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Automated vehicles and the facilitating state

Doctoral thesis

NTNU
Norwegian University of Science and Technology
Thesis for the Degree of
Philosophiae Doctor
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Preface

Summary

In 2017, the Norwegian Government flagged its interest in automated vehicles, and established legislation that allowed for automated vehicles to be tested on public roads. Proponents of automated vehicles claim that such vehicles represent an opportunity for making road transport greener, safer, and more efficient, as well as a considerable opportunity for industrial development and economic growth. This thesis takes innovation processes relating to automated vehicles as a starting point for understanding the roles ascribed to new technologies in and beyond the transport sector.

The thesis is composed of three articles and an overarching essay. The first article concerns the translation of a set of generalised expectations into a more specific vision of how the development of automated vehicles might benefit the Norwegian state, and, by extension, what future automated vehicles might render possible. The second article concerns public expectations regarding automated vehicles in Norway as expressed through a public hearing, how these expectations are reflected in innovation practices, and how the practices shape further expectations. The third article focuses on the temporal aspect of innovation, and contrasts technology innovation with policy innovation in order to draw out the implications of the two approaches to shaping the future of transport.

The overarching essay analyses, synthesises, and draws conclusions from across the three articles to enable a discussion of the transformative role often ascribed to technology. Whereas the importance of technology should not be discounted offhand, transport innovation in Norway is configured in a way that ultimately promotes the continuation and preservation of established transport patterns in particular, as well as society more generally. The expectation that future technology will help ameliorate or even solve the problems associated with today's transport system allows present-day action to be deferred indefinitely. However, expectations are always associated with considerable uncertainty. Hence, it is crucial not only to ask what benefits new technologies might bring, and to assess any such claims critically, but also to plan for a future in which expectations for new technologies might not be realised.

Acknowledgments

'It's time. There's some fear, some fear in letting go.' Margaret Lanterman speaks these words during her final conversation with Deputy Chief Hawk in David Lynch's *Twin Peaks: The Return*. These words aptly summarise my feelings regarding the finalising of this dissertation. Indeed, it's time, and there's some fear, but I am letting go of this thesis. That also means that it is time to express gratitude to all those who have supported me throughout the last three and a half years.

To my supervisors, Tomas Moe Skjølsvold and Marianne Ryghaug. Thank you for all your guidance, for our fruitful discussions, for reining me in every time I have tried to write an article that should have been two, and for time and time again trying to convince me that scientific papers should not be structured like crime novels. I might not be there yet, but hopefully, I am getting closer. You have been patient and caring, and this thesis could not have been written without your help.

To the mainstays of the Wednesday Club, Maria, Susanne, and Thomas. Thank you for making the final stretch of the PhD bearable. Maria, I am glad to know someone who can out-nerd me and who shares my proclivity to read messages without replying. It is certainly *klikk* to finally hand in a thesis. Susanne, thank you for being bright, funny, and wholesome. You know where to find me if you need another document formatted. Thomas, we have shared office throughout the whole PhD, barring some months where there was some pandemic or something. You have been a fabulous conversation partner, regardless of whether the discussion has concerned academic or non-academic matters. Beyond the Wednesday Club, thank you Martin. Your open door-policy might not have increased my – or our – efficiency, but it was certainly conducive to my well-being. Thanks also go out to all the other lovely PhD candidates at KULT, past and present.

The preceding paragraphs point to a general characteristic of the Department of Interdisciplinary Studies of Culture. The atmosphere is relaxed and friendly, and it has been a joy to write my thesis here. A special thank you to the administrative personnel, Kari Bergheim, Lotte Sæther, and Åse Marit Skarholt, who have guided me through the university's sometimes labyrinthine bureaucratic systems.

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Finally, and most importantly: thank you, Stine. Thank you for always being there for me, through every high, through every low. The world might be a den of thieves and night might be falling, to paraphrase a certain Ekdahl, but you always remind me to find pleasure in the little world. With the addition of Ragni, our little world just became a little bigger. Now, with two final words, I can turn my undivided attention towards this world: *tamám shud*. It is finished.

Trondheim, April 2022
Bård Torvetjønn Haugland

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Part A: Introduction and overview

Chapter 1: Introduction

In June 2018, an automated shuttle bus drove onto a public road at Forus outside the city of Stavanger, on Norway's south-western coast. It was the first automated vehicle to be tested on a public road in Norway, and thus also the first materialisation of the Norwegian Government's recent effort to explore the merits of automated vehicles. The Norwegian Government's interest in such vehicles was motivated by the prospect of making road transport safer, greener, and more efficient. This framing presents automated vehicles as an opportunity. However, an alternative framing might read as follows: the Norwegian Government's interest in automated vehicles was motivated by the prospect of addressing the myriad of problems currently associated with road transport. As this thesis makes clear, the difference in framing is consequential. The emphasis on ameliorating and improving the road transport system through technology may preclude engagement with the system's currently unsustainable configuration. To provide the necessary context for discussing this issue, this chapter discusses Norwegian transport policy and shows how the Norwegian Government has sought out and facilitated automated vehicle innovation.

1.1 The problems and prospects of road-based mobility

Throughout the 20th century, the automobile spread around the world, accompanied by the expansion of road networks (Sørensen, 1990; Urry, 2004). This came with a series of increasingly obvious problems. Road transport is the source of 15% of global CO_2 emissions (Ritchie, 2020), and thus represents a major source of local and global pollution. It is also a public health hazard in terms of accidents: 1.35 million people are killed in traffic accidents worldwide every year (World Health Organization, 2018). Simultaneously, car-based planning has caused landscapes to be organised in a disjointed manner, which has fragmented land and limited the mobility of non-motorists (Holden et al., 2020: 2; Urry, 2004). These are but a few of the factors that suggest that current road-based transport should be characterised as unsustainable (Banister, 2008; Holden et al., 2020; Hoogma et al., 2002).

The problems associated with road transport result from its central role in societies around the world (Holden et al., 2020). Road transport has become intimately tied to human well-being (Lamb & Steinberger, 2017), to such an extent that the car may be considered *the* quintessential technology of everyday life (Baudrillard, 1988: 52–55; Lefebvre, 1971: 101). Over time, this has given rise to a built environment that is primarily organised around the private car (Sheller & Urry, 2000; Sørensen, 1990). We have driven ourselves into a cul-de-sac: there is an obvious need to mitigate the negative aspects of road transport, but simultaneously, everyday life, the built environment, the economy, and the political system, and even the rhythms of society, are attuned to car use (Blue, 2019; Mattioli et al., 2020; Østby, 1995). Due to this interconnectedness, changes to road transport will necessarily entail changes to society, too (Kemp et al., 1998).

A series of strategies has been proposed to address the problems of road transport, most of which fall into one of three categories (Holden et al., 2020). First, there are strategies that seek to improve the environmental performance and accessibility of existing modes of travel, whether through new technology (alternative fuels, automation) or by improving access to information (e.g. mobility-as-a-service, intelligent transport systems). Second, there are strategies that seek to alter travel patterns through a modal shift, in which individual travel is replaced with public transport and/or zero-emission modes of transport (walking, bicycling). Third, and finally, there are strategies that seek to reduce motorised travel altogether (Holden et al., 2020: 2–3). Whereas a transition towards a more sustainable transport system will probably have to encompass all the above-mentioned strategies, efficiency-based strategies tend to be prioritised, not least because of the economic allure of technological innovations (Schwanen et al., 2011: 999).

Road transport appears to be at a crossroads, but the exact form of the future road transport system remains undecided. While it has been claimed that new technologies might revolutionise road transport (e.g. Sperling, 2018), technologies do not simply assemble themselves in preordained patterns. Rather, any sociotechnical system, whether at present or in the future, will be the outcome of considerable work (Hughes, 1987). Hence, in this thesis, I seek to understand how various actors act to shape the future of road transport. To explore this topic, I mobilise insights from sustainability transitions research and science and technology studies (STS). Sustainability transitions research provides a perspective on the role of innovation in sociotechnical change, including strategies for directing technological development (Kemp et al., 1998; Markard et al., 2012). However, my interest is not limited to how successful change may be attained. Rather, I seek to examine how innovation activities shape society more generally, regardless of whether those activities are useful in terms of the goal of enabling a sociotechnical transition. To do so, I mobilise insights from STS, a field that has long been concerned with the mutual shaping of science, technology, and society. In combination, the above-mentioned perspectives provide a basis for exploring the role or roles that emerging technologies are ascribed in transitioning towards more sustainable road transport systems.

As implied by the opening vignette, the empirical focus of this thesis is automated vehicle innovation in Norway.[1] While Norway has often been acclaimed for its success in electrifying road transport (Anfinsen, 2021; Ryghaug & Skjølsvold, 2019; Ryghaug & Toftaker, 2016), the ongoing electrification of the Norwegian transport system has also been cited as conducive for the deployment of automated vehicles (KPMG, 2019). The first time the Norwegian Government flagged interest in automated vehicles was in the White Paper titled *Nasjonal transportplan 2018–2029* ('National Transport Plan 2018–2029') (Meld. St. 33 (2016–2017)). In the same document, the Government ascribed an important role to trials and pilot projects with new and emerging transport technologies. Such activities were considered an important means for assessing the potential of new technologies (Meld. St. 33 (2016–2017): 26). To facilitate such activities, the Government developed legislation that would allow interested parties to run pilot projects with automated vehicles on Norwegian roads (Lov om utprøving av selvkjørende kjøretøy, 2017), and the first pilot projects with automated vehicles were set in motion in 2018.

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[1] Other commonly used terms are autonomous vehicle, driverless vehicle, and self-driving vehicle (Shladover, 2016: 54). In Part A and Part C of this thesis, I consistently use the term automated vehicle. In the articles making up Part B, I have used the term self-driving vehicle. This inconsistency reflects my change of mind regarding the preferrable terminology. The reasoning behind this, as well as a discussion of the merits and shortcomings of the various terms, is provided in Section 3.2. However, despite the inconsistency, both terms in practice refer to the same concept: a vehicle that uses some combination of software, hardware, and/or connectivity to navigate roads without driver input (Ibañez-Guzmán et al., 2012).

1.2 Research questions and thesis structure

Against the background presented above, I seek to understand how innovations relating to automated vehicles are expected to contribute to change in and beyond the Norwegian transport sector. Embedded in this overarching topic are three subquestions:

RQ1: How do various actors shape expectations regarding automated vehicles?
RQ2: How are pilot projects expected to instigate sociotechnical change?
RQ3: What motivates the Norwegian state to support transport innovations?

To answer the questions, this thesis proceeds in three main parts (Parts A–C). In the remaining part of Part A, I start by presenting the necessary background information on transport and innovation in Norway, in order to contextualise the focus on automated vehicles and pilot projects with such technology (Chapter 1). Then, I present and elaborate upon theoretical perspectives and concepts that are relevant for understanding the shaping of technology (Chapter 2), which I follow with a review of existing literature on automated vehicles (Chapter 3). In the final chapter of Part A, I elaborate upon my methods of data generation and analysis (Chapter 4).

Part B consists of the three articles that make up the empirical part of this thesis. As implied by referring to them as articles rather than chapters, these are stand-alone pieces of work, which nevertheless relate to the questions set forth above (see Table 1.1). Article 1 concerns the translation of a set of generalised expectations into a more specific vision of how the development of automated vehicles might benefit the Norwegian state, and, by extension, which future society it is claimed that automated vehicles will enable. Article 2 focuses on public expectations regarding automated vehicles in Norway, as expressed through a public hearing, how those expectations are reflected in innovation practices, and how, in turn, those practices shape further expectations. Article 3 contrasts automated vehicle innovation with low-tech policy innovation, in order to draw out the implications of the two approaches to shaping the future of transport. In Part C of the thesis, I discuss and synthesise the empirical findings (Chapter 5), before concluding the thesis with some final remarks on the role of transport innovation in Norwegian society (Chapter 6).

Table 1.1: Relationship between thesis research questions and articles

	RQ1	RQ2	RQ3
Article 1	X		X
Article 2	X	X	X
Article 3	X	X	

1.3 Norwegian transport policy and innovation

The private car has become a central constituent of Norwegian society (Eriksen, 2020; Sørensen, 1990; Østby, 1995). Since the 1960s, most area and transport planning in Norway has used the car as a starting point. This resulted in a 'pattern where new urban and rural areas were made use of in a senseless way, seen from the perspective of any other means of transport than the private car' (Sørensen, 1990: 11). As much of the built environment has been organised around car use, road transport represents a significant source of Norwegian greenhouse gas emissions. Measured by sector, road transport is the third largest source of such emissions (17% of total emissions, or 8.4 million tons CO_2 equivalents), surpassed only by emissions from oil and gas production and industry (Statistisk sentralbyrå, 2021c).

Electric vehicles have long been considered an important tool for decarbonising the Norwegian road transport sector (Anfinsen, 2021; Ryghaug & Toftaker, 2016), not least because the Norwegian energy mix is made up of 98% renewable energy. The Norwegian Government's effort to promote electric vehicles has a decades-long history (Ryghaug & Skjølsvold, 2019). The first tax exemptions for electric vehicles were implemented in the 1990s, in an attempt to foster a national electric vehicle industry. While the industrial venture eventually failed, the exemptions remained in place.

Throughout the 2000s, new models of electric vehicles increasingly exhibited technical capabilities akin to those of fossil-fuelled cars. Simultaneously, the Norwegian Government funded the development of charging infrastructure and implemented further policies promoting the uptake of electric vehicles, including VAT exemption, road toll exemption, and access to bus lanes (for a complete overview of relevant policies, see Ryghaug & Skjølsvold, 2019: 159–160). The combination of improved technical capabilities, increased access to chargers, and policy measures turned out to be conducive to the public adaption of electric vehicles (Bjerkan et al., 2016; Ryghaug & Skjølsvold, 2019): in 2010, there were 3000 registered electric vehicles in Norway, and as of December 2020, there were more than 340,000 (Statistisk sentralbyrå, 2021a). Although one might argue that electric vehicles simply ameliorate one aspect of the system of automobility (Anfinsen, 2021; Urry, 2004), the uptake of electric vehicles has generally been considered a success story by the Norwegian Government.

In addition to electric vehicles, the Norwegian Government has also sought to implement policies that reduce or at least curb car use. These policies have tended to focus on urban areas, where most of Norway's population reside (on climate-friendly transport policies in rural areas, see Tønnesen et al., 2022).[2] For example, in 2012, the Norwegian Government formulated, as part of its climate policy, the zero-growth goal, which stated that any increase in passenger transport in urban areas should be absorbed by public transport, cycling, and walking (Meld. St. 21 (2011–2012): 13). The Government has since established Urban Growth Agreements as an important instrument for achieving the zero-growth goal. The exact content of these agreements is not important for this thesis. Suffice it to say they stipulate collaboration between municipal, county, and state authorities, and thus allow for the mutual adjustment of previously isolated areas of responsibility (Meld. St. 33 (2016–2017): 159; Tønnesen et al., 2019).

