews were conducted in person and on location. The interviews lasted from half an hour up to a full hour. Although I used a working concept of the topic list, it was not very strictly adhered to. A loose approach led to differences in duration, topics, and depth.

3.3.1. Broadening scope

The following points each deal with one topic regarding vehicle automation, vehicle sharing, or a relating field. I return to these topics in the discussion of the case study in the chapter 5.4. Interview transcripts are available on request.

- **Mixed traffic makes vehicle automation difficult**: Mixed traffic occurs when AVs and manually driven vehicles mix in everyday traffic. Technically speaking, programming AVs to drive on dedicated roads is fairly simple. However, anticipating and reacting to pedestrians, cyclists, and manually-operated vehicles is very complex.

- **Trend or hype**: Both vehicle automation and vehicle sharing could be little more than hype. Both developments are still in their infancy. There are no large numbers of automated vehicles nor SVs on the roads today. Vehicle sharing especially is regarded as a niche.

3.3.2. Improving the Phase 2 topic list

From Phase 1 interviews and two scenario studies, it became clear that different transition pathways could help ‘warm up’ the interviewees without restricting the conversation. In other words: to facilitate free flow of thoughts on the topic at the start of the interviews. The three pathways as defined by (Fraedrich et al., 2015) were chosen because of their relative simplicity and their unique fit within the adopted ST-systems perspective by (Geels, 2004).

S1. **Evolution** of personal mobility: the vehicle will be complemented with technology assistance and the eventual replacement of the driver.

---

**Key factors for vehicle use** (Steg, 2005):

1. **Instrumental motives**: may be defined as the convenience or inconvenience caused by car use, which is related to, among other things, its speed, flexibility and safety.

2. **Symbolic or social motives**: people can express themselves and their social position by means of (the use of) their car, they can compare their (use of the) car with others and to social norms.

3. **Affective motives**: refer to emotions evoked by driving a car, i.e., driving may potentially affect people’s mood and they may anticipate these feelings when making travel choices.
S2. **Revolution** of personal mobility: to induce a fundamental change in how individuals use personal mobility by players with a background in internet search and online services business.

S3. **Transformation** of personal mobility: aims at reinventing personal mobility by combining the advantages of the personally used automobile and public transportation, addressing the ‘last mile’ problem.

**Scenario question: breaking the ice or influencing the interviewee?**

Adding the scenario question to the topic list creates a dilemma. From the explorative interviews I learned that it was oftentimes necessary to give the interviewee some context and directions. In other words: ‘to break the ice’. On the other hand, the interviewee might be limited in his or her answer when asked for elaboration on scenarios selected by the interviewer. In doing so, the interviewer invites the interviewee to step in his or her frame instead of the other way around. However, in the end I think my choice for including scenarios in the topic list was justified for two reasons:

1. Without these scenarios a substantial number of interviews would have ended prematurely and resulted in no impact of vehicle automation on vehicle sharing nor vice versa.
2. I did not design the scenarios myself, instead the scenarios were derived from a previous study by other scholars. These scenarios do not reflect any personal beliefs and if so, only by coincidence.

### 3.4. Chapter conclusions

In this chapter, I reported on the search for answers to the first sub-question, and thereby conclude on the first phase of the research project. I searched for definitions and factors that might be relevant for describing the impact of vehicle automation on vehicle sharing and vice versa.

Based on the literature study and the unstructured interviews, I was able to narrow down the scope and define vehicle automation, vehicle sharing, and two adjoining concepts. Vehicle automation is defined by the six levels of (private) vehicle automation, which span from no automation (Level 0) to full automation (Level 5). Other technological capabilities such as communication with other vehicles or infrastructure are not included in the scope of the study. Vehicle sharing is considered to be a business to consumer type of service. Peer-to-peer and other private sharing schemes are excluded from the scope. The reason for this limited scope is mainly practical. Conducting interviews takes a lot for time and the total project time totals approximately six months. See chapter 8 for reflection on the interviews.

Key factors for the development of the research subjects are the second deliverable from Phase 1. These key factors are used to discuss the findings of the case study in chapter 6.

The unstructured interviews presented me with some lose ends. I will come back to these findings in chapter 6 and 7, when discussing the results of the case study. The unstructured interviews also resulted in adding the scenario question to the topic list. This alteration of the topic list proved to be very useful. See chapter 4 in this respect.
4. Case study: Descriptive results

In this chapter I report on the second phase of the research project: the case study, specifically the descriptive results. Over the course of several months, I interviewed experts in the fields of vehicle automation and vehicle sharing in the Netherlands. This chapter follows the structure of the interviews. These interviews began by exploring the future development of vehicle automation as well as the future development of vehicle sharing. This was achieved by asking experts to identify several key factors (4.1) that were essential, in their view, to the future development these developments. I then presented the experts with three predefined scenarios (4.3) and asked what they deemed was the probability of each scenario’s realisation. Additionally, depending on the time, pros and cons of each scenario were discussed. Finally, from this ‘warm-up’ we moved to the core of the interview: possible causalities between the research subjects (4.4). Reporting on the perceived causalities closely follows the interviews, while result interpretation and analysis is discussed in the following chapters.

4.1. Interview execution

Except for interviewee number 3, all interviewees were working in the Netherlands at the time of the interview.\(^{33}\) The semi-structured interviews proved more difficult to arrange than the explorative interviews, especially with regard to experts in business. Eventually, I managed to interview 9 out of 19 experts from a business perspective.\(^{34}\) Except for interview number 19, no companies currently active in vehicle sharing were willing to participate.

As previously mentioned, the data collection proceeds until the so-called ‘theoretical saturation’ is achieved. This means that new data does not add new information; because data was derived from a literature study and expert interviews, the theoretical saturation criteria was applied to both. The point of saturation is a subjective decision as one can never know if further interviews would yield more information. In the absence of an objective criterion, Hallberg, (2006) advises ‘not to start theoretical sampling too early in the data collection process. Rather, the researcher should continue open sampling to maximise variations, and theoretical sampling should be used later in the process’. Open sampling refers to maximising variations in experiences and descriptions by using participants from contrasting milieus and backgrounds. Additionally, I adopted the theoretical perspective a priori. By frontloading the topic list with different analytical dimensions, I ensured additional variation in descriptions that interviewees gave. The perspective also enabled me to reveal the direction of the theoretical sampling ex post.

4.2. Key factors for future development

The semi-structured interviews started by exploring the future development of both research subjects independently. The interviewees generated eight key factors for the future development of vehicle automation and eight key factors for the future development of vehicle sharing (4.2.1 and 4.2.2, respectively). According to the interviewees, the key factors they identify are central themes in determining the

---

\(^{33}\) Since question A IV of the topic list for Phase 2 is based on the works of Fraedrich et al., (2015) I asked the authors for an interview.

\(^{34}\) This number includes Carlo van de Weijer who works for both Eindhoven University of Technology and at TomTom.
development of vehicle automation. Interviewees were asked for both enabling and restraining factors. I grouped factors relating to the same or similar topics together. There are eight of each factor group, which is a mere coincidence.

4.2.1. Vehicle automation

It is considered that the future development of vehicle automation will be determined by the eight key factors listed below (Table 5). The key factors are ordered (#) by the number of interviewees that have mentioned them (Entries).

Table 5–Key Factors determining future development of vehicle automation

<table>
<thead>
<tr>
<th>#</th>
<th>Key Factor</th>
<th>Entries</th>
<th>Description according to experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Legislation</td>
<td>12</td>
<td>New national legislation should be adopted in order to accommodate AVs. Besides, harmonisation of legislation throughout the European Union was also mentioned several times within the context of legislation.</td>
</tr>
<tr>
<td>2</td>
<td>Liability</td>
<td>6</td>
<td>This relates to the question: who will be responsible (or: liable) when an AV crashes?</td>
</tr>
<tr>
<td>3</td>
<td>Consumer Acceptance</td>
<td>5</td>
<td>Consumer acceptance of new technology relates to the question: will consumers embrace AV technology? One expert explicitly pointed to the Technology Acceptance Model.</td>
</tr>
<tr>
<td>4</td>
<td>Safety</td>
<td>5</td>
<td>Will AVs ever be safe enough? An incident or accident with an AV can change public opinion of AVs.</td>
</tr>
<tr>
<td>5</td>
<td>Technological Development</td>
<td>4</td>
<td>Will fully AVs become reality or remain science fiction? Future automated driving on highways seems realistic, while city driving seems far less so. In others words: what is the highest achievable level of vehicle automation?</td>
</tr>
<tr>
<td>6</td>
<td>Legacy</td>
<td>3</td>
<td>Vehicles currently on the roads will have to be replaced by fully AVs or updated with automated driving capabilities.</td>
</tr>
<tr>
<td>7</td>
<td>Mixed traffic</td>
<td>2</td>
<td>Mixed traffic relates to the interaction between manually driven vehicles, cyclists, pedestrians and AVs. Anticipating human behaviour in traffic situations proves to be highly challenging from a technological standpoint.</td>
</tr>
<tr>
<td>8</td>
<td>Purchase Costs</td>
<td>2</td>
<td>Adding the required technology to vehicles also adds costs.</td>
</tr>
</tbody>
</table>

4.2.2. Vehicle sharing

For the other subject—the future development of vehicle sharing—interviewees also identified eight key factors (Table 6). The key factors are ordered (#) by the number of interviewees that mentions them (Entries).

