Automated vehicles:

Navigating towards a smarter future in a network of expectations

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Navigating towards a smarter future in a network of expectations

A case study on automated vehicles in the Netherlands

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Abstract

The automated vehicle has increasingly gained traction in academia, business, and government as a technological innovation that promises significant impacts on sustainable mobility, including safety improvements, congestion reduction, environmental efficiency, and various other social domains. These optimistic understandings of technology as an enabler of greener, safer and more efficient transportation tend to dominate present-day debates on automated vehicles. Understanding the interplay between different actors' expectations helps the government and businesses in prioritizing future technological developments and effective policy and decision making. For this purpose, this research draws on recent literature in socio-technical system transitions and social expectations dynamics, and addresses the question: *How do expectations shape innovation processes in the automated vehicle industry, and which implications can be derived for government and business?* An explorative and qualitative research was performed in which expectations held by different actors involved in vehicle automation were collected and analyzed. Thereafter, these expectations were used as input to construct different socio-technical scenarios. This resulted in three scenarios for future innovation processes differentiating in expectations about changes in niches, regimes, and the landscape. In two scenarios automated vehicles have the potential to overthrow the existing regime when environmental pressure from the landscape causes business or government to invest in automated vehicles. In one scenario, the actual benefits of automated vehicles remain unclear, preventing a socio-technical transition towards fully automated vehicles. Depending on the preferred outcome regarding the realization of collective and individual interests, government and businesses may influence the direction of the innovation process with respect to vehicle automation. The government can adopt the roles of actively coordinating the innovation process, leaving the innovation process to the market while ensuring basic mobility needs, or convincing and stimulating business and users to invest in vehicle automation. In addition, businesses can adapt the roles of responding to governmental demands, optimizing individual business models, or creating competition in a cooperative society. To conclude, there is an interaction between these different roles for government and businesses. Actor groups can try to form coalitions to create uniformity in expectations. As such, the proposed scenarios and roles can be used as a tool for a better identification of potential cooperative strategies between businesses and government. Furthermore, they can structure future debates about social and political priorities with respect to innovation processes involved with vehicle automation.

Keywords: automated vehicles, socio-technical transition, sustainable mobility, socio-technical scenarios, roles, expectations, innovation processes.

Preface

This document represents the results of the Master Thesis Project of the master program Sustainable Business and Innovation at Utrecht University. This research was conducted in collaboration with the Planbureau voor de Leefomgeving (PBL) and contributes to the third edition of the ‘signalenrapport’. In this report, PBL examines the effects of ICT developments on public infrastructure. In particular, the consequences of ICT on public interests, including accessibility, safety, innovative capacity, and future resistance are examined. As such, this research covers the topic of innovation processes in the automated vehicle industry in a network of expectations.

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List of abbreviations

AI	Automotive Industry
AV	Automated Vehicle
CE	Collective Expectation
CPB	Centraal Planbureau
DITCM	Dutch Integrated Testsite for Cooperative Mobility
EV	Electric Vehicle
IE	Individual Expectation
ICT	Information and Communication Technology
ITS	Intelligent Transport Systems
KI	Knowledge Institute
KiM	Kennisinstituut voor Mobiliteitsbeleid
MLP	Multi-level Perspective
NG	National Government
NGO	Non-Governmental Organization
PBL	Planbureau voor de Leefomgeving
PPP	Public Private Partnership
RG	Regional Government
SAE	Society of Automotive Engineers
STSc	Socio-technical Scenarios
TC	Traditional Car
TM	Traffic Management Company
UU	Utrecht University
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle

1. Introduction

Mobility has changed tremendously over history. In 1900 approximately zero passengers traveled by car. Nowadays, over 600 million passengers worldwide travel the roads by car each day (van Wee, Annema, & Banister, 2013). Over the last fifty years, it became apparent that there is also a drawback on the welfare that technological developments in transport created. The (car) mobility domain is coping with large problems such as emission of pollutants, congestion, and noise nuisance. One of the challenges is to ensure and enhance sustainable accessibility and mobility for populations through new logistic and infrastructural concepts (Batty et al., 2012; Nijkamp & Kourtit, 2012). (Urban) mobility is confronted with ever-rising mobility trends, that form the basis of the most important challenges related to mobility and transport, respectively quality and accessibility, utilization of space, impact on health and living conditions and the contribution to regional and global sustainability issues (Nijkamp & Kourtit, 2012).

Meeting these challenges will assure the effective and efficient movement of goods and passengers, that are basic to a vital society (Nijkamp & Kourtit, 2012). This makes the car mobility domain an agglomeration of technological innovations (Pel, van Est, & Raven, 2014). Especially information and communication technologies (ICTs) to stimulate economic development and to augment traffic management have increased in popularity (Batty et al., 2012; Söderström, Paasche, & Klauser, 2014). In order to respond to societal problems associated with traffic and transport, automated vehicles (AVs), recently gained traction. AVs are often seen as the symbol of combined innovations. They promise significant impact on driver safety, congestion, fuel efficiency, and enlarging road capacity (Fagnant & Kockelman, 2015; Klinger, 2016; Merat & Lee, 2012). Hence, the automated vehicle contributes somehow to sustainable mobility, and can be considered the ‘game-changing technology’ at the forefront of a socio-technical transition towards sustainable development (Pel et al., 2014).

These optimistic understandings of technology as an enabler of more sustainable mobility tend to dominate present-day debates on AV developments. When taking a techno-optimistic perspective, AVs promise to be greener, safer and more efficient (Klinger, 2016; Litman, 2014). However, this techno-optimism ignores the fact that technological solutions alone do not lead to sustainable mobility. A technological innovation requires social innovations as much as technological innovations (Pinch & Bijker, 1987). Technological fixes have often provided only temporary or partial solutions, as a result of rebound effects or other negative externalities (Farla, Markard, Raven, & Coenen, 2012). If automated driving is to change transportation dramatically, it needs to be both widespread and flawless. Turning such a complex technology into a commercial product is unlikely to be simple. It could take decades for the technology to come down in cost (Rotmans, Kemp, & van Asselt, 2001), and it might take even longer for it to work safely enough that we trust AVs to drive us around.

The diversity of expectations about the future has been a source of acute interest in literature on shaping socio-technical transitions (Borup, Brown, Konrad, & van Lente, 2006). Novel technologies do not substantively pre-exist themselves, except and only in terms of expectations that have shaped their potential (Borup et al., 2006). Since expectations held by different actor groups are intrinsic to social action (Berkhout, 2006; Truffer et al., 2008), they are a key element in understanding technological change. By giving definition to roles, they offer some shared shape of what to expect and how to prepare for opportunities and risks (Borup et al., 2006). Furthermore, by forming coalitions around positive expectations, protagonists of a technology can collectively create a certain vision and diffuse scenarios about its future potential in order to convince relevant actor groups, e.g. policymakers or businesses, to invest in it (Geels & Smit, 2000). However, these expectations can potentially betray vested interests, which may end up reinforcing power geometries and inequalities (Kouw, 2016). Present policy strategies are ill-equipped to deal with actor dynamics and the way they affect innovation processes (Kouw, 2016). The basic idea is that decision-making in firms and policy settings benefits from 'precautionary foresights' based on expectations (van Lente, 2012). It can help policymakers and business to better structure future debate about social and political priorities with respect to AV innovation processes. This is especially important given the rather self-congratulatory tendency that currently dominates the debate on automated vehicles (Townsend, 2014). Therefore, the following research question is formulated:

How do expectations shape innovation processes in the automated vehicle industry, and which implications can be derived for government and business?

In order to answer this research question, a qualitative analysis of expectations about AVs, specifically through semi-structured interviews, was conducted. This research takes an explorative approach towards answering the research question, in which expectations in socio-technical transitions are used to construct socio-technical scenarios about the innovation processes involved with AVs.

The choice of this socio-technical perspective has social relevance since looking at expectations can help prioritize future technological developments for the government, but also for scientists, engineers and business in decision-making processes (Eames & McDowall, 2010). This research seeks to engage with the innovation process and observe patterns within the diverse expectations in the socio-technical transition towards AVs. Subsequently, when the patterns are structured into scenarios, the scenarios can be used by the government as valuable guidelines for future debates to improve the effectiveness of policymaking. Thereby, it can help to answer which technologies should be supported and how investments in future technologies should be done. This is especially important when discussing the extent to which collective interests, e.g. sustainable mobility, is realized by a technological innovation. To reach sustainable mobility, scenarios are used as more heuristic tools to guide, structure and facilitate pluralistic forms of goal formation (Stirling, 2006).

Furthermore, emphasizing the scientific relevance of this research, this thesis complements existing scenario analyses on the AV industry by taking a socio-technical perspective. The advantage of such an approach is that discussions on technological developments should not be framed as a technocratic exercise, but as an intertwined process between technological and social innovation as argued in the aforementioned paragraphs. This has not been done in existing literature. In addition, this thesis pays attention to the specific allocation of roles for government and business. With an empirical approach building on socio-technical transition concepts, this thesis contributes to the call for development tools for precautionary foresights (Stirling, 2006) that allow policy and decision makers to engage and explore a wide range of actors' interests.

The outline of this research proposal will be as follows. Subsequent to this introduction, chapter 2 contains a description of the theoretical framework, from which a conceptual model is derived. In chapter 3 the methods are explained, followed chapter 4 in which results are shown and analyzed. Finally, in chapter 5 the results are discussed, and in chapter 6 a conclusion is drawn.

2. Theoretical framework

The following chapter provides an overview of the used theories based on the concepts of socio-technical transitions and the multi-level perspective, sociology of expectations, roles, and a literature review on the automated vehicle. In the end of this chapter, a conceptual model is derived from the discussed concepts.

2.1. Socio-technical transition and the multi-level perspective

In order to understand the relevance of expectations in shaping a transition, a better understanding of socio-technical transitions is necessary. A transition is a gradual, continuous process of change where the structural character of a society transforms from one socio-technical system to another (Farla, Alkemade, & Suurs, 2010; Geels, 2005). A core tenet in associated literature is that the terms *technical* and *social* are intimately intertwined, and interplay must be perceived as a co-evolutionary process between a technology and its social environment (Kemp, Schot, & Hoogma, 1998). This is also called the mutual shaping of co-evolution (Meijer, 2015), and can differ per country, sector, or innovation system (Faber & Hoppe, 2013). Taking these co-evolutionary dynamics of technical change as a starting point, technological transitions require changes in different dimensions including infrastructures, technological artifacts, institutional contexts, user practices, cultural artifacts and regulatory aspects (Truffer et al., 2008). Hence, the emergence of new technologies is co-evolutionary in the sense that they are seen as being formed by, and embedded within, particular economic, social, cultural and institutional structures and systems of beliefs. Conversely, technological configurations themselves constitute, order, and change the nature of these encompassing structures (Berkhout, Smith, & Stirling, 2004). At the heart of the transition theory interdependent patterns at three 'levels' can be distinguished, referred to as the multi-level perspective (MLP).

Socio-technical niches

Innovations are often developed in protected spaces called *niches* outside the regime. These niches could progressively come to influence, modify and substitute the established regime (Berkhout, 2006; van Wee et al., 2013). Therefore, transitions crucially depend upon activities within niches.

Socio-technical regimes

A mutually aligned, established set of dimensions is defined as a technological *regime*. According to Geels (2002) regimes can be characterized along seven dimensions: technology, user practices and application domains, symbolic meanings of technology, infrastructures, industry structure, policy, and knowledge. A certain structure of these dimensions can both enable and constrain specific changes (Kemp et al., 1998).

Socio-technical landscape

The landscape can be defined as a background variable such as sustainable development, or political culture and coalitions, which channel transition process and change themselves slowly in an autonomous way (Berkhout et al., 2004).

The socio-technical *regime* occupies an intermediate position between the *niche* and the socio-technical *landscape*, as shown in figure 1. A socio-technical transition might take place when the existing regime experience pressure from the broader socio-technical landscape, indicating problems (Elzen, Geels, Hofman, & Green, 2002b). For example, the increasing mobility demands that cause congestion or environmental concerns due to pollution in traffic. Furthermore, there are always groups or individuals in society seeking for novelties within the existing regime, which can cause the existing regime to become less stable. Subsequently from 'below', new socio-technical configurations in niches that pose alternatives to or require adaptions of the regime's structure can grow (Truffer et al., 2008). New configurations that might become successful gradually move from the niche-level to the landscape, while slowly adapting, influencing and changing all dimensions in the existing regime until they become constitutive and emblematic in the landscape. In recent years, academics argued that addressing change towards a sustainable direction does not only involve technical change but requires a fundamental socio-technical transition that restructures human society (Eames & McDowall, 2010).

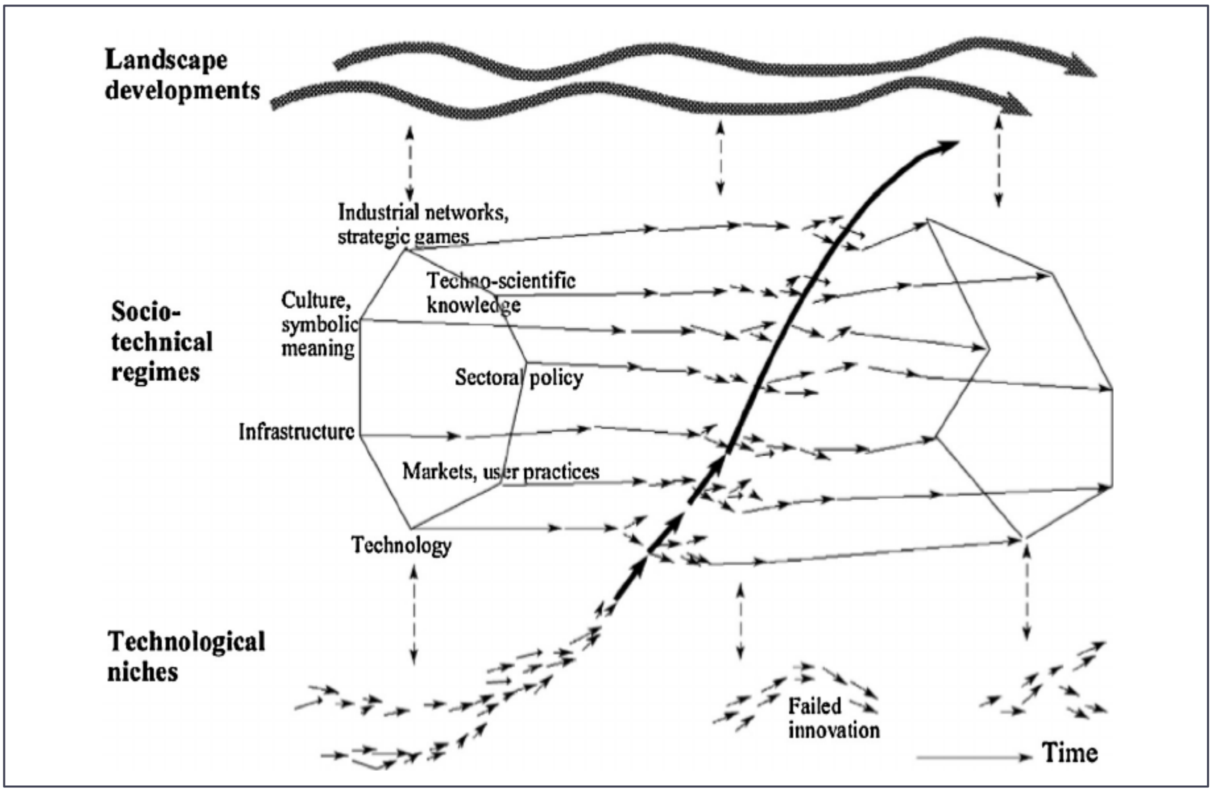

Figure 1: A dynamic multi-level perspective on transition management, adapted from Geels (2002)

In practice, very few local configurations developed in niches are successful in seeding a regime transition (Berkhout et al., 2004). No single actor has enough power to oversee and control all aspects of such a co-evolutionary process (Truffer et al., 2008). Therefore, innovation occurs as the outcome of linkages between developments at the different levels (Geels, 2002). Four phases of transition can be distinguished (Rotmans et al., 2001):

- The pre-development phase, in which radical innovations are developed at the niche level, and the status quo does not visibly change

- Take-off phase, in which specific innovations develop in market niches with specific selection criteria, and change gets under way.
- Breakthrough, in which the current regime becomes less stable, causing visible structural change, and therefore innovations can start to grow in mass markets.
- Stabilization, in which a new regime is substituted and a new dynamic equilibrium is reached.

Within these phases, different social processes come into play (Rotmans et al., 2001). In recent years, dynamics of expectations increasingly gained attention as an explanatory factor of the emergence of new socio-technical configurations, since they can be seen as ‘bids’ about what the future might be like, that are offered by actors in the context of other expectation bids (Berkhout, 2006).

2.2. Sociology of expectations

Actors continuously and explicitly refer to what is possible in the future. Therefore, in the absence of an already materialized reality, these references are *expectations* about the future and can serve as narrative infrastructures which enable and constrain activity and innovation (Berkhout, 2006; Truffer et al., 2008). The *performative* nature of expectations enables them to steer, stimulate and coordinate action, and thereby shape developments or transitions in science and technology (Borup et al., 2006; van Lente & Bakker, 2010; Truffer et al., 2008). The conceptualization of expectations is called the ‘sociology of expectations’ and was first introduced by van Lente (1993).