Whereas the Urban Growth Agreements help cities implement strategies for reducing greenhouse gas emissions and improving urban environments, these are not the only goals within the transport sector. Other goals include transport efficiency, regional development, and value creation (Oseland & Haarstad, 2018), all of which may conflict with previously established aims, such as those pursued through Urban Growth Agreements. For example, while the development of new highway corridors might allow for more efficient freight transport and the expansion of housing and labour markets, it might simultaneously direct higher traffic volumes towards urban areas and thus undermine policy targets such as the zero-growth goal (Tønnesen et al., 2019: 39). Such

[2] In total, 82.4% of Norway's entire population live in urban areas, with ca. 34.3% of the entire population residing in the vicinity of the five largest urban areas (Statistisk sentralbyrå, 2021b). Ordered from most to least populous, the five areas are Oslo, Bergen, the Stavanger-Sandnes conurbation, Trondheim, and the Fredrikstad-Sarpsborg conurbation.

conflicting policy goals may be termed target conflicts (Oseland & Haarstad, 2018), and they exemplify the difficulty of establishing completely overlapping goals across a variety of sectors. Nevertheless, the above examples show two approaches to addressing the problems associated with road transport: one that emphasises efficiency-based strategies and one that emphasises modal shifts (Holden et al., 2020)

In terms of Norwegian transport policy, the White Paper titled *Nasjonal transportplan* (National Transport Plan, hereafter abbreviated as NTP) is undoubtedly the most central document. A new NTP White Paper is published every four years and sets out the Government's transport priorities for the next twelve years.[3] The NTP is a somewhat curious document in the sense that it sets out the Government's priorities and expectations for the transport sector, and includes some quite specific sums for funding, while simultaneously being nothing more than an expression of intent. To be enacted, the projects and initiatives listed in the NTP must be prioritised in the Government's annual budgetary discussions.

In the context of this thesis, the NTP for 2018–2029 (Meld. St. 33 (2016–2017)) is notable for containing the earliest in-depth treatment of automated vehicles in Norwegian policy.[4] It is also the first NTP to include a chapter dedicated to the future of mobility. In that chapter, simply headed 'Fremtidens mobilitet – transportsystemet i en brytningstid' (Mobility in the future – the transport system in a period of transition), the Government

[3] Prior to the NTP for 2018–2029, earlier NTPs set out the priorities for the next ten years, rather than twelve.

[4] The first reference to automated vehicles in Norwegian policy documents came in the previous year, in the White Paper titled *Trafikksikkerhetsarbeidet – samordning og organisering* (Traffic safety work – coordination and organisation) (Meld. St. 40 (2015–2016)). In that White Paper, the Government posits that advances within vehicle automation would have a positive effect on traffic safety (Meld. St. 40, (2015–2016): 21–22)). Automated vehicles are also referenced in the White Paper titled *Industrien – grønnere, smartere og mer nyskapende* (Industry – greener, smarter, and more innovative) (Meld. St. 27 (2016–2017)), in which the Government argued that national initiatives pertaining to new transport technologies might help to realise the Government's transport policy goals, while also promoting industrial development (Meld. St. 27 (2016–2017): 49). The statement clearly shows the dual purpose ascribed to innovation: on the one hand, innovation is expected to improve a particular sector; on the other hand, it is expected to contribute to industrial development and presumably to value creation through industrialisation.

expresses its hopes and expectations for new and emerging technologies, including automated vehicles (Meld. St. 33 (2016–2017): 26–49). The Government has envisioned that such technologies might trigger a series of beneficial developments, and that through the implementation of those technologies, the overarching policy goal of increased mobility, improved safety, and lower greenhouse gas emissions can be realised (Meld. St. 33 (2016–2017): 26). These expectations echo other nations' policies on automated vehicles, including Sweden (Hansson, 2020: 5–6), Finland (Mladenović et al., 2020), Germany (Schreurs & Steuwer, 2016), and the UK (Hopkins & Schwanen, 2018a). This suggests that automated vehicles are the subject of *collective expectations*, a set of expectations that has resulted from a combination of distributed discourses and innovation activities, and hence cannot be attributed to a specific group (Konrad, 2006: 431–433).

1.4 Facilitating automated vehicles

The NTP for 2018–2029 lays out the Government's strategies for successfully reaping the benefits ostensibly offered by promising new technologies. The Government cites instruments such as public procurement, taxes and duties, and trials and pilot projects, as well as the importance of adapting existing legislation and infrastructures (Meld. St. 33 (2016–2017): 26). However, in addition, the Government announced its intent to direct NOK 1 billion (approximately EUR 100 million) – sometimes referred to as the 'technology billion' (e.g. AT, 2017; Samferdselsdepartementet, 2017a; TU, 2017) – towards transport innovations over the next twelve years. The technology billion was accompanied by the founding of two innovation initiatives, Pilot-T and Smartere transport ('Smarter transport'). This marked the first time such innovation initiatives were established *outside* the Governmental transport agencies (Meld. St. 33 (2016–2017): 38).[5] In this section, I elaborate upon the rationale underpinning the technology billion and the

[5] The Norwegian transport sector is organised through four government agencies, which are responsible for all of Norway's transport infrastructure: the Norwegian Public Roads Administration (roads), the Norwegian Coastal Administration (ports and seaways), the Norwegian Railway Directorate (railways), and Avinor (airports and air traffic control).

two initiatives discussed above and describe how they reflect a more general shift in Norwegian innovation strategy.

The principal motivation underpinning the technology billion was to enable organisations to 'explore the potential of new technological solutions through trials and pilot projects' (Meld. St. 33 (2016–2017): 26). By organising the two initiatives funded through the technology billion according to competitive principles (Meld. St. 33 (2016–2017): 38), applicants would be compelled to develop high-quality projects (Meld. St. 33 (2016–2017): 38–39). Simultaneously, the availability of funding would reduce the economic risks associated with running pilot projects with new technologies, particularly for private actors (TU, 2017). In sum, the technology billion was established to facilitate the most promising pilot projects with emerging technologies, as ascertained through competitive principles, while also reducing the economic risk undertaken by the company, institution, or organisation responsible for the project. This motivation is also clearly reflected in the organisation of the two initiatives funded by the technology billion.

Pilot-T was established as an R&D programme under the joint organisation of the Research Council of Norway and Innovation Norway, two of the central instruments in Norwegian research and innovation policy. Pilot-T was inspired by similar national initiatives in countries such as Sweden and the UK (Drive Sweden and Transport Systems Catapult, respectively) (Meld. St. 33 (2016–2017): 38). Every year, the programme invites companies, both public and private, to develop projects that combine mobility with information and communication technologies. Applicants are expected to develop, test, and/or pilot new technologies or business models, as well as to develop new knowledge or apply existing knowledge to new areas. The ultimate purpose of these activities is to hasten the rate of adoption of 'new and smart mobility solutions'.[6]

Smartere transport was organised as a one-off competition in which the Ministry of Transport invited all the Norwegian counties and Oslo Municipality to develop a concept for testing new technologies, such as technologies for automation, automated vehicles, and/or sensor-based infrastructures (Meld. St. 33 (2016–2017): 39; Samferdsels-departementet, 2017b: 11–15). The most promising project or projects were to be awarded

[6] https://www.forskningsradet.no/utlysninger/2021/pilot-t-mobilitetslosninger/ (accessed 10 October 2021)

up to NOK 100 million. Ultimately, the prize money was split between five projects, four of which involved automated vehicles (the fifth involved an automated ferry). Again, this shows how the Government helped to facilitate pilot projects with new technologies, as well as how automated vehicles were considered an attractive and viable technology.[7]

The NTP for 2018–2029 emphasises the importance of pilot projects in gaining experience with emerging technologies, producing knowledge about them, and hastening their diffusion (Meld St. 33 (2016–2017): 26). The fact that the technology billion was prioritised in budgetary discussions further substantiates the importance ascribed to pilot projects.[8] Both Pilot-T and Smartere transport helped to facilitate such projects and, regardless of their specific organisation, both initiatives helped to direct Government funds towards trialling a certain technology or set of technologies. However, an additional measure needed to be in place for trialling automated vehicles: legislation allowing such vehicles to be tested in public.

A crucial step in facilitating the public testing of automated vehicles was the development and implementation of the 2017 *Lov om utprøving av selvkjørende kjøretøy* ('Act relating to testing of self-driving vehicles') (Lov om utprøving av selvkjørende kjøretøy, 2017). The legislation was adopted by the Norwegian Parliament in December 2017 and implemented in January 2018. The Act specifies the conditions under which interested parties are allowed to test automated vehicles on public roads. It specifies that any person, whether physical or legal (e.g. institution, company, municipality), may apply

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[7] Upon announcing the competition, the then Minister of Transport and Communications, Ketil Solvik-Olsen, stated that the competition was inspired by similar initiatives in the US. https://www.regjeringen.no/no/aktuelt/regjeringens-konkurranse-om-smartere-transport-i-gang-100-millioner-kroner-i-premiepotten/id2578517/ (accessed 11 October 2021). This probably refers to the US Department of Transportation's competition-based funding of so-called University Transportation Centers. However, Smartere transport is simultaneously aligned with a long-standing tradition of using competitions to promote or further technological development (Kaldewey, 2018; Maibaum, 2018). A relevant example is the DARPA Grand Challenges with automated vehicles (Broggi et al., 2016), which the UK Government cited as inspiration in its 2017 Industrial Strategy (Tennant, Howard et al., 2021). The DARPA Grand Challenges are discussed in more detail in Chapter 3.

[8] The NOK 100 million funding for Smartere transport was awarded in 2018. Pilot-T is funded annually and thus far NOK 225 million have been made available through the programme.

to the Directorate of Road Transport for a permit to conduct testing. The applicant must specify the period and place of testing, as well as describe any necessary adaptations to the physical environment and/or required exemptions from *Vegtrafikkloven* ('The Road Traffic Act'), which is Norway's overarching legislative framework for road traffic.

Whereas simple demonstrations of automated vehicles could be accommodated within the existing regulatory framework, the Government considered the framework too limiting. Because the field of automated driving was perceived to be advancing at a rapid pace, the Government sought to develop a framework for testing that would be able to accommodate a whole range of technologies. Thus, the Government would not have to renew the framework every few years to reflect recent technological developments. Hence, the resulting Act is characterised by considerable *adjustment flexibility* (Hansson, 2020): it is sufficiently general to accommodate a variety of technological configurations, as long as the test in question fulfils a set of basic requirements with regard to vehicle control, traffic safety, and emergency procedures.

The adjustment flexibility is clearly discernible in the legislation text. The legislation requires testing to be conducted 'gradually, especially concerning the maturity of the technology' (Lov om utprøving av selvkjørende kjøretøy, 2017: §1), and further states that the primary purpose of such testing is knowledge production.[9] This suggests that the knowledge produced during a trial may also inform the decisions of the governing body. For example, if a trial establishes that a particular vehicle is safe at a certain speed, that knowledge might be used to request more lenient test conditions. Hence, there is a reciprocal relationship between the body governing the tests and the actors conducting them (Hansson, 2020: 9).

The establishment and adoption of the above-discussed legislation must be understood as an integral part of the overall strategy outlined out by the Government in the NTP for 2018–2029, which points out the importance of continuous and intensified knowledge collection and the use of trials and pilot projects to gauge the usefulness of new transport technologies (Meld. St. 33 (2016–2017): 26). Without this legislation, neither set of activities could have taken place.

[9] Throughout this thesis, I quote documents that have only been published in Norwegian. Unless otherwise indicated, the translation provided is my own.

The Norwegian Government's approach to fostering transport innovation clearly reflects historical developments within Norwegian industry and innovation policy. In the aftermath of the worldwide economic crisis of the mid-1970s (1973–ca. 1975), the Norwegian industrial strategy began to shift. While the state had long funded the preservation of specific companies or industries, funding then shifted towards innovation and industrial adaptation (Espeli, 1992: 189). One exception was the then emerging technology areas such as information technology, biotechnology, and new materials, which were supported throughout the 1980s, but those efforts were eventually discontinued (Wicken, 2009). Throughout the 1980s, generalised support schemes became an increasingly common strategy for facilitating innovation (Gulbrandsen & Nerdrum, 2009: 298–299). The shift in industrial strategy also reflects a shift in the state's role with regard to innovation: while the state had previously been directly involved in innovation, it now simply sought to facilitate it (Sørensen, 2016: 127). This development still reverberates today, as exemplified by the support schemes for transport innovation discussed above.

The Norwegian Government appears to have been motivated by a need to understand whether and how new transport technologies, such as automated vehicles, might bring improvements to the road transport sector. It has also prescribed trials and pilot projects as activities that may help to make sense of automated vehicles. In the next chapter, I present theoretical perspectives that help to make sense of innovation activities and their relationship to the state, as well as the role of expectations and experimentation in innovation.

Chapter 2: Theory and relevant concepts

As presented in the preceding chapter, the purpose of this thesis is to understand the role ascribed to automated vehicle innovation in and beyond the Norwegian transport sector. In this chapter, I introduce a set of theoretical concepts that may help elucidate the topic. First, I discuss sustainability transitions research, in order to establish a perspective on the role of technological innovation in sociotechnical change, before discussing how innovation can be understood more generally. Thereafter, I present strategic niche management as an example of an approach to steering innovation. Building upon the main tenets of strategic niche management, I then discuss the dynamics of expectations in sociotechnical change, before introducing different perspectives on the role of experimentation in triggering such change. Specifically, I discuss how sociotechnical experimentation is understood within sustainability transitions research and compare this with STS perspectives on experimentation. Finally, I elaborate upon the concept of co-production, in order to provide a starting point for discussing how new innovation practices may affect and change society more generally, regardless of whether those practices are able to instigate a full transition to sustainability.