Table 6–Key Factors determining future development of vehicle sharing

<table>
<thead>
<tr>
<th>#</th>
<th>Key Factor</th>
<th>Entries</th>
<th>Interpretation by experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accessibility of SVs</td>
<td>9</td>
<td>Relates to the question of whether the sharing service is easy to use or user friendly.</td>
</tr>
<tr>
<td>2</td>
<td>Availability of SVs</td>
<td>5</td>
<td>Having a free vehicle available nearby whenever the user pleases.</td>
</tr>
</tbody>
</table>

35 The Technology Acceptance Model (TAM) models how users – in this case consumers – come to accept and use technology. Consumers will only accept new technology under certain conditions. Since its genesis the TAM has been extended – see TAM 2 (Venkatesh & Davis, 2000).
<table>
<thead>
<tr>
<th></th>
<th>Privately Owned Vehicle as Status Symbol</th>
<th></th>
<th>The privately owned vehicle as status symbol; an expression of identity, autonomy and individuality (Gartman, 2004).</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Urbanisation</td>
<td>4</td>
<td>The increase in the proportion of people living in towns and cities.</td>
</tr>
<tr>
<td>5</td>
<td>Critical number of SVs available</td>
<td>3</td>
<td>The minimum number of SVs needed for successful adoption by the public. This relates to the availability of SVs.</td>
</tr>
<tr>
<td>6</td>
<td>Access-based consumption mind-set</td>
<td>3</td>
<td>Market mediated transactions where no transfer of ownership takes place (Bardhi &amp; Eckhardt, 2012). Relates to a presumably changing preference of the general public when choosing to make use of a shared vehicle instead of owning a vehicle.</td>
</tr>
<tr>
<td>7</td>
<td>Parking costs and space</td>
<td>3</td>
<td>Parking a privately owned vehicle can be difficult due to high parking costs and scarce parking space. Shared vehicle services oftentimes are free to park and/or make use of reserved parking spots. This relates to accessibility and availability, and to the cost of ownership.</td>
</tr>
<tr>
<td>8</td>
<td>Total cost of ownership</td>
<td>2</td>
<td>The cost of owning a vehicle from the time of purchase, through its operation and maintenance to the time it leaves the possession of the owner. Experts mentioned fixed and variable costs, for example: purchase price, maintenance costs, insurance costs, and fuel costs.</td>
</tr>
</tbody>
</table>

**4.3. Scenarios**

Among others, a goal of the first series of expert interviews was to improve upon the topic list that was designed to be used for the second series of interviews. The second series is also referred to by the case study. Its results are at the core of this chapter. In the first series of interviews, it seemed that the experts found it difficult to envision—or even talk about—the future of vehicle ownership and vehicle sharing. I explained the necessity of a change and motivate the choice for adding the scenario question to the topic list (see 3.3.2).

Out of the total of 19 interviews, 8 interviewees unequivocally considered *S1: Evolution of personal mobility* the most likely. This scenario implies that vehicles will be complemented with technology assisting and eventually replacing the driver. None of the interviewees opted for the second scenario; *S2: Revolution of vehicle usage*. This scenario implies that non-automotive technology companies will enter the field. The scenario was not completely ruled out because two interviewees suggested that a combination of the first two scenarios was most likely. Next, one interviewee thought that all three scenarios were likely to happen. The third scenario *S3: Transformation of personal mobility* implies reinventing personal mobility by combining the advantages of the personally used automobile and public transportation. One interviewee considered it the most likely scenario, one interviewee considered it the most likely scenario in combination with the first scenario. Finally, 6 out of 19 interviewees had no opinion about the likelihood of the three scenarios. See Figure 5 for the complete distribution of scenario likelihood to interviewees.
Although the scenario question was added to the topic list to ‘warm-up’ interviewees, the answers are interesting to compare to the other findings—both from the literature and the case study. Because the answers to this question are not open for transformation, I return to the scenario question answers when discussing the results in chapter 6.

4.4. Causalities: Emerging narratives

After discussing the scenarios, we moved on to possible causalities between the research subjects. This was the core of the interview and took up most of the time. The aim was to find out whether the experts think vehicle automation and vehicle sharing somehow affect one or another, and if so, what causal mechanisms are evident.

Over the course of the interviews, I found that interviewees often responded with narratives instead of abstract causalities. Some narratives are clearly abstract, but others are specific and use-case oriented. Based on my notes and audio recordings, I distilled eight narratives that seemed plausible, or at least cohesive.

The interview data that is relevant to the research question must be extracted from interview texts that also contain irrelevant information. This is referred to by ‘Linking raw data to the research question’. The steps to do so and arrive at a description of the results, are listed below.

- **For each interview individually:**
  - Texts, sentences, and causalities relating to the research subjects were grouped together.
  - Scattered information relating to the research question that was found in other segments of the transcripts were added to a narrative section.

- **For all interviews together:**
  - Texts, sentences, and causalities relating to the research subjects were grouped together. Narratives from different experts were not combined.

The information contained in the texts is linked to the main research question and structured according to the theoretical background against which the research question was formulated. This theoretical background includes the definitions, but does not
include the key factors derived from literature study. The literature generally reaches the consensus that ‘the construction of theoretical categories, whether empirically grounded or not, cannot start ab ovo, but have to draw on already existing stocks of knowledge’ (Kelle, 2007). Therefore, I deviated from the idea of omitting all prior knowledge; instead I actively searched for literature in adjoining fields.

**From interviews to narratives: coding or no coding?**
The overarching goal of this study is to find possible causalities between research subjects. In all GT studies or similar (including this one), data must be structured in a form that supports pattern recognition. Irrelevant information must be filtered out in order for relevant factors and causalities to ‘emerge’. However, because this case study is based on 19 interviews that resulted in very specific narratives, filtering out large chunks of information was not necessary. These narrative interviews were aimed at identifying structures of whole texts. So, what was said, in what order, and in which context was crucial to note. Such an emphasis makes every utterance in the text extremely important (Gläser & Laudel, 2013). Additionally, I concluded that feeding categories into the interviews by use of a predefined topic list, coding the interview transcripts, and subsequently generating categories from the data, would result in a loop in which I partly ‘generate’ my own pre-conceived categories. Because of these aforementioned reasons, coding was not used in this study.

The narratives can be found below, ordered by decreasing level of abstraction. These narratives demonstrate that the more specific and use-case oriented the narrative became, the more elaboration was needed.

4.4.1. N1: The legacy delay
There are a number of human operated vehicles on the roads today. Replacing them with AVs will take years. Satisfying the same transportation demand by replacement of privately owned vehicles with shared AVs will take less time.

4.4.2. N2: AV technology increases appeal of using vehicles in general
Partly-AVs will be able to find a parking spot outside of the city centre after dropping off the passenger. This feature could potentially lower costs of using AVs, especially in urbanised areas. This advantage only thrives when parking in city centres becomes increasingly expensive and difficult. Automated parking technology improves the proposition of the vehicle for passengers. It adds comfort by allowing door to door service without the hassle and costs of city centre parking. This benefit could be used as a sales driver because it increases the overall attractiveness of the vehicle.

Safety and ‘gadget appeal’ were also mentioned by interviewees as typical characteristics of vehicle automation that are attractive to users and might persuade them to buy a vehicle.

4.4.3. N3: High utilisation of SVs speeds up adoption of vehicle automation technology
Due to high utilisation of shared vehicles compared to non-SVs, vehicles, SVs will need to be renewed faster than non-shard vehicles. This could potentially lead to faster implementation of AV technology. A fleet of SVs that is constantly used by its users will have to be serviced and renewed more frequently than a traditional fleet that is rarely used.
4.4.4. **N4: SAVs as automated taxis**

A fully automated vehicle that drives around picking up and dropping off passengers whenever and wherever they please is, in fact, an automated taxi. The greatest benefits for users are lower costs, greater comfort thanks to a smoother ride, and more privacy than a regular taxi. Unlike in their own vehicles, they can also multi-task while travelling.

In this case, sharing the vehicle (not rides) with other users drives the cost-per-user down. Systems that also facilitate ride sharing, with acquaintances, strangers or both, would lower cost even further. Moreover, the more users, the bigger the fleet will have to be, thereby increasing availability for all users. Economies of scale will be required to facilitate low cost and availability.