Expectations contain a *script*, that is a description of the future situation and a concomitant distribution of roles for selves, others, and technologies (van Lente, 1995). They depend on individual experiences, priorities and positions, but can also be seen as relational objects and as a result of social interaction (Berkhout, 2006; Truffer et al., 2008). Many scholars have pointed to the variety of expectations: they may be positive, referred to as promises or negative, they can vary in level (which is discussed later), they may vary in content concerning technical, commercial, societal aspects or a mix of these, and their modalities may range from taken for granted statements that do not meet any resistance, to meticulously organized arguments to counteract foreseen rebuttals (Borup et al., 2006; van Lente, 2012). When expectations can be mobilized, legitimized and exploited, managing a transition can be achieved through facilitating alignment of actors around common visions, defining research priorities, stimulating resources for R&D, reducing uncertainty in decision making for innovative developers, and by regulatory support (van Lente, 1993). However, successfully managing expectations depends on the *robustness* of the expectation. When an expectation is less robust, it needs more additional argumentation and justification when used as an argument or reason for certain actions.

Although expectations represent the general utility of a specific action that an actor is undergoing, they also reflect an actor’s own interest. Positive expectations of a technological option’s future potential are vital to its further development (Bakker, van Lente, & Meeus, 2012). As a result, actors may try to create positive expectations of ‘their’ technologies. Therefore, the script of expectations is not necessarily substantively correct, but when it is shared it can be used as a tool to reduce uncertainty (van Lente, 1995) and to realize a coalition's common vision, possibly at the expense of other visions. Hence, when a new technological opportunity emerges, its protagonists formulate promises and diffuse scenarios about its future potential in order to convince relevant actor groups, e.g. policymakers or businesses, to invest in it (Geels & Smit, 2000). Over time, choices are made and priorities are set. Van Lente (1993) refers to this as the '*agenda',* which reflects on what is believed to be a fruitful direction for progress in political or technological agenda setting. The agenda is a list of subjects or problems to which actors pay serious attention at a given time (Kingdon, 1984). In addition, expectations that help technologies to develop do not guarantee success for this specific technology later on (van Merkerk, 2007).

Expectations that are individually formed, are defined as *individual expectations*, and once they are shared and become widespread across different actor groups, they are defined as *collective expectations* (Truffer et al., 2008). Collective expectations are powerful since they are taken into account in decision-making processes by almost all actors even if they are more skeptical about the expectation (Truffer et al., 2008). Widely shared expectations cannot be ignored by the innovating actors, and therefore can form a crucial impulse for new technological developments (van Lente, 1993). A related term that is commonly used is the term *vision*. Visions are designed to articulate a group of collective expectations of a selected coalition of actors and have a formalized character, while expectations are often more fragmented and less formalized (Eames, Mcdowall, Hodson, & Marvin, 2006). The aim of a vision is to create a protected space, or niche through the construction of interlocking collective expectations that protect and control technological developments (van Lente, 1995). Thereafter, visions are used to steer bottom-up, niche-to-regime processes of transition management (Berkhout et al., 2004), through the protected environment of the created niche. Hence, visions offer a potentiality that requires the endorsement and affiliation of other actors before it can be actualized (Berkhout, 2006). This is called the degree to which expectations have an *interpretative flexibility*, or the ease with which they can be matched to circumstances and can influence the cohesiveness and robustness of a coalition organized around a vision (Berkhout, 2006) A degree of flexibility over the interpretation of a vision can widen its relevance to greater number of actors, and offer a base for concrete and constructive action. However, too much flexibility can lead to a valueless vision and interpretive instability that harm its capacity to coordinate and shape the actions of actors (Berkhout, 2006).

Furthermore, the level of influence that an actor may exercise over the script of the expectation can differ. Expectations that cannot be addressed by strategic actions of individual actors, including socio-economic framework conditions or political situations, are termed as contextual expectations, whereas expectations in which specific actions of actors influence behavior of other actors are termed as behavioral expectations (Truffer et al., 2008). In socio-technical transitions, the former refers to expectations on landscapes and regimes, and the latter is more important at the niche level. These characterizations of expectations are shown in table 1.

Table 1: Topography of expectations related to potential system transitions, differentiated with regard to the level of analysis and the scope of social support, adapted from Truffer et al. (2008)

	Individual expectations	← →	Collective expectations
Landscape	Individual beliefs about long-term trends	Projections of future context conditions as shared with specific actor groups (e.g. impacts of climate change as identified by scientific experts)	Broad societal visions about the future
Regime	Individual beliefs about ability of regimes to respond to external pressures	Expectations shared with specific actor groups (e.g. associations of transport utilities about future sector structures)	Broadly shared visions about future sector structures
Niche	Individual assessment of development potential for specific innovative technologies and products	Hopeful alternatives preferred by certain actor groups (e.g. NGOs support for a future smart mobility)	Sectoral national priorities in innovation policy to support “promising” technologies

A further distinction can be made between explicit and implicit expectations. Implicit expectations are unquestioned assumptions by specific actors or groups and are perceived as taken for granted, whereas explicit expectations are expressed by its beholder when considering alternatives to retrace evidence for his or her assumption (Truffer et al., 2008).

Important to notice is that expectations are not stable and can change over time in response and adaption to new conditions or emergent problems (Borup et al., 2006). The development of new technologies is often accompanied by a *hype* (Budde, 2015). A hype is a phase that is “characterized by an upsurge of public attention and high rising expectations about the potential of an innovation, followed by a considerable decline of attention that may go hand in hand with a disappointment of the hyped expectations” (Ruef & Markard, 2010, p. 317). These hype cycles may have a strong impact on the actual development of an innovation (Truffer et al., 2008). If many actors base their choices on similar decision rules, expectations can become increasingly powerful, regardless of whether the actor really believes in their adequacy. When a technology is surrounded by high rising expectation about the potential of an innovation, there is a possibility that it cannot live up to these high promises. However, this does not imply that companies should not invest in a technology because it is being hyped. In order to be successful, an innovation needs to gain attention to attract resources (Ruef & Markard, 2010). In order to use the momentum of positive expectations, it is important to stabilize these expectations (even in they are hyped) in forms of more stable institutions such as long-term funding schemes or commitments by a larger variety of actors (Budde, 2015).

2.3. Roles

Of particular importance are the implicit or explicit roles embedded in expectations (Borup et al., 2006; van Lente, 1995). A role can traditionally be described as a pattern of expectations about behavior and attitudes that apply to a particular social identity (Turner, 2001). However, as argued by van Lente (1993) in a socio-technical context allocation or positioning of a role is central. Adopting a position involves the use of rhetorical devices by which oneself and other participants are presented as standing in various kinds of relations. Thus every position exists only as the reciprocal of some other position (Langenhove & Harré, 1994). The allocation of roles includes roles directly for others and artifacts (*explicit roles*) and assuming roles for others and artifacts to add power to the statement (*implicit roles*) (van Lente, 1995). Whether such expectations about the role of others and the role that an actor has in mind for himself are in line with each other likely influences interaction as well (van Merkerk, 2007). In addition, for emerging technologies, it is argued that the interrelatedness of actors and their roles is often undetermined and uncertain (van Merkerk, 2007).

Within early stages of technological development, it is likely that attributed roles will be ambiguous, lacking form or agreement, and there is a high level of market uncertainty and competitions between innovations (Borup et al., 2006). It is argued that in this phase shared expectations are of high importance since enrolling a wider range of stakeholders increases the possibility of success (Borup et al., 2006).

2.4. The Automated vehicle

The automotive industry has been a proliferation of innovations in order to respond to societal problems associated with traffic and transport, including increasing emissions, congestion, environmental pressure and climate change (Elzen et al., 2002b). The discourse on the automated vehicle is suggestive of a transition take-off for sustainability, although it is doubtful whether these developments tend towards a true regime shift (Pel et al., 2014). This makes the introduction of automated driving one of the main uncertainties of the future transport system (Milakis, Snelder, Arem, Wee, & De Almeida Correia, 2016).

The first ideas and predictions of cars that could drive extensively automated date back to General Motor's highly influential Futurama exhibit at the 1939 World's Fair in New York (Townsend, 2014). There it was argued that cars in 1960 would drive with devices that would correct the faults of human beings as drivers. In a distinct shift from the last 50 years, when transportation innovation was shaped by big public infrastructure projects, this transformation is being driven by the private sector. The internal driver of the developments around vehicle automation largely revolved around innovations by car manufacturers to become more competitive and gain new markets. This includes product and accessories development which increases their competitive advantage (Elzen et al., 2002b). As a response to this competition, and to previously mentioned uncertainties of future transport systems, traditional car mobility shifts towards cars that are basically information technology-based products (Jeekel, 2015).

In many ways, the AV can be considered as a model were two parallel innovation streams come together: cooperative system innovations and innovations in-car. The initial option refers to systems that promote cooperative driving, including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications systems around the vehicle to improve traffic management and the inhabitant's mobility (Connecting mobility, 2015; Nor & Wahap, 2014) The latter refers to innovations inside the car, mainly aimed at increasing efficiency and safety inside the vehicle, including vehicles, ships, and aircraft, and is often defined as *autonomous* driving (Wilmink, Malone, Soekroella, & Schuurman, 2014).

Currently, new entrants such as Google and Apple, slowly start to influence and push the car industry worldwide towards ICT car-based solutions (Fagnant & Kockelman, 2015). Therefore, for incumbents in the car industry, it seems necessary to adapt to new markets. By looking at the chains in car mobility, partner networks can be organized with providers of information technology, industries and mobility services (Jeekel, 2015). As a response to increased competition, actor relationships changed from traditional linear system to an ecosystem value chain in which different actors have multiple relationships that are interchangeable to create and deliver the most sustainable products or services (Krijeveld, Deuten, & Van Est, 2014).

In this study, the taxonomy for the manual-to-automated vehicle of the Society of Automotive Engineers (SAE) is used (figure 2). In the first three levels, the driver it is assumed that the driver will control all driving tasks. In level 3, 4 and 5 automated driving system takes control of all dynamic tasks of driving. In addition, in conditional and high automation the driver is expected to be available for occasional control while in full automation the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip (SAE International, 2014).

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

Figure 2: SAE International's levels of driving automation for on-road vehicles, adapted from SAE International (2014).

Within scientific research, some explorations about the future of automated driving have been done (Kennisinstituut voor mobiliteitsbeleid (KiM), 2015; Milakes, Snelder, Van Arem, Van

Wee, & De Almeida Correia, 2015; Townsend, 2014). Milakis et al. (2016) expect that fully automated vehicles will likely be a reality between 2025 and 2045, and developed four scenarios that estimate the potential implications for traffic, travel behavior and transport planning. They argue that the pace of development largely depends on technological evolution, policies, and customers' attitude, but fully automation will be reached. To the contrary, the KiM (2015) conducted a scenario analysis in which they argue that the level of automation and the amount of sharing are the highest uncertainties for future transport and mobility systems. They argue that in two of the four possible scenarios fully automated vehicles will not be developed. Also, the importance of expectations in publically available reports has been recognized and used as a source for scenario development. Townsend (2014) conducted a scenario analysis for North America and used four archetypes, i.e. growth, collapse, constraint, and transformation, as a way to structure different expectations. As such statements in publically available reports about the future of mobility were 'forced' into one of these four archetypes.

2.5. Conceptual model

Based on the abovementioned concepts, the conceptual model is derived as presented in figure 3. The context is the automated vehicle industry in which expectations are formed. The dependent variable is innovation process that is influenced by expectations about the automated vehicle industry. When individual expectations (IE) are shared and become collective expectations (CE) they can form a vision of an expected future. If an expectation is shared it becomes more powerful. In order to generate activities and determine roles that will lead to a socio-technical transition, expectations have to be congruent in all levels (i.e. landscape, regime and niche). Furthermore, it is assumed that these different visions will guide activity and lead to the allocation of roles, and thereby shape the innovation process.

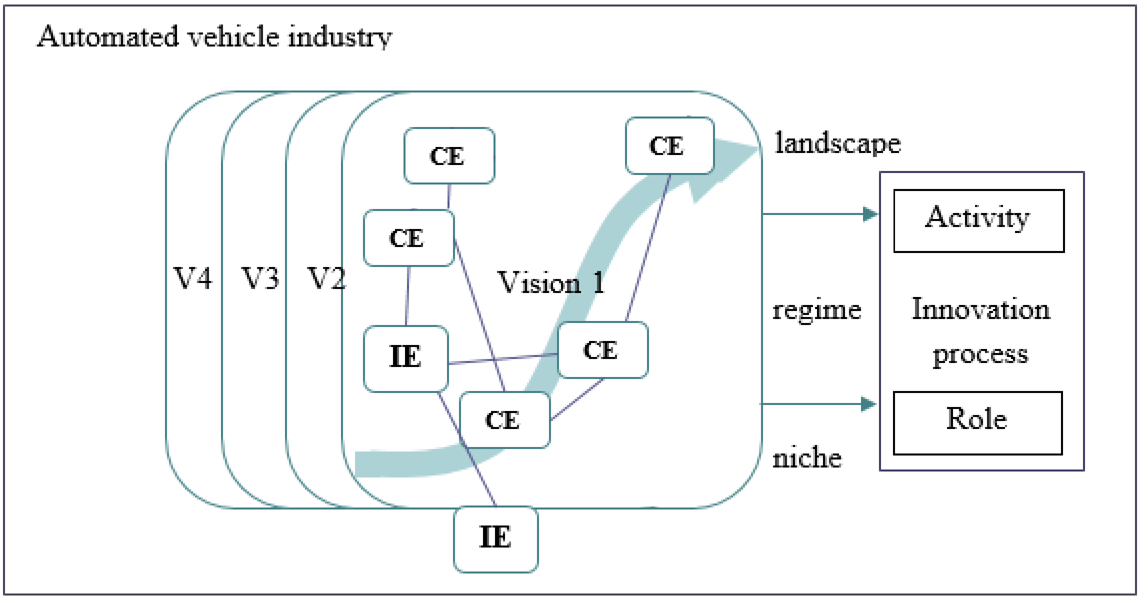

Figure 3: Conceptual Model

3. Methods

In this section, the methods used are presented. Hence, firstly the research design will be described, followed by data collection, and data preparation and analysis.

3.1. Research design

The aim of this study is to map, assess, and reflect on expectations of involved actors in AVs which will provide answer to the questions; how did the expectations arise, develop, grow or disappear, how will they transform into activities, and how they relate to specific actors, organizations, narratives or other expectations (van Lente, 1995). When the analysis takes actors as a starting point, expectations are used as a source to legitimize behavior, mobilize others, and so on. This results in the problem that the actual content of the expectations moves to the background. When centralizing expectations as a starting point of analysis these characteristic becomes clearly visible, through focusing on the script that allocates roles in technology (van Lente, 1995). Therefore, in order to answer the question how expectations shape the innovation process, an in-depth study focusing on the content of expectations is necessary to elucidate the dynamics in a socio-technical transition.

In order to study expectations, a qualitative research method is chosen. Through qualitative research, detailed and in-depth data can be obtained (Bryman, 2012). In addition, Smith, Voß, & Grin (2010) point out that quantitative analysis may be limited to relatively stable socio-technical situations where parameters and characteristics are well known, which is not the case for the transition to AVs. The research is exploratory in nature, and through inductive reasoning, specific observations are analyzed to discern patterns that are assumed to be generalizable with respect to the AV industry. Furthermore, the theoretical framework will serve as a guideline to collect data, and the expectations articulated will subsequently be used to construct socio-technical scenarios. The conceptual model in figure three will serve as a tool for mapping out the socio-technical scenarios and topology.

In this research, a case study on the AV industry in the Netherlands was conducted, providing an in-depth exploration of the complexity and uniqueness of socio-technical transition dynamics in a real-life context by gathering various insights of different actors (Thomas, 2011). A case study allows a detailed examination of a single example of a class phenomenon (Abercrombie et al., 1984 in Flyvbjerg, 2006). Therefore, a case study inquiry is an appropriate method for this research.

3.2. Data collection

This research was comprised of several research steps as shown in figure 4. The first phase consisted of a preliminary literature study to demarcate the concepts and boundaries of the AV industry. This was done by searching for the keywords 'automated vehicles', 'autonomous cars', 'sustainable mobility', 'ICTs and mobility', 'expectations about automated cars', and 'innovations in mobility'. Furthermore, explorative conversations with experts directly or indirectly involved in the industry, and the attendance of several workshop and conferences provided input to identify relevant actors for further interviews in the next phase. This sampling method is also known as snowball sampling which is considered appropriate to a case which features niche markets (Biernacki & Waldorf, 1981).

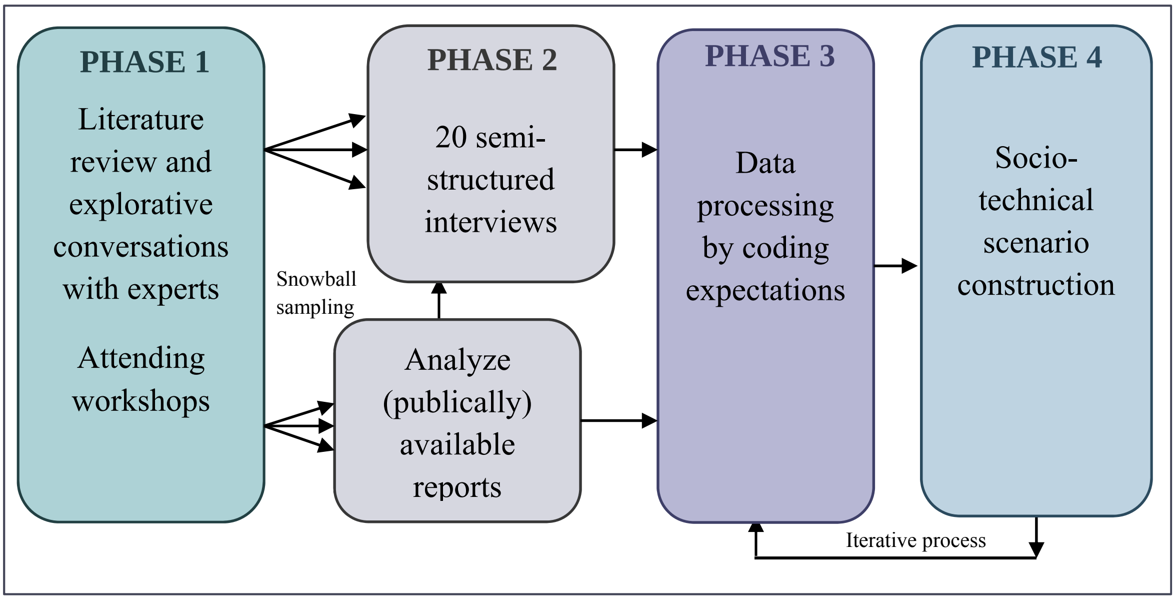

Figure 4: Research phases

In phase two, publically available reports[1] (table two) were analyzed to identify and complement the list of potential interviewees.