2.1 Sustainability transitions research

Modern societies face a series of sustainability challenges (Köhler et al., 2019).[1] Within sustainability transitions research, these challenges are traced back to the series of complex systems upon which societies rely. Such systems provide services and facilitate practices that are perceived as essential (e.g. transport, energy supply, water supply, food

[1] It is worth emphasising that sustainability is a contested concept. While a prospective formulation of the concept of sustainability was evident in the report *Our Common Future* (World Commission on Environment and Development, 1987), the concept continues to carry different meanings for different groups (Pel et al., 2016: 456; for some examples of the concept's interpretative flexibility, see Guy & Farmer, 2001; Holden et al., 2020; Jasanoff, 2010; Ozaki et al., 2013).

systems, and agriculture).[2] Simultaneously, the systems have been configured in an unsustainable manner, which has led to problems such as climate change, resource depletion, (local and global) pollution, accidents, and energy poverty (Coad et al., 2020; Markard et al., 2012). Despite an ever-growing awareness of the problems, they have generally remained unsolved.

Within the scholarly field of sustainability transitions, the sociotechnical system is a key concept for explaining systemic obduracy or slowness of change. Sustainability transitions research starts from the observation that societies are constructed around or even constituted by a series of sociotechnical systems, which are complex systems that provide and/or facilitate specific practices or services, such as transport and energy (Markard et al., 2012: 956). These large-scale systems are made up of infrastructures that consist of and connect a wide variety of specialised and often complex technologies. However, in addition to their material components, such systems are constituted by a range of actors, institutions, practices, technical and practical knowledges, regulations, legislation, standards, and so forth. Because they consist of such a comprehensive range of heterogenous, complex, and partially interlocking elements, sociotechnical systems tend to change slowly.

The field of sustainability transitions is committed to facilitating sociotechnical transitions towards more sustainable societies (Köhler et al., 2019; Pel et al., 2016). Such transitions are comprehensive processes that take place over a timespan of fifty years or more, and in which an existing system is replaced with a more sustainable one. This necessitates both social and material changes to the existing system, and might even impact adjoining systems (Markard et al., 2012: 956). As opposed to a technological transition, a sociotechnical transition entails changes across cultural, institutional, organisational, regulatory, economic, political, and cultural dimensions, in addition to the

[2] Whether these systems *are* essential is currently debated, which is why I write 'are *perceived as* essential'. A growing body of literature questions the assumptions relating to these systems and explores the prospect of sufficiency (Mattiolo, 2016; Steinberger & Roberts, 2010; Waygood et al., 2019).

technological one.[3] The road transport system offers a relevant example to illustrate the complexities and magnitude of a sociotechnical transition.

Transport systems have been conceptualised in a variety of ways. For a long time, transport systems were mainly conceptualised in terms of their material components, namely vehicles, technologies, and infrastructures (Banister, 2008; Schwanen et al., 2011). In some definitions, transport system would refer to distinct modes of travel (e.g. planes, trains, automobiles) or infrastructures (e.g. airports, railways, roads), while in others, the transport system was defined as 'the combination of physical and informational inputs that allow a transport activity to take place' (Button & Hensher, 2001: 3). Such definitions have often been employed by engineers and transport planners (Banister, 2008; Stephenson et al., 2014), and have one thing in common: they are primarily instrumental definitions used for analysing and planning transport, and/or transport investments.

The instrumental view of the transport system has been challenged (Schwanen et al., 2011; Stephenson et al., 2014; Sørensen, 1990). For example, Mokhtarian and Salomon (2001) challenged the long-held view that travel was a derived demand. Rather than travel being an activity that results from the desire to partake in an activity at another location than the current one, they found that travel is sometimes undertaken for its own sake. Adding to this critique, Banister (2008) argued that rather than focusing on minimising travel time, transport policies should promote sustainable mobility. The above-cited articles reflect a larger development within transport studies and adjacent fields, in which the transport system is analysed in sociotechnical terms.

By viewing road transport as a sociotechnical system, change cannot be reduced to a question of upgrading the car fleet and providing new infrastructures, or, for example,

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[3] Leo Marx (1997) argues that technologies, by definition, encompass social and institutional aspects. He describes how the *concept* of technology arose in the 19th century to fill the semantic void created by the emergence of complex sociotechnical systems such as the railway. Such systems comprised infrastructures, economics, various technical knowledge, skilled workers, regulations, and institutions – that is, complex systems that could not be properly described by words such as 'machine' or 'invention'. Following this line of argument, the physical component that we often refer to when invoking the word 'technology' is 'merely one part of a complex social and institutional matrix' (Marx, 1997: 979).

exchanging human drivers for algorithms and sensors. Rather, transport systems lie at the intersection between daily life, politics, and economy (Mattioli et al., 2020; Sørensen, 1999; Urry, 2004; Wentland, 2017; Østby, 1995: 9). Hence, the problems associated with road transport cannot be mitigated solely by exchanging some of the material elements; it will also be necessary to reconfigure attitudes, business models, practices, cultures, infrastructures, and technologies, and perhaps even the nature-culture divide (Haugland et al., in press). This is undoubtedly a daunting task, and one that prompts the question of how to achieve it. Innovation is often cited as a central instrument for transitioning towards more sustainable sociotechnical systems, both within and beyond the transport sector (e.g. Banister, 2008; Hoogma et al., 2002; Markard et al., 2012). However, this raises another, perhaps equally complicated question: what is innovation?

2.2 What is innovation?

Despite its prevalence in contemporary policy discourses (Godin, 2015; Pfotenhauer & Jasanoff, 2017a), the concept of innovation is curiously hard to pin down. In the 17th century, 'innovation' stood alongside words such as 'heresy' and 'revolution': innovators were people who sought to instigate societal change without having the political or ecclesiastical authority to do so (Godin, 2015). By the end of the 20th century, the concept had been thoroughly rehabilitated, not least through its association with the post-World War II economic growth (Godin, 2019: 222; Schot & Steinmueller, 2018).[4]

Everett Rogers, whose book *Diffusion of Innovations* (first published in 1962) is considered a core text within innovation studies, defines innovation as 'an idea, practice, or object that is perceived as new by an individual or other unit of adoption' (Rogers, 2003: 12). Rogers's definition is a useful reminder of the flexibility of innovation as a concept: generally speaking, the term may be applied to any combination of technological, organisational, and/or social elements. Still, the term innovation tends to refer to technological innovation, rather than to social or organisational innovation

[4] In the post-World War II period, economic output was considered the function of the input of labour and capital. In the mid-1950s, that explanation fell short of explaining the post-war spurt in economic growth. The economist Robert Solow (1957) chalked this disparity up to technological change (i.e. innovation), while others shrugged and stated, slightly paraphrased, 'darned if I know' (Abramovitz, 1956: 11).

(Godin, 2019: 128). To reflect common usage, I also use the term innovation to refer to technological innovation. However, innovation can never be exclusively technological (Marx, 1997; Rip & Kemp, 1998: 365). Hence, in the remaining part of this section, I discuss the relationship between innovations and their social and societal context. I argue that technologies are socially constructed, and that this has ramifications for how we think about the role of innovation in sociotechnical change.[5]

The simplest conceptualisation of the innovation process is the linear innovation model (Godin, 2006; Pinch & Bijker, 1984; Rip & Kemp, 1998). The model posits a specific relationship between research and innovation. First, scientific knowledge is produced through *basic research*. Then, the insights from basic research are put to practical use through *applied research*, where potential areas of use are identified. These areas then become the basis for the *development* stage (i.e. product development). Finally, after finalising the development, production begins, and the resulting product is *diffused* through society by way of the market (Godin, 2006). While the linear innovation model might never have existed in the sense of being a formalised theory of innovation (Edgerton, 2004), it has still exerted a considerable influence on post-World War II literature on innovation and technological change, not least through the development of statistics that reproduced the linear conception of innovation processes by positing a particular relationship between knowledge and its application (Godin, 2006). This focus is clearly visible in early work within innovation studies.

Innovation studies, especially in the form advocated by scholars such as Freeman, Lundevall, and Nelson, tend to ground their studies in the post-World War II view of innovation as a public good (Schot & Steinmueller, 2018). The innovation systems literature is often concerned with innovation as a statistical phenomenon, namely the innovation system as the sum of factors such as national R&D expenditure (Fagerberg et al., 2009; on the relationship between the linear innovation model and such statistics, see Godin, 2006). By studying national or regional innovation systems in this manner, the

[5] I am aware that the term 'socially constructed' invokes a long-standing debate in STS, namely the debate about the agency held by technological objects (and non-humans more generally) (Akrich, 1992). Here, I am simply using the term to distinguish the human and non-human shaping of technology from the act of assembling the material components that together constitute a technology.

characteristics of successful innovation systems can be identified and thus also transferred to other contexts and replicated in them. Conversely, the problems plaguing 'underperforming' systems can be identified and then ameliorated.

While STS and innovation studies have been concerned with many of the same topics, they diverge with regard to their intellectual origins and their epistemological assumptions. Within innovation studies, the primary motivation for studying innovation has been to facilitate it better, often at the policy level. Hence, such studies have tended to be large-scale and often statistical studies that lend themselves to cross-country comparisons (Pfotenhauer & Juhl, 2017: 77; Williams, 2019). This tendency contrasts with STS, an academic field whose objective has been to pry open the black box of technology development by studying innovation in practice.

Early constructivist studies of technology observed that much innovation scholarship paid little attention to the dynamics of technology development. Rather, innovation processes tended to be black-boxed: whereas innovation scholars engaged with aspects such as firm characteristics, statistical measures of innovative capacity, and macro-economic factors (Godin, 2006; Pinch & Bijker, 1984), the practical details of innovation were left unexplored. Technological innovations were treated in the same way as any other product: with innovation primarily being gauged according to economic measures, the firms 'might as well have produced meat pies' (Pinch & Bijker, 1984: 404). The few studies that engaged more closely with innovation processes tended to describe the innovation process as teleological: every step that led to a discovery or an invention was meant to happen.

The black-boxed treatment of technology reflects the still common tendency to ascribe technology as having a logic of its own (Winner, 1977; Wyatt, 2008). This tendency, termed technological determinism, comprises two related views on the place of technology in society: (1) technologies are produced outside society, and thus are not subject to cultural, economic, or political influences, and (2) technologies are the driving or even determining force behind social change (Wyatt, 2008: 168).[6] However, if

[6] Technological determinism might be of both positive and negative valence: the positive view sees technology as the solution to all of society's problems; the negative view sees technology as the source of the same problems.

technologies unfold according to their own internal logic, there is no room for either individual choice or government intervention. By peeking inside the black boxes of innovation processes, early scholarship within STS set out to show that the shape and trajectory of an innovation was not a given.

STS scholars have exerted considerable effort to show that technologies are shaped at a variety of sites and in a variety of ways. Technologies are shaped according to engineers' ideas about who will use the technology and their competences (Akrich, 1992; Woolgar, 1990). Technologies are also shaped by the needs of various user groups, which are often conflicting and/or diverse (Pinch & Bijker, 1984), and they are shaped by users in the process of adopting a technology (Sørensen, 2006). Furthermore, technologies are shaped by the societal conditions in which the technology will be introduced, both in terms of existing systems and expected societal developments (Callon, 1987; Kemp et al., 1998: 181; van Lente, 2012), and they are shaped by the assumed and actual cognitive and practical capabilities of the public (Barnett et al., 2012; Sørensen, 2006). This also means that the *effect* or *effects* of an innovation cannot be ascertained in advance. For example, the environmental effects of a new transport technology do not depend exclusively on the technology's environmental performance, but also on how it affects overall usage patterns (Milakis et al., 2017; Ozaki et al., 2013; Schwanen et al., 2011).[7] Rather than being predetermined (cf. Wyatt, 2008), technologies are characterised by a fundamental uncertainty: they do not emerge from the R&D department in their final form, nor can their societal effects be fully determined before they have been implemented, as their use and the resulting use patterns are, at least in part, decided by users rather than producers.

[7] This is the first half of the Collingridge dilemma, which states that one cannot reliably ascertain the harmful effects of a technology before it has been implemented. The second half of the dilemma states that the harmful effects of a technology first become visible upon its large-scale implementation, which makes it hard to implement measures to control the technology and/or mitigate its harmful effects (Collingridge, 1980). Automated vehicles, a technology that is characterised by considerable uncertainty with regard to its configuration and mode or modes of implementation, are clearly subject to this dilemma (Cohen et al., 2018; Milakis et al., 2017; Mladenović, 2019; Mladenović et al., 2020; Stilgoe, 2020).

Innovation is ascribed considerable importance, both within sustainability transitions research and in society more generally (Pel et al., 2016; Pfotenhauer & Jasanoff, 2017a). With regard to innovation, STS scholarship offers an important insight: through contemporary and historical studies of technology development, it has shown that sociotechnical systems do not unfold according to some intrinsic logic. Rather, they are the outcome of considerable work, whether by system builders (Hughes, 1987) or by more diffuse and distributed networks (Sørensen, 1990). Whereas sociotechnical systems may appear obdurate (Hommels, 2005), and even exhibit a soft determinism upon growing to a certain size and complexity (Hughes, 1987: 54–55), they are still the outcome of societal choices. Accordingly, existing systems can be changed, and emerging technologies may be controlled, at least initially (Collingridge, 1980; Hughes, 1987). Hence, the question is not *whether* technologies and the direction of technological development can be steered, but *how*. One approach to such steering is strategic niche management. To some extent, the approach reflects the Norwegian Government's approach to facilitating transport innovations. Hence, the contents of strategic niche management help to turn attention to activities, strategies, and concepts that may also be of use when analysing Norwegian actors' attempts at transport innovation.

2.3 Strategic niche management

The strategic niche management approach emerged throughout the late 1990s and early 2000s, and it sought to respond to a particular conundrum: while more sustainable alternatives to established technologies often existed, they tended not to be the most widespread (Kemp et al., 1998). Innovation scholars sought to understand why that was the case, in order to develop a tool to ease the hardship often faced by emerging technologies. The resulting tool was strategic niche management, defined as follows:

> the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology. (Kemp et al., 1998: 186)

Strategic niche management was developed as a policy perspective (Hoogma et al., 2002: 4). The perspective is characterised by a co-evolutionary view of society and technology, a view that may be inferred from the above-quoted definition: by conducting experiments to learn about the societal and technical merits of a new technology, relevant organisations (e.g. governments) may simultaneously identify how to facilitate its diffusion better, such as by adapting regulations (Rip & Kemp, 1998).

Additionally, strategic niche management is characterised by a quasi-evolutionary view of sociotechnical change, in which technology development is likened to biological evolution.[8] This view posits that technologies exist in a selection environment, which might encompass elements such as 'production practices and routines, consumption patterns, engineering and management belief systems, and cultural values' (Kemp et al., 1998: 182), as well as 'regulation, consumer preferences, infrastructure, and price structure' (Hoogma et al., 2002: 20). In general, this environment changes gradually. However, strategic niche management suggests that the selection environment may be actively modified in order to promote certain technologies, such as through the development of technological niches. However, to understand the purpose of niche development, it is first necessary to understand the technological regime.