4.4.5. **N5: A 'last mile' solution**

Vehicle automation technology eliminates the need for a human driver. The ‘last mile’ is a term used in transportation planning to describe the movement of people and goods from a transportation hub to a final destination. Here, the problem lies with public transport in areas with low population density, such as the northern provinces of the Netherlands. An underused bus service, for example, can be expensive to operate. Substituting the human bus driver with a fully AV could lower operating costs. This narrative is not limited to public transport; it could also apply to SAVs and private AVs, serving as a substitute for underused public transport.

4.4.6. **N6: SAVs as solution for imbalanced sharing systems**

SAVs which are fully automated (SAVs) could solve balancing issues that vehicle sharing systems suffer from. Vehicle sharing services typically operate a fleet of vehicles scattered around a city for the use of a group of members. Emerging one-way vehicle sharing systems, where a vehicle may be dropped off at any station, add uncertainty concerning pick-up location. Free-floating vehicle sharing systems also allow vehicles to be picked up anywhere. These systems oftentimes suffer from ‘balancing issues’ that add more uncertainty and planning issues than traditional vehicle sharing systems with designated parking spots. Currently, vehicle sharing companies work around these problems by fining the user if the vehicle is parked outside of a predefined geographical area, and in some cases even send a driver to return the vehicle. With level-5 automation, it becomes possible for SAVs to return to a specified location and/or navigate to a new user on their own, thus decreasing imbalance in the system.

4.4.7. **N7: Centralised ownership increases share of sharing systems**

The increasing popularity of private lease contracts in The Netherlands has led to more centralised ownership of new vehicles. Although company lease contracts are renounced or ended, oftentimes employees are offered a mobility plan or travel compensation instead. One option for these employees is to choose private lease. Instead of a business-to-business contract lease, companies now contract with employees directly. Moreover, cost transparency and predictability also seems to persuade private car owners to enter into private lease contracts.

As ownership over the vehicle transfers from users to fleet owners—such as lease companies—it becomes easier to share. The scheme could look very similar to peer-to-peer vehicle sharing, but without the peer-to-peer ‘hassle’. Hence the lessee need
not worry about how others treat his/her vehicle. Service, maintenance, and insurance are all covered by the lessor.

4.4.8. N8: AV technology makes driving safer and could thereby lower insurance costs.

Adaptation of driver aid systems could prevent crashes, decrease insurance costs and thereby lower vehicle sharing system costs. AV technology could lower the insurance costs of SVs and of private vehicles.

4.5. Chapter conclusions

Based on data from 19 semi-structured expert interviews, I distilled eight key factors determining the future development of vehicle automation and eight key factors determining the future development of vehicle sharing. Interviewees have estimated the probability of three preselected scenarios: S1: Evolution of the personal automobile turned out to be the most likely scenario with eight votes, leaving six interviewees with no opinion. After the scenario ‘warm-up’, the interviewees identified eight narratives relating to vehicle automation and/or vehicle sharing. These narratives require interpretation. Causal modelling, based on the System Dynamics methodology, were adopted to interpret the narratives. I report on this interpretation in chapter 5.
5. Case study: Interpretation

The narratives that emerged from interviews become meaningful when placed in context. In this chapter, I prepare the qualitative data from the case study for comparison with literature and reflection by explaining causal links through causal modelling. This includes the key factors and the narratives. Searching for patterns in the data is referred to by ‘interpretation’.

5.1. Key factors

The two diagrams below consist of key factors that have been interpreted. When necessary, key factors according to the interviewees were transformed into ‘factors’—a particular noun phrase that denotes some variable system property. Every factor can increase or decrease.

5.1.1. Vehicle automation

This figure is a summarised interpretation of what experts have said during the interviews (Figure 6). During the interviews, I explained the future development of AVs as an increase or decrease in the ‘Utilisation of AVs’. Hence, this factor can rise or fall. A positive causality denoted with a '+' indicates that if a key factor (oval) increases, the ‘Utilisation of AVs’ also increases. See, for example, ‘Consumer Acceptance’. The question marks relate to factors that are quite abstract, thus resulting in relationships with ‘Utilisation of AVs’ that cannot be described as a positive or negative causality.

![Figure 6–Key Factors determining AV utilisation](image)

The table below depicts the perceived relationship (+/-) between the key factors and the future development of AVs (Table 7). The two factors, ‘Legislation’ and ‘Liability’, were not transformed into a noun phrase because these concepts relate to several more factors.

<table>
<thead>
<tr>
<th>#</th>
<th>Key Factor</th>
<th>+/-</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Legislation</td>
<td>?</td>
<td>Not a noun phrase: greater or lesser legislation does not lead to greater or lesser utilisation of AVs.</td>
</tr>
</tbody>
</table>
2. Liability

? 
Not a noun phrase: greater or lesser liability does not lead to greater or lesser utilisation of AVs.

3. Consumer Acceptance

+ 
The higher the consumer acceptance of AVs, the more likely it becomes for consumers to start using AVs.

4. Safety

+ 
The safer AVs become, the more likely it becomes for consumers to start using AVs.

5. Technological Development

+ 
More technological development will result in more ways in which vehicle automation will be utilised.

6. Legacy

- 
The bigger the fleet of human operated vehicles, the longer it takes to substitute them all with AVs.

7. Mixed Traffic

? 
Not a noun phrase: more or less mixed traffic does not lead to more or less utilisation of AVs. However, traffic that includes both AVs and human operated vehicles adds complexity.

8. Purchase Costs

- 
The higher the purchase costs for AVs, the less likely it becomes that consumers will buy one.

5.1.2. Vehicle sharing

The results of the key factor questions relating to the ‘Utilisation of SVs’ are also summarised in a similar figure. Again, it should be noted that causalities in reality could also be indirect.

![Figure 7–Key Factors determining SV utilisation](image)

The same is true for the utilisation of SVs (Table 8).

<table>
<thead>
<tr>
<th>#</th>
<th>Key Factor</th>
<th>+/-</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accessibility of SVs</td>
<td>+</td>
<td>Increasing accessibility leads to increasing utilisation of SVs.</td>
</tr>
<tr>
<td>2</td>
<td>Availability of SVs</td>
<td>+</td>
<td>Increasing availability leads to increasing utilisation of SVs.</td>
</tr>
<tr>
<td>3</td>
<td>Status of a Privately Owned Vehicle</td>
<td>-</td>
<td>Decreasing status of privately owned vehicles leads to increasing utilisation of SVs.</td>
</tr>
<tr>
<td>4</td>
<td>Urbanisation</td>
<td>+</td>
<td>Increasing urbanisation leads to increasing utilisation of SVs.</td>
</tr>
<tr>
<td>5</td>
<td>SV fleet size</td>
<td>+</td>
<td>Increasing shared vehicle fleet size leads to increasing utilisation of SVs.</td>
</tr>
</tbody>
</table>
6. Consumers’ Willingness to Consume by Sharing + Increasing willingness to consume by sharing (instead of owning) leads to increasing utilisation of SVs.

7. Parking Costs and Parking Space + Increase in parking costs and parking space leads to increasing utilisation of SVs.

8. Total Cost of Vehicle Ownership + Increase in total cost of vehicle ownership leads to increasing utilisation of SVs.

The following narratives below provide further details regarding some of the presumed causal links by interviewees.

5.2. Causalities

I began by extracting factors and causal influences based on the narratives suggested by interviewees. The steps taken to arrive at causal loop diagrams were loosely based on the works of El Halabi, Doolan, & Cardew-Hall (2012).

- **Memo creation**: for every narrative a memo was created. In each memo the following points were addressed in sequential manner: observation, relevance to main research question, emerging theory, conditions, identified variables, and causal links.
- **Observation**: these are the literal narratives.
- **Relevance to main research question**: does this narrative contain mechanism that explains a relationship between vehicle automation and vehicle sharing or vice versa?
- **Emerging theory**: A leads to B if X increases.
- **Conditions**: does the emerging theory always hold or are there conditions?
- **Identified variables**: what variables were mentioned? In case they are missing: what variables are likely to be needed here?
- **Causal links**: indicate their relationships using a simple one-way causality notation.

The following causal diagrams reflect my interpretation of the interviews. El Halabi, Doolan, & Cardew-Hall (2012) point out the ‘reiterative nature’ of creating causal loop diagrams from the emerging variables and causal links. ‘As diagrams are created the variables names and definitions may need to be changed. This in turn forces a revision of the causal relationships as well as checking conformity with the observations made and the interview data’. This can also be seen as the ‘creativity’ that Gläser & Laudel (2013) refer to.

5.2.1. N1: The legacy delay

The same transport demand could be met by a smaller fleet of AVs that drive more miles than the traditional private vehicles do on average. Empty trips from and to users require Level 5 vehicle automation. If Total vehicle travel demand increases, the number of Private Vehicles will increase. An increase in Private Vehicles decreases the User vehicle ratio. As the User vehicle ratio decreases. Based on the interviews, it remains unknown how the User vehicle ratio relates to the number of Empty trips.
5.2.2. N2: AV technology increases appeal of using vehicles in general

Interviewees stressed the added Comfort, Safety and ‘Gadget appeal’ of buying a private vehicle with AV technology. This results in a linear causal model.