Table 2: Overview of the analyzed reports[2]

Title of Report	Author(s)	Data type
Drivers of Change	Bamonte (2013)	Governmental agency report
Google self-driving car Project monthly report, February 2016	Google (2016)	Individual company report
Automated and Autonomous Driving: Regulation under uncertainty	International Transport Forum / OECD (2015)	OECD report
Paving the Way for Driverless Cars: A policy Roadmap	Klinger (2016)	Scientific Report
Autonomous Vehicle Implementation Predictions: Implications for Transport Planning	Litman (2014)	Interdepend Research Organization report
Speech minister Schultz for the start of the WEpod project in January 2016	"Toespraak van minister Schultz van Haegen bij de start van de	Governmental report

[1] In line with the recognition that activity takes place on different levels as discussed by van Merkerk (2007), the chosen reports aimed at representing activity on the different levels.
[2] Complete references of the reports can be found in the reference list

	testfase van de WEpod" (2016)	
Coöperatieve systemen & Automatisch rijden	Wilmink et al. (2014)	Consultancy report

Furthermore, when identifying the most suitable interviewees, it was kept in mind that private-public collaboration is necessary to reach successful implementation of ICTs in existing urban systems (Hajer & Dassen, 2014). Therefore, both the private and public sector were approached for interviews. This resulted in 20 interviews with experts directly or indirectly involved in the AV industry in the Netherlands, as presented in table 3.

Table 3: List of interviewed organizations

	Organization	Type of organization
1	Vialis	TM (Traffic Management)
2	Innovatiecentrale	TM
3	Intraffic	TM
4	Siemens	TM
5	Dynniq	TM
6	Ministry of Infrastructure and Environment	NG (National Government)
7	Rijksdienst Wegverkeer	NG
8	Rijksdienst Wegverkeer	NG
9	Inspectie leefomgeving en Transport	NG
10	Connecting Mobility	NG
11	Kadaster	NG
12	AutomotiveNL	AI (Automotive Industry)
13	FIER	AI
14	HERE	AI
15	Nissan	AI
16	Gemeente Den Haag	RG (Regional Government)
17	Provincie Noord-Holland	RG
18	Knowledge institute for Mobility policy	KI (Knowledge Institute)
19	CROW	KI
20	Planbureau voor de Leefomgeving	KI

The interviews were semi-structured, meaning that the main topics were set while the interviewee had room to address new subjects (Bryman, 2012). The abovementioned reports (table two) were then used to identify the main topics that served as guidance during the interviews (i.e. infrastructure, technology, public-private partnerships and networks, car sharing, user acceptation, consumer behavior, legislation and mobility in general). The interviews started with open and general questions about the actor's own experiences with AVs. Hereafter, the questions would go in depth on expectations about the different dimensions. The complete interview design can be found in appendix A.

In phase 3 the data was analyzed and processed, resulting in socio-technical scenarios in phase 4. A continuous reflection in phase 3 and 4 is presented by the arrow in figure 4 since the construction of the scenarios is the result of an iterative process, which is discussed in detail in the next section.

3.3. Data preparation and analysis

In order to analyze the collected data, interviews were recorded, transcribed and coded with the use of NVivo. Bryman (2012) shows that NVivo is a suitable software for analyzing qualitative data since it enables the researcher with statistical capabilities for the analysis. In order to analyze and structure the heterogeneous set of data, three steps were undertaken:

Step 1 Expectations classification

The main themes identified in phase two were used as a starting point for the classification of expectations within NVivo. Hence, they were created as the parent *nodes*[3]. Within these themes, new sub (child) nodes were created to create a hierarchy for expectations that would fit into the corresponding theme (for example, 'there will be separated lanes on highways for AVs' was coded as a child node under the parent node 'infrastructure'). Through an iterative process, the evaluator went several times through the data to identify possible patterns between expectations. These patterns then resulted in the separation or merging of nodes, after which the text was analyzed again.

Furthermore, within most expectations, interviewees stated what roles they allocated to specific actors or organizations to translate expectations into activities. Adopting and attributing a position involves the use of rhetorical devices by which oneself and other participants are presented as standing in various kinds of relations. These allocated roles were created as the parent *cases*[4]. The cases together with the nodes subsequently form the base for the next phase of scenario construction.

Step 2 Socio-technical scenarios

The second step included the development of socio-technical scenarios, hereafter STSc. Making expectations explicit by embedding them into a scenario enables the researcher to capture expectations and visions into consistent and rich stories (Geels, 2002). Furthermore, scenarios help to order these individual and actor group specific expectations in a broader discursive context, and can be used as a synthesizing set of individual expectations of all participants into coherent potential future regime structures (Truffer et al., 2008). Not all scenarios correspond directly with individual expectations, but they are rather clustered into a narrative that can be used as a reference point for all actors involved in the socio-technical transition. A broad range of scenario methods exists. According to Hofman et al. (2004), scenarios are usually constructed following a sequence of steps, presented in table 4. This served as a guideline for the scenarios developed in this research.

Table 4: Methodological steps in scenario building, adapted from (Hofman et al., 2004)

Step 1	Identify focal issue or decision
Step 2	Make an empirical analysis of aspects and processes which directly and indirectly influence the focal issue
Step 3	Rank aspects and processes by importance and uncertainty

[3] Nodes in NVivo are described as containers for your coding that represent themes, concepts, ideas, opinions or experiences (QSR International, 2015)
[4] Cases in NVivo are described as containers for your coding that represents your 'units of observations' – for example, people, places, organizations or artifacts (QSR International, 2015)

Step 4	Select scenario logics (skeleton): give different scores to those aspects and processes which are most uncertain and have most effect
Step 5	Flesh out and write the scenarios
Step 6	Derive implications for initial decision or issue

This research uses *socio-technical scenarios* as discussed by Elzen, Geels, Hofman, & Green (2002a). STSc is a narrative that describes possible future developments, making use of patterns that can be observed in the multi-level perspective and expectation dynamics (Eames & McDowall, 2010). STSc main distinctive feature compared to other scenario methods is that it can identify linkage possibilities. These linkage possibilities are defined as dimensions at each of the three levels (niche, regime, landscape) that could link up to create a socio-technical transition (Elzen et al., 2002a). By simultaneously focusing on how technologies develop in niches and regimes, a better insight can be provided on innovation processes in the AV industry.

To construct the scenario, the outcomes (i.e. expectations) of step one that were mentioned by at least two persons would be considered as ‘important’, and therefore be part of a scenario. A key objective at this stage was to ensure that the set of scenarios included the broad possibility space that was found in the interviews and that no relevant future was excluded. Firstly, the most divergent expectations were coded under scenarios. When two expectations within a dimension were the direct opposite, they would be coded as scenario one, and scenario two. For example: “AV will lead to more cars” against “AV will lead to fewer cars”. Subsequently, by going through the data several times, linkages were made between different dimensions. For example: “people like to drive” should be combined with a scenario that states “Users can still turn off their automated systems”. Thereafter, all remaining expectations were fit into a scenario. It is important to notice that the final number of scenarios was not pre-determined, meaning that they were sometimes merged or separated until the results showed consistent and congruent stories in which interrelations between the dimensions at all levels were present.

Step 3: Support of scenarios per actor group

When the expectations were all coded under a scenario, the next step was to look which specific actors (i.e. automotive industry, traffic management companies, knowledge institutes, national government, and regional government) were supporting a specific scenario. The scenario that had the largest correspondence with an actor’s expectations was indicated with ‘++’, the scenario that was expected less by the same actor with a ‘+’, and the scenario that was the least expected by that actor was indicated with a ‘-’.

4. Results

In this section, the results are presented. Firstly, a historical narrative of the (automated) vehicle industry in the Netherlands is shown. This is needed to get a better overview of the current situation of actors operating at the different levels including the landscape, regime, and niches. Thereafter, an STSc was constructed building on insights from the interviews.

4.1. Background of the AV industry in the Netherlands

The Netherlands is considered a front runner within the domain of AVs, especially in providing essential components for cooperative systems (Wilmink et al., 2014). In figure 5 the most important current projects in cooperative and automated innovations, and a future roadmap for the Netherlands is presented. Besides the active participation in European projects, many Dutch organizations and overarching platforms aim at promoting the Netherlands as a hot spot for smart mobility initiatives (Connecting mobility, 2015; Wilmink et al., 2014).

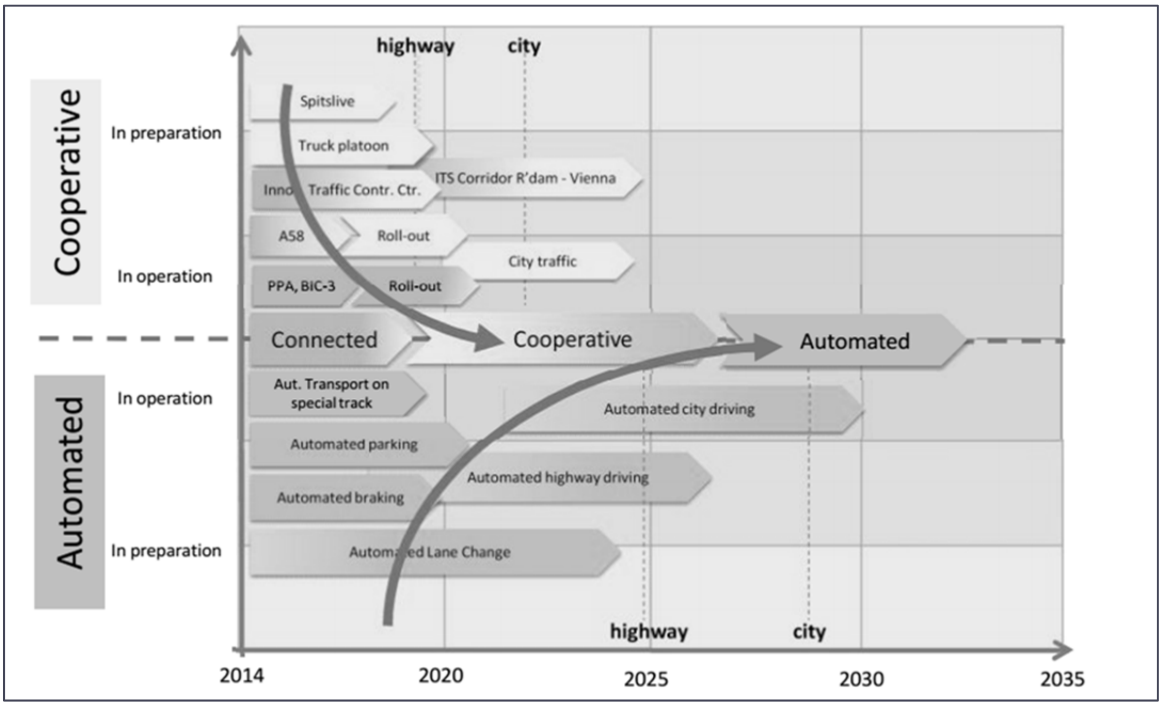

Figure 5: Developments in cooperative and automated driving in the Netherlands, adapted from AutomotiveNL (2014)

As shown, developments of the AVs started with development in connected systems. This refers to information systems that provide consumers with individually optimized information. This data forms the real-time input for innovations in cooperative and automated systems (Connecting mobility, 2015).

Within the Netherlands, in the past decennia, the number of cars continued to increase (CPB & PBL, 2015). Relative to 2010, the largest growth in car use is perceived outside peak hours, and on the main roads (CPB & PBL, 2015). This growth increasingly puts pressure on highways causing economic and societal problems, including pressure on the environment and safety issues (AutomotiveNL, 2014). The government responded to these external pressures by new and different subsidy programs, the stimulation of AV development through promoting experimentations, demonstrations projects, and an official letter from the minister of Infrastructure and the Environment to the Dutch parliament in 2014. In this letter the minister suggests that AVs will use cooperative systems and thereby contribute to social goals (Wilmink et al., 2014), thereby large scale testing on public roads should be stimulated. The past two years, different demonstrations were done. Most were initialized on a local scale and place specific conditions, including the following recently started and continuing projects (Wilmink et al., 2014):

- Practice test Amsterdam
- Brabant In-car II projects
- Wepod
- A2 cooperative driving test
- A58 'spookfile' project

Furthermore, several public-private partnerships (PPPs) were established. For example, DITCM (Dutch Integrated Testsite for Cooperative Mobility) was set up as a partnership between the government, industry and knowledge institutes to stimulate and facilitate the introduction of cooperative traffic systems (Wilmink et al., 2014). Despite the fact that automated driving recently became a popular topic in the public debate, in academic literature a decline in publications can be seen since 2014. Dynamics in the academic literature on AVs are shown in figure 6.

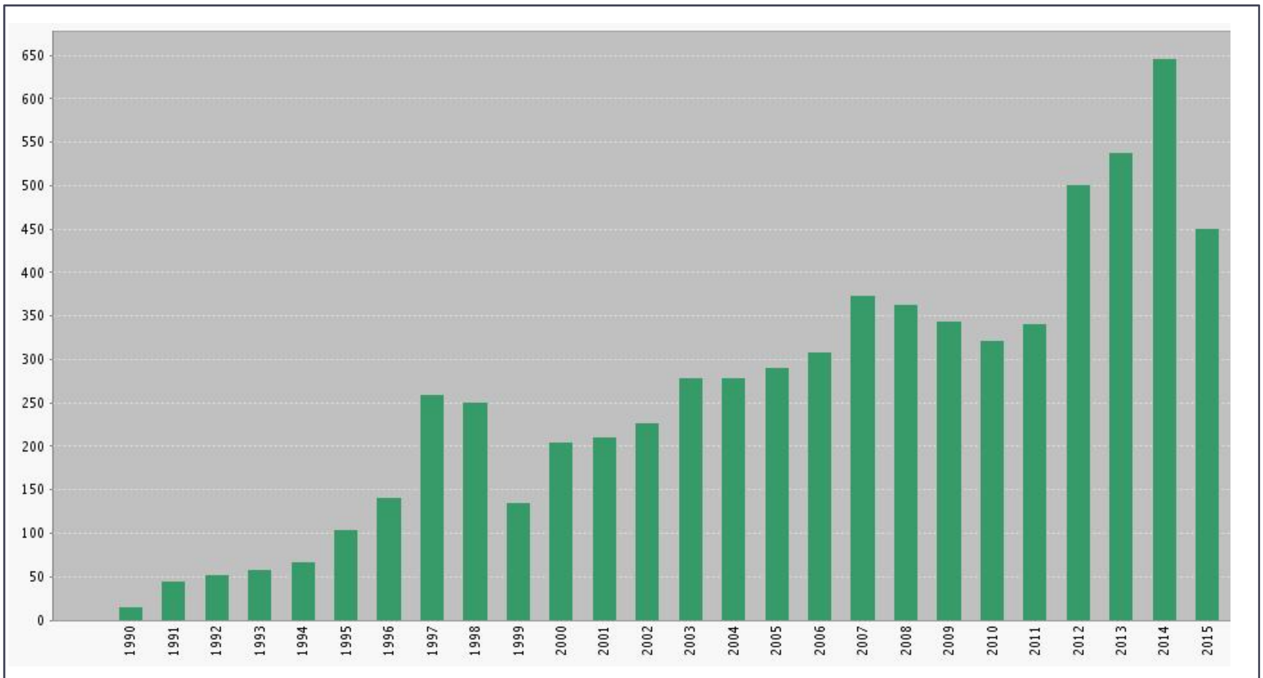

Figure 6: ISI articles including 'automated vehicles' or 'self-driving car' or 'autonomous car' or 'automated car' in the title (derived May 25, 2016).

4.2. Socio-technical scenario analysis

Building on the insights from the interviews with experts, a set of three scenarios was developed. First, a description of the expectations within the different dimensions is provided, followed by the scenarios.

4.2.1. Expectations

Analyzing the coded references and sources, eight different recurrent dimensions were used in line with affected dimensions in technological regimes according to the literature: technology, user acceptance, infrastructure, mobility (user practices), regulatory framework, car ownership (cultural changes), new business models (markets), and other trends that could influence AVs. In total, 70 different expectations and 29 roles were found, which are presented in appendix B and C. The next paragraphs provide a detailed description of the expectations in the different dimensions, including a supportive quote of the expectation. At the end of each dimension, a small conclusion is presented showing the most divergent expectations within that dimension.

Technology

Mentioned by all interviewees were expectations about the development of technologies in and around AVs. Expectations were found to be divergent discussing the cooperativeness of the vehicles. The first group of actors argued that a cooperative communication system including V2I communication is the most efficient way of organizing AVs. The majority mentioned the government as being responsible for these systems.