The concept of a *technological regime* refers to a set of rules associated with a particular technology and its functioning in society (Kemp et al., 1998: 181–183). The rules associated with a technological regime are not fixed rules, but rather refer to an obdurate set of, for example, established practices, problem definitions, product characteristics, and roles (Rip & Kemp, 1998: 338). A relevant example of a technological regime is the one surrounding the automobile, which encompasses engineering knowledge and practices, manufacturing processes and equipment, organisational routines, and product characteristics, as well as infrastructures (e.g. roads and fuel distribution), repair and maintenance systems, economic aspects, and travel and mobility patterns (Hoogma et al., 2002: 18). The list could be further extended by including the automobile's role in constituting a symbolic order and its embedding in the political system (Sørensen, 1990; Mattioli et al., 2020; Urry, 2004).

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[8] Such analogies have a less-than-stellar track record in the social sciences: the biological analogy places strategic niche management in the questionable company of 'dubious or discarded research programs that built on biological models', including 'research on natural law, eugenics, race, and social Darwinism' (Jasanoff, 2004b: 37). Evolutionary psychology could be added to the list (S. E. Smith, 2020).

Because technological regimes consist of a wide variety of interrelated components, change tends to be slow and incremental. Hence, incumbent regimes are a problem with regard to sustainability: they represent a set of (cognitive, technological, economic, social, and cultural) barriers that must be overcome in order to achieve meaningful change (Kemp et al., 1998: 183; Markard et al., 2012). Through the formation of technological niches, it might be possible to overcome such barriers and initiate a regime shift. As opposed to regimes, niches are protected spaces in which expensive and cumbersome technologies may be developed and nurtured without immediately being exposed to the selection pressures of regimes, which are likely to be unfavourable to the technology in question (Hoogma et al., 2002: 4; Rip & Kemp, 1998: 357).

While strategic niche management prescribes the establishment of niches, it does not prescribe who should establish them. Niches may be established by a variety of actors, including governments (e.g. by subsidising demonstration projects), specialised users (e.g. the military), companies (e.g. by establishing a team to work on novel products), and engaged citizens (e.g. communities that develop eco-housing) (Köhler et al., 2019: 4; Rip & Kemp, 1998: 382; A. Smith, 2007). The examples imply that niches may emerge both from above and below (Hoogma et al., 2002: 4), even though powerful actors such as governments might appear better equipped for developing niches. Ultimately, what counts is the capability of niche actors to establish networks that allow them to shape the overall regime in favour of the emerging technology (Kemp et al., 1998: 186). Three processes have been hypothesised as important for the successful formation and development of sociotechnical niches: expectation articulation, network formation, and learning processes (Kemp et al., 1998: 189–191; Rip & Kemp, 1998: 382; Schot & Geels, 2008: 540–541). In the following, I elaborate upon these three processes in turn.

Strategic niche management considers the articulation of expectations to be crucial in directing technological development. Emerging technologies are necessarily characterised by uncertainty with regard to their eventual technical capabilities, their ability to meet user needs, and their overall societal desirability. Hence, a set of expectations is necessary to direct technology development. Ideally, these expectations should be both shared between actors and specific in terms of which societal problem or problems the technology might address. Additionally, the expectations should be credible, meaning that the realism of expectations should be substantiated, whether through facts and tests, and/or by conducting research and employing experts (Kemp et al., 1998: 190).

The importance of network formation can be inferred from the co-evolutionary view of technological change (Rip & Kemp, 1998: 390): if regime shifts result from the co-evolution of society and technology, niches will need to encompass actors that are capable of influencing a wide variety of social and technical aspects. Ideally, networks should be both broad (i.e. encompass a variety of actors across different fields) and deep (i.e. consist of actors capable of mobilising resources within their respective companies, institutions, or organisations) in order to enable change (Schot & Geels, 2008: 541). Regardless of their formalisation, the purpose of such networks is to link variation and selection processes, in order to adjust both processes simultaneously.[9]

A niche should facilitate both first-order learning and second-order learning (Schot & Geels, 2008: 541). First-order learning refers to the accumulation of facts and data. This is crucial for identifying potential barriers (e.g. restrictive policies, technological limitations, user attitudes), as well as for substantiating expectations (Kemp et al., 1998: 190). Second-order learning refers to the questioning of established conceptions about, for example, the technology itself, user needs, or regulations (Hoogma et al., 2002: 29). A learning process that combines first-order and second-order learning helps the involved actors to articulate the needs, problems, and possibilities associated with the technology in question. Thus, such composite learning is also conducive for identifying and making ostensibly beneficial adjustments to the niche itself.

Despite being presented as distinct processes, the processes described in the preceding paragraphs are interconnected. For example, expectations may play a crucial role in establishing a network. Simultaneously, the network itself may be needed to make

[9] In the early formulation of strategic niche management, little attention was paid to non-users and groups that stood to be negatively affected. For example, Kemp et al. (1998) warn that technology development should not be dominated by industry. Third parties, among which are 'actors who are affected by the results of the technology, or organizations such as citizen groups and environmental groups' (Kemp et al., 1998: 191), should also be allowed to contribute views and ideas. However, by placing the text in the quotation at the end of their discussion, the authors give the (hopefully unintended) impression that the views of such actors and groups are of marginal importance.

the necessary adaptations (technical, economic, and/or institutional) for conducting testing and learning about the technology, processes which then contribute towards the realisation of the initial expectations.

To summarise, strategic niche management builds upon two fundamental assumptions (Hoogma et al., 2002: 4). The first assumption is that the implementation of new technology is a social process, meaning a process that cannot be fully explained with reference to market mechanisms or the internal workings of scientific and technological development. This conception of innovation clearly shows how strategic niche management draws upon STS insights (Markard et al., 2012: 957). The second assumption is that experiments in the co-evolution of technology, policy, and markets are key to realising beneficial societal outcomes. Through open-ended experiments in the co-evolution of social and technological aspects, it is possible to promote the development and diffusion of new and more sustainable technologies. However, placing such emphasis on promising new technologies (Hoogma et al., 2002; Kemp et al., 1998: 186; Rip & Kemp, 1998: 386; Schot & Geels, 2008: 539) gives rise to the following question: can the promises associated with emerging technologies be reliably assessed? As the Norwegian legislation on automated vehicles was in part motivated by the prospect of assessing such promises, the answer to this question is not inconsequential. In this regard, the sociology of expectations literature provides some useful insights.

2.4 Visions, expectations, and hype

Within strategic niche management there is emphasis on establishing shared and robust visions and expectations, which suggests an awareness that expectations are not neutral statements about the future (van Lente, 2012: 772). Rather, they are *performative* statements (Michael, 2000; Rip & Kemp, 1998: 366). Predictions about the future (e.g. regarding markets, use cases, technological capabilities) also serve to direct both funds and efforts towards the realisation of that future, possibly turning predictions into self-fulfilling prophecies. For example, the use of the prediction-based language of statistics and prognoses regarding future car use was instrumental in justifying the development of the Norwegian road network (Sørensen, 1990: 10–12). However, pointing out a self-fulfilling prophecy is descriptive rather than explanatory, which means that the precise dynamics of expectations are left unexplored. The sociology of expectations has taken up the task of exploring these dynamics (Borup et al., 2006; N. Brown & Michael, 2003; N. Brown et al., 2000; van Lente, 2012).

The sociology of expectations has described three distinct dynamics surrounding expectations (van Lente, 2012). First, expectations provide direction for search processes within laboratories and research departments. Rather than being paralysed by the seemingly unlimited number of directions to pursue, expectations help whittle down endless possibilities into a more manageable number (Rip & Kemp, 1998). For example, expectations regarding regime developments, or lack thereof, inform the direction or directions of search processes. Accordingly, if a regime is expected to remain stable, search processes will be unlikely to change substantially. However, search processes may also be adjusted or modified to anticipate or even instigate change in a regime (Kemp et al., 1998: 181). Regardless of whether expectations lead actors and organisations to pursue new paths or remain on the existing course, they clearly play a role in the co-evolution of a technology and its selection environment.

Second, expectations coordinate behaviour. For example, collectively held expectations may help to coordinate innovation efforts among a set of heterogenous actors (Konrad, 2006), which is the role ascribed to expectations in strategic niche management (Hoogma et al., 2002: 21, 25). In cases of technology development where there is no central coordination, expectations may still help direct efforts. For example, in the case of automated vehicles, a series of different hardware and software configurations are being considered (Schwarting et al., 2018; Van Brummelen et al., 2018). The uncertainty associated with the technology may then lead to a kind of spontaneous order, in which companies direct their efforts towards the configurations they consider most viable. In such a situation, various companies or clusters thereof would focus on specific tasks (e.g. developing stereovision cameras or algorithms for urban driving). Other tasks would be left for other companies, either on the grounds that they are part of a configuration considered unviable or because the company in question lacks the necessary competence. Conversely, if expectations take on a clear direction, regardless of factual basis, companies might move in a herd to adapt their activities in anticipation of a specific future (Kemp et al., 1998: 181; van Lente, 2012: 774).

Third, and finally, expectations may legitimise actions and investments, whether by governments, companies, or organisations (Borup et al., 2006). Government funding might be legitimised with reference to the purported capabilities of future technology. For example, expensive research with experimental nuclear reactors has been funded for decades, despite producing negligible results (Geels & Smit, 2000; van Lente, 2012: 774). Conversely, and perhaps less developed in the expectations literature, an investment might also be deferred or put off with reference to promising or ostensibly promising technological developments (Suboticki & Sørensen, 2020: 166). As such, expectations are not at all inconsequential; they are quite literally setting funding priorities.

If expectations are considered performative, it raises an important question: can expectations be distinguished from hype? The short answer is no. Hype can only be attributed in hindsight, after expectations have failed to materialise within a predicted time span. As expectations are at their most intensive at the start of development, this means that expectations and future reality will probably differ considerably (Borup et al., 2006; Geels & Smit, 2000).

Srnicek (2016) describes how technological hype is an important component in what he terms *platform capitalism*. After the global financial crisis of 2007–2008, interest rates approached zero, leading investors to seek new ways of accumulating capital. One possible route was to invest in promising tech start-ups. Such start-ups tend to be companies that develop a technology that might disrupt a sector (e.g. transport) to such an extent that the start-up will attain a monopoly-like position. Upon attaining such a position, the company will be highly profitable and thus able to deliver profit to its shareholders. However, to reach the monopoly-like position, the company must be held afloat by venture capital for an indeterminate time span (G. Martin, 2020: 25; Srnicek, 2016), a logic that is reminiscent of strategic niche management, though more obviously in the service of capitalist interests. The ride-hailing company Uber is one example: the company's investment in automated vehicles has helped to substantiate claims that its business model will become profitable (Bissell, 2018; Doctorow, 2021). This exemplifies how expectations regarding technology are bound up in dynamics that might generate profits but are not necessarily conducive to realising those expectations (N. Brown & Michael, 2003: 13).

Expectations are not pre-existing entities, and they vary across time and space. Rather than an expected future being inherently plausible, specific futures are *made to seem* more plausible than others. Different strategies are used for this purpose: invested actors may draw upon established rhetorical repertoires (Hilgartner, 2015), compare contemporaneous technological developments to past examples of successful technological trajectories (Schnaars, 2009), or cite recent technological advancements as conducive to the development of the technology in question (Cohen & Jones, 2020; Wetmore, 2003). This suggests that the articulation of expectations within niches, or even the establishment of niches in itself, is not a neutral activity. Rather, such articulations often attempt to carve out a normative space in which the technology in question is associated with widely shared values and/or contrasted with possible undesirable developments, in order to appear preferrable (Berkhout, 2006). Whereas the appeal to such values might be conducive to building a network, contestations often arise when specific projects are about to be implemented (Eames et al., 2006). Hence, one might argue that shared expectations temporarily cover up or postpone possible contestations. As expectations come closer to realisation at specific locations, expectations are also modulated in a heterogenous manner.

By their nature, expectations are burdened with uncertainty. This is a challenge with regard to assessing and governing technologies, and especially emerging ones. Whereas strategic niche management emphasises the importance of picking promising technologies (Kemp et al., 1998: 186; Rip & Kemp, 1998: 386; Schot & Geels, 2008: 539), a government – one among many possible niche actors (Schot & Geels, 2008) – will not necessarily be well-equipped to assess whether a new technology is promising (Geels & Smit, 2000; Rip & Kemp, 1998: 391). This links back to the difficulty of separating realistic expectations from hype: whereas technology developers (e.g. engineers) often know that there is considerable uncertainty associated with a technology, prospective users – including governments or other institutions and organisations – might not be fully aware of that uncertainty (N. Brown & Michael, 2003; van Lente, 2012: 775). Hence, to be able to govern new technologies properly, it is necessary for governments to manage uncertainty. However, such an assessment will often 'involve the same activities as trying to build the technology' (Borup et al., 2006: 289; Collingridge, 1980). The uncertainty associated with expectations is what motivates the promotion of niche experimentation in strategic niche management: through experimentation, it is possible – at least in theory (van Lente, 2012: 777) – to substantiate or refute expectations while simultaneously steering technology development in a desired direction.

Expectations are characterised by a certain degree of ambiguity. On the one hand, they are powerful, in the sense that they may give direction to both imagination and funding. On the other hand, expectations are elusive, in the sense that their realism can only be assessed should they come to fruition, in one form or another. This ambiguity appears to have been what motivated the Norwegian Government to allow for the testing of automated vehicles: trials and pilot projects would make it possible to assess the high expectations associated with automated vehicles (Meld. St. 33 (2016–2017): 26). However, while activities such as trials and pilot projects, or 'experiments' as they are often termed in sustainability transitions research, can help to substantiate or refute expectations, they may also affect the environments in which they are conducted. This warrants a closer look at the effects ascribed to these activities.

2.5 Experiments in society

Experimentation holds an important place in sustainability transitions research (Markard et al., 2012), including strategic niche management (Hoogma et al., 2002; Kemp et al., 1998; Rip & Kemp, 1998; Schot & Geels, 2008).[10] Indeed, the emphasis on experimentation may be *the* aspect that sets sustainability transitions apart from adjacent fields such as social change and policy theory (Sengers et al., 2019). However, this conception of experimentation differs considerably from the conception employed in the natural sciences (Weiland et al., 2017). Therefore, before discussing the nature of experiments within sustainability transitions, a closer look at the characteristics ascribed to scientific experimentation is warranted in order to understand how the two differ.