5.2.3. N3: High utilisation of SVs speeds up adoption of vehicle automation technology

This causal link is straightforward: the more Miles travelled per vehicle per time period, the shorter the Average vehicle lifespan becomes due to wear and tear. The vehicle will be replaced sooner, allowing for a new vehicle with new technology such as Vehicle Automation technology to replace the old vehicle. Level 5 vehicle automation allows for Empty miles travelled per vehicle, which adds to the total of Miles travelled per vehicle. Vehicle Sharing amplifies this negative causal loop because SVs typically drive more than private vehicles.
Notes

I. SVs nowadays are oftentimes affordable small city cars. AV technology is mainly introduced on large luxury vehicles and then trickles down the portfolio and ends with small city cars. This process the main loop.

II. This narrative assumes centralised shared vehicle fleets. New players to the market of SVs – perhaps OEMs or internet companies – could take a different approach. A recent example is Tesla, which just announced their plans to enter the market of sharing by adding sharing functionality over the air to vehicles now on sale. Instead of owning a large fleet and building a vehicle sharing system ‘top down’, Tesla enables their customers to share ‘bottom up’.

5.2.4. N4: SAVs as automated taxies

This diagram shows three causal loops, one negative and two positive (Figure 11). I elaborate from least to most significant.

- With an increase in the amount of SVs in one fleet, the Availability of Vehicles increases. The higher the Availability of Vehicles becomes, the smaller the Required Fleet Size will become. This leads to less SVs and completes the negative loop.

- The second causal loop deviates from Availability of Vehicles. An increase in Availability of Vehicles makes the Attractiveness of the Service grow, which attracts more Shared Vehicle users. An increase in users obligates the Required Fleet Size to grow, and thereby the amount of SVs.

- The third and last loop relates to Economies of Scale: the number of SVs allows for the fleet manager to spread the fixed costs over more Shared Vehicle users, resulting in lower Travel costs per user and thereby an increase in Attractiveness of the Service.

Vehicle Automation and Ride Sharing both increase the Availability of Vehicles. Vehicle Automation of level 5 allows for Empty Trips and thus increasing the number of trips a shared vehicle can make and thereby increasing the Availability of Vehicles.
for the users. *Vehicle Automation* also adds comfort and privacy, which increases the *Attractiveness of the Service,* despite increased *Availability of Vehicles.*

*Ride Sharing* increases the *Availability of Vehicles* by allowing strangers to merge parts trips. A normally-occupied shared vehicle is now available. *Ride Sharing* also decreases the *Travel costs per user* because the costs are spread over multiple passengers.

![Figure 11–N4: SAVs as automated taxies](image)

In this narrative, *Vehicle Automation* has no incoming arrows, while SVs does. *Vehicle Automation* consequently increases the *Attractiveness of the Service, Shared Vehicle users* and thus SVs. Additionally, only in the case of Level 5 will *Vehicle Automation* enable *Empty Trips* and thus increase the *Availability of Vehicles,* lower the *Required Fleet Size,* and lower the number of SVs.

**Notes**

1. When comparing the SAV system with traditional taxi services, two differences become apparent. *Empty Trips* are possible with human operated taxis—where ‘empty’ refers to no passengers. Adding *Vehicle Automation* to a taxi system rather than a shared vehicle system decreases the *Travel costs per user* via a decrease in variable costs because no human driver is needed (see 4.4.1 and 5.2.1).

5.2.5. N5: A ‘last mile’ solution

The diagram below illustrates the dynamics of N1: A ‘last mile’ solution (Figure 12). Normally, in low-urbanised areas, the service utilisation may be low, which forces the exploitation costs to be relatively high. This could result in a negative feedback loop involving increasing the ticket prices. With the introduction of AV technologies on busses, the fixed costs increase, also making exploitation costlier. However, when Level 5 becomes available, the number of bus drivers can be decreased, thereby lowering the variable costs and thus exploitation costs. Adopting this new technology is therefore attractive to transport operators, especially those who operate unprofitable routes.

---

36 The Dutch government allows private operators to have a monopoly on certain routes via licensing (also: concessions). In exchange, private operators are sometimes obliged to maintain other unprofitable routes.
In any case, public transport is not a requirement for this ‘last mile’ solution. Number of drivers could, for example, also relate to taxi drivers. Moreover, in relation to N4 and N7, shared AVs could offer a substitute to the public transport for the ‘last mile’.

5.2.6. N6: SAVs as solution for imbalanced sharing systems

As Vehicle Sharing increases, the number of One-way trips also increases—assuming one-way systems. When Level 5 Vehicle Automation becomes possible, it will become possible for vehicles to perform Empty trips. These Empty trips increase the One-way trips because the availability of SVs rises. Vehicle Sharing and Vehicle Automation would both drive the same positive causal loop, stimulating the miles travelled by both used and empty SVs (Figure 13).

Notes

I. Several studies conclude that vehicle sharing systems generate the problem of vehicle imbalance due to the one-way nature of the trips (Jorge & Correia, 2013). However, the question remains how many extra miles will be driven by empty SAVs returning to the station or picking up another user.37

5.2.7. N7: Centralised ownership increases share of sharing systems

This narrative could not be interpreted as such. The decoupling of private ownership and private use as such could not be transformed into a causal loop diagram that adds clarity.

Notes

37 One of the first studies in this field miles was done by (Correia & van Arem, 2016). However, their research focusses on privately owned vehicles only.
I. This narrative might not apply in other countries. Private lease is trending in The Netherlands.

II. Required technology for this narrative—such as AV technology and communication technology—will generally be fitted in new and relatively expensive cars, whereas privately-leased vehicles are normally relatively affordable and not fully equipped with new technology.

III. Traditional lessees see the vehicle as their own possession, although legally speaking it is not. Letting others make use of the vehicle requires a different mind-set from the lessee. Small pilots with business lessees confirm this difficulty.

IV. It is easier to start from scratch with users who have never owned a vehicle than convincing current lessees. Technology could (partly) solve this problem by allowing for flexible, tailored personalisation depending on the user of the vehicle.

5.2.8. N8: AV technology makes driving safer and could thereby lower insurance costs

Vehicle Automation technology enhances Safety by avoiding accidents and damage to vehicles. Therefore, Insurance costs could go down. Lower Insurance costs result in lower Total Cost of Ownership and thus making Vehicle Ownership more attractive.

![Figure 14–N8: AV technology makes driving safer and could thereby lower insurance costs](image)

**Legend**
- Conditional causal link
- Causal link
- Conditional variable
- Research subject

**Notes**

I. Driver aid systems are relatively expensive, whereas traditional SVs are not. The question is: will the decrease in damage and thereby insurance costs outweigh the expensive safety options?

II. Increase in safety with increase in levels? See level 3 debate
5.3. Causalities: an overview

The potential impact of vehicle automation on vehicle sharing and vice versa, took shape through eight narratives, describing several relationships between the subjects. Broadly speaking, in most narratives the highest level of vehicle automation is conditional for the potential impact to appear.
### Table 9–Causalities: an overview

<table>
<thead>
<tr>
<th>Narrative</th>
<th>Start</th>
<th>+/-</th>
<th>End</th>
<th>Key factor</th>
<th>Interpretation of causality</th>
<th>Level 5 automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>SVs</td>
<td>+</td>
<td>Vehicle automation</td>
<td>Empty trips (new)</td>
<td>Replacing privately owned vehicles with AVs requires more time than replacing privately owned vehicles with SAVs. The reason is that a single SAV can satisfy more trips in one day than a privately owned vehicle. Vehicle Sharing therefore could increase the speed of adoption of Vehicle Automation technology.</td>
<td>Required</td>
</tr>
<tr>
<td>N2</td>
<td>Vehicle automation</td>
<td>+</td>
<td>Vehicle ownership &amp; vehicle sharing</td>
<td>Comfort (new) Safety (new) Gadget appeal (new)</td>
<td>With increasing levels of vehicle automation, comfort, safety and gadget appeal also increase, making vehicle usage in general more appealing.</td>
<td>Not required</td>
</tr>
<tr>
<td>N3</td>
<td>Vehicle sharing</td>
<td>+</td>
<td>Vehicle automation</td>
<td>Average vehicle lifespan (new)</td>
<td>Wear &amp; tear causes shorter life cycles</td>
<td>Required</td>
</tr>
<tr>
<td>N4</td>
<td>Vehicle automation</td>
<td>-</td>
<td>Shared vehicles</td>
<td>Empty trips (new)</td>
<td>Fully AVs could make the use of SAVs as automated taxis possible. This requires fewer vehicles than conventional taxi services to service the same transport demand.</td>
<td>Required</td>
</tr>
<tr>
<td>N5</td>
<td>Vehicle automation</td>
<td>+</td>
<td>Vehicle sharing</td>
<td>Cost of usage (new)</td>
<td>This causal relationship is implicit. When the last mile solution can become much cheaper with fully automated vehicles.</td>
<td>Required</td>
</tr>
<tr>
<td>N6</td>
<td>Vehicle automation</td>
<td>+</td>
<td>Vehicle sharing</td>
<td>Availability Cost of usage (new)</td>
<td>Fitting SVs with level 5 Vehicle Automation – resulting in SAVs – enables sharing companies to stabilise their imbalanced fleets. This results in higher availability and lower costs, because it requires fewer vehicles for the same amount of trips. This attracts more Vehicle Sharing users.</td>
<td>Required</td>
</tr>
<tr>
<td>N7</td>
<td>Vehicle sharing</td>
<td>+</td>
<td>Vehicle sharing</td>
<td>N.A.</td>
<td>Increase in centralized ownership makes sharing these ‘private’ vehicles easier.</td>
<td>Not required</td>
</tr>
<tr>
<td>N8</td>
<td>Vehicle automation</td>
<td>+</td>
<td>Vehicle ownership</td>
<td>Total cost of ownership</td>
<td>Vehicle Automation on different levels is assumed to prevent accidents and thereby increasing Safety in general. With fewer accidents, insurance costs can go down resulting in lower Total cost of ownership and thus increasing the appeal of private vehicle ownership.</td>
<td>Not required</td>
</tr>
</tbody>
</table>
5.4. Chapter conclusions