"A cooperative system has the benefits to enable the government to intervene when collective interests including traffic flow, environment and safety are threatened, and as control mechanisms for road authorities [...] Although vehicle to vehicle communication can organize traffic, it does not optimize the system as a whole" (#1)[2]

On the other hand, it was argued that governmental investments in roadside infrastructures are relatively expensive when you can invest in in-car systems. As argued by some interviewees V2V communication is preferred since the industry does not depend on governmental investments. Through smart solutions, cars can sufficiently respond to upcoming traffic situation by high definition maps offered in navigation systems.

"When the industry depends on cooperative systems implemented by the government, we have a long road ahead [...]. I think onboard detection will be developed sufficiently to let cars drive automatically." (#8)

Furthermore, all actors agreed that the development of high definition maps is a required technological 'innovation' to enable positioning of the car relative to its environment when no communication with infrastructures is made.

[5] The reference numbers do not correspond to table 3 in the method sections due to anonymity of the interviewees

"You need satellites and receivers to position a car relatively to its environment, and not necessarily posts along the road. High definition maps are probably cheaper" (#3)

Regarding safety improvements of AVs compared to traditional vehicles, most expectations are congruent. Hence, there is a general agreement that AVs remove approximately 95% of the accidents that are caused by human failures. Therefore, the risk of fatal accidents is lower with AVs than with traditional vehicles.

"Software cannot be distracted and traffic becomes more predictable so the number of fatal accidents will go down" (#12)

This is also in line with expectations about the use of trusted software. Most interviewees argued that security of software is very important and should deserve attention. However, this will not form a barrier for further developments. Two interviewees made a footnote of concern relating to the emergence of cyber terrorism and the hackability of V2V communications. The vehicle authority (governmental organization) is expected to play a major role in controlling the security of in-car software.

"It is very important to have security standards, especially when the vehicle becomes connected. The government has to ensure that car manufacturers take their responsibility and permanently invest in anti-hacking systems" (#8)

Finally, there is a division in expectations about technological possibilities to reach full automation (i.e. level 5). The majority of the interviewees expected that level 5 will be technologically possible. No technological barriers were identified, and therefore navigation through complex city centers and mixed traffic situations is possible in the future.

"Technologically AVs are possible. We could even implement it tomorrow" (#3)

However, according to other interviewees, there will be no incentive for higher levels of automation than driving assistance systems (i.e. level 4). Large safety improvements can be achieved by investments in systems that assist users in specific situations. Technologically these situations are less complex, since they are in specific conditions, and not in mixed traffic.

"I think that safety improvements can be done by driving assistant systems, and this is also faster and cheaper than investing a lot of money in level 5 automation" (#7)

This also relates to expectations about difficulties in programming code of conduct or human behavior in complex urban areas including city centers with bicycles, pedestrians, and other unexpected traffic situation.

"There is not always congruence between traffic regulations and safe traffic behavior […]. It would be very hard to program a car to efficiently break the rules" (#13)

Finally, data ownership and privacy are not expected to be an issue in the future. It is expected that new technologies make it possible to sufficiently anonymize data. In addition, two interviewees mentioned that the concept of privacy will change in the future, due to the emergence of ‘big data’ and ‘the internet of things’. Currently, privacy issues that society is facing in other disciplines will lead to sufficient solutions in order disciplines. Therefore, it is expected that privacy protection is not an issue for automated vehicles.

“You need to make sure that data is anonymized [...]. For some reason, there is a lot of attention around privacy but think about all the camera’s that are currently registering you in public places. This might be even more sensible for privacy, and easier hackable. Everything should be put into perspective” (#20)

Table 5: Summary of divergent expectations in the Technology dimension

Technology		
V2I systems should be developed	⟷	V2V systems are sufficient, and should be the focus point
Full automation in every situation will be reached	⟷	Maximum incentive for driver assistant systems, technological barriers

User acceptance

The second dimension relates to expectations about the acceptance of AVs by users. Mentioned explicitly by two-thirds of the interviewees was that AVs are more comfortable than existing transport modes. There are mainly two argumentations that supported this statement. Firstly, AVs can assist drivers in situations that are sketched as most unpleasant. According to the interviewees, these include driving in traffic jams, long distance driving, tanking, and parking.

“AVs are an extension of an assistant and they provide security and calmness” (#10)

Secondly, it was expected by some interviewees that full AVs can combine data of agendas and other traffic. This way it can optimize your route to get to your destination in a highly efficient way. In addition, time that someone actually spends in traffic can be used more efficiently which causes drivers to value traveling time as less important.

“We spend a lot of time in our cars, with AVs we can use all this time more efficiently” (#2)

Another expected benefit was to create accessibility to mobility for new users including elderly, blind, or people that were afraid of driving. These potential new customers can motivate the car manufacturers for full automation developments. Furthermore, the government can stop investing in unprofitable bus routes, but use AVs to fill the rural gap.

“An AV is similar to a robot taxi. This leads to the question whether we should still put limitations to who can drive or take place in such vehicle” (#5)

Several interviewees expected that the automation of traffic will increase fuel efficiency. Since traffic can be more constant through V2V communication a car can drive more efficiently. This is expected to create a financial incentive for users to invest in AVs.

“Most pollution in transport is from trucks. If they could drive in a platooning train, they would save fuel, causing a financial benefit” (#3)

To the contrary, one-third of the interviewees was more skeptical about the acceptance of AVs by users. Firstly, many references referred to users that simply like to drive. This is human behavior too well embedded in our norms and values, and therefore not changeable. Hence, users want to be able to turn the automation system off if they want to drive manually.

"People like to drive, driving in a car is simply fun. Long distances can be done automatically, but when I drive in the mountains I want to steer myself." (#13)

Secondly, there was distrust in technology by some interviewees. People tend to trust humans more than a computer. Historically, according to some interviewees, there is evidence that people do not trust technology, therefore they expected that AVs will also not simply be trusted by users.

"In London, they created a light rail that could drive fully automatically. However, people did not step into the train because they did not trust it. In the end, they had to replace the driver by a dummy [...] why would people trust AVs?" (#14)

Thirdly, to gain this trust it was argued that AVs should show human behavior in mixed traffic situations. However, the advantages of efficiency then become unclear, which leads to unclear incentives for users to actually invest.

"If we limit a car to130 kilometers per hour because humans are used to that, we lose the efficiency improvement" (#13)

Finally, most actors argued explicitly that price remains an important driver for users to switch to AVs in the future. However, pricing of AVs remained unclear and expectations are divergent in price developments. Depending on an increase or decrease in the price of AVs compared to current vehicles, actors express subsequently in favor of user acceptance or user acceptance as a barrier for AVs.

"Semi-automated vehicles can be implemented easily through expensive cars mainly used for commuting. This will then become cheaper and cheaper" (#11)

"People are not necessarily willing to pay more for a safer car" (#5)

Table 6: Summary of divergent expectations in the User Acceptance dimension

User acceptance		
Users want AVs because of more effective time management and efficient time use.	⟷	Users do not trust AV technologies
	⟷	Users still 'like to drive'

Infrastructure

The following dimension of infrastructure is intertwined with previously mentioned expectations on governmental regulations, and technology. Concretely, depending on the possibility of full automated navigation in city centers, hard (roads, signs) and soft (digital) infrastructural implications differ.

Firstly, discussing hard infrastructural implications, a first group expected that adjustments are not essential to enable AVs, which relates to developing in-car technology instead of vehicle-to-infrastructure communication systems. This group argued that an AV will be able to navigate on a basic infrastructure similar to the existing one. The benefits are that no additional investments have to be done. Investments that are similar to current expenses on infrastructural are expected to remain.

"You could have a very basic infrastructure which saves a lot of money" (#14)

One interviewee noted that when AVs drive in a train, the same part of asphalt will be used more, and therefore also wears faster. This requires a different type of constructing asphalt, and therefore business as usual is impossible with AVs. A second group expected that if we want AVs to be implemented in urban areas, we have to redesign the current infrastructure. This relates to the low trust in technology to navigate through complex city centers.

"As a pedestrian, you can disrupt the system because the car will stop for you at any time. Maybe we need separate lanes for pedestrians to prevent mixed traffic situations that cannot be solved with AVs" (3)

In addition to the separation of lanes in city centers, a quarter of the interviewees suggested separated lanes for AVs on highways. This can be done mainly as stimulation in the transition phase to increase benefits for owners of AVs.

"Think about dedicated highway lanes where cars can notify that they are coming" (#10)

A third group expected that redesigning the city center can be beneficial for the availability of public space. By removing parking places to the outskirts of the city, more space can be redesigned for public goals and thereby increase livability in cities.

"Around the edges of the city, there will be big parking towers where no humans are allowed. This way cars can stand close to each other and built more efficiently" (#16)

However, expectations about what is meant exactly by redesigning a city center differed between every interviewee, or was not specified. Some examples related to car-free city centers or more green in a city. However, no clear congruence exists in expectations about hard infrastructural implications in city centers.

"We have to redesign the city center. The government has to decide how to do this" (#9)

On highways, most interviewees congruently expect that infrastructure can be simplified. Road signs and complex roadside systems including safety barriers become unnecessary and could, therefore, be removed.

"We are placing road signs, traffic lights, and complex peak hour specific algorithms. In the future, we can just tell people digitally what is allowed and what not" (#20)

Regarding soft infrastructural implications, the discussion continued similarly as in the technology dimension. Depending on the trust in technological development, some interviewees suggested that there should be a central point that collects all information about the roads and also sends out relevant information to all AVs about current traffic. Other interviewees stated that V2V communication only is sufficient.

"I think that especially in city centers you will always need infrastructure that supports transport systems because it is very complicated. Some extra eyes will never do any harm" (#20)

Table 7: Summary of divergent expectations in the Infrastructure dimension

Infrastructure		
Basic infrastructure on highways (reducing road signs etc.)	⟷	Separated lanes on highways for AVs
Basic infrastructure in cities	⟷	Separated lanes in cities for different transport modes
Current infrastructure	⟷	Redesign city center, more public space, less parking
Partly digitalized traffic management through V2V communication	⟷	Digitalized traffic management including V2I communication

Mobility

The third dimension relates to expectations about future mobility, including changes in public and private transport and effects on congestion due to increasing car use.

Several interviewees stated that AVs will cause an increase of privately owned cars. Firstly, they will be more comfortable and take away current hassles with cars. In addition, some experts argued that people like to have privacy, and therefore AVs mostly replace existing cars but have limited effect on existing public transport. Furthermore, empty rides and the inclusion of new users are expected to increase car use.

"We might even get more cars in the city than we have right now. I think that is not a desirable future for many cities. [..] In fact, you even get an extra movement of empty cars or cars that are driving back to parking towers around city centers" (#1)

Therefore, some interviewees argued that the development of AVs should be complemented by mobility on demand and car sharing concepts. Examples of these concepts were AVs used for short distances, mobility on demand, and car sharing programs. They were expected to create business opportunities in coupling supply and demand by offering door to door services and removing last mile problems when using public transport. New entrants such as telecom companies are expected to disrupt the existing car industry by offering better services. This increases the attractiveness of public transport, and thereby finally a possible decrease in privately owned cars.

"At some point, you will have a contract with a mobility provider, and a computer system calculates the route that fulfills your wishes. Then you walk to the station, take the train, and an AV will pick you up when you want to go home" (#11)

"AVs are a different type of public transport. By offering mobility as a service you create a different world in which the type of car is not important anymore since it is the same for everyone." (#19)

In addition, other interviewees suggested that the use of AVs should be regulated in a collective mobility system that pursues collective interests, including less pressure on the environment, and a higher quality of life. On highways, all cars can adapt to a collective train which increases traffic throughput.

"AVs could lead to a new transport system, and it is up to companies that transport people to adequately react on that. [..]I always suggested that we make a train of all individual cars on highways." (#10)

Some of the interviewees expected technology to solve the problem of congestion since AVs will increase traffic throughput by intelligent in-car systems that can be better organized and aligned.

"Adaptive cruise control will improve traffic throughput and thereby reduce congestion" (#8)

Finally, one of the risks that were addressed by an interviewee is that there is a low incentive to take the bicycle, which can lead to a lack of exercise.

"There are people that state that with 'mobility as a service' we only need 10% of the existing fleet. I think it will go the other way. If the car is safer, cleaner, cheaper [...], and always accessible, why would you not buy one? It is your ultimate freedom machine" (#2)

Table 8: Summary of divergent expectations in the Mobility dimension

Mobility		
AVs lead to more car use (including empty rides)	⟷	mobility on demand
	⟷	Car sharing alternatives

Regulatory framework

In this dimension expectations about regulations and the forcing of AVs through policy are discussed. More than half of the interviewees argued explicitly that new regulations have to be implemented, especially when collective interests are threatened.

On the long term, some actors' expectations were divergent in the prohibition of traditional cars. Firstly, it was argued that traditional cars will be prohibited in the future, or that there should be car-free city centers. This could cause safety improvements and redesign of city centers because less public space is needed for parking lots and roads. Some interviewees argued that knowledge institutes can play an important role in defining the boundaries of technological developments.

"At some point, some areas are only for self-driving cars. This decreases the risk of accidents with pedestrians or bicycles, and also could affect the way we use public space." (#11)

In addition, some interviewees referenced to alternatives for traditional and privately owned vehicles. Businesses should offer collective, or individual customized transport to the city centers. This could be accomplished by supporting policies for car sharing.

"The government has to influence individual behavior by making car sharing more attractive" (#8)

To the contrary, some interviewees expected that there should be no legally binding obligations for AVs. Users need to have an incentive themselves to buy AVs, and thereby the freedom of choosing their own transportation mode.

"I think that the time of obligations by the government is over. Of course, the government should reflect collective interest in their goals, but in the short term they have to work together with the industry, and stand side by side" (#5)

In the meanwhile, the government is expected by both camps to play a role in facilitating (inter)national access to data. This is expected to be one of the first steps towards more effective traffic management.

"The first step is to develop a uniform standard for data so it can be effectively shared with public and private actors" (#2)

Furthermore, mentioned by some interviewees is the international context that AVs will operate in. On the long term, this requires international standards for AV. However, some actors are skeptical about the efficiency of this process, although this should not withhold anyone from developing and improving AVs or driving assistance systems.

"We have to discuss internationally what standards we want for AVs" (#10)

Regarding liability, most actors did not implicitly and explicitly expect future problems. Explicitly mentioned by some actors is that the current liability model will still count for AVs. However, the role of car insurance companies will change because cars are expected to be safer, and business models should reward users through discounts for the risk reduction of accidents.

"The current insurance system lets you pay more for a more expensive car regardless if it is safer. This should change." (#1)

Table 9: Summary of divergent expectations in the Regulatory Framework dimension

Regulatory framework		
Traditional car-free zones, and limited access for AVs	↔	AVs are not obligatory
AVs are obligatory	↔	

New business models

As a dimension that is intertwined with all other dimensions, many interviewees explicitly mentioned the importance of partnerships within the current actor network. Several suggestions for future partnerships were done. Expected by almost all interviewees is that public-private partnerships (PPPs) are one of the requirements for a successful implementation of AVs. Businesses are expected to have the expertise to offer technological solutions, while the government sets the preconditions and regulatory framework in which the market can operate. By opening up the dialogue, business and governments can position themselves in the innovation process, which prevents both from ending up in an undesired scenario. This could be facilitated by knowledge platforms aimed at bringing different actors together, including universities.

"The government could manage data streams for traffic management, but needs companies and knowledge institutes to develop these systems in a way that it also supports internal production of companies" (#15)

Some interviewees, however, argued that conflicting interests might form a barrier to successful cooperation, for example in sharing data. Some interviewees expected that there has to be communication between business and government to ensure efficient traffic management, but that companies should start with developing standards together.

"If car manufacturers are not working together to develop a standard, then we cannot make traffic lights that can effectively react to them. We must develop standards and share data (#9)

Table 10: Summary of divergent expectations in the New Business Models dimension

New business models		
PPPs to optimize traffic management	⟷	Mainly private partnerships, government sets preconditions

Car ownership

The car ownership dimension relates to a change in cultural values that are currently given to the ownership of cars. Depending on this, the benefit of increasing traffic throughput that can be reached by automating driving is questioned by some interviewees. As discussed in the mobility dimension the first group of interviewees expected that there will be more privately owned cars because they become cheaper, safer and more environmentally friendly.

"People nowadays are living in cities for a longer period, in which they cannot afford or want a car, but after they get kids and move to a village they still want a car" (#7)

The second group of interviewees expected car sharing to increase, which causes a decrease of the total amount of cars. It is expected that AVs stimulates this development since it makes car sharing cheaper, and easier.

"I think concepts like Greenwheels are the future. If the supply is highly flexible, everyone prefers this over a train. Sounds easy right?" (#18)

This will also attract more companies to the car sharing market. There are also some interviewees that argued that car sharing can also be done on a consumer to consumer base. Consumers can have a financial incentive to share their car while it is not being used.

"The first car for commuting remains, if the second car is not used daily then maybe you can consider sharing because you might make some money" (#16)

Table 11: Summary of divergent expectations in Car Ownership dimension

Car Ownership		
Car ownership increases	⟷	Car sharing increases and public transport decreases

Other trends

Most interviewees referenced to other technological, social, and infrastructural trends that they expect in the future. These trends are considered as parallel developments that could influence the development of AVs. Firstly, almost half of the interviewees implicitly or explicitly stated that AVs will automatically be electric vehicles (EVs).

"For sure that we will go to electric cars" (#19)

In addition, some interviewees argued that EVs *should* be developed at the same time because solely relying on AVs will not positively affect the environment.