Experiments, in the sense employed within the natural sciences, refers to a specific kind of work that has been and continues to be conducted in laboratories. Laboratories

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[10] In sustainability transitions research, niche activities are usually described as experiments so as to emphasise the importance of learning in such processes (Hoogma et al., 2002: 5; Markard et al., 2012). However, throughout the articles in Part B, I use the term pilot project, rather than experiment. In part, this has been done to reflect the term used by my interviewees. Additionally, pilot project is a term used to describe activities that precede a larger-scale project and that are conducted to establish the viability of the subsequent project. As such, the term pilot project helps to stress the temporal dimension of niche activities as well as the intention, whether implicit or explicit, to scale up the project in question (Engels et al., 2019; Naber et al., 2017; Pfotenhauer et al., 2022).

are spaces where the link between knowledge production and society ostensibly has been severed, both physically (Callon et al., 2009: 43–48; Latour, 1987: 174–175) and rhetorically (Knorr-Cetina, 1981; Latour & Woolgar, 1986). There, scientists can control the parameters they deem relevant to the experiment, a form of control that also allows them to establish reliable causal connections pertaining to the phenomena in question (Weiland et al., 2017). As such, scientists are the only persons in charge of conducting and interpreting an experiment. The public will only be presented with the resulting knowledge, possibly through spectacular demonstrations (Collins, 1988), but more often through *immutable mobiles* such as charts, tables, figures (images), and texts (Latour, 1987: 227). This also means that any uncertainty regarding outcomes is restricted to the laboratory: until the scientist has established an understanding of the phenomenon, however provisional, the experiment will remain within the laboratory (Guggenheim, 2012).[11]

The conception of experiments employed within sustainability transitions differs quite substantially from how experiments are understood in the natural sciences. Weiland et al. (2017: 31–33) suggest that the two conceptions differ along three crucial dimensions. *First*, they differ with regard to the aim of experimentation. Whereas experiments within the natural sciences seek to generate knowledge about natural phenomena and their interrelations, experiments within sustainability transitions seek to

[11] Not all scientific knowledge is produced in controlled settings. Within field sciences such as geology, oceanography, and palaeontology, practitioners conduct science outdoors, in unpredictable and often unfamiliar settings (Kuklick & Kohler, 1996). Still, scientific knowledge produced in the field may transcend the specificities of the site at which it was produced and become accepted as a fact. However, this requires the site to be established as a 'truth-spot', which is a 'geographic, architectural and rhetorical construction' that lends credence to the claims originating from the site (Gieryn, 2002: 113). The credence may be further substantiated by, for example, establishing flexible guidelines for specimen collection (Star & Griesemer, 1989), training scientific personnel (Kuklick & Kohler, 1996), or '[moving] parts of the metropolis out to the field' (McCook, 1996: 197). Due to its clearly artificial nature, the laboratory might seem like a more obvious 'truth-spot'. However, this too is in part a rhetorical construction rather than an architectural one: when accounting for their experiments, scientists often *omit* the architecture and spatial configuration of the laboratory, and in the resulting text the laboratory takes on a nondescript and standardised character despite the fact that the experiments that are being reported were conducted at a specific location (Knorr-Cetina, 1981; Latour & Woolgar, 1986).

produce knowledge that may help to achieve specific outcomes. The purpose of experimentation is to generate a deeper understanding of the sociotechnical system in question: what characterises this system (systems knowledge), what change is desirable (target knowledge), and how can the change be achieved (transformation knowledge) (Grunwald, 2004; Schot & Geels, 2008).

Second, the exact configuration of experiments is no longer left to scientists. Indeed, as conceived of within sustainability transitions, experiments may be configured without involving any kind of scientific expertise. Simultaneously, the actors conducting the experiment (whether individuals or organisations) are implicated in society, as observers, participants, and/or evaluators.

Third, and finally, social and societal settings do not exhibit the controllability associated with laboratories. Rather, uncertainty is an essential element of experiments within sustainability transitions. As such, actors that organise sustainability experiments must acknowledge that outcomes are unpredictable and might have effects also outside the delineated experiment (Engels et al., 2019: 8; Weiland et al., 2017). On this basis, experiments may be defined as 'practice-based endeavours of social actors that aim to directly impact society to advance sustainability transformations' (Weiland et al., 2017: 36) or, more elaborately, as 'an inclusive, practice-based and challenge-led initiative designed to promote system innovation through social learning under conditions of uncertainty and ambiguity' (Sengers et al., 2019: 161).

Sengers et al. (2019) argue that the sustainability transitions literature on experimentation can be divided into two interconnected streams. One stream draws upon insights from niche-based approaches and transition management (Hoogma et al., 2002; Loorbach et al., 2015; Naber et al., 2017), and emphasises the technological and managerial aspects of sustainability transitions. This stream seeks to identify how the development and upscaling of green technologies might be facilitated, as well as which markets and policies might promote the adoption of such technologies. The other stream focuses on the social and civic aspects of sustainability transitions, with particular emphasis on the potential th at lies in alternative social organisation (H. Brown et al., 2003; Hegger et al., 2007; Seyfang & A. Smith, 2007). This stream emphasises experimentation from below, and focuses in particular on how new practices, rather than new technologies, may be conducive to sociotechnical change. This is not to argue that the two streams are mutually exclusive or even clearly distinguishable from each other. Rather, the two streams tend to treat both social and technical aspects, and they only differ with regard to the relative weight ascribed to those aspects (Sengers et al., 2019; A. Smith, 2007).

Whereas both social and technological configurations have been subject to considerable experimentation, less attention has been paid to policy experimentation (Kivimaa & Rogge, 2022; Sengers et al., 2019). For example, despite being a policy perspective, strategic niche management and associated theoretical approaches cast policy in a supporting role: ultimately, its purpose is to facilitate the development and diffusion of new, green technologies through gradual adaptations to policy (Kemp et al., 1998: 185). According to Sengers et al. (2021), policy experimentation refers to 'something new being tried out with a high degree of autonomy through a deliberate intervention that differs from the status quo' (Sengers et al., 2021: 1152).

Policy experimentation tends to emerge from below, whether from subnational actors such as municipalities, counties, and provinces, or from non-state actors such as companies and non-government organisations. For example, Bulkeley and Broto (2013) note how climate change has acted as an umbrella under which a wide variety of policy experiments may be conducted (cf. Berkhout, 2006). Policy experimentation builds on a simple idea: 'start with the experiments and then analyse the politics they produce that can lead to different pathways' (Bernstein & Hoffmann, 2018: 194). As such, policy experimentation stands out from approaches such as strategic niche management by remaining open, or more open, to possible outcomes.

Finally, it is worth noting that the merits of experiments have been questioned (Schot & Geels, 2008). Some authors have critiqued the normative foundations of sustainability transitions research, including its emphasis on niche activities and its pro-innovation bias (Pel et al., 2016; Weiland et al., 2017). Others have questioned the emphasis on shared visions, as there is reason to believe that regime shifts will entail both controversies and conflicts (Jørgensen, 2012; A. Smith et al., 2005; Torrens et al., 2019). Yet others have suggested that rather than experiments, niche activities often look more like demonstrations of technological viability (Engels et al., 2019), and that the mechanisms of upscaling are unclear (Weiland et al., 2017). However, my interest is not simply in how experiments may promote the development of more sustainable transport technologies. Rather, experiments may also be considered as instruments for reshaping society, not least because of the transformative capabilities of scientific and technological activities. Hence, it is worth taking a closer look at scholarship characterised by a slightly different view on the relationship between experimentation and sociotechnical change.

Latour (1983, 1988) has suggested that the transformative capabilities of scientific experiments do not stem from the inherent objectivity of the scientific knowledge produced through experimentation. Rather, they stem from the replication of sufficiently laboratory-like conditions at extra-laboratory locations. Latour developed this understanding through his studies of the 19th century microbiologist Louis Pasteur, who discovered the principles of vaccination. In his laboratory, Pasteur was able to reproduce the epizootics of smallpox, as well as to reduce the severity of the illness through vaccination. To prove the vaccine's efficiency outside the laboratory, Pasteur required farmers to follow principles of 'disinfection, cleanliness, conservation, inoculation gesture, timing and recording' (Latour, 1983: 152). These prescriptions were followed in preparation for a staging (Latour, 1983: 151), at which contemporaneous mass media were invited to witness the efficiency of the vaccine on three separate occasions. Because the farmers had replicated laboratory-like conditions on their farms, the demonstrations unfolded according to Pasteur's claims, and the vaccination was proven successful. According to Latour, such extension of laboratory conditions into the real world is how scientific knowledge attains its ability to change the world. This idea has since been termed the laboratisation thesis (Marres & Stark, 2020: 439).

The laboratisation thesis may also be applied to technology. Rather than making the determinist argument that a technology succeeds because it works well, one might turn this argument on its head: the technology works well because it has succeeded. This claim may require elaboration. The argument is that the success of a technology (or a knowledge claim, as in the case of Pasteur) relies upon successfully replicating the settings necessary for its functioning, rather than succeeding because of some intrinsic characteristic of the technology (cf. Marx, 1997). The car serves as an instructive example: without a whole set of supporting systems and infrastructures (e.g. roads, fuelling stations, car manufacturers, repair shops, fuel refineries, oil producers), a motorist would quite literally not get very far (Sørensen, 1990; Urry, 2004; Østby, 1995).

While the laboratisation thesis and its emphasis on the replication of laboratory-like settings holds considerable explanatory power, it presupposes a back-and-forth movement between controlled and uncontrolled spaces (Guggenheim, 2012; Latour, 1988; Voß & Simons, 2018). However, the prevalence of experiments being conducted in explicitly social settings, such as the experiments promoted within sustainability transitions, suggests an expectation that society may be reconfigured from within other sites than laboratories.

Recent scholarship within STS has argued that the increasing prevalence of testing in societal environments requires a new analytical approach (Marres & Stark, 2020).[12] As opposed to previous approaches to experimentation in society, where technologies were implemented in pre-existing settings to assess their compatibility with a setting, settings are now being modified to accommodate the technology. This means that rather than the technology, it is the social itself that is being experimented upon – that is, the subject of experimentation is the social and material interrelations that together make up social life (Latour, 2005).

The grounds for calling for a new sociology of testing is the contemporaneous trend of deliberately modifying societal settings, whether in real time or for a limited period. The increasing prevalence of such initiatives means that parts of the population become test subjects (in a broad sense) and that the border between test arenas and 'normal' social life are broken down. Additionally, the testing is dominated by experts, which makes it harder to counteract. Such interventions may operate on both material and ephemeral phenomena: a test may modify everything from traffic flow to trust. However, the goal of implementing technologies in societal settings remains the same. Rather than researching social life, the goal is to intervene: the more capable the test is of modifying the behaviour of its subjects, the more successful it is (Marres & Stark, 2020: 436).

Despite differences in their geographical foci, the laboratisation thesis and the new sociology of testing have one thing in common: an interest in the role of scientific and

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[12] Testing is here taken to encompass a variety of approaches, including real-world experiments, platform-based testing, and randomised control trials (Marres & Stark, 2020: 425), as well as interventions that are 'inflicted by exogenous, interested agencies, like engineering, or "strategic niche management", or experimental governance' (Marres & Stark, 2020: 437).

technological activities in constituting and changing the elements that make up the social: 'Today's test environments are key sites where forms of life, forms of experience are defined, contested, and indeed, tested today' (Marres & Stark, 2020: 438). This insight suggests that the automated vehicle trials facilitated by the Norwegian Government are not simply niche activities. Rather, being conducted in public, these trials are activities that may also reshape society. As such, the public testing of technologies may be considered a kind of co-production (Jasanoff, 2004c; Voß & Simons, 2018), as these activities may reforge the relationship between technology and society.

2.6 Technologies of co-production

The idiom of co-production offers a vocabulary for discussing the role of science and technology in constituting society (Jasanoff, 2004c).[13] The main tenet of this idiom is simple, almost deceptively so: co-production starts out from the observation that 'the ways in which we know and represent the world (both nature and society) are inseparable from the ways we choose to live in it' (Jasanoff, 2004a: 2). In other words, descriptions that are acknowledged as authoritative descriptions of the world we live in will shape the ways in which social and societal problems are understood and can be addressed. For example, if the public's transport needs are understood as static (Mladenović, 2019: 118; Schot & Geels, 2008: 541), this will inevitably limit the interventions society considers viable or justified to address problems associated with transport. Consequentially, social life is shaped both by the knowledge and by the methods of knowledge production that are recognised as valid, whether by authorities or by the public more generally.[14] By

[13] Within strategic niche management and associated frameworks, the word co-production is sometimes used as a synonym for words such as co-evolution and co-construction (e.g. Hoogma et al., 2002: 3). However, as I will detail in this section, co-production seeks to describe something more than the co-evolution of technologies and their social environment. Hence, whenever the word co-production is used throughout this thesis, it refers to co-production in the sense discussed by Jasanoff (2004a).

[14] This is not to say that the ways in which we think about the world change its material composition, at least not instantly. Rather, the ways in which we think about the world shape the actions that we consider are viable and even what we consider is possible and not possible (e.g. Fisher, 2009). This means that eventually, our ideas of the world, including its constituent parts and their possible interactions, come to shape the same world, including both social and material aspects.

turning attention to the role of knowledge in constituting the social (Latour, 2005), co-production offers an entry point for studying 'how power originates, where it gets lodged, who wields it, by what means, and with what effect' (Jasanoff, 2004a: 5). In short, co-production attunes or sensitises us to the often tight-knit relationship between knowledge and power.

Broadly speaking, co-production may be divided into two streams: the constitutive stream and the interactional stream (Jasanoff, 2004b: 19). The constitutive stream is concerned with the role of knowledge in constituting the world. Scholarship within this stream focuses on how humans and non-humans are assembled into human concepts such as statehood (Scott, 1998) or the reciprocal categories of nature and culture (Latour, 1993). While concepts and categories are not pre-existing and immutable, they nonetheless shape interaction. Accordingly, it is crucial to turn attention to how they are forged and reshaped, as well as to their constituent parts (Latour, 2005). Due to the authority ascribed to science and technology, these are powerful tools for reshaping society (Latour, 1988).