Seven out of eight narratives were translated directly into causal models. These causal models show that the key factors as identified by the experts do not play a significant role in the narratives and consequently the causalities, articulated by the same experts. Total cost of ownership was the only returning key factor in model eighth. Together with model five, model eight does not explicitly cover a causal link between the two research subjects. Model five does this implicitly however. Next, five out of eight narratives require full vehicle automation (level 5).
6. Discussion of results

In this chapter I compare the results and interpretation of the results with literature findings I (see chapter 3). This reveals what possible new insights and where knowledge gaps remain. Again, following the same sequence as the research framework, I subsequently compare key factors, scenarios and finally impact.

6.1.1. Key factors

The eight key factors determining the development of vehicle automation that were found in the case study differ from an earlier study among Dutch experts (see Milakis, Snelder, et al. (2015)). A two by two matrix in Appendix E: Vehicle automation key factor comparison was used to make these differences explicit. This comparison is summarised below (Table 10).

Table 10–Literature comparison: case study vs. Milakis, Snelder, et al. (2015)

<table>
<thead>
<tr>
<th>Key factor case study</th>
<th>Could relate to key factor by Milakis, Snelder, et al. (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislation</td>
<td>Interoperability among AV technologies</td>
</tr>
<tr>
<td></td>
<td>Development of AV in EU</td>
</tr>
<tr>
<td></td>
<td>Legal/ institutional context (national and European)</td>
</tr>
<tr>
<td></td>
<td>Public/private expenditures on infrastructure</td>
</tr>
<tr>
<td></td>
<td>Stability of policies</td>
</tr>
<tr>
<td>Liability</td>
<td>Development of AV in EU</td>
</tr>
<tr>
<td>Consumer Acceptance</td>
<td>Psychological barriers (Citizens and customers)</td>
</tr>
<tr>
<td></td>
<td>Marketing/ image of AV</td>
</tr>
<tr>
<td>Safety</td>
<td>AV technology trials</td>
</tr>
<tr>
<td></td>
<td>Incidences</td>
</tr>
<tr>
<td>Technological Development</td>
<td>AV technology trials</td>
</tr>
<tr>
<td></td>
<td>Interoperability among AV technologies</td>
</tr>
<tr>
<td>Legacy</td>
<td>Interoperability among AV technologies</td>
</tr>
<tr>
<td>Mixed traffic</td>
<td>AV technology trials</td>
</tr>
<tr>
<td></td>
<td>Interoperability among AV technologies</td>
</tr>
<tr>
<td>Purchase Costs</td>
<td>Costs/benefits of AV technology</td>
</tr>
<tr>
<td></td>
<td>Accessibility, social equity</td>
</tr>
</tbody>
</table>

This research project is aimed at exploring possible causalities between vehicle automation and vehicle sharing, thus exploring the common ground between the two subjects. Key factors for vehicle automation could be influenced by vehicle sharing or the other way around. Notably, Dutch experts in this project did not mention AV ownership structure (public vs private) as a key factor for the development of vehicle automation.

The eight key factors determining the development of vehicle sharing that were detailed in the case study also differ from an earlier study (see (KiM Netherlands Institute for Transport Policy Analysis, 2015b)). A two by two matrix in ‘Appendix F:
Vehicle sharing key factor comparison was used to make these differences explicit. This comparison is summarised below (Table 11).

Table 11–Literature comparison: case study vs. KiM Netherlands Institute for Transport Policy Analysis (2015b)

<table>
<thead>
<tr>
<th>Key factor case study</th>
<th>Could relate to key factor by (KiM Netherlands Institute for Transport Policy Analysis, 2015b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility of SVs</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Availability of SVs</td>
<td>Big fleet size and variety of vehicles and providers</td>
</tr>
<tr>
<td>Status of a privately owned vehicle</td>
<td>Marketing and profiling.</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Urbanisation</td>
</tr>
<tr>
<td>SV fleet size</td>
<td>Big fleet size and variety of vehicles and providers</td>
</tr>
<tr>
<td>Access-based consumption mind-set</td>
<td>Marketing and profiling.</td>
</tr>
<tr>
<td>Parking costs and space</td>
<td>New in this case study</td>
</tr>
<tr>
<td>Total cost of ownership</td>
<td>New in this case study</td>
</tr>
</tbody>
</table>

The experts in this project did not mention Political and administrative support from the municipality nor Coordination and integration of the vehicle sharing to public transport as a key factor for the development of vehicle sharing. However, although the latter was not explicitly mentioned as a key factor, it should be noted that narrative 5 links to public transport since it offers a ‘last mile’ solution.

Secondly, Parking costs and space and Total cost of ownership are two key factors that were not mentioned by KiM Netherlands Institute for Transport Policy Analysis (2015b). The project, and thereby the interviews, are focused on private ownership versus vehicle sharing, whereas the study by KiM Netherlands Institute for Transport Policy Analysis, (2015b) is only focused on vehicle sharing. The first factor is also found by Steg (2005) to be a determinant factor for vehicle use—that is, if we interpret Parking costs and space as a dimension of convenience. Total cost of ownership is also found in a previous study to be a determinant factor for car ownership (see Dargay (2001)).

6.1.2. Scenarios

Although the scenario question was added to the topic list as a ‘warm-up’ question, it did lead to surprising results. Most of the experts thought that personal mobility would evolve with gradually improving technology, assisting and eventually replacing the driver. In other words: OEMs will probably keep adding vehicle automation technology to new vehicles until the point at which the newly sold vehicles are fully automated. However, during the unstructured interviews in Phase 1, several experts expressed their concerns relating to level 3 vehicle automation. With this level, the human driver becomes the back-up to the automated vehicle. The now ‘passenger’ in the driver’s seat would patently take his eyes off of the road, and his or her reaction time would decrease sharply; this would render the ‘passenger’ a very poor back-up driver and possibly pose safety concerns.
According to (ERTRAC, 2013), the predominant vision among experts is fully automated driving. This means that ultimately—whenever this might be—society will benefit from fully AVs capable of driving in every situation. Interestingly, this vision is not shared by all of the interviewees in this project. In the unstructured interviews, an expert expressed doubt about whether we would even reach the final level of vehicle automation, simply because the context of modern day traffic is so complex. This relates to the Mixed traffic key factor mentioned in the case study, but also to the unstructured interviews.

6.1.3. Causalities

To my knowledge, there is no literature available covering narratives relating to the impact of vehicle automation on vehicle sharing and vice versa. Comparison to other studies was not possible at this time.

6.2. Chapter conclusions

Comparing the findings of this study with literature resulted in a few interesting considerations:

- When comparing the key factors from the case study to the literature study, the following difference appeared. In a previous study, the AV ownership structure (public vs private) was listed as the fifth most important key factor for the future development of vehicle automation. However, in this case study, it was not mentioned at all as a key factor—neither negative nor positive. However, with regard to the possible causalities, this research also shows that vehicle sharing as an ownership structure, could have a positive impact on vehicle automation. So, despite not being listed as key factor, a positive impact might be possible according to the interviewees. I suspect that the causalities as found will not be as important to the interviewees as other key factors for the future development of vehicle sharing.