"I think that the advantages of AV developments were much lower if they would not be developed together with EVs, and car sharing. EVs are good for sharing because they have to be reloaded. [..] Sharing electric AVs would be the ideal situation" (#3)

According to some interviewees, the role of the government is to stimulate the development of EVs by facilitating some financial incentives, in particular through pricing of electricity.

"For example decreasing the price on charging stations for electric vehicles creates a financial incentive for users to invest in EVs" (#3)

Secondly, according to some other interviewees, the concepts of peak hours and commuting time will decrease due to an increase of technological alternatives and telecommuting. More people will work at home, and face to face contact is less important since technological solutions provide the same experience. This is expected to cause a change in mobility behavior to more leisure traffic. This also requires a different way of traffic management.

"The idea of peak hours will disappear because working hours will change. Within the local government, the working hours already became more flexible which is causing a shift in hours. Ministries are reorganized for 2 to 3 persons per desk, and working at home is stimulated" (#9)

One interviewee stated that, due to this shift, leisure and transport of goods will remain while commuting becomes easier and will decrease per person. This will change the way we value cars as an ultimate freedom machine, and therefore cars will become less important.

"Transport of goods and leisure will remain, but commuting will change: it becomes less and easier." (#3)

Lastly, as discussed shortly in the infrastructure dimensions, some interviewees argue that city centers were never built for cars in the first place. Since AVs can more efficiently manage the movements of passengers and goods, they can stimulate to make city centers car free again.

"Imagine a city with only pedestrian areas where nothing drives, but accessible through a separated automated infrastructure that manages mobility and supply" (#4)

Table 12: Summary of divergent expectations in the Other Trends dimension

Other Trends		
AVs should be stimulated parallel to EVs	⟷	EVs will automatically develop parallel to AVs

Divergent expectations

The combined divergent expectations as shown in table 13 were used as a starting point to construct the scenarios. This subdivision resulted in three scenarios, as described in the methods. Subsequently, the remaining expectations from appendix B were fit into a scenario. This subdivision is shown in appendix D.

Table 13: Summary of divergent expectations per scenario

		Scenario		
	Expectation	**1**	**2**	**3**
Technology	V2I systems should be developed	X		
	Full automation in every situation will be reached	X		X
	V2V systems should be developed		X	
	Maximum incentive for driver assistant systems		X	
User acceptance	Users want full AVs because of more effective time management and efficient time use.			X
	Users do not trust AV technologies		X	
	Users still 'like to drive'		X	X
Mobility	Car use increases		X	
	Car sharing alternatives	X		X
	Mobility on demand			X
Regulatory framework	Traditional car-free zones and limited AV access	X		
	AVs are obligatory	X		
	AVs not obligatory		X	X
Infrastructure	Basic infrastructure on highways (reducing road signs etc.)	X		
	Basic infrastructure in cities	X		
	Separated lanes in cities for different transport modes	X		
	Current infrastructure			X
	Separated lanes on highways for different transport modes		X	
	Partly digitalized traffic management through V2V communication		X	
	Digitalized traffic management including V2I communication	X		X
	Redesign city center, more public space, less parking	X		
Car ownership	Car ownership increases		X	
	Car sharing increases and public transport decreases	X		X
Other trends	EVs should be stimulated by the government parallel to AVs	X	X	
	EVs will automatically develop parallel to AVs			X
New business models	PPPs to optimize traffic management	X		
	Mainly private partnerships, government sets preconditions			X

4.2.2. Narratives of the automated vehicle scenarios

The following section provides descriptions of the scenarios together with a multilevel transition diagram for each scenario. Three STSc were constructed. Two dimensions of change are shown to be the most divergent among all expectations (see figure 7).

(i) A technological axis, representing the degree to which technologies will develop. At one end, high automation will assist users in some driving tasks, but end users will remain involved in the control of these devices. For example, long distance autopilot or parking assistants. At the other end, fully automated systems are developed in which the system is full-time performing all driving tasks.

(ii) An individual-collective axis, representing the degree to which mobility is organized and realized as the optimum for one or for the collective. At one end, the mobility system is optimized for the individual, while at the other end the government guides, coordinates and influences the innovation process to ensure that collective interests are reflected in the mobility system.

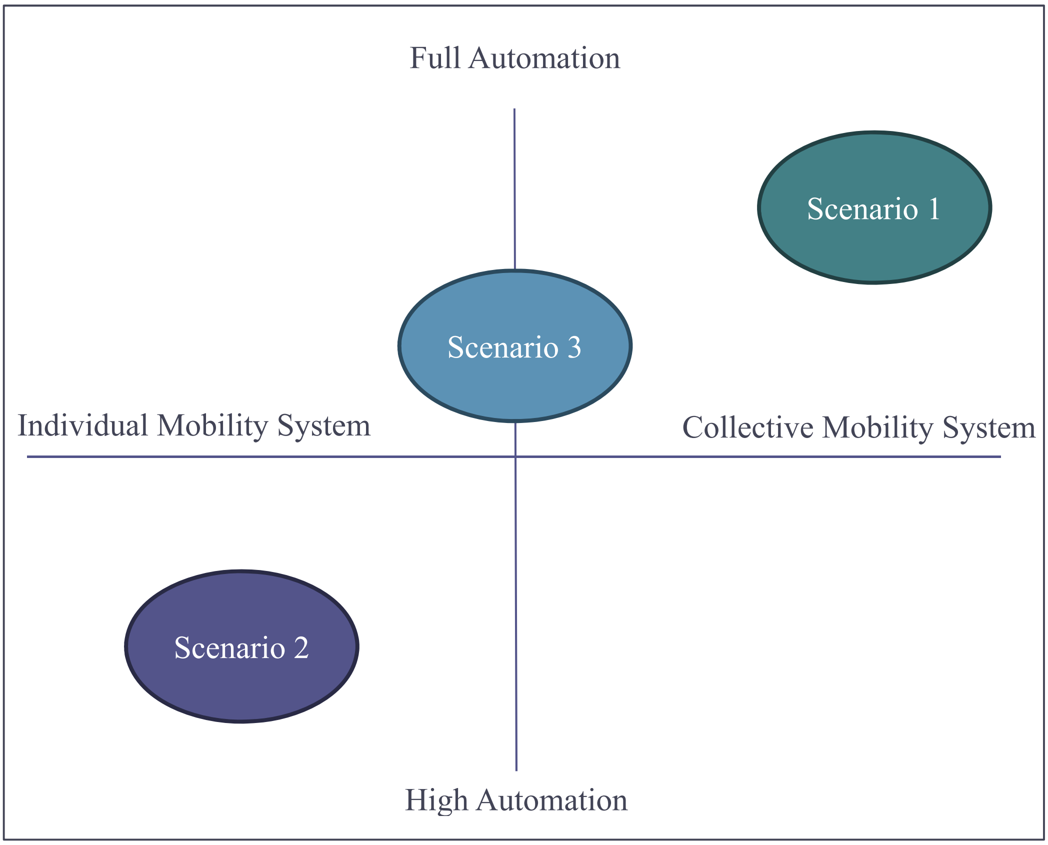

Figure 7: The AVs scenarios

The next section contains three scenarios, respectively scenario 1: ‘centrally organized mobility system’, scenario 2: ‘ubiquitous and comfortable vehicles’, and scenario 3: ‘competition in a cooperative society’. To highlight the expectations from the result section, these are presented in color.

Scenario 1: Centrally organized mobility system

In this scenario, on the socio-technical landscape-level problems of urbanization and the enhancement of sustainable accessibility and mobility for the Dutch population were seen as too pressing to be left to the market. The increased risk of congestion that was associated with the development of AVs, the increased mobility demand, and the urbanization put internal and external pressure on the existing regime and required more direct governmental intervention. These factors created potentials for technological developments around the automated vehicle to emerge out of their niche market.

More specifically, innovation was driven by different actors and institutions. Technologies in niches developed from two different angles. Technological developments that focused on in-car technologies and systems that focused on cooperative driving including vehicle to vehicle (V2V) communication, and communication with the infrastructure (V2I). In-car and V2V systems aimed at improving traffic safety and increasing traffic throughput. V2I systems aimed at ensuring sustainable accessibility for society. As such, these systems allowed more efficient traffic management by enabling vehicles to communicate with traffic lights and vice versa. Hereafter, PPPs were established in which data on traffic management that was generated by the abovementioned technologies was shared within such partnerships. This gave businesses and the government the opportunity to combine different data streams to optimize the transport system. This data sharing policy worked so effectively that a centralized traffic management system for the Netherlands was created in which collective interests that were prioritized by the government were leading in managing traffic. This included for example speed limits to prevent congestion or to minimize noise pollution.

Furthermore, the competition inspired businesses to invest more in EV technologies, which was also stimulated by the government. The government lowered the price of electricity, which thereby became in favor of fuel pricing. By this time fully automated vehicles (level 5) were developed, because businesses responded to governmental needs causing an acceleration of the innovation process. Furthermore, the government fulfilled a monitoring function by controlling if safety requirements regarding in-car and cooperative technologies were met. This was the result of a growing concern in cybersecurity issues. Instead of relying solely on market solutions including security through telephone networks, the governments' vehicle authority operationalized new policies on communication networks with vehicles. The actual development and management of these technologies were outsourced to private companies with expertise in software security.

The overall number of vehicles continued to grow, causing concerns from city authorities about the quality of life in cities. They imposed an increasing variety of measures to enhance livability. Firstly, public authorities sought to encourage the use of public transport. In a growing number of cities, passengers arriving from elsewhere, mainly by train or private car could choose from a variety of options to continue their trip. By setting up public and private car sharing programs, the regional government aimed at increasing attractiveness of public transportation. These shared vehicles were complementing existing public transport and thereby reduced the last mile problem which made public transport more attractive. Furthermore, bus lines were replaced by smaller AVs that could easily be optimized for real-time demand. This saved national governmental expenses on underutilized bus rides and led to social inclusion since new users including elderly, blind or children became mobile, ensuring mobility and accessibility for a larger part of the population. On highways, drivers would connect to a 'train' of other automated vehicles in which they could not control their vehicles anymore.

Shortly after, local authorities introduced car-free zones within city centers. Companies offered smaller electricity-driven AVs that were limitedly allowed into these car-free zones in compliance with local governments. Within these partnerships, businesses offered services that would fit user preferences within the boundaries set by the government to ensure collective interests. Public transport became a cheap alternative for private vehicles and had advantages in limited access areas to transport people from the center to transit hubs for large distance public transport. This had the effect that in urban areas public transport was quicker than driving a private vehicle, which reduced the number of privately owned cars. Most users changed from privately owned cars to other transport modes. Especially second or third personal cars were sold because costs did not outweigh benefits. By encouraging public transport, the government anticipated on the risk of congestion due to empty rides with AVs.

These measures led to the possibility of restructuring the existing infrastructure. Knowledge institutes played a major role in research on effective implementation methods for redesigning urban infrastructure. Slowly, public spaces in city centers were given 'back' to its inhabitants. All parking lots in city centers moved to parking towers on the outskirts of the city and were replaced by parks or used for other purposes. From the outskirts, short distance public AVs transported people to kiss & ride zones to drop off passengers. The limited access zones were highly valued by citizens. Most car manufacturers and car software developers joined coalitions with local governments. By offering the most excellent service, and the most comfortable ride they tried to distinguish themselves from competitors and to respond best to government's demand.

At a certain point in time, the government decided to make AVs obligatory, and thereby ban traditional vehicles. Although this caused some resistance from users, this was a background effect. From the perspective of the traveler, the regime had slowly changed from controlling mobility to being controlled. Users could not control their own vehicles, which enabled the government to optimize the system for the collective. Users benefitted from these developments by increased safety in traffic, and by being able to use traveling time differently. By making AVs obligatory, highway lanes could be simplified. Road signs and road tracks became redundant and therefore were digitalized. Furthermore, congestion decreased because highway lanes could adapt to the amount of traffic that was on the road. At peak hours, traffic would collectively drive slower on five lanes while during the night traffic would go with 200 km/hour on two lanes.

To conclude, with the collective advantages of fully automated vehicles that were obligated, the transition to a collective automated transport system was facilitated and guided strongly by the government at both the regional and national level. Public-private partnerships enabled efficient redesign to an automated vehicle infrastructure that led to more public space in city centers. The overall effects were that congestion decreased, safety improved, and the quality of life in cities increased. Furthermore, since these AVs were also EVs environmental pressure from the transport section reduced.

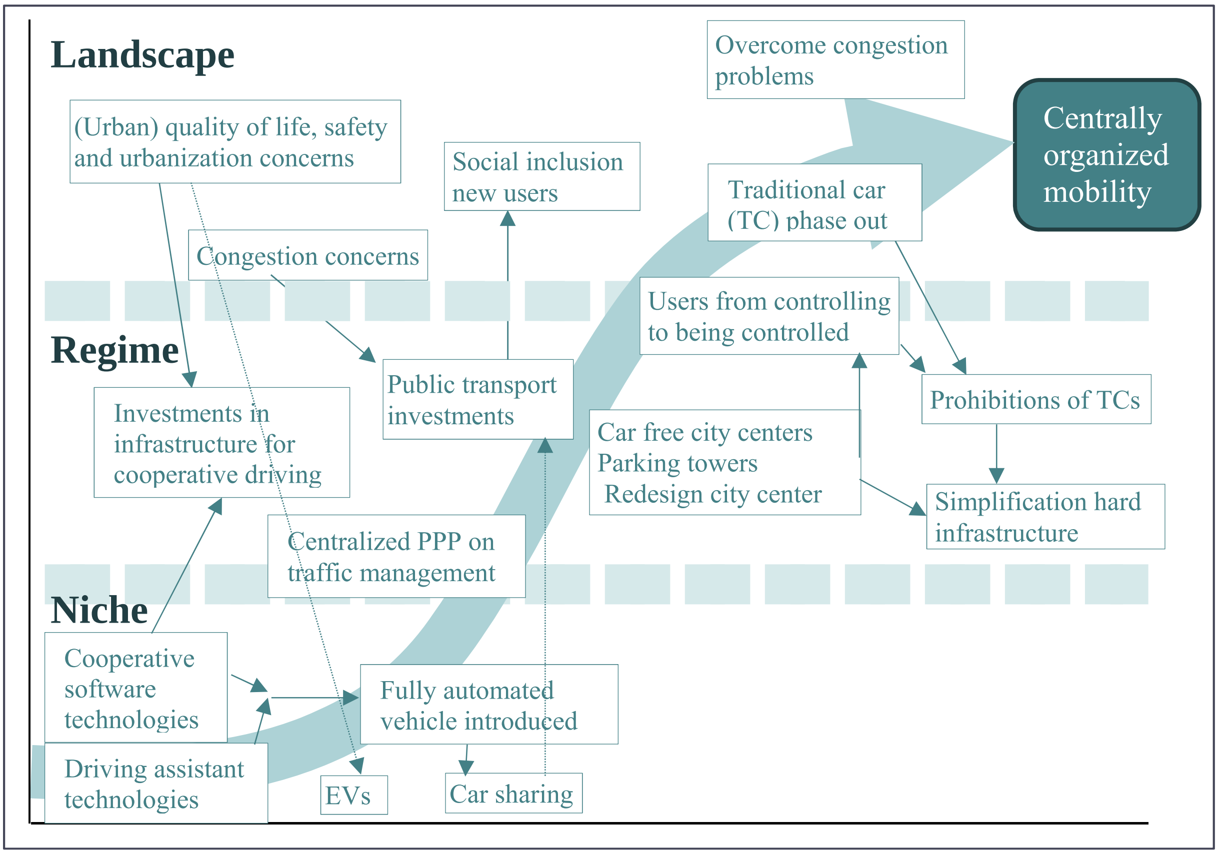

Figure 8: Scenario 1 'Centrally organized mobility system'

Allocation of roles in scenario 1

Traffic management companies: Establish PPPs and shares data with the government to incorporate collective interests including fewer congestions, higher quality of life, and sustainability in traffic management.

Automotive industry: Accelerate technological development by responding to the needs of the government. This includes PPPs to develop communication systems that enable V2I communication. Car manufacturers should get involved in car sharing and offer (public) transport services

National government: Provide strong coordination and guidance. Generate new regulations and pricing systems for mobility mainly through PPPs with traffic management companies. Redesign of city centers together with RG.

Regional government: Introduce car-free city centers and invest in the attractiveness of public transport

Knowledge institutes: Research on redesign of city centers and the pre-conditions for effective city management

Scenario 2: Ubiquitous and comfortable vehicles

In this scenario, congestion and traffic safety were the elusive problems that triggered the innovation process. To tackle these problems, the government's main approach was to increase the capacity of existing infrastructures, while technological innovation was mainly driven by existing businesses that wanted to increase their consumer base. Two technological developments were visible: in-car driving assistant systems and V2V communication systems. A strategic race continued among car manufacturers that offered individually optimized transportation. Since users evaluated long-distance driving, traffic jam driving, and parking as highly uncomfortable, lane keeping systems, parking assistant, and traffic jam assistance that aimed at taking over these tasks were developed. Secondly, the V2V communication systems were developed to increase comfort and safety for users. Data was generated through these new communication systems and other navigation devices. Thereby, companies were able to anticipate on live traffic flows and offer drivers alternative navigation routes when needed. These information applications increased and created new opportunities for private partnerships on sharing data between map developers, navigation companies, and car manufacturers to optimize technologies. The more data that a partnership was able to collect the more effectively traffic management could be done. These strategic choices led to strong coalitions of different types of businesses that were responsible for their expertise in the value chain. Furthermore, since skepticism around automated driving systems was still present, special attention was paid to the use of secure software to ensure safety.