The interactional stream is concerned with the relationship between science and politics. This stream started out from the observation that science is a social activity: regardless of its physical seclusion from society, scientific knowledge is not produced in settings outside society (Latour, 1987). Rather, scientific institutions inhabit a distinct position *in* society. The products of science, whether abstract or tangible, are considered authoritative and are therefore useful tools for consolidating or reshaping society.[15] For

[15] Much of the work within co-production is concerned with the relationship between 'science, technology and governmental power, or its close correlate, economic power' (Jasanoff, 2004b: 34). However, while state and economic actors may be powerful, some studies show how such actors, despite their capacity to inscribe, redefine, and categorise, sometimes fails to realise their vision (e.g. Scott, 1998). This runs counter to scholarship that argues that, eventually, technologies and/or sociotechnical systems will come to reflect the interests of the powerful (e.g. Noble, 1984; Winner, 1980). However, arguing that the configuration of a specific sociotechnical arrangement, such as a technological regime (Kemp et al., 1998), results from the power wielded by certain actors is not necessarily an explanation. Rather, the ascription of power stands in

example, scientific expertise plays an important role in decision-making processes (Grundmann, 2017; Sørensen et al., 2018). This also suggests that the organisation of knowledge production is related to societal organisation. The relationship between science and society is not static, it has already been reconfigured multiple times throughout history (Callon et al., 2009: 42–48; Ezrahi, 1990; Shapin & Schaffer, 1985), and there is no shortage of contemporaneous attempts at rethinking and reconfiguring knowledge production (Etzkowitz & Leydesdorff, 2000; Frahm et al., 2021; Jasanoff, 2018; Mazzucato, 2013; Nowotny et al., 2001; Owen et al., 2012; Schot & Steimueller, 2018). Regardless of slightly different foci, both streams of co-production acknowledge the centrality of science and technology in constituting modern societies.[16]

The global proliferation of national and regional innovation initiatives may also be considered an expression of co-production (Pfotenhauer & Juhl, 2017: 79). On the one hand, these initiatives are grounded in the expectation that advances within science and technology will engender a more beneficial societal organisation (Jasanoff, 2015a). These advances may help to address specific societal ills (Pfotenhauer & Jasanoff, 2017a), or they may contribute to social progress and economic development more generally (Pfotenhauer & Jasanoff, 2017b: 418; Schot & Steinmueller, 2018). On the other hand, innovation initiatives contain a normative dimension. Regardless of whether these initiatives build upon codified or commonsensical models of innovation (Godin, 2015; Pfotenhauer & Jasanoff, 2017a), they presuppose or even prescribe a specific relationship between societal institutions, such as universities, industries, and governments (Etzkowitz & Leydesdorff, 2000). This also applies to sustainability transitions: in its normative commitment to fostering sustainability on a societal scale (Markard et al., 2012), the field makes certain assumptions regarding the role of innovation in

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for an explanation of the dynamics of sociotechnical change that preceded the arrangement in question (Rip & Kemp, 1998: 359; a similar critique is offered by Jasanoff, 2004b: 31). Furthermore, one might claim that such an argument runs into problems of causality: the power wielded within, for example, a technological regime might as well be the *outcome* of sociotechnical change, rather than the cause of it.

[16] Scholarship on co-production often focuses on scientific knowledge, but the insights presented above apply to other kinds of knowledge too. States acknowledge and use knowledge produced outside scientific settings, such as the knowledge produced by consultants (Grundmann, 2017) or activists (Pauli, 2019; on the prospect of developing counter-expertise, see also Marres & Stark, 2020).

sociotechnical change, which also justifies the prescription of specific ways of organising society (Pel et al., 2016: 455–456). As such, it is not only science and technology that shape society; *ideas* regarding the transformative capacities of science and technology may be just as important (Jasanoff, 2015b: 332–337; for examples, see Lamb et al., 2020; Peeters et al., 2016), as they prescribe that society should be organised in a specific manner to facilitate innovation and reap its benefits.

Despite the role of technologies in producing knowledge, scholarship on co-production has often relegated technology to the margins. The starting point for co-production appears to be technoscience, meaning the proposition that what we refer to as ‘science and technology’ is an outcome, rather than being a set of elements that can immediately and undoubtedly be classified as ‘science and technology’. Technoscience refers to the wide variety of elements – human (e.g. individuals, interest groups, organisations, institutions) and non-human (e.g. infrastructures, technologies, animals) – that eventually solidify into science and technology (Latour, 1987: 174–175; see also Callon, 1984; Law, 1987). Because co-production scholarship often emphasises science over technology, technologies tend to be reduced to the material embodiment of knowledge, despite the fact that technology forcefully ‘embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions – in short, in all of the building blocks of what we term the *social*’ (Jasanoff, 2004a: 3, emphasis in original; Jasanoff, 2004b: 21, 30–31).

Considering the preceding discussion of experimentation (Marres & Stark, 2020; Sengers et al., 2019; Weiland et al., 2017), it seems clear that co-production scholarship may benefit from more active engagement with technology. Technologies are being moved out of laboratories and R&D departments, and into explicitly social environments, all the while modifying the very settings in which they are being tested (Marres & Stark, 2020). This means that pilot project organisers produce knowledge about technologies and their surrounding sociotechnical system while simultaneously trying to alter the constituent elements of the system they seek to understand. If experimentation possesses the transformative capabilities ascribed by sustainability transitions scholarship (Sengers et al., 2019), this suggests that sustainability experiments may be powerful devices for ordering or reordering society, given that they are implicated in both constitutive and interactional dynamics.

Chapter 3: Literature review

In the preceding chapter, I have presented a series of theoretical insights that are intended to elucidate the topic of this thesis, namely how automated vehicle innovation is expected to contribute to sociotechnical change in and beyond the Norwegian transport sector. In this chapter, I present a series of relevant insights from previous literature on automated vehicles. I begin by tracing one possible history of automated vehicles from the dawn of motorisation and until today, before discussing the terminology surrounding automated vehicles. Thereafter, I discuss the uncertainty surrounding automated vehicles, using their effect on emissions as an example. This uncertainty is almost non-existent in the subsequent section, in which I discuss various nations' visions and expectations of automated vehicles. The final three sections turn attention to the interface between automated vehicles and society, including visual representations of automated vehicles, the deployment of automated vehicle prototypes in society, and the role envisioned for the public in the shaping of automated vehicles.

Before proceeding with the literature review, it is worth emphasising that this chapter does not contain in-depth discussions of aspects such as data or liability. While I acknowledge that these are important discussions with regard to automated vehicles (Cohen et al., 2020), they are not the conversations to which this thesis contributes substantially. Following this caveat, I open the literature review by discussing automated vehicles in a historical context, before returning my discussion to the present day.

3.1 Vehicular automation through the ages

While the concept of automated vehicles has multiple plausible stories (Cohen et al., 2018), visions of such vehicles are almost as old as mass-motorisation itself (Broggi et al., 2016; Kröger, 2016). The first *driverless* vehicle might have been the 'Phantom Auto', a radio-controlled vehicle that was showcased in a series of American cities throughout the 1920s and 1930s (Kröger, 2016). A more comprehensive vision of automated road transport was presented at the World's Fair held in 1939 in New York, where industrial designer Norman Bel Geddes presented his *Futurama* exhibit. Commissioned by General Motors, *Futurama* presented Bel Geddes's vision of the World of Tomorrow, which then was the world of 1960. From an aerial view, spectators were able to look down at a diorama measuring ca. 3300 square metres (Morshed, 2004). The automobile played a central part in that future: the modernist architecture of the city was to be traversed via automated highways. The idea was later expanded upon in Bel Geddes' book *Magic Motorways*, which included musings such as the following:

> But with the changes in the car, will the driver too be changed? Will he have lost one bad trait which made him years ago a menace to his own safety and a nuisance to others? Don't count on it. But these cars of 1960 and the highways on which they drive will have in them devices which will correct the faults of human beings as drivers. (Bel Geddes, 1940: 56)

Bel Geddes's vision never came to fruition, and there is little evidence to suggest that General Motors actively pursued his exact vision (Wetmore, 2003). Still, starting in the 1940s, the research division of General Motors was developing technologies that it believed could contribute to the goal of establishing an Automated Highway System in the US (Broggi et al., 2016: 1628). While General Motors's research efforts dwindled in the 1960s (Wetmore, 2003), the dream of automated road transport did not die – far from it. However, it has since been transfigured through technological developments within both hardware and software.

Whereas early conceptualisations of automated driving relied upon automated vehicles being supported by dedicated infrastructures, today's vision of full automation, in which vehicles operate on their own without input from either drivers or communications infrastructure, can be traced back to the 1980s. Taking cues from the military, industry began developing vehicles that could drive on their own without infrastructural support, a prerequisite for being able to apply them in war zones (Broggi et al., 2016: 1629). The mid-2000s are often cited as a watershed moment in time for automated vehicles. Notably, it was when the USA's Defense Advanced Research Projects Agency (DARPA) carried out three competitions: the Grand Challenges of 2004 and 2005, and 2007.

DARPA's Grand Challenges were central in the most recent efforts to develop automated vehicles, as they provided a clear task for engineers to undertake: to build a vehicle capable of navigating a pre-established route without human input. By offering participants the chance to win a prize of one million dollars, DARPA prompted institutions and companies to assemble teams capable of solving the task at hand. In this regard, the DARPA Grand Challenges represent an example of new technologies being developed for application in military settings and then being considered for implementation in civil society (Kemp et al., 1998: 183–184; Rip & Kemp, 1998: 47–48). As such, the Grand Challenges may be considered a niche (in the strategic niche management sense of the word): the three competitions provided a specific direction for engineering challenges, as well as an arena for learning about technological configurations that were visibly unwieldy (for pictures, see Broggi et al., 2016: 1631) and, judging from the number of vehicles that never crossed the finish line, barely functional.[1]

With the DARPA Urban Challenge of 2007, attention shifted away from off-road applications and towards urban environments (Ibañez-Guzmán et al., 2012: 1302). The competition was held in an area of unpopulated housing on the disused George Air Force Base in California (Buehler et al., 2009). There, the competing vehicles were expected to navigate a variety of situations and spaces (including streets, parking spaces, intersections) while simultaneously complying with traffic rules. The vehicles also had to interact with each other, as well as with vehicles driven by stuntpersons (Matthaei et al., 2015: 1522–1523). The shift towards urban environments is notable: while urban environments had been part of automated vehicle concepts in the past, those concepts had tended to rely upon infrastructures (Wetmore, 2003). With the Urban Challenge, vehicle-centric approaches to automation entered a domain that had previously focused on infrastructural support.

In the years following the Urban Challenge, several of the participating research teams continued to develop their concepts (Both, 2020: 48; Markoff, 2010; Tennant & Stilgoe, 2021), ushering in a new wave of research into vehicular automation (Faisal et

[1] None of the fifteen entrants completed the 2004 Grand Challenge, which left the prize money unclaimed. The prize money was increased to two million dollars for the 2005 and 2007 Grand Challenges. In 2005, five out of twenty-three entrants finished, four of them within the ten-hour time limit. In 2007, six out of eleven entrants finished, four of them within the six-hour time limit.

al., 2021: 46). Simultaneously, automobile manufacturers and automotive suppliers launched their own automated vehicle initiatives (Matthaei et al., 2015: 1523), efforts that were in part made possible by advances in computing (Stilgoe, 2018: 32). Hence, the Grand Challenges, and perhaps the Urban Challenge in particular, may be considered important events that rejuvenated interest in automated vehicles while also pointing out a specific direction for future technology development (cf. Kemp et al, 1998: 181).

The above presentation might suggest a neat and straightforward chronology, in which approaches that emphasised the capabilities of the individual vehicle gradually replaced approaches that relied upon supporting infrastructures (cf. Ibañez-Guzmán et al., 2012). The shift from the infrastructure-reliant vehicles of Bel Geddes' *Futurama* and General Motor's Automated Highway Systems to the ostensibly self-sufficient vehicles showcased in DARPA's Grand Challenges and Urban Challenge might suggest a typical narrative: through technological progress, today's automated vehicles have become sufficiently advanced to navigate roads on their own, without having to rely on supporting infrastructures, physical and/or digital. However, I have sought to show how this vision of vehicular automation is only the latest among many, and that it emerged in a specific context: with the Urban Challenge, concept vehicles equipped to handle off-road environments were suddenly being tested in a mock urban environment (Buehler et al., 2009), without considering that deserts and cities may require such a vehicle to have different capabilities (Stilgoe, 2017: 9–10). As such, there is still ample room for reconsidering whether vehicle-centred concepts are the best fit for complex urban environments.

Automated vehicles might still develop into diverging *technological styles* (Hughes, 1987: 68–70; Tennant & Stilgoe, 2021: 864–865). For example, in Silicon Valley, visions of automated vehicles are clearly focused on individual vehicles (Stilgoe, 2018), while the EU's interest in connected, cooperative, and automated mobility suggests an infrastructure-based approach (cf. Ibañez-Guzmán et al., 2012: 1295). These differences may result from different approaches to development and deployment. In the US, the process has been dominated by private actors with a concomitant focus on commercialisation (Hess, 2020), while initiatives in Europe have been funded by national governments and by the European Union, and have emphasised public transport applications (Broggi et al., 2016: 1629–1630). These differences also denote different regional approaches to both innovation and governance (Mladenović et al., 2020; Pfotenhauer & Jasanoff, 2017b; Stilgoe, 2017: 16).

The ebb and flow of interest in automated vehicles also reflects the temporal patterning of expectations (Borup et al., 2006). Expectations are subject to change over time, whether due to changing societal conditions, technological disappointments, or exciting new developments. For example, in the 1950s and 1960s, advances within vacuum tubes and transistors were claimed to herald the imminent realisation of Automated Highway Systems in the US. However, despite the emergence of this new and exciting technology, the systems have remained on the drawing board (Wetmore, 2003: 16). Currently, technological advancements within fields such as sensors, algorithms, and artificial intelligence are cited as facilitators for new developments within transportation, including automated vehicles (Cohen & Jones, 2020; Hopkins & Schwanen, 2018b; Mouratidis et al., 2021). While the realism of such claims can be hard to gauge (van Lente, 2012), as exemplified by the aforementioned vacuum tubes and transistors, such claims can simultaneously be instrumental in making specific futures appear plausible or even inevitable. This same observation also applies to the vocabulary surrounding automated vehicles.