- Evolution of the personal automobile vs human factors at level 3: a small majority of the interviewees think that the scenario towards fully automated driving is an evolutionary one in which vehicles will be complemented with technology assistance, and eventually replacing the driver. This is interesting because other experts find an evolutionary transition path of vehicle automation dangerous. This was corroborated in literature. At one point halfway the levels of automation: ‘the system can relinquish control with no advance warning and the driver must be ready to control the vehicle safely’ (Blanco et al., 2015). ‘Overtrust describes a system in which the user’s trust in the automation exceeds the actual capabilities…[it]can lead to misuse of the automated system, where the driver applies the automation to a roadway environment that is outside the automation operational scenarios. Distrust describes a scenario in which the user believes that the automation performance is less than it actually is’ (Blanco et al., 2015). Some experts in the interviews did express their concern about this occurrence.
7. Conclusions & Recommendations

The aim of this research project was to increase the knowledge about the potential impact of vehicle automation on vehicle sharing and vice versa. Next to filling this scientific gap, this study is also relevant from a societal standpoint. Increasing the understanding of the impact of vehicle automation on vehicle sharing and the other way around could be relevant for policy-making to address the undesired effects caused by non-automated and non-SVs.

7.1. Returning to the main research question

Given that vehicle automation and vehicle sharing are still emerging, literature in the area of synergy between the two remains sparse. Therefore, the research question central to this thesis that was answered is explorative: ‘What could be the impact of vehicle automation on vehicle sharing and vice versa?’

Based on expert interviews, this study concludes that vehicle automation could impact vehicle sharing. Moreover, the data indicates that the opposite may also be possible: vehicle sharing may impact vehicle automation.

- **Vehicle automation could have a positive impact on vehicle sharing**, for three reasons:
  
  Firstly, vehicle automation makes vehicles in general more appealing because it increases comfort, safety, and ‘gadget appeal’. This applies to personal vehicles in general, both private and shared. The higher the level of comfort, the stronger this relationship becomes. When vehicle sharing companies add vehicles to their fleets equipped with automated vehicle technology, it thus increases the appeal of the shared vehicle.

  Secondly, with level 5 vehicle automation becoming available, unprofitable bus services might become profitable again. The number of bus drivers can be decreased, thereby lowering the variable costs and thus exploitation costs. Such automated bus service would allow for flexible time schedules and stops, lowering the exploitation costs and potentially providing new passengers with access to the service. Lower costs and new users increases the service utilisation and thus vehicle sharing.

  Thirdly, fitting SVs with level 5 vehicle automation enables sharing companies to stabilise their currently imbalanced fleets. This results in higher availability and lower costs, because it requires fewer vehicles to satisfy the same transport demand. This attracts more users and thus increases vehicle sharing.

- **Vehicle automation could have a negative impact on SVs**: If fully automated vehicles become a reality, it will enable ‘empty trips’. Empty trips are trips executed by the vehicle without a passenger (nor driver). Fewer SVs will be needed to satisfy the same transport demand. Full vehicle automation thus leads to a decrease in the volume of shared vehicles—but not vehicle sharing.

Vehicle sharing could also impact vehicle automation. A negative impact of vehicle sharing on vehicle automation was not found.
• Vehicle sharing could have a positive impact on vehicle automation, because of two reasons:
  Firstly, fewer SVs can fulfil the same transport demand as private vehicles do now. If vehicle sharing increases, the total number of vehicles needed for the same transport demand can decrease. Assuming the growth of vehicle sharing requires new vehicles, these vehicles could be fitted with AV technology. If both assumptions are true, replacing existing private vehicles with new automated SVs increases the total miles driven with a shared vehicle that is equipped with automated vehicle technology.
  Secondly, similar to the previous causality, fewer SVs can fulfil the same transport demand as private vehicles do now. These SVs are utilised more than private vehicles on average, which causes wear and tear. The lifecycle of a shared vehicle is therefore shorter than a private vehicle. Replacing SVs more often allows for new automated vehicle technology to be adopted faster. This does make the vehicle more expensive.

7.2. Additional findings
Apart from the possible causalities between the research subjects, the study revealed additional findings. These findings are listed below.

• Vehicle automation could have a positive impact on private vehicle ownership: vehicle automation makes vehicles in general more appealing because of the increased comfort, safety, and gadget appeal. This applies to private and SVs. The higher the level of comfort, the stronger this relationship becomes. This is the same causality as mentioned before.

• Full vehicle automation is conditional: full vehicle automation (level 5) is conditional to four out of five narratives describing a positive causality from vehicle automation to vehicle sharing. The opposite was not found in this study; the positive impact of vehicle sharing on vehicle automation does not require level 5. Full vehicle automation could strengthen the causality though.

• Evolution of the personal automobile vs vehicle sharing: eight out nineteen experts thought that the scenario moving towards fully automated driving is an evolutionary one in which vehicles will be complemented with technology assistance, eventually replacing the driver. Six out of nineteen had no opinion on the matter. The five remaining experts were divided over combinations of scenarios. Vehicle sharing is part of the second and third scenario, which were not popular. This means that the experts consulted in this study were more optimistic about the future of vehicle automation than vehicle sharing or a combination of both developments. This suggestion is further supported by the fact that the AV ownership structure (public vs private) is listed as the fifth most important key factor by a previous study, but was not found in this study.

7.3. Lessons beyond the case study
Although methodologically speaking, one cannot simply generalise findings from a case study, the results of this study do not indicate any ‘uniqueness’. The initial focus of the research is on the Netherlands. All interviewees apart from one, were working in the Netherlands at the time of the interviews and the interview questions were aimed at the Netherlands. However, the interview findings as listed in this chapter are
arguably not unique to the Netherlands. That means that the possible causalities between vehicle automation and vehicle sharing might not be unique for the Netherlands, and perhaps also apply for other countries. However, it should be clear that I merely suggest that it may not be isolated data.

The relevance of the results of this study from a societal standpoint requires some elaboration. As noted, understanding possible causalities between the research subjects can be relevant to policy-making. However, the results of this study as such do not directly offer grounds for policy-making. The study offers specific leads consisting of hypotheses articulated by experts and based on my own interpretations. In other words, this research project was only one of the first–or even the first attempts to systematically map possible causalities between vehicle automation and vehicle sharing. Its value lies not in its generalisability nor in its capability to accurately predict the future of personal car mobility. What this study does is shed some light on how two developments could relate to each other. I believe that follow-up research that builds on these results could therefore eventually yield more practically actionable data.

7.4. Recommendations for future research

The first recommendation for future research relates to an expansion of the scope. Both definitions of the research subjects were narrower than how other scholars tend to define the subjects. Vehicle automation for the purpose of this thesis is only defined by ‘the extent to which the human driver monitors the driving environment and executes aspects of the dynamic driving task’ (Milakis, Snelder, et al., 2015). The second axis, relating to ‘autonomy’ of the vehicle was left out. Vehicle sharing was also demarcated with a commercial definition only. Private vehicle sharing, such as peer-to-peer sharing, was not included in the scope of this project. Expanding the scope by explicitly including the aforementioned dimensions allows for more key factors for future development and causalities to be discovered. It should be noted that one increases the complexity of the research by expanding the scope. This could require different methods or adaptations to the methods used in this study.

Some key factors, as found in the case study, might also have an indirect relationship with one another. For example, urbanisation limits the number of parking spaces that exist in a city. However, interviewees were not asked for causal structures when this topic was broached. Experts were merely asked to list and elaborate on key factors for the development of both research subjects. This is due to the demarcation of the research and could followed up on in future research. For further discussion on the demarcation and research scope I refer to the reflection in chapter 8.

This qualitative study only focussed on what might be possible. Different conditions restrict different transition pathways. As experts have pointed out in Phase 1 interviews, the volume of automated and/or shared vehicles in use is also of great importance when assessing impact. If one of the two developments does not become mainstream, will one still impact the other? In other words: what are the conditions for certain causalities? And will thresholds–other than level 5 automation–become likely? Examples may include: volume, price etc.

Ending on perhaps the most important recommendation for future research: validation of causal models. The causal models as designed for the purpose of this study were based on expert interviews. Possible relationships between variables are
at the core of each model. Such relationships are considered possible by one or more experts interviewed during this research project. Research to verify each specific relationship has yet to be started.
8. Reflection

This chapter provides a reflection on the research project. The first half relates to the research design, which has impacted the outcomes and depth of this research. By the end of this section, I will provide the reader with suggestions for improvement upon this research project. The second part of this chapter is reserved for a personal reflection on the graduation project.

8.1. Reflection on research design & suggestions for improvement

Firstly, the research framework was built out of several different building blocks: the principles of the GT methodology, the theoretical perspective based on Geels (2004), three research phases, and several research methods such as literature study and interviews. The adopted theoretical perspective does fit the research and the adopted principles of GT well. In fact, I think it was essential to this research project for the following three reasons:

1. Gläser and Strauss (1967) acknowledge the following: ‘the researcher does not approach reality as a tabula rasa. He must have a perspective that will help him see relevant data and abstract significant categories from his scrutiny of the data’. In other words: even Gläser and Strauss think that a GT based research methodology requires some perspective a priori.

2. GT assumes a data-driven approach. The theoretical perspective actually ensures the collection of richer data than would otherwise be collected. The particular perspective of socio-technical regimes builds on prior research and adds several analytical dimensions. It thereby ensures that many directions are explored. Considering the perspective when designing the topic list for the semi-structured interviews prevented a relatively inexperienced researcher to accidentally overlook several analytical dimensions.