These developments in niches slowly proved to be beneficial for traffic safety. Driving assistance decreased the number of fatal accidents since most accidents were caused by human failures due to distracted drivers. This caused a change in the business models of insurance companies. Since AVs caused fewer accidents, premiums went down regardless of the purchase price of a vehicle, causing an extra financial incentive for people to invest in automated assistant systems.

Therefore, car use continued to increase, causing a growing pressure on responsibilities for the government to ensure mobility for inhabitants and reduce congestion. The V2V systems in niche markets slowly influenced the existing regime by proving that, even with small penetration rates, they could positively influence congestion on highways. Therefore, with a growing pressure on the existing regime, the government introduced dedicated lanes for AVs, starting at peak hours. On these lanes, traffic throughput was maximized, creating an extra incentive for commuting users to buy highly AVs. During this period, the private car remained the dominant mode of transport, but the overall congestion on highways indeed went down. The dedicated infrastructure for automated vehicles opened up new business opportunities for car sharing companies. People that could not afford an AV could use car sharing programs that offered AVs. In this way, users could still use the dedicated lane, which was especially popular by commuting people.

However, since most AVs were owned by commuting drivers for whom highways were the most inefficient and time-consuming part of their trip, technological development slowed down. Innovation processes finally stagnated at the complexity of mixed traffic situations. Developers failed in programming AVs in such a way that they could imitate human behavior.

This was essential to prevent cars from showing unexpected behavior for other (traditional) transport modes, and thereby causing dangerous traffic situations. As a consequence, the government exerted high safety margins for fully automated driving systems. These high safety margins caused users to turn off their automated systems in mixed traffic situations since benefits were not clearly visible. This made it hard for software developers to experiment and test their fully automated vehicles and thereby further innovation slowed down. This impeded a technological disruption towards fully automated driving. Instead, a road traffic system arose that was similar to air traffic. During takeoff and landing drivers would assist cars, while in the meantime users could use their time differently.

From a user perspective, existing values and norms regarding car ownership and the preference that people had for manually driving remained. People wanted to be in control of their own vehicle and liked to drive if they wanted to. As long as people had the ‘freedom of choice’, they did not feel the urge to disrupt the existing regime. The government facilitated in ensuring basic mobility needs, and problems of congestion and road capacities were primarily tackled by creating new infrastructure, and thereby continuing existing regime policies. However, external pressure from the landscape including environmental concerns kept on increasing. This opened up the opportunity for other niches to develop sustainable alternatives for transportation. One of the technologies that was able to break out of its niche was electric vehicles (EVs). Environmental benefits of EVs were more transparent than for AVs, which caused businesses and government to invest.

This caused a reduction of emissions in transport. However, congestion and quality of living in many cities continued to get worse. The main instruments to discourage car usage were high parking rates and prioritization of public transport. Furthermore, since AV developments stagnated, the government started a telecommuting campaign. With over a million employees the government introduced flexible working hours and stimulated working at home. Furthermore, they stimulated business to follow their example, which was the starting point of a change in mindset in nine to five working days. This reduced congestion in peak hours and spread out traffic more during the entire day.

To conclude, with the role of the government largely restricted to ensuring basic mobility needs and fostering competitive markets, automated vehicle developments for full automation failed to take off. Since fully AVs would not necessarily attract new consumers, businesses had a low incentive to continue the innovation process. Hence, technological obstacles to enable AVs to navigate through complex city centers formed a barrier that impeded a socio-technical transition. However, environmental concerns remained, creating the opportunity for the EV niche to destabilize the existing regime.

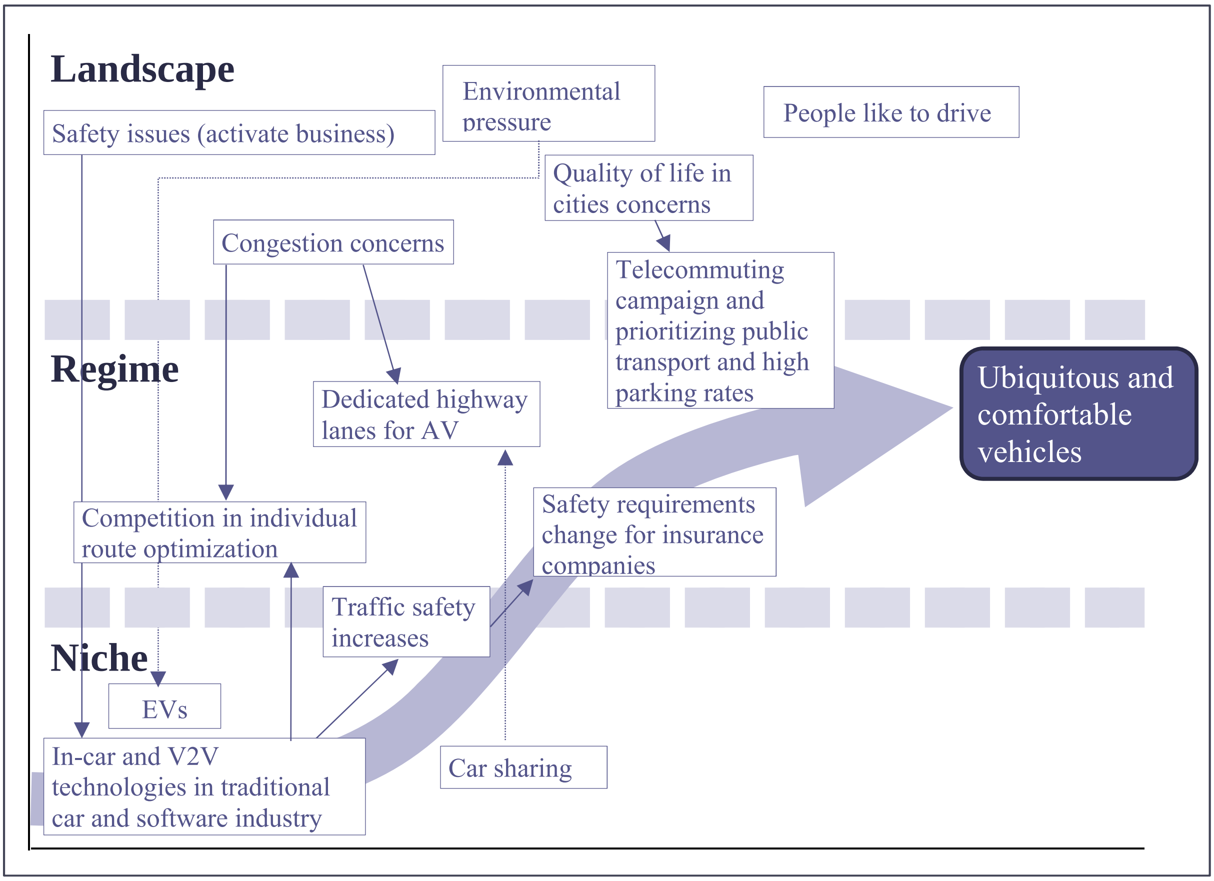

Figure 9: Scenario 2 'Ubiquitous and comfortable vehicles'

Allocation of roles in scenario 2

Traffic management companies: Ensure traffic optimization on existing infrastructures

Automotive industry: Develop in-car communication systems, V2V communication systems, and EVs to optimize transportation for the user.

National government: Ensure basic mobility needs, foster competition, and stimulate partly vehicle automation by introducing dedicated highway lanes. Search for alternatives to decrease urbanization problems including flexibility of work and opening hours to spread out traffic during the day.

Regional government: Discourage car use in city centers by high parking costs, and stimulate public transport

Knowledge institutes: Undefined

Scenario 3: Competition in a cooperative society

In this scenario, pressure from the landscape including concerns on sustainable accessibility and mobility for the Dutch society opened up new business opportunities. Therefore, mainly private companies were motivated to do long-term investments and thereby trigger innovation processes involved with vehicle automation.

A key role was taken by newly entered businesses that emerged outside incumbent actors in the automotive industry. These new dynamics in the industry caused two technological niches to further develop. Firstly, software developing companies and car manufacturers together continued to invest in automation in-car. This was expected to increase traffic safety, user comfort and the efficiency of driving. Secondly, V2V technological developments were developed within coalitions of telephone providers, car manufacturers, and map developers. This was expected to decrease congestion, and essential to make the step to fully automated vehicles since it enabled cars to position themselves within their environment.

At the same time, companies were building platforms and joined mainly private coalitions of organizations that invested in the development of EVs and car sharing alternatives. These strategic choices were made since these technological niches stimulated each other. Similar types of technologies and software were needed to make vehicles automatic and electric. Furthermore, the technological development in vehicle automation eased the implementation of car sharing activities since it allowed a car to drive automatically from door to door instead of being parked and picked up in a parking lot. To increase their consumer base and to gain competitive advantage, businesses offered individuals to choose their preferred route of traveling. For example, 'the quickest route', 'the most energy efficient route', 'self-driving', or 'the most comfortable route with an AV', could be chosen on an application.

This internal competition accelerated the development of fully AVs, causing the first prototypes to be able to drive without human intervention. The penetration of automated systems in cars grew, but users could still control their vehicles and thereby experience driving manually. The previous developments mainly caused a decrease in congestion on highways. However, pollution and congestion remained a major problem in cities. The concern about the accessibility of mobility exerted continuous pressure on the regime. In order to increase the penetration rate of AVs, which was beneficial for congestions, the government introduced temporary financial incentives for car sharing and AVs. When users replaced their car by AVs, a discount was given by the government. Furthermore, various city authorities tried to push back the role of the car, by promoting car sharing and mobility on demand. Coalitions of businesses were inspired under the adage 'from product to service', and used AVs to provide citizens with transportation. A business that could successfully adapt their business model to service oriented mobility remained competitive. In particular, several companies were specialized in still offering a 'driver' as a host to help people to the vehicle. On the other hand, several companies offered low-budget rides by making cars very robust and basic, without any professional driver on board. Companies increased their customer base by exploring market opportunities for individuals that could not afford AVs or users that could not drive traditional cars including blind or elderly. This development was stimulated by the government since it led to social inclusion by providing mobility for a larger part of the population.

Furthermore, the government played an important role in providing demonstration opportunities for users to show the benefits to actually use automated driving systems. Since traffic in cities was mainly mixed, a lot of users turned their systems off in city centers. Local government played an informative role towards users to make them more aware of the collective benefits that public transport and car sharing has over privately owned vehicles. In addition, the government invested in AVs to replace existing public transport system of buses and trams which led to an increasing number of AV prototypes that were put on trial in various cities in the Netherlands.

Due to an increasing demand for AVs by companies and government, the overall exploitation costs of AVs went down. This caused an acceleration of the penetration rate of AVs and slowly al short-distance public transport was automatic and electric. On the other hand, the low prices of AVs made them affordable for lower incomes. This caused an increase of car use again, putting pressure on existing infrastructures. Local and national authorities responded by implementing an open data policy to allow businesses, together with local authorities to optimize traffic management. As such, the government joined partnerships together with knowledge institutes and many PPPs were established. This increased efficiency in managing traffic, and on the other hand allowed companies to use the data for optimizing their software systems. Several investments were done to improve vehicle to infrastructure communication systems that could send out signals in critical areas. For example, during peak hours on crowded highways, mobility on demand services would be offered alternative routes or regulated to leave at another hours which had a minimum effect on the estimated time of arrival.

Finally, a change in user behavior from wanting ‘private fast transport’ to a role of informed citizen that wanted ‘less traffic and higher quality of life in cities’ caused a regime change in user behavior. The multiple choices that were offered by different companies enabled users to satisfy their needs depending on the situation. But these new citizens were more aware and wanted a higher quality of life, which changed their norms and values regarding mobility and car ownership. As such, traffic could be managed to reach an optimum in which a more constant and spread out stream of limited traffic was needed to ensure the movement of goods and passengers in and around city centers.

Although congestion on highways did not completely disappear, this was seen as a private problem, since a wide variety of alternatives was offered. To increase competitive advantage, companies started to offer AVs for long distance trips. Therefore, they replaced traditional public transport. A large majority of cars that were sold now were electricity-driven AVs that allowed people to turn off the systems mainly for holidays when drivers wanted to experience driving through the mountains. However, on average car ownership went down.

To conclude, competition among companies to offer sustainable, accessible, and safe transportation modes caused a clear shift from car ownership to mobility on demand services. This was, in particular for city authorities, a welcoming trend since fewer cars were needed to provide people with mobility. Therefore, the government aimed at convincing and demonstrating the benefits of AVs to the Dutch society.

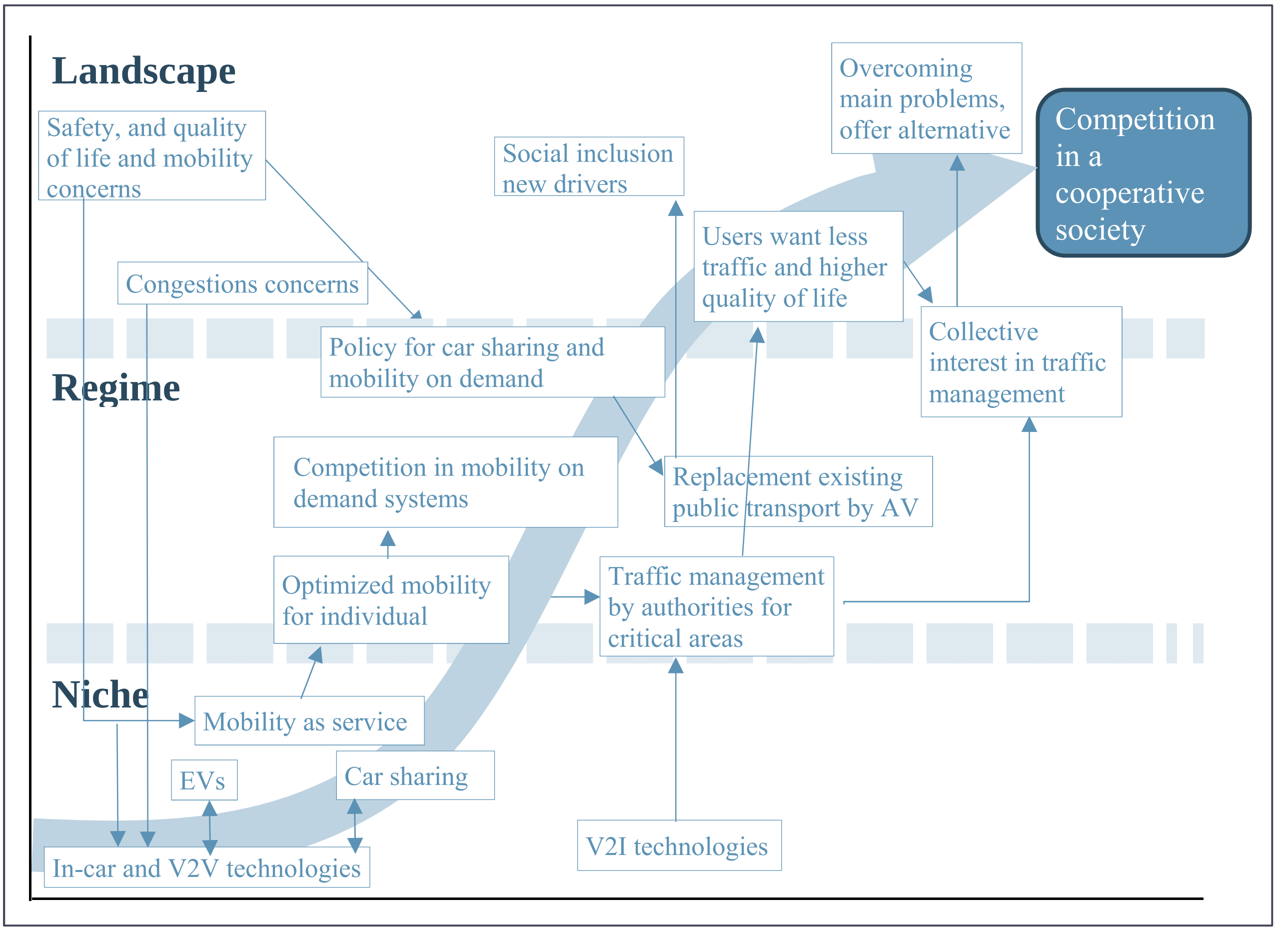

Figure 10: Scenario 3 'Equilibrium of corporate opportunities'

Allocation of roles in scenario 3

Traffic management companies: Use open data to compete on offering optimized traffic management with collective interest implemented in algorithms to calculate the optimum

Automotive industry: New entrants cause a movement from traditional product vending of cars to coalitions of organizations that offer cars, services, and specific requirements that an individual prefers for mobility.

National government: Should stimulate competition by showing users benefits of different mobility services through demonstration projects, and (temporary) financial incentives for AVs

Regional government: Support mobility on demand, and replace existing public transport by short distance AVs in city centers

Knowledge institutes: Join PPPs to support and research the effects of AVs.