3.2 Emerging technology, emerging terminology

The emergence of new technologies is often accompanied by a new vocabulary (Kassens-Noor et al., 2021: 7–8). Indeed, the word technology itself entered into common use in response to technological emergence: when early sociotechnical systems were developed throughout the 19th century (e.g. railways), there was no concept that aptly described such systems. That semantic void was eventually filled through the introduction of the concept of technology (Marx, 1997). At the dawn of motorisation, another semantic void opened: the novel sociotechnical object currently known as the automobile had yet to be named. A series of names were suggested, both by members of the public and by manufacturers, and included the horseless carriage, the motor wagon, and the Locomobile. These early names share a characteristic: rather than being defined by what they were, they were defined in relation to established modes of transport, such as the horse-drawn carriage/wagon and the locomotive.[2]

The emergence of automated vehicles seems to have opened yet another semantic void. Various creative suggestions have been offered, including cybercars, robo-cars/robo-taxis, and smart/intelligent vehicles. However, the terminology appears to have converged around four other alternatives: autonomous vehicles, self-driving vehicles, automated/fully automated vehicles, and driverless vehicles (Kassens-Noor et al., 2021; Liu et al., 2021; Payre et al., 2021; Reilhac et al., 2016). In everyday use, the four terms tend to be used interchangeably. This also means that the terms are applied to vehicles that differ considerably with regard to functionality (Schwarting et al., 2018; Van Brummelen et al., 2018), including partly automated and fully automated vehicles of different shapes, sizes, and functionalities (Fraedrich & Lenz, 2016: 621–622; Nordhoff et al., 2016: 60; Shladover, 2016: 54). However, the anarchic conflation of terms in everyday use should not preclude a scholarly discussion of what, if anything, separates the various terms.

Starting with *autonomous vehicles*, the word 'autonomous' has two meanings in everyday use. The first meaning relates to self-sufficiency, which is the degree to which an actor is independent of their surroundings. The second meaning concerns the ability to formulate and follow one's own goals freely (Bradshaw et al., 2013: 54). However, the vehicles commonly described as autonomous exhibit little autonomy, in either sense of the word. With regard to self-sufficiency, the operations of 'autonomous vehicles' depend upon infrastructure, other road users, and connectivity (e.g. between vehicles or between vehicle and infrastructure or infrastructures, including GPS data). Furthermore, goals are not decided upon by the vehicle itself. Rather, the formulation and effectuation of an action results from the interplay between sensor input and decision-making algorithms

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[2] Locomobile is a portmanteau of locomotive and automobile, an apt name for a company whose vehicles, like locomotives, were steam powered. However, the Locomobile Company of America was originally called the Automobile Company of America, and only changed its name in response to another company that had already claimed the moniker (Villalon & Laux, 1979: 70). Hence, one might argue that the Locomobile moniker was as much a pragmatic choice as it was an attempt to define the company's products in relation to the locomotive.

(Payre et al., 2021). As such, the technical aspects of autonomous vehicle operations do not support the labelling of vehicles as autonomous.

Outside the technical realm, 'autonomous' carries certain connotations. When applied to technology, the word recalls internalist accounts of technology and sociotechnical change (Pinch & Bijker, 1984; Winner, 1977), accounts in which technology is ascribed a will of its own and placed outside the sphere of human influence (Wyatt, 2008). In the case of autonomous vehicles, determinist accounts have been levelled by manufacturers such as Tesla as to promote a deregulatory and liberalist agenda. In this deterministic narrative, autonomous vehicles are claimed to be an inevitable feature of the future, a future that will come with undeniable benefits. Hence, the deployment of such vehicles should not be halted by government regulations (Stilgoe, 2018: 35).

Furthermore, the characteristics ascribed to autonomous vehicles, including anthropomorphic features such as intelligence and autonomy, shape how society sees the technology (Ganesh, 2020). The road to autonomous driving is posited as a transition in which the vehicle performs increasingly more of the driving task on its own, with full automation ostensibly being the final goal (Hopkins & Schwanen, 2021; Stayton & Stilgoe, 2020). However, by focusing solely on the autonomous vehicle and its purported independence, all the work that is necessary to enable full automation is made invisible, as are resulting changes to power relations (Bissell, 2018; Both, 2020; Ganesh, 2020; Tubaro & Casilli, 2019). To summarise, the term autonomous vehicle is problematic in two ways: first, it is imprecise with regard to actual technical capabilities; second, it promotes an understanding of the technology that is currently being levelled to support specific political agendas.

Whether *self-driving vehicle* is preferrable to 'autonomous vehicle' depends on how the prefix 'self-' is interpreted. In the simplest interpretation, 'self-' may be taken to imply that a vehicle contains such a combination of sensors, algorithms, and actuators as to be able to navigate roads without driver input. Barring the fact that self-driving vehicles often rely upon connectivity, such an interpretation appears valid. However, as Ganesh (2020) suggests, the 'self-' in self-driving vehicles might also be taken to imply that the vehicle carries within it a sense of personhood, including the capability to decide upon its own goals and carry them out. Interpreted in this sense, the term self-driving vehicle takes on connotations akin to those associated with autonomous vehicles, including the problematic aspects outlined in the preceding paragraphs.

Driverless vehicle is the least used among the four most common terms (Payre et al., 2021), perhaps due its ambiguity. The term clearly suggests that the vehicle does not have a driver, at least not in the traditional sense. However, this might either suggest that the driver has been replaced by automation or that the vehicle is operated from elsewhere, such as through telecommunications (Ibañez-Guzmán et al., 2012: 1291). Hence, the term obscures more than it does elucidate.

Finally, with regard to *automated vehicles*, the word 'automated', like autonomous, has its roots in the Greek language, and is a combination of the words *autos* ('self') and *matos* ('thinking', 'animated'). It follows that automated means 'self-thinking' or 'self-animated', which might suggest that the term automated vehicle is burdened by the same connotations of selfhood and consciousness as those that burden self-driving and autonomous vehicles. However, as the etymological roots of words are seldom given consideration in daily use of the words, it is worth considering the everyday understanding of automation. In general, automation denotes a determinate process: an automated system follows a set of pre-determined rules, possibly complex and comprehensive rules, that eventually dictate action (Hancock, 2017: 284). In this sense, automation is the antithesis of autonomy.

As discussed earlier in this section, with regard to *autonomous vehicles*, autonomy implies the ability to act according to one's own will. Hence, autonomy suggests indeterminacy and the possibility to adapt behaviour, as opposed to the determinacy of automation. However, automation and autonomy may be said to exist on a continuum (Hancock, 2019: 481). This may be exemplified by Tesla's Autopilot.[3] The Autopilot – a problematic misnomer for an advanced driver assistance system (Dixon, 2020) – is

[3] Many computational systems used in automated vehicles, including Tesla's Autopilot, represent the world through probabilities. From the available sensor input, the vehicle's systems compute the probability of the future state of its surrounding objects and thus also the probability of specific situations arising. Comparing the probability (and improbability) of specific events occurring, the system determines and effectuates what it considers the optimal action in response to the situation calculated as the most probable one (Sprenger, 2022: 629).

regularly updated. Through a process called ‘fleet learning’, input from individual vehicles is used to train and improve the algorithm underpinning the Autopilot (Stilgoe, 2018: 35). As such, the actions undertaken by the Autopilot are not necessarily fixed over time. However, this does not undermine the fact that Tesla’s vehicles do not drive autonomously: they drive with the help of automation, involving complex algorithms with rules that are regularly revised and updated, but this is nonetheless automation.

Considering the arguments in the preceding discussion, I find ‘automated vehicle’ is the preferrable term. While it is not perfect, the term is not quite as burdened by implications of consciousness and selfhood, or by the common conception of automated vehicles as a technology that is heroically independent of any supporting infrastructure (Stilgoe, 2017: 8). The term ‘automated vehicle’ also leaves room for connectivity: if automation is the act of ‘[replacing] human manual control, planning and problem solving by automatic devices and computers’ (Bainbridge, 1983: 775), then a vehicle is automated regardless of whether tasks such as image processing and subsequent planning are achieved through on-board computational units, edge computing, or cloud-based services. As such, automated vehicle is the term I use hereafter throughout this thesis. However, a crucial question remains: what exactly is an automated vehicle?

3.2.1 What is an automated vehicle?

The most frequently invoked framework for defining automated vehicles is the J3016, a standard developed by the Society of Automation Engineers. The standard, titled *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* (Society of Automation Engineers, 2014), codifies the extent to which the *driving task* (rather than the vehicle) has been automated. The J3016 divides automation into six distinct levels, ranging from level 0 (no automation) to level 5 (full automation). At levels 0–2, technologies support the driver, whether through warnings, momentary assistance (e.g. anti-lock braking system), or features that control acceleration and/or steering. Between levels 2 and 3, there is a crucial shift: level 3 automation is capable of driving *under certain conditions*, such as in traffic jams. However, the driver must always be ready to retake control, should the system request it. At level 4, a vehicle is able to drive itself under certain conditions, without needing the driver as back up. At level 5, the vehicle's systems are capable of operating under the same conditions a driver would.

Despite the J3016 having become the de facto standard for matters relating to automated vehicles (Hopkins & Schwanen, 2021), it has also been criticised. With regard to the definition of the term automated vehicle, the main problem is that the ordering of levels in a stepwise fashion posits, whether inadvertently or not, level 5 automation as the ultimate goal of the innovation process, rather than one alternative among many (Hancock, 2019: 482–483; Stayton & Stilgoe, 2020). The idea of level 5 being the ultimate goal has been further reinforced by automobile manufacturers. Some manufacturers use the SAE levels to describe their vehicles' new driver assistance but add modifiers such as decimal points (2.5) or plus signs (2+) to give the impression of being at the forefront of automated vehicle development. Other manufacturers have simply advertised their cars as self-driving without being able to back up their claims (Dixon, 2020). While the J3016 was initially created to provide guidance for policymakers in an effort to speed up the establishment of a regulatory framework (Society of Automation Engineers, 2014), it also helped set a distinct direction for technology development (Hopkins & Schwanen, 2021).

A different way of understanding automated vehicles would be to consider them as a range of options, rather than a specific innovation trajectory towards full automation, as suggested by the J3016. For example, Ibañez-Guzmán et al. (2012) offer a framework that distinguishes between three approaches to vehicle automation: driver-centric, network-centric, and vehicle-centric approaches. Rather than present one of the approaches as preferrable, the three are presented on a continuum (Ibañez-Guzmán et al., 2012: 1298). In the typology, attention is paid to the relationship between the driver, the vehicle, and the surrounding environments and infrastructures (physical and digital). Not least, the typology serves to emphasise the possibility of different configurations of drivers, technologies, and infrastructures, all of which might function. Hence, full and unconditional automation is not posited as the ultimate goal, but rather presented as one among many possible configurations.

In light of the preceding discussion, I offer the following working definition of an automated vehicle: an automated vehicle is one that uses some combination of hardware (e.g. sensors, cameras, radars, LiDAR (light detection and ranging), as well as extra-vehicular infrastructures such as GPS, vehicle-to-infrastructure communications, and machine-readable road signs) and software (e.g. data processing, planning and decision-making algorithms, machine vision, and object recognition) in order to be able to navigate road-based environments without significant human input. This also means that rather than being an isolated artefact, an automated vehicle is already a system on its own, as well as an artefact that further depends on a larger sociotechnical system (Cohen et al., 2018; McDowell-Naylor, 2018: 85).

Although my definition is indeed broad, I would argue that such a broad definition is necessary. As automated vehicles are a technology still in the making, the scholarly literature on such vehicles discusses quite a range of variously configured vehicles (Nordhoff et al., 2016: 60). Examples include the demonstrator vehicle built by the AutoNOMOS research team at Freie Universität Berlin (Both, 2020), the Autopilot feature of Tesla's high-end electric vehicles (Stilgoe, 2018), the two-seater 'pod' vehicles used in trials in Milton Keynes (Wigley & Rose, 2020), and the six-seater automated shuttle buses often employed in pilot projects (e.g. Haque & Brakewood, 2020; Launonen et al., 2021; Payre et al., 2021). Indeed, this richness of concepts suggests a selection environment for automated vehicles (Kemp et al., 1998: 177): various designs and use cases are being tested, but they have not converged into a dominant design (Anderson & Tushman, 1990). Simultaneously, the heterogeneity characterising current approaches to automated vehicles may also be said to mirror the differing automated vehicle concepts that were proposed throughout the 20th century.

While recent advances and expected near-future developments within technology might help to substantiate the probability and even, at least for some time, the inevitability of a specific technological future (Hilgartner, 2015; Hopkins & Schwanen, 2018a), emerging technologies such as automated vehicles are not being pursued merely because technological developments suddenly make them appear feasible. Rather, they are sought out because of the future that seems attainable due to those developments (Jasanoff, 2015a). In practice, this also means that the purported emergence of new technology is accompanied by claims that make a particular innovation pathway appear desirable.

3.3 The uncertain benefits of automated vehicles

As is often the case with emerging technologies, the positive prospects of vehicle automation tend to be emphasised, whereas the negative impacts are ignored or downplayed (Cohen et al., 2020: 4; G. Martin, 2019a; Mladenović et al., 2020: 255; Woods, 2016: 131). This also applies to automated vehicles. Proponents cite a range of purported benefits, ranging from improvements within road transport to society-wide benefits (Duarte & Ratti, 2018; Milakis et al., 2017; Taiebat et al., 2018). However, as discussed in Chapter 2, claims regarding the capabilities of new technologies cannot be reliably assessed in advance (van Lente, 2012). The supposed environmental benefits of automated vehicles serve as an illuminating example.

Road transport is the source of 15% of global greenhouse gas emissions (Ritchie, 2020), while also being a sector that is notoriously hard to abate (Lamb et al., 2022). Hence, there has been considerable interest in whether vehicle automation might help to reduce the emissions. In a recent literature review, the environmental impacts of automated vehicles were assessed across four units of analysis – individual vehicles, transportation system, urban system, and society – which revealed an important insight: the benefits and downsides of automated vehicles can hardly be ascertained before their implementation (Taiebat et al., 2018: 11450).

At the level of the individual vehicle, the effects of automation on aspects such as fuel efficiency can be assessed with relative ease. In this regard, studies have found that the implementation of automated systems in vehicles with internal combustion engines may increase fuel savings and reduce harmful emissions (Barth & Boriboonsomsin, 2009; Fagnant & Kockelman, 2014). However, according to some authors, 'digitally-enhanced fossil fuel efficiencies are not the key to maximizing automobile environmental sustainability' (G. Martin, 2019a: 59; Wadud et al., 2016). Rather, it seems probable that the main environmental benefit of automated vehicles stands to be gained through electrification, rather than automation (Taeibat et al., 2018; Sperling, 2018). Indeed, it is increasingly common to assume that automated vehicles will also be electric, for both engineering and policy reasons (Baxter et al., 2018: 944). At the individual vehicle level, electrification would be almost guaranteed to reduce greenhouse gas emissions, regardless of how the electricity used for charging the vehicle had been generated (Taiebat et al., 2018).