3. The theoretical perspective allows the interview results to be categorised into an ex post perspective. It helped classifying the topics and causalities the experts in this study find important and what dimensions might be missing from the results. This is particularly important because due to the novelty of the study, there is little to no material to juxtapose with these results and help contextualise the results.

Next, I am grateful that I had the opportunity to conduct the interviews. It was truly inspiring and motivating to be able to speak with experts in their fields. Initially, I was unaware of how much time the interviews would cost—including scheduling, preparation, travelling, processing and following up. After I finished the unstructured interviews in Phase 1, it became clear that I had underestimated the time required to properly handle each interview. Time became a limiting factor for conducting the unstructured interviews in Phase 2. It became apparent that the topic list was too long for a one-hour interview. This meant that I had to prioritise my questions even further. I decided to consider answers to the following questions as ‘nice to have’, but not crucial:

| Topic | # | Question |

| 54 |
At the beginning, I struggled with whether or not to specifically list scenarios. I did not intend to actively feed the expert with information or to influence their response. However, from the explorative interviews, I learned that it was oftentimes necessary to give the expert some context and directions. In the end, I think my choice of including scenarios in the topic list was justified. Without these scenarios, a substantial number of interviews would have ended prematurely. Consequently, presenting the interviewees with scenarios created a difficulty for me as moderator of the interview. By asking about the likelihood of scenarios, I tried to ‘warm-up’ the expert and encourage free thinking. However, by introducing scenarios, I also introduced the danger of the interview becoming stuck within the limited scope of the scenarios.

The preference for S1: Evolution over S2: Revolution and S3: Transformation by 8 out of 19 interviewees might also be explained by the names of these scenarios. A gradual development or ‘Evolution’ is much more comfortable than ‘Revolution’ or ‘Transformation’. Additionally, ordering the scenarios by numbering might also have played a role. Not naming the scenarios at all, but instead referring to them by the letters A, B, and C rules out this possible bias.

Nonetheless, it was sometimes difficult to arrange the interviews for Phase 2. Vehicle sharing companies are clearly lacking in the list of interview participants. These companies were exceptionally difficult to contact, let alone arrange an interview. Companies in this field receive a lot of similar requests from graduate students and cannot meet all of them. This was one of the recurring replies. Another reason for their reluctance might be the sensitive nature of the questions. Asking how they think vehicle automation and vehicle sharing might relate, perhaps reveals competitive advantages. However, as time went on and my efforts did not sort any positive responses from the vehicle sharing companies, I chose to not delay the research project and to continue without their participation.

Despite the reliance on expert opinions, the research also heavily depended on my research skills. Moreover, the way in which the research framework was set up in combination with the applied methods, did not allow for any external validation. Literature research and two series of interviews together formed the primary research methods for Phase 1 and 2 of the project. These methods were only applied by me. Phase 3, in which the causal models were build and analysed, heavily relied on my capabilities and creativity to bring the information together in a transparent and responsible manner. This leads me to question can the results of this study be replicated (by someone else)?

Probably not. The first explanation can be best described via an analogy. Could two persons take the exact same photograph of a landscape? No, since the landscape always changes. The findings of this report should be seen in the same light: as a snapshot in an ever changing landscape. Moreover, I do not think this difficulty of reproducibility is a problem, as long as this study and its results are put in the right context. This links to the goal and deliverables of this study: contributing to prior
academic knowledge by mapping possible causalities (according to experts). These narratives and causal models represent are a snapshot and form a starting point for further research.

8.2. Personal reflection on the research project

In this final section, I reflect on my journey that was the graduation project: the execution of the research process. Because this graduation project was my first truly independent research project, I started off having no clue of what the end result would look like. I reviewed literature and studied various theoretical perspectives. This led me to the conclusion that the conjunction of both fields was barely studied nor documented at all. The more I read, the more I realised that the available literature provided no answer to my research question. This absence of studies to build upon made the research project both exciting and challenging at the same time.

I think that I have improved my communication skills by improving my presentation skills; both verbally and written. The thesis committee really challenged me repeatedly to ask myself what message I was trying to convey and how best to convey it, which some also refer to as ‘the art of storytelling’. Thus, I would like to conclude this personal reflection on the graduation project with an important lesson that I have learned during the project. Although I have never actually owned a car in my life, I do consider myself a ‘car guy’. I am therefore very interested in the subject matter (intersection of vehicle automation and vehicle sharing). This might have been one of the reasons why I found it challenging to draw conclusions from the data and to write them down. It occurred to me that a well-informed reader would surely already know the answers to my research questions. However, the thesis committee disagreed. The longer you examine a certain topic, the more knowledgeable you become on that particular topic, while, others are not usually comparably well-informed. This is where the art of storytelling comes in.

Along the way I believe that I have grown, both as a researcher and as a person. I have improved my interpersonal and communication skills. For example, during the interviews I had to listen attentively, which at first this proved to be challenging, especially as I had to execute a number of different tasks at the same time. I had to listen, think, ask follow-up questions, make notes, and maintain the flow of the conversation. While I advanced through the interviews, listening became more natural for me and I began to enjoy the task.

Because of the selected research methods (literature research and interviews), I have put myself in the role of research instrument. This common ground applies to all interviews (Wimpenny & Gass, 2000). The overall quality of the transcriptions and the subsequent interpretation partly depended on my personal observational and reflective skills as an interviewer and researcher. I feel that these skills did improve during the project and could probably improve much more with every research project I might take on in the future. The overall quality of the transcriptions and the subsequent interpretation partly depended on my personal observational and reflective skills as an interviewer and researcher. I feel that these skills did improve during the project and could probably improve much more with every research project I might take on in the future.


Appendix A: List of Participants in explorative interviews

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Affiliated organisation</th>
<th>Position</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dimitris Milakis</td>
<td>Delft University of Technology</td>
<td>Assistant Professor of Smart and Sustainable Transport Systems&lt;sup&gt;38&lt;/sup&gt;</td>
<td>20 January 2016</td>
</tr>
<tr>
<td>2</td>
<td>Bert van Wee</td>
<td>Delft University of Technology</td>
<td>Professor in Transport Policy&lt;sup&gt;39&lt;/sup&gt;</td>
<td>16 March 2016</td>
</tr>
<tr>
<td>3</td>
<td>Miltos Kyriakidis</td>
<td>Singapore-ETH Centre, ETH Zurich</td>
<td>Researcher People and Operations in Resilient Systems</td>
<td>14 April 2016</td>
</tr>
<tr>
<td>4</td>
<td>Taede Tillema</td>
<td>KIM Netherlands Institute for Transport Policy Analysis, Min. of Infrastructure and the Environment</td>
<td>Senior researcher</td>
<td>20 April 2016</td>
</tr>
<tr>
<td>5</td>
<td>Koen Frenken</td>
<td>Utrecht University</td>
<td>Professor in Innovation Studies</td>
<td>21 April 2016</td>
</tr>
<tr>
<td>6</td>
<td>Joost de Winter</td>
<td>Delft University of Technology</td>
<td>Assistant professor at the BioMechanical Engineering Department</td>
<td>28 April 2016</td>
</tr>
<tr>
<td>7</td>
<td>Riender Happee</td>
<td>Delft University of Technology</td>
<td>Assistant professor / Program Manager Automotive</td>
<td>28 April 2016</td>
</tr>
</tbody>
</table>

<sup>38</sup> Mr. Milakis is also one of four thesis committee members for this Master’s research project.

<sup>39</sup> Mr. Van Wee is also the chair of the thesis committee for this Master’s research project.
Appendix B: Topic list semi-structured interviews

Impact of vehicle automation on vehicle ownership and sharing – Topic list

This interview takes place in the context of the thesis research into the impact of vehicle automation on vehicle sharing and vice versa. This interview is part of the second round of interviews.

This topic list allows you to prepare for this interview.

We would like to talk about the following four topics:

A. AVs in the future
   I What aspects do you identify that enable or constrain the implementation as well as the adoption of fully AVs in the future?
   II Do these effects differ depending on automation level (e.g. Level 1 – 5)?
   III What players do you think will benefit the most of implementation and adoption of AVs?
   IV What scenario do you think is most likely and why?

<table>
<thead>
<tr>
<th>Evolution of Driver Assistance</th>
<th>Revolution of Automobile Usage</th>
<th>Transformation of Personal Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key players</td>
<td>OEMs</td>
<td>Internet search &amp; online services (non-automotive)</td>
</tr>
<tr>
<td>Value proposition</td>
<td>Highly advanced Driver Assistance systems</td>
<td>AVs in dedicated areas</td>
</tr>
<tr>
<td>Ownership</td>
<td>Consumer</td>
<td>Centralised</td>
</tr>
</tbody>
</table>

B. Vehicle ownership, sharing, and technology
   I What are the reasons and motives for owning cars?
   II What are the reasons and motives for sharing cars?
   III Could the aforementioned reasons and motives be effected or changed by automated vehicle technology?
   IV Do these effects differ depending on automation level (e.g. Level 1 – 5)?
   V Do you think the development of vehicle automation has effects on vehicle ownership? If so, please indicate which coherence in economic, technical and social matters?
   VI Do you think the development of vehicle automation is associated with vehicle or ride sharing? If so, please indicate which coherence in economic, technical and social matters?