Table 14: Summaries of the AV transition scenarios

	Scenario 1	Scenario 2	Scenario 3
End vision	**Central mobility system**	**Ubiquitous and comfortable cars**	**Competition in a cooperative society**
Dimensions of change	• Strong national government and social and environmental concerns • Fully automated cars	• Corporate push with individual interests reflected by businesses, low governmental coordination • Highly automated cars	• Strong national government and social and environmental concerns • Fully and highly automated cars
Expectations that influence activity	• Congestion and car use increase • Redesign of city center, more public space, less parking in city center increases quality of life • One traffic control center can reduce congestion and increase traffic throughput • Car sharing leads to social inclusion • Reduction of infrastructural investments because it can be digitalized	• Users do not trust and like fully AV technologies • V2V and in-car technologies make traffic safer and lead to less congestion • More room for EV niche as a response to pressure from the landscape	• More efficient time use in AV • Users like to drive and therefore want the freedom to turn an AV on or off • Mobility on demand, EVs and car sharing alternatives can increase with AVs which all contributes to sustainability • No big hard infrastructural investment necessary
Role Government	• Strong guidance • New regulations and pricing of electricity • Prohibit traditional cars • RG: Car-free city centers • NG/RG: Redesign public infrastructure • Traffic management through PPPs	• Ensuring basic mobility needs, and fostering competitive markets • Stimulate users to invest in highly AVs by introducing priority lanes on highways • Increase telecommuting	• Demonstration projects for AVs • Financial incentives for car sharing • Replacement public transport by more efficient AVs through PPPs • Traffic Management through PPPs and open data policy
Role Business	• Traffic management through PPPs • Develop technologies including V2I communication systems • Respond to the needs of the government	• Development V2V communication systems • Enable highly automated cars • Respond to the needs of users	• Drive innovation through identifying new business opportunities in AVs
Role Users	• From controlling mobility to being controlled	• Remains individualistic in traffic • Low trust in technology	• Informed citizens: from private fast transport to less traffic and a higher quality of life

4.2.3. Support of the scenarios per actor

In figure 11 the number of references (i.e. expectations) that support the different scenarios per actor type (Automotive Industry organization, Traffic Management Company, National Government, Regional Government, and Knowledge Institutes) is shown. Three circles are attributed to each type of actor. The smallest circle (-) represents the least supported scenario based on the number of references, while the largest circle (++) represents the most supported scenario for the corresponding actor group.

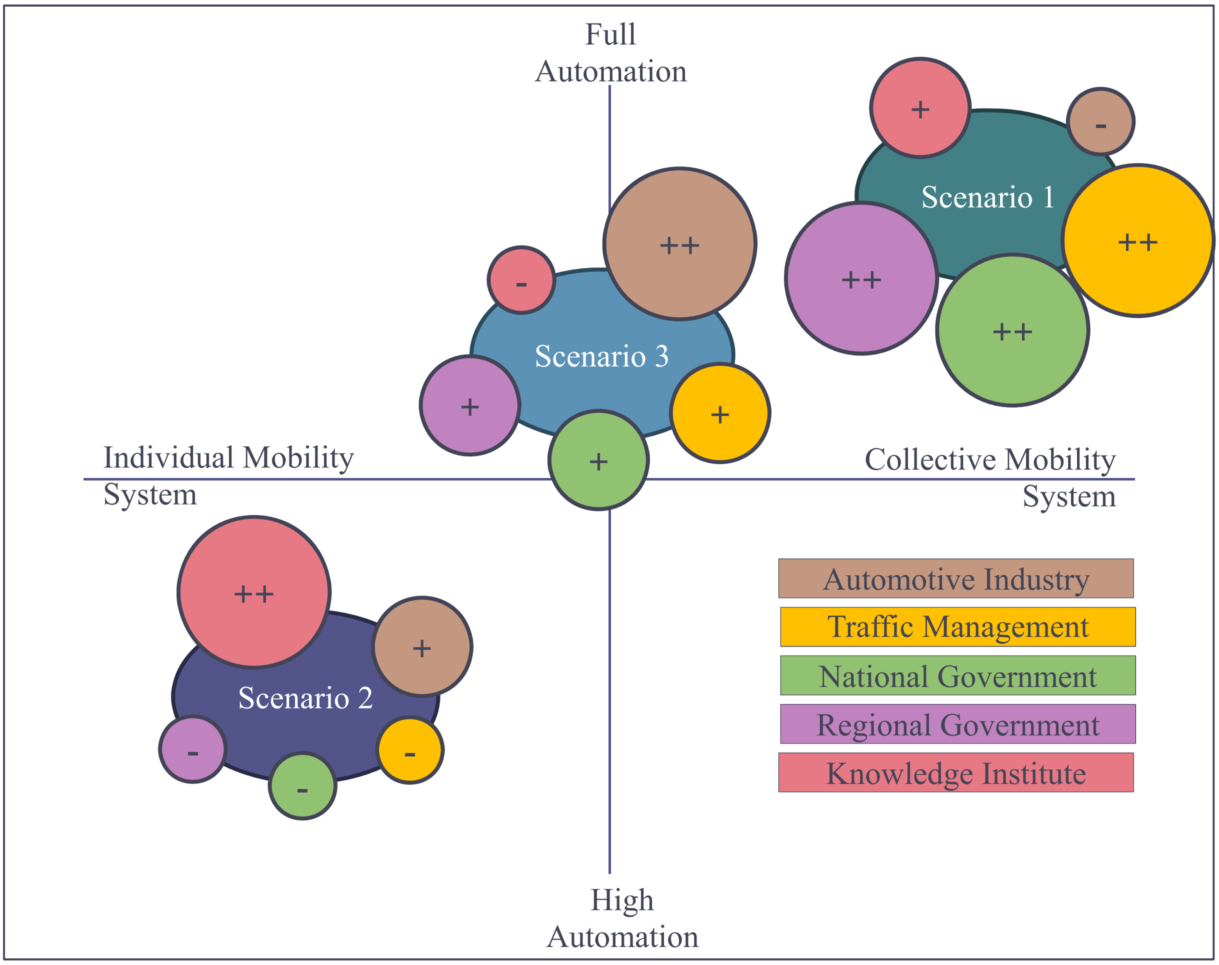

Figure 11: Scenario support by type of actor compared by number of references

The following key observations can be done based on figure 11:

- Expectations from (national and regional) government mostly match with scenario 1.
- Expectations from knowledge institutes mostly match with scenario 2, whereas most other actors are least supportive for this scenario.
- Expectations from the Automotive industry mostly match with scenario 3, and the least with a scenario is which the government forces the industry.

5. Discussion

This chapter starts with the limitations of the research. Thereafter, wider implications are discussed, followed by the scientific implications. Finally, several avenues for further research are suggested.

5.1. Limitations of the research

Limitations of a study relate to the reliability and validity of the research design and results (Saunders, Lewis, & Thornhill, 2009). The extent to which the applied data collection techniques will yield consistent findings and the degree to which a study can be replicated, relates to the reliability of a research. Validity describes the extent to which a causal relationship can be established and thereby if the methods accurately measure what they intended to measure (Yin, 2003). The prime interest of this research is to map expectations and visions to learn about how the future is 'made' today. The importance of expectations in innovation and socio-technical transitions is widely acknowledged. Expectations can be seen as bids for the future (Berkhout, 2006), and thereby have the potential to partially elucidate the future innovation process of AVs. However, when interpreting the results some footnotes on validity should be considered.

As discussed in the theoretical framework, the articulation of expectations is not a straightforward process of representing images of the future in a disinterested way (Berkhout, 2006). At stake are attitudes and interests in the present. It is important to notice that actors individually or collectively seek to construct a future or scenario. Therefore, when discussing the desired future, such scenarios bear witness to resources deployed by actors in pursuit of private or sectorial interests. Actors express their expectations, but at the same time are subject to distributions of power and personal agendas. By forming coalitions around positive expectations, actors can collectively create a certain vision which reflects personal interests, and not necessarily reflects what they really expect to happen. These dynamics in the articulation of expectations and vision are not researched in their finest details in this thesis. As such, the future pathways and 'end visions' (i.e. 'Centrally organized mobility system', 'Ubiquitous and comfortable vehicles', 'Competition in a cooperative society') that are the result of this thesis cannot be seen as predictions of the future, but they can rather be used as a *tool* for structuring future discussions on AVs, especially by creating a broader perspective on socio-technological developments.

Furthermore, as discussed by Truffer et al. (2008), no single actor has the power to oversee a co-evolutionary innovation process. The interviewees in this thesis were chosen for their involvement, interest, or work experience within the AV industry. Therefore, there is a chance that these actors were biased when discussing their expectations. In addition, there is a possibility of group thinking among the interviewees, since the names of several interviewees collectively popped up in several reports, workshop participant lists or conference attendances.

Finally, taking a research design concerning a single case study, i.e. the Dutch automated vehicle industry does influence the degree to which the results are generalizable (Saunders et al., 2009). Firstly, as the results of this thesis show, several interviewees implicitly or explicitly expected other technologies or innovations to evolve simultaneously. Demarcating a single technology makes it possible to do an in-depth study on the specific technology. However, it might underestimate the uncertainties of other technological developments in niche markets that have the potential to break through and affect the existing regime. Secondly, innovation processes can differ between countries and sectors (Faber & Hoppe, 2013), and therefore the results should be interpreted with the Dutch context in mind. The results can therefore not easily be generalized as scenarios for other countries. However, the used method is applicable for unraveling AV innovation processes in other contexts.

5.2. Wider implications

Taking into account the context and limitations of this research, several implications for government, business and wider society can be made. Depending on the role that an actor adopts, they may influence the direction of the innovation process with respect to vehicle automation.

5.2.1. Implications for government

Role 1: A coordinating government

The first role describes the government as a strong coordinator and facilitator of the innovation process. In this case, external pressures motivate the government to invest in cooperative technology. Thereby, AVs have the potential to overthrow the existing regime towards a more sustainable mobility system. A coordinating government that sets clear boundaries is expected to be essential to achieve a mobility system that optimizes traffic throughput, improves traffic safety and raises the quality of living in cities. As such, the process and development of AVs is more or less politically forced by the Dutch government and then proliferates due to the businesses competing. In order to realize the above-mentioned collective interests, traffic management should be done on a national scale together with businesses in public-private partnerships. These partnerships motivate companies to develop technologies for AVs including cooperative communication systems since regulations are in their favor. For local authorities, this role implies the introduction of car-free zones with limited access for several AV service companies. These areas eventually enable the governmental to give 'back' public spaces to its inhabitants, increasing the quality of life in cities. This can only be achieved when traditional vehicles are prohibited on the long-term. Possible limitations regarding the forcing role of the government are the large infrastructure investments that are required, and the major political efforts that require a more centralized government which is against the current trends of decentralization (Snellen, Hamers, & Tennekes, 2015).

Role 2: A responsive government

The second role of the government describes the government as more reactive and letting the innovation process be mainly market-driven. In this case, the government limits its role to ensuring basic mobility needs and fostering competitive markets. This results in safety improvements in transportation, retaining of current social values regarding car ownership, and more effective transport management. On a national level, ensuring mobility needs can be done by increasing the capacity of existing infrastructure. Fostering competitive markets can be done by introducing dedicated highway lanes for (partly) automated vehicles. A limitation of this role is that sustainability impacts of AVs remain absent. Expectations about the AVs to potentially change the current regime are low, since individual improvements of traditional cars are mainly driven by safety and comfort improvements. Since new technologies might make cars more attractive, there is a possibility that AV development negatively affects the quality of life and congestion in cities. As such, the government should find other ways to respond to these problems.

Role 3: A convincing and supporting government

The third role of the government is a convincing and supporting role towards the automotive industry to invest in innovations involved with AVs. When the government takes such a role, AVs have the potential to contribute to safety improvements in traffic, more effective transport systems, and a reduction of environmental pressure. In order to take this role, more room has to be created for a variety of niches in mobility, including automated vehicles, electric vehicles, car sharing, and mobility on demand services. This room can be created by implementing an open data policy to foster competition and by investing in a digital infrastructure for cooperative driving. Secondly, the government can actively demonstrate the successfulness of alternatives for traditional vehicles by engaging in demonstration projects for AVs and providing financial incentives for car sharing to users. This can convince users to invest in AV technologies, and thereby make investments in these technologies more attractive. A limitation of this role is that positive effects on quality of life in cities might be limited. Since AVs are not mandatory, mixed traffic with traditional vehicles reduces the potential benefits of effective traffic management and hinders a complete redesign of a city center, since society has the freedom to turn off their AVs.

5.2.2. Implications for business

Role 1: Responsive businesses

The first role of businesses relates to the responsiveness of businesses to governmental demands. When innovation is mainly driven by the government through strong coordination and guidance, policy and business interests should be merged into a shared mission that aims at reducing congestion, improving traffic safety, and raising the quality of living in cities. As such, businesses can adapt to the role of being responsive to governmental needs. To successfully do this, they should invest in public-private partnerships to make use of extensive benefits set up by the government for AV developments. When establishing PPPs, businesses have to opportunity to continue in their field of expertise, while being more protected against competition in a partnership with the government. A limitation of this role is that businesses largely depend on governmental investments and decision making.

Role 2: Individually optimized businesses

The second role that businesses can adopt is to optimize their products and services to users' preferences. Businesses could mainly focus on increasing their consumer base by providing more individually optimized mobility options. This role is mainly market orientated and enlarges consumer bases of businesses. Therefore, this requires a clear picture of what users want to leave to a car and what not. Limitations are that sustainability impacts might remain absent without having clear the benefits for users, businesses and government.

Role 3: Cooperative and competitive businesses

The third role for businesses emphasizes the role and power of competition and the potentially positive outcomes of a competitive society as a driver for the innovation process. In this case, external pressures, including quality of living and environmental concerns motivate businesses to innovate. This attracts new entrants to the automotive industry which destabilize the existing regime. Businesses can adapt to the role of identifying and deploying new business opportunities by forming coalitions of organizations that offer mobility, cars, services, and new innovations that are optimized for the individual user. Since the government supports companies to innovate, there are multiple windows of opportunity for novelties that stimulate actors to experiment with many technical options. Companies are then part of a strategic race and have the role of developing and innovating in AV technologies to 'win' this race. The openly accessible data from the government can be used to optimize traffic management and thereby gain a competitive advantage compared to other coalitions. Potential areas of innovation are automated vehicles, electric vehicles, car sharing, and mobility on demand services. In the case of the Netherlands, there is no large traditional automotive industry present (compared to other countries). However, the Netherlands has some major companies providing essential components for cooperative systems (Wilmink et al., 2014). Therefore, economic benefits could be achieved in developments of AVs in which cooperative systems are part of the innovation process. Limitations of this role are that it requires changes in current user practices regarding mobility and that the penetration rate of AVs will increase slowly without governmental constraints.

5.2.3. Implications for users

Role 1: User that accept a controlling government

When the government aims at strong coordination and guidance to improve mobility, it is required that users are willing to accept that their role will switch from controlling their own vehicle to being controlled by the government. A limitation is that this role is might be difficult since it is not in line with current decentralization policies of the government.

Role 2: Critical users towards AV

Users can have the role of criticizing AV developments. The advantage is that technological developments will be beneficial and optimized for the individual user and that current social norms and values remain. A limitation is that the potential of contributing to sustainable mobility are low.

Role 3: Informed citizens

If AVs want to contribute to a high quality of living in cities, users should be willing to prioritize collective interests over personal interests. By informing citizens about the pros and cons of technological developments other actors can influence the users. Acceptance by users is probably high since they still have the freedom to choose their preferred transport. A limitation is that the benefits of less congestion and a higher quality of living are questionable. Since users can choose to turn off a system an unpredictable factor participates in traffic which reduces efficiency.

5.2.4. Interaction between the roles

The roles as described in the previous section are summarized in table 15 and correspond with the three STSc. As shown previously in figure 11, expectations from (national and regional) government mostly match with role 1 and 3, while the expectations from the industry are more spread out over the different roles. This indicates that there is a divergence between adopting a role and allocating roles to other actors in the innovation process.

Table 15: Role per scenario for the government, businesses, and users

<table>
<tr><th></th><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 3</th></tr>
<tr><td>Government</td><td>Role 1: A coordinating government</td><td>Role 2: A responsive government</td><td>Role 3: A convincing and supporting government</td></tr>
<tr><td></td><td>• Strong guidance and coordination of the innovation process
• New regulations including prohibition of traditional cars
• Car-free city centers with limited AV access
• Redesign public infrastructure
• Traffic management through PPPs</td><td>• Market-driven innovation process
• Ensuring basic mobility needs
• Fostering competitive markets
• Stimulate users to turn on driving assistance on highways: introduce priority lanes on highways
• Increase telecommuting</td><td>• Stimulation and support of the innovation process
• Open data policy to stimulate competition
• Demonstration projects for AVs
• Financial incentives for car sharing
• Replacement public transport by more efficient AVs</td></tr>
<tr><td>Businesses</td><td>Role 2: Responsive businesses</td><td>Role 3: Individually optimized businesses</td><td>Role 3: Cooperative and competitive businesses</td></tr>
<tr><td></td><td>• Respond to governmental needs
• Traffic management through PPPs
• Develop technologies including V2I communication systems</td><td>• Optimize the business model for user preferences
• Develop V2V communication systems
• Enable highly automated cars</td><td>• Drive innovation through identifying new business opportunities in AVs
• Find coalitions of organizations to optimize your product or services for users</td></tr>
<tr><td>Users</td><td>Role 1: Acceptance of the controlling government</td><td>Role 2: Critical towards AVs</td><td>Role 3: Informed citizens</td></tr>
<tr><td></td><td>• From controlling mobility to being controlled</td><td>• A car driver remains individualistic and users do not trust ICTs in cars</td><td>• Informed citizens: from private fast transport to less traffic and a higher quality of life</td></tr>
</table>

This divergence could cause friction between the actor groups depending on the trade-off that actors make between different conditions of sustainability (i.e. quality of living, economic interests, safety improvements, or social values). The outcomes on sustainability performance depend on the attempts by policy and decision makers in the government and businesses to enhance sustainable mobility, and the way they communicate this to the wider society. The roles as presented in table 15 interact since every position exists only as the reciprocal of some other position (Langenhove & Harré, 1994). Uniformity in the role adoption is essential to reach a desired outcome. For example, when the government aims at adopting the role of a convincing and supporting government, it should actively engage in create congruence with the users by providing them with information about the benefits of AVs. When there is insufficient congruence between all relevant actors on future expectations, there is the possibility of destruction of all the promises around AV development. This could indicate that AVs are experiencing a hype, as argued by Budde (2015), which could potentially cause a backlash on technological development. The constructed STSc and roles are a *tool* to assist the different actors in a better identification of potential cooperative strategies between businesses and government. In this way, the process of articulating expectations and ideas for the future becomes an opportunity for real deliberation and debate about social and political priorities with respect to a new technology (Eames & McDowall, 2010). These scenarios will give traffic managers, policymakers and other actors involved permission to think far more creatively about what might play out and what they can do to guide it to a desirable outcome.