C. Suggestions
   I Do you have suggestions for experts I should speak with–in the context of this thesis?
   II Do you have suggestions for documents that you think I should study–in the context of this thesis? If so, could you send it?
Appendix C: Application of theoretical perspective in the topic list

The six notions by (Geels, 2004) were all used in the topic list for the semi-structured interviews (see Figure 1):

1. Involvement of human actors and organisations. In particular, question A III relates to human actors and organisations: What players do you think will benefit most of implementation and adoption of automated vehicles? Secondly, question A IV also relates to human actors and organisations by implicitly asking for use cases.

2. Existing rules, regimes and institutions provide constraining and enabling contexts for actors. Question A I, A V, B V and B VI allowed for the interviewer and interviewee to touch upon rules and institutions.

3. Similar to notion 2, actors carry and (re)produce the rules in their activities. By acknowledging this, it could be taken into account with regard to 2.

4. Socio-technical systems form a structuring context for human action; humans interact in a huge technical context. This was already clearly established by means of the Phase 1 interviews and study of the literature. Moreover, question B V and B VI explicitly highlight this technological context.

5. Rules can also be embedded in artefacts and practices. For example: future Vehicle-to-Infrastructure (V2I) communication relates to wireless exchange of critical safety and operational data between vehicles and roadway infrastructure. Such a new standard on specific motorways could potentially exclude vehicles that are not equipped with compatible hardware. The infrastructure design in this case constrains movement of certain actors. This abstract notion was noted, but not explicitly incorporated in the topic list. Because of the complexity of this idea, it was deemed unfit to be incorporated into interview that lasted less than one hour.

6. New technology shapes rules and institutions. This was also pointed out by several interviewees in Phase 1 and was something I was very well aware of in the Phase 2 interviews.

Figure 15–Six notions relating to the extended ST-system perspective (Geels, 2004)
## Appendix D: List of Participants in semi-structured interviews

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Affiliated organisation</th>
<th>Position</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bart van Arem</td>
<td>Delft University of Technology</td>
<td>Professor Transport Modelling</td>
<td>3 May 2016</td>
</tr>
<tr>
<td>2</td>
<td>Michiel Beck</td>
<td>Ministry of Infrastructure and the Environment</td>
<td>Project Manager Intelligent Transportation Systems</td>
<td>4 May 2016</td>
</tr>
<tr>
<td>3</td>
<td>Eva Fraedrich</td>
<td>Humboldt University of Berlin</td>
<td>PhD. researcher</td>
<td>6 May 2016</td>
</tr>
<tr>
<td>4</td>
<td>Hans Jeekel</td>
<td>Eindhoven University of Technology</td>
<td>Part time Professor Societal Aspects of Smart Mobility</td>
<td>9 May 2016</td>
</tr>
<tr>
<td>5</td>
<td>Gonçalo Homem de Almeida Correia</td>
<td>Delft University of Technology</td>
<td>Assistant Professor Planning &amp; Design of Transport Systems</td>
<td>10 May 2016</td>
</tr>
<tr>
<td>6</td>
<td>Maaike Snelder</td>
<td>TNO</td>
<td>Senior Research Scientist Mobility and Infrastructure</td>
<td>10 May 2016</td>
</tr>
<tr>
<td>7</td>
<td>Gerben Feddes</td>
<td>RDW (the Netherlands Vehicle Authority in the mobility chain)</td>
<td>Senior Advisor Product Development</td>
<td>11 May 2016</td>
</tr>
<tr>
<td>8</td>
<td>Tom Alkim</td>
<td>Rijkswaterstaat, Ministry of Infrastructure and the Environment</td>
<td>Senior Advisor C-ITS and Automated Driving</td>
<td>12 May 2016</td>
</tr>
<tr>
<td>9</td>
<td>Florie van der Windt</td>
<td>Ministry of Infrastructure and the Environment</td>
<td>Project Manager Autonooms Driving</td>
<td>17 May 2016</td>
</tr>
<tr>
<td>10</td>
<td>Alexander Prinssen</td>
<td>Athlon International</td>
<td>VP Consulting and Mobility Solutions</td>
<td>20 May 2016</td>
</tr>
<tr>
<td>11</td>
<td>Caspar Chorus</td>
<td>Delft University of Technology</td>
<td>Professor of Choice Behaviour Modelling</td>
<td>23 May 2016</td>
</tr>
<tr>
<td>12</td>
<td>Carlo van de Weijer</td>
<td>Eindhoven University of Technology</td>
<td>Director Strategic Area Smart Mobility, Global Expert ITS</td>
<td>23 May 2016</td>
</tr>
<tr>
<td>13</td>
<td>Evert-Jeen van der Meer</td>
<td>Aon</td>
<td>Industry Director Risk Solutions</td>
<td>27 May 2016</td>
</tr>
<tr>
<td>14</td>
<td>Jolande Waterschoot</td>
<td>Aon</td>
<td>Managing Consultant</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Rens Braat</td>
<td>Louwman &amp; Parqui (importer of Toyota and Lexus in the Netherlands)</td>
<td>Manager After Sales Service</td>
<td>6 June 2016</td>
</tr>
<tr>
<td>16</td>
<td>Igor Jacobs</td>
<td>Mercedes-Benz NL</td>
<td>Product Manager Cars</td>
<td>10 June 2016</td>
</tr>
<tr>
<td>17</td>
<td>Andrew Mason</td>
<td>BMW Group NL</td>
<td>Product Communications Manager</td>
<td>10 June 2016</td>
</tr>
<tr>
<td>18</td>
<td>Wout Benning</td>
<td>RAI Association (Dutch automotive branch organisation)</td>
<td>Policy Advisor Sustainability and Technology</td>
<td>16 June 2016</td>
</tr>
<tr>
<td>19</td>
<td>Niki Sie</td>
<td>Mobility Heroes</td>
<td>Co-owner and founder</td>
<td>17 June 2016</td>
</tr>
</tbody>
</table>
## Appendix E: Vehicle automation key factor comparison

<table>
<thead>
<tr>
<th>Case study → Similar research⁴⁰</th>
<th>Legislation</th>
<th>Liability</th>
<th>Consumer Acceptance</th>
<th>Safety</th>
<th>Technological Development</th>
<th>Legacy</th>
<th>Mixed traffic</th>
<th>Purchase Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV technology trials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td>Relates to</td>
<td></td>
</tr>
<tr>
<td>Interoperability among AV technologies</td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td>Relates to</td>
<td></td>
</tr>
<tr>
<td>Costs/benefits of AV technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
</tr>
<tr>
<td>Development of AV in EU</td>
<td>Relates to</td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AV ownership structure (public vs private)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not mentioned as key factor in this case study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition steps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not mentioned as key factor in this case study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, emissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not mentioned as key factor in this case study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal/institutional context (national and European)</td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public/private expenditures on infrastructure</td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability of policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility, social equity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological barriers (Citizens and customers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing/image of AV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes towards AV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

⁴⁰ (Milakis, Snelder, et al., 2015)
### Appendix F: Vehicle sharing key factor comparison

<table>
<thead>
<tr>
<th>Case study → Similar research(^{41}) ↓</th>
<th>Accessibility of SVs</th>
<th>Availability of SVs</th>
<th>Status of a Privately Owned Vehicle</th>
<th>Urbanisation</th>
<th>SV fleet size</th>
<th>Consumers’ Willingness to Consume by Sharing</th>
<th>Parking Costs and Parking Space</th>
<th>Total Cost of Vehicle Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political and administrative support from the municipality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not mentioned as key factor in this case study</td>
</tr>
<tr>
<td>Big fleet size and variety of vehicles and providers</td>
<td>Relates to</td>
<td>Relates to</td>
<td></td>
<td></td>
<td>Partly the same</td>
<td></td>
<td></td>
<td>New in this case study</td>
</tr>
<tr>
<td>Urbanisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>New in this case study</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Relates to</td>
<td>Relates to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>New in this case study</td>
</tr>
<tr>
<td>Coordination and integration of the vehicle sharing to public transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not mentioned as key factor in this case study(^{42})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing and profiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{41}\) Based on (KiM Netherlands Institute for Transport Policy Analysis, 2015b). Because the second key factor according to (KiM Netherlands Institute for Transport Policy Analysis, 2015b) consists of two separable concepts, it was split into (1) a big fleet size and a variety of vehicles and providers was separated and (2) urbanisation.

\(^{42}\) Not explicitly mentioned as a key factor in this case study, but it was mentioned in narrative 5.