Technological optimism

A final remark regarding future policy making should be made. As the results indicate, there is a majority that expects AVs to be introduced on the Dutch roads quite soon. This is also indicated by the fact that the technology dimension has been discussed substantially more than the other dimensions and that most expectations fit into the technologically optimistic scenarios. Pursuing such technocratic approach has several risks as argued in the introduction. In order to avoid these aforementioned risks, it would be recommended to consider *inclusive policy making* for future technological developments. In this case, technological innovations are placed in the context of their social environment. This way, the interplay between different actors' expectations will be part of decision making, which provides insights on actor dynamics and distributions of power that can shape (or disturb) innovation processes that are crucial for understanding the resulting transition dynamics in the AV industry.

5.3. Scientific implications

This research led to several insights that are relevant for the scientific debate on AVs. Firstly, it responds to the call for the development of tools for 'precautionary foresight' that allows policy and decision makers to engage and explore a wide range of actors' interests (Stirling, 2006). As argued in the previous section, using an STSc as a tool to assist government and business in transition policy and decision making has the advantage to include more qualitative elements in future explorations (Elzen et al., 2002a). This thesis complements previous scenarios in giving the central stage to expectations and approaching the AV industry from a socio-technical perspective. Furthermore, this research pays attention to the allocation of roles for government and business, while other studies focussed more on implications from a technological point of view. The advantages of such approach are that it allows actors to use these scenarios as a heuristic tool in future debates. In addition, it allows policy makers to reflect on the extent to which collective interests are realized within an innovation process.

Furthermore, considering the multi-level perspective as a concept to analyze patterns in expectations provides important insights on innovation processes involved with AVs. However, the multi-level framework might limit its utility when discussing infrastructural or spatial implications of technological developments (Bulkeley, Castán Broto, & Maassen, 2014). As the results show, current demonstration projects are operationalized on a place-specific and local scale. However, little is known about the place-specific formation of socio-technical regimes (Bulkeley et al., 2014). In the context of the Netherlands, investments in transport infrastructure are made by the government and highly centralized. In contrast, urban development is funded almost entirely locally by varying consortiums of local investors, housing corporations, municipalities and regional organizations. National funding for urban planning has almost completely disappeared (Snellen et al., 2015). Therefore, this allows different regimes (e.g. infrastructural or regulatory) within the Netherlands to exist at the same time depending on the scale. This could cause different expectation dynamics in different regimes within the same landscape and thereby influence the innovation processes.

5.4. Avenues for further research

This research took an explorative approach to elucidate innovation processes on AVs. Actors and groups in powerful position will have greater ability to define the pathway towards AVs. This thesis brings the divergent expectations to light, but a more in-depth actor analysis would be an avenue for further research. This provides insights in distributions of power and as such, a better understanding of the dynamics around the innovation process involved with AVs. This can be done on a local, country or European scale, which allows comparison of different case studies. Thereby, this suggestion for further research can also contribute to analyzing how the decentralization of several policies influences the innovation process as described in the aforementioned paragraph.

Furthermore, the promises around AVs tend to attach future visions to landscape promises, without having clearly defined what the actual definition of sustainability is. As argued before, sustainability tends to be a trade-off between different conditions (e.g. quality of life, social values, etc.). Therefore, sustainability can be seen as a ‘black box’ that can be opened in different ways that are beneficial to the actor’s own interest. The question arises how the different conditions influence the dynamics in the existing regime. Overall, the findings point to the need for rigor and nuance in the use of the concept of sustainability. Therefore, it is recommended to further break down the concept of sustainability into different conditions. In doing so, expectations should be part of the research since they can provide insights into the actor dynamics.

Lastly, in all three scenarios, it is expected that there is a link between EV and AV development. The majority of the interviewees argued that electric vehicles will decrease environmental pressure, regardless of AV development. Furthermore, it is assumed that electrification and AV technology are excellent complements for one another, which has been supported by several scientists (Klinger, 2016). Further research is required on the interaction between these different technologies, and how they possibly have to compete among each other in terms of visibility and credibility.

6. Conclusion

This research examines expectations about vehicle automation for analyzing innovation processes. Having mapped expectations in three scenarios of innovation processes involved with (parts of) AVs, the observations can be used to answer the research question:

How do expectations shape innovation processes in the automated vehicle industry, and which implications can be derived for government and business?

Three scenarios indicate the wide range of possible future developments paths, whose direction, scale and speed are influenced by government policy and business decision-making. The results show that automated vehicles have the potential to overthrow the existing regime when pressure from the landscape causes business and government to invest in automated vehicles. These investments can then cause a transition towards optimization of the mobility system as a whole, and move away from our current dependence on individual car mobility. However, one of the scenarios takes a less optimistic vision for AV development. When the benefits of automated vehicles for users, business and government remain unclear, expectations about AVs to potentially change the current regime are low, and therefore the technology will not break out of the niche market.

Depending on the preferred outcome regarding the realization of collective and individual interests, government and business may influence the direction of the innovation process with respect to vehicle automation. Firstly, the government can adopt the role of actively coordinating the innovation process. This would result in a reduction of congestion, higher quality of living in cities and a safer traffic system. Secondly, the government can leave the innovation process to the market while ensuring basic mobility needs. This would result in an innovation process that is mainly focused on traffic optimization for the individual, which is expected to be safer and more efficient. Thirdly, the government can actively convince and stimulate businesses and users to invest in AVs, and thereby influence the innovation process. This can be done by loosening up of the existing regime to create multiple windows of opportunity for novelties and stimulate actors (i.e. businesses and users) to experiment with many technical options. This would result in a highly efficient and safe traffic system where users have the freedom to choose their preferred transportation mode. In addition, there are three roles that businesses can adopt. Firstly, they can respond to governmental demands in developing cooperative (V2I and V2V) automation systems. This results in a mobility system that is more sustainable including a reduction of congestion, higher quality of living in cities and a safer traffic system. Secondly, businesses can aim at optimizing individual business models. This will increase their consumer base since it optimizes services and products according to users' preferences. However, it impedes a technological disruption towards fully automated vehicles. Thirdly, businesses can identify and explore new business opportunities to respond to landscape pressures, and to keep up with competition within the industry. This can increase the number of consumers, and therefore stimulates the automotive industry to innovate in alternatives for traditional cars while keeping the preferences of the user in mind.

As these different roles indicate, there is not one straightforward allocation of roles for the actor groups in the AV innovation process that emerges from the expectations. However, the results show that there is an interaction between the different roles and depending on the preferred outcome, actor groups can try to form coalitions to identify potential strategies for further decision making on technological developments. These possible coalitions can be: [1] a coordinating government, responsive businesses, and user that accept a controlling government, [2] a responsive government, individually optimized businesses, and critical users towards AV, [3] a convincing and stimulating government, cooperative and competitive businesses, and informed citizens. These coalitions can help to create uniformity between the role adoption and the allocation of roles to other actors which is essential for shaping the innovation process. If there is no congruence between the roles, the innovation processes might stagnate or the development of AVs might experience a hype which can slow down the overall process.

To conclude, the proposed scenarios and roles can be used as a tool to create uniformity among the involved actor groups. They can structure future debates about social and political priorities with respect to innovation processes involved with vehicle automation and other technological developments. The substantially different future scenarios can become an opportunity for real deliberation and thereby help to identify potential cooperative strategies between business and government. In that sense, the constructed scenarios and corresponding roles may be seen as a useful tool for future decision-making in companies and policy settings.

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8. Appendices

Appendix A: Interview design

About your organization

1. Can you describe your background in the context of the autonomous car and General Motors?
2. How did your organization get involved with AVs?
3. Why did you start with these developments?
4. What do you hope to achieve within General Motors?
5. What changed within your organization since your involvement in AVs developments?

General questions about AVs

6. What are your expectations for AVs in general?
7. Could you give a time indication of future developments?
8. How do you think that this development will influence our society?
    a. Infrastructure
    b. Technology
    c. Public-private partnerships/ networks
    d. Car sharing
    e. User acceptation
    f. Consumer behavior
    g. Legislation
    h. Mobility in general
9. How do these expectations match with current experiences?

Other actors

10. Is your organization in contact with other actors and could you describe the communication with other actors?
11. Are you personally involved with other actors?
12. What do you expect from other actors?
13. How do you think that automated vehicle developments influence other actors?
14. What do you want specifically from other actors?
15. What do other actors want from you and how do they communicate this?

The future

16. What are your plans for the future?
17. How would you describe your ideal future regarding mobility?
18. How do you want to contribute to reaching this future?
19. Are there other actors that stimulated you to reach this future?

Appendix B: Node structure of expectations

Table 16 shows the node structure of coded sources and references and the subdivision per scenario. The nodes are structured to the different dimensions of a technological regime. The sub-nodes represent the different expectations that emerged from the data. The column 'sources' corresponds to the number of interviewees that were coded under the expectations. The column 'references' corresponds to the number of references that were coded under an expectation.

Table 16: Node structure of expectations

Expectation	Sources	References
Technology	20	274
Cooperative communication systems including V2I should be developed	16	77
AVs are safer	16	36
Footnote safety improvement questionable	6	8
Use of secure software and data in the future	8	25
Focus on automation in-car technologies	11	23
Automation in-car only is too slow to improve traffic	1	3
Full automation in every situation will be reached (level 5)	11	22
Focus on V2V communication technologies	7	20
Programming human behavior is a barrier	10	18
AVs are technologically not possible in urban areas	7	14
Traffic is too complex for every situation	7	12
Maximum incentive for driver assistant systems (level 4)	4	11
Data ownership and privacy is no issue in the future	6	10
Large safety margins will hinder technological development	6	6
User acceptance	20	154
AVs are more comfortable	15	29
Low incentive for level 5 automation for users	6	20
Price remains important factor for users	10	17
New users can use AV which could not use traditional cars	9	15
AVs has a more efficient fuel use	8	14
Incremental development will increase adoption	7	10
AVs can increase efficient use of traveling time	7	10
Users want highway automation	6	8
Users can choose to turn the driving assistant on or off	4	7
AVs become affordable	4	6
Low incentives because users like driving	5	6
Other transport modes change their behavior	3	5
Low trust in technology	3	5
Professional drivers remain important	2	2
Infrastructure	19	140
Basic infrastructure with fewer road signs	11	28
Basics infrastructure in cities	4	12
Current infrastructure	8	20

Digitalized traffic management including V2I communication	11	38
Parking towers	10	19
Partly digitalized traffic management through V2V communication	5	12
Redesign of urban infrastructure	8	18
Redesign infrastructure too expensive	2	5
Separated lanes on highways	5	11
Separations lead to exclusion of other forms of transport	2	3
Separation takes even more space	1	1
Less asphalt used	5	6
One traffic control center	3	4
AVs are only possible in developed countries	3	4
Mobility	20	121
AVs complement existing transport	14	30
AVs can be used in rural areas	3	3
AVs increase traffic throughput	14	27
Footnote peak moments remain	3	5
Collective mobility system where individual cars become a train	8	20
Mobility on demand	12	20
AVs lead to more car use (including empty rides)	9	14
AVs replace existing (public) transport	6	7
Large penetration necessary before AVs influence mobility	1	3
Regulatory framework	18	95
new regulations	12	33
international standards for AVs	11	17
open data policy	7	10
financial incentives for AVs and EVs	6	9
no legally binding obligation of AVs	4	7
redefinition of existing regulations	2	7
traditional liability model	3	5
other modes of transport should be regulated	1	4
supporting policy for car sharing	2	3
New business models	18	93
PPPs are necessary to optimize traffic management	18	48
Private partnerships, government sets preconditions	14	21
Less professional drivers necessary	3	3
Car ownership	15	56
Less privately owned cars, car sharing increases	9	28
Car ownership remains important and increases	8	22
AV eases car sharing	3	6
Other trends	17	50
AVs and EVs should be parallel developments	8	18
Telecommuting increases	5	12
From collective to individual provision of information	6	11
EVs will automatically develop parallel to AVs	7	8
Car-free city centers	3	6

Appendix C: Case structure of actors

Table 17 shows the case structure of coded actors. The cases are divided into three main actors: government, business, and users. The sub-nodes represent the different actors that emerged from the data. The column 'sources' corresponds to the number of interviewees that were coded under the case. The column 'references' corresponds to the number of references that were coded under a case.

Table 17: Case structure of roles

Actor	Sources	References
Business	20	189
Architect	1	3
Automotive industry	14	35
Car manufacturer	14	14
Car sharing company	6	7
Insurance company	4	17
Map developer	8	29
Software developer	9	13
Telecom company	4	14
Traffic management company	16	27
Driving standards agency	1	2
Existing public transport company	12	14
Goods transport company	2	3
Government	20	162
Data center	2	6
Local government/ city authority	14	23
National government	19	85
Regional government	5	12
Vehicle authority	4	10
Road authority	9	26
Users	20	121
Wealthy consumer	2	6
Knowledge Institutes	8	39
Knowledge institute	7	19
Knowledge platform	5	18
University	1	2
Early adapter	6	18

Appendix D: Division of expectations in scenarios

Table 18 shows a subdivision of the expectations per scenario. Firstly, the most divergent scenarios as shown the result section were divided, followed by the remaining expectations. The columns '1', '2', and '3' represent the three scenarios.

Table 18: Subdivision of expectations per scenario

			Scenarios		
Expectation	**Sources**	**Ref.**	**1**	**2**	**3**
Technology	20	274			
Cooperative communication systems including V2I should be developed	16	77	X		
AVs are safer	16	36	X	X	X
Footnote safety improvement too pressing to be left to the market	6	8	X		
Use of secure software and data in the future	8	25	X	X	X
Focus on automation in-car technologies	11	23		X	
Automation in-car only is too slow to improve traffic	1	3			X
Full automation in every situation will be reached (level 5)	11	22	X		X
Focus on V2V communication technologies	7	20		X	
Programming human behavior is a barrier	10	18		X	
AVs are technologically not possible in urban areas	7	14		X	
Traffic is too complex for every situation	7	12		X	
Maximum incentive for driver assistant systems (level 4)	4	11		X	
Data ownership and privacy is no issue in the future	6	10	X	X	X
Large safety margins will hinder technological development	6	6		X	
User acceptance	20	154			
AVs are more comfortable	15	29		X	X
Low incentive for level 5 automation for users	6	20		X	
Price remains important factor for users	10	17			X
New users can use AV which could not use traditional cars	9	15	X		X
AVs has a more efficient fuel use	8	14			X
Incremental development will increase adoption	7	10			X
AVs can increase efficient use of traveling time	7	10			X
Users want highway automation	6	8		X	
Users can choose to turn the driving assistant on or off	4	7		X	X
AVs become affordable	4	6			X
Low incentives because users like driving	5	6		X	
Other transport modes change their behavior	3	5		X	
Users do not trust AV technology	3	5		X	
Professional drivers remain important	2	2			X
Infrastructure	19	140			
Basic infrastructure with fewer road signs	11	28	X		
Basics infrastructure in cities	4	12	X		
Current infrastructure	8	20		X	X
Digitalized traffic management including V2I communication	11	38	X		X
Parking towers	10	19	X		X

Partly digitalized traffic management through V2V communication	5	12		X	
Redesign of urban infrastructure	8	18	X		
Redesign infrastructure too expensive	2	5		X	X
Separated lanes on highways	5	11		X	
Separations lead to exclusion of other forms of transport	2	3			
Separation takes even more space	1	1			
Less asphalt used	5	6	X		
One traffic control center	3	4	X		
AVs are only possible in developed countries	3	4			
Mobility	20	121			
AVs complement existing transport	14	30	X		
AVs can be used in rural areas	3	3	X		X
AVs increase traffic throughput	14	27	X	X	X
Footnote peak moments remain	3	5	X	X	X
Collective mobility system where individual cars become a train	8	20	X		
Mobility on demand	12	20			X
AVs lead to more car use (including empty rides)	9	14	X	X	X
AVs replace existing (public) transport	6	7			X
Large penetration necessary before AVs influence mobility	1	3		X	
Regulatory framework	18	95			
new regulations	12	33	X		
international standards for AVs	11	17	X		X
open data policy	7	10			X
financial incentives for AVs and EVs	6	9	X		X
no legally binding obligation of AVs	4	7		X	X
redefinition of existing regulations	2	7	X		X
traditional liability model	3	5	X	X	X
other modes of transport should be regulated	1	4	X		
supporting policy for car sharing	2	3			X
New business models	18	93			
PPP are necessary to optimize traffic management	18	48	X		
Private partnerships, government sets preconditions	14	21		X	X
Less professional drivers necessary	3	3			X
Car ownership	15	56			
Less privately owned cars, car sharing increases	9	28	X		C
Car ownership remains important and increases	8	22		X	
AV eases car sharing	3	6		X	X
Other trends	17	50			
AVs and EVs should be parallel developments	8	18	X	X	X
Telecommuting increases	5	12		X	
From collective to individual provision of information	6	11		X	X
EVs will automatically develop parallel to AVs	7	8			X
Car-free city centers, with limited access for AVs	3	6	X		