When the unit of analysis is expanded beyond the individual vehicle, uncertainties start to emerge (Milakis et al., 2017; Wadud et al., 2016). At the level of the transport system, the environmental impact of automated vehicles will depend upon how such vehicles interact with public transportation. At the urban level, the impact of automated vehicles on urban land use will play a part in determining their environmental impact, such as whether they allow for further exacerbation of urban sprawl (Milakis et al., 2018). At the societal level, the environmental impacts depend upon the changes automated vehicles induce in overall travel behaviour, as well as how vehicle automation synergises with other sectors (e.g. online retail). The above-mentioned impacts hardly constitute a complete list and they are not meant as such. However, the select examples are sufficient to argue the following: rather than arising from the fuel-efficiency or drivetrain of automated vehicles, the environmental impact of automated vehicles is determined by the sociotechnical system that both facilitates and results from the implementation of automated vehicles.

The growing uncertainty as focus shifts away from the individual vehicle shows the limitation of an object-centred perspective, a perspective that focuses on a novel technological artefact rather than the sociotechnical system within which it will operate (Mladenović et al., 2019: 156). Whereas claims regarding the benefits of the individual automated and electric vehicle may be reliably assessed, their large-scale effects over time remain uncertain (cf. Collingridge, 1980). This is because the emergence of a new technology does not presuppose the emergence of a particular sociotechnical system, but rather makes a whole range of futures possible (Blyth et al., 2016; Cohen et al., 2020; Milakis et al., 2018). Hence, the benefits of a technology, such as its environmental impacts, depend entirely upon how that technology is used and the system that surrounds it, rather than being an intrinsic characteristic of the technology itself (Graf & Sonnberger, 2020; Ozaki et al., 2013; Schwanen et al., 2011). With regard to automated vehicles, this applies also to aspects other than environmental impacts, such as safety (R. Braun & Randell, 2020; Stilgoe, 2021) and accessibility (Milakis et al., 2018). The societal impact of automated vehicles will depend upon societal and political choices, rather than being an outcome preordained by the technology in question (Stilgoe, 2017). However, the uncertainty discussed above is seldom discernible when nations state their motivations for pursuing the development and/or deployment of automated vehicles.

3.4 The national adoption of automated vehicles

Automated vehicles have come to be associated with a set of collective expectations with regard to emissions, safety, and efficiency. However, such vehicles are also ascribed more specific roles in regional and national contexts: rather than representing advances within transport, innovation pertaining to automated vehicles is ascribed an instrumental role in regional and national futures (Jasanoff, 2015a). The formulation of this role often combines a diagnosis of current societal ailments with the articulation of desirable futures (Blyth et al., 2016; Pfotenhauer & Jasanoff, 2017a). Hence, by studying the national adaptation of a technology, one might also become attuned to the power relations in which science and technology are embroiled (Jasanoff, 2004b; Winner, 1980): who are promoting and/or facilitating which technological future, and for what reason or reasons? In this section, I discuss some of the roles in which nations and regions have cast automated vehicles.

In the UK, the emergence of automated vehicles is seen as an opportunity to exhibit global leadership with regard to technology development (Mladenović et al., 2020). Through such leadership, the nation seeks to rejuvenate an economy still struggling with the impacts of the global financial crisis of 2007–2008, as well as to establish an industrial base for a post-Brexit economy (Hopkins & Schwanen, 2018a: 8; McDowell-Naylor, 2018: 107). The British effort has included the establishment of the Centre for Connected and Autonomous Vehicles, an organisation that has since facilitated and funded the public testing of automated vehicles in the UK (Marres, 2020a).[4] The push for public testing has been accompanied by relatively lenient regulations, which have been justified on the grounds that they create an environment that is both business-friendly and conducive to technology development (Hopkins & Schwanen, 2018a: 14; Taeihagh & Lim, 2019: 108). The UK vision of automated vehicles is that they are an opportunity to be seized (Cohen et al., 2018: 270): if the UK wins what is perceived as a race towards full automation (Tennant, Howard et al., 2021), as facilitated through the free market (Hopkins &

[4] Considering the discussion of automated vehicle nomenclature, the juxtaposition of 'connected' and 'autonomous' in the centre's name is a curious one. If a vehicle's operations rely upon connectivity, it cannot be considered autonomous in any sense of the word (Stilgoe, 2018: 35).

Schwanen, 2018a), automated vehicles might play a part in restoring the nation's economy to its former glory.

Germany, too, considers that automated vehicles represent an opportunity for economic growth (Mladenović et al., 2020: 245). Germany's vision of the future is grounded in the nation's past, with automated vehicles being considered a new opportunity for the country's automotive industry (Both, 2020: 41; Mladenović et al., 2020: 245; Wentland, 2017). For example, the opening paragraph of the *Strategy for Automated and Connected Driving* states that 'the major innovations associated with the car – from the four-stroke engine to the anti-lock braking system – come from Germany' (BMDV, 2015: 3). Time and again, the German automotive industry has been at the technological vanguard. Hence, the emergence of automated vehicles is seen as yet another opportunity for the country to assert technological leadership and reap the associated economic benefits.

In Finland, there is a slightly different orientation. Throughout the 1990s, the Finnish economy began shifting from export industries (including forestry, metallurgy, and electronics) towards a knowledge-based economy (Halme et al., 2014; Salminen & Lamminmäki, 2014). The emergence of automated vehicles is considered an opportunity in the context of this larger industrial shift (Blyth, 2019: 237–238). In Finnish policy documents it is argued that the global value networks surrounding automated vehicles represent a considerable opportunity for the Finnish economy: in addition to national initiatives promoting the development of 5G communications and sensor technologies, the country is implementing policies to facilitate ICT innovation even further, as well as measures to foster digital literacy and competence in the overall population (Mladenović et al., 2020: 244–245). As such, Finland sees itself as a cog in a larger machine: as a modern, knowledge-based economy with considerable competence within ICT, Finland might establish itself as a technological frontrunner with regard to automated vehicle software.[5]

In the US, state actors draw upon a rhetorical repertoire similar to that of both Germany and the UK. In a strategic plan released by the U.S. Department of Transportation in 2018, the then Secretary of Transportation, Elaine Chao, wrote: 'With the development of automated vehicles, American creativity and innovation hold the potential to once again transform mobility' (U.S. Department of Transportation, 2018: ii). However, the realisation of that potential has been left to the individual states (Hess, 2020). In 2011, Nevada was the first state to introduce legislation for automated vehicles, and Florida and California soon followed suit by announcing their regulations, together with statements that emphasised technological progress, leadership, and economic opportunities (Schreurs & Steuwer, 2016: 160). Subsequently, the lack of federal regulations appears to have fostered an interstate race towards deregulation in hopes of attracting companies developing and testing automated vehicles (Bissell, 2018: 62; Hess, 2020: 4). The approach seems to suggest that the best way to unleash American creativity and innovation would be to adopt a deregulatory and market-based approach, despite the challenge of balancing such an approach with the safety and needs of US citizens (Bissell, 2018; Hess, 2020).

The above-discussed cases show how countries mobilise both national history and identity, as well as desirable and undesirable futures in order to substantiate the importance of pursuing automated vehicle innovation. They also tend to underline why the country in question is properly, often uniquely, equipped to facilitate such innovation. Similar justifications can be seen in other countries, too. Upon developing guidelines for pilot projects with automated vehicles, the Government of Sweden emphasised that such projects would be important to the Swedish economy generally and the Swedish

[5] For example, the Norwegian public transport provider Ruter has recently started to collaborate with the Finnish company Sensible 4, which produces LiDAR-based positioning software that is claimed to be capable of handling all-weather operations (https://sensible4.fi/technology/ accessed 22 December 2021). The weather conditions have been cited as a further benefit of developing automated vehicles in Finland: if the technology functions during snowy and cold winters with low light, it should also be able to handle less demanding situations (Mladenović et al., 2020: 247).

automotive industry specifically (Hansson, 2020: 5–6; Schreurs & Steuwer, 2016: 162–163). In Japan, automated vehicles are considered a possible area of application for artificial intelligence, which might help to rejuvenate the country's automotive industry and thus act as a boon to the economy of a nation characterised by declining birth rates and an aging population (Hatani, 2020: 212, 223; Schreurs & Steuwer, 2016: 161–162). Singapore has sought to establish a business-friendly regulatory environment for automated vehicles to attract foreign companies that might further the country's Smart Nation agenda (Tan & Taeihagh, 2021).

The above discussion is not meant to present an exhaustive list of countries, states, and regions pursuing the development of automated vehicles and their reasons for doing so. Rather, the point is to argue that a particular technology is not only sought out for the benefits that the technology itself is claimed to offer. Whereas the reasoning might differ somewhat, such as with regard to how a nation's past and future are mobilised, most countries pursuing automated vehicle development (or some aspect thereof) also see automated vehicles as a source of economic growth (Schreurs & Steuwer, 2016: 167). Often, the nation in question claims to be particularly well-equipped for facilitating such development, whether through its specific competences (e.g. Finland) or through the facilitation of lenient and business-friendly regulatory environments (e.g. the UK). This is also suggestive of the power of collective expectations (Konrad, 2006). Such expectations appear to prompt spontaneous organisation (van Lente, 2012), with nations casting themselves in specific roles with regard to automated vehicle development (Mladenović et al., 2020: 244).

The preceding discussion shows how automated vehicles have entered discourses outside the transport sector, which include ideas about the role of innovation in vitalising or revitalising national economies. As such, they are part of more comprehensive ideas of what a society might become through technological advances (Jasanoff, 2015a), such as one with a burgeoning knowledge-based economy or a global frontrunner in automated vehicle innovation. This view can be summarised by Hatani's claim that 'taking a wait-and-see attitude will not work in technological competition' (Hatani, 2020: 215). Taken at face value, this suggests that uncertainties should be ignored, and whereas the future is uncertain, the *prospect* of profit of becoming the world leader in a new market should be sufficient to invest in innovation relating to automated vehicles (Hatani, 2020; Hopkins

& Schwanen, 2018a). State interest in automated vehicles appears to be grounded in a paradigm in which the economic prospects associated with innovation are prioritised over other values, such as sustainability and social equity (Hopkins & Schwanen, 2018b: 78; Pfotenhauer et al., 2019; von Schönfeld & Ferreira, 2021).

3.5 The discursive shaping of automated vehicles

State conceptions of automated vehicles tend to be rather vague and are often built upon the assumption that automated vehicles will exhibit the benefits claimed by their proponents. However, as argued earlier in this chapter (Section 3.3), automated vehicles are still characterised by considerable heterogeneity in terms of both their technological configuration and modes of implementation. Different actors employ different configurations (Pel et al., 2020), and direct considerable efforts towards visual and audiovisual representations that promote specific futures (R. Braun & Randell, 2020: 2; Weber & Kröger, 2018: 17). These representations, in which 'scientific fact and imaginative fiction are blurred' (Forlano, 2019: 2812), are an instrument for attracting capital and building a constituency behind a specific vision (Both, 2020: 94f; Kemp et al., 1998: 184; Wigley & Rose, 2020: 158). National and local governments are often poorly equipped to assess the merits of emerging technologies realistically (McAslan et al., 2021: 12; Rip & Kemp, 1998: 391), which makes the representations important objects of study: which futures do they promote, and at the expense of which other futures? A nascent literature has begun to explore these questions.

In analysing two sets of automated vehicle visualisations, Robert Martin (2021) questions the notion that automated vehicles will be the defining technology of the future. In the first set of visualisations, produced by the automotive corporation Daimler, automated vehicles take centre stage. Although Daimler's visualisations include other modes of transport, such as public transport and bicycles, automated vehicles are their focal point. The vehicles are presented in the context of an urban environment dominated by car infrastructure and it is strongly implied that they have the same convenient and flexible characteristics as today's private vehicles. Alternative transport modes are clearly communicated as subordinate; they seem to have been included chiefly to 'mask an otherwise typical depiction of a streetscape within the system of automobility' (R. Martin, 2021: 8). As such, Daimler's visualisations position automated vehicles as a continuation of automobility, all the while presenting this prospect as a desirable future.

The second set of visualisations, created by JAJA Architects, presents a quite different future. Rather than being the focal point of the visualisations, automated vehicles are simply seen as present in diverse urban and suburban environments, whether in the background or as component of a multimodal transport system. The effect is striking. In contrast to Daimler's visualisations, JAJA Architects present automated vehicles as part of a future society without presenting them as the technology that defines this future. JAJA Architects' visualisation focuses on a certain brand of urbanism that may accommodate automated vehicles but does not *require* them. Representations such as those produced by Daimler and JAJA Architects propagate certain expectations, and thus also shape how we see the future, as well as how we act to bring it about. Whereas Daimler's visualisations promote the continuation of automobility, JAJA Architects' visualisations promote a future that may be realised even without automated vehicles. In this way, the two visualisations suggest different transition pathways, meaning that it is not inconsequential which visualisation might gain traction over the other. The visualisations vary with regard to which actions and alliances need to be pursued in order to realise the future in question.

In an analysis of the promotional material accompanying an automated vehicle project conducted in the city of Milton Keynes, UK, Wigley and Rose (2020) ask what use and what users are imagined. In terms of use, the material suggests that automated vehicles will offer seamless multimodal travel that leaves the passenger free to study or prepare for work. This also reveals a specific imagined user (Woolgar, 1990): the white, able-bodied professional whose hectic everyday life may be alleviated through automated travel. Although it is often claimed that automated vehicles will increase accessibility (Bissell et al., 2020; Cohen et al., 2020), the Milton Keynes visualisations in no way suggest improved accessibility for all. Rather, they elicit an image of the 'kinetic elite'

(Costas, 2013; Cresswell, 2006: 255–257), a class of people who are capable of and can afford to move seamlessly, effortlessly, and luxuriously.[6]

Beyond the narrow conception of the future user, the analysed promotional material is also interesting because of the nondescript environment in which the automated vehicles are presented (Wigley & Rose, 2020). While the promotional material was produced in Milton Keynes, most of the city's identifying features have been excised from that material. As a result, the promotional material is characterised by a certain placelessness (as was also the case with Daimler's visualisations; R. Martin, 2021). Wigley and Rose (2020) suggest that this placelessness helps to facilitate the 'spreadability' of the images produced (Rose & Willis, 2019), while also suggesting scalability. Rather than a solution to specific, localised problems, the generic urban environments in which the vehicles are pictured or visualised turn the vehicles into a product that can easily be transferred to other locations (Wigley & Rose, 2020: 168; on scalability, see also Pfotenhauer et al., 2022). As such, the material reproduces an assumption often seen both within the notion of technology transfer (Akrich, 1992) and within the circulation of innovation models (Pfotenhauer & Jasanoff, 2017a): the

[6] The use of nondescript places in the promotional material brings to mind the notion of 'non-places', which are sites such as hotels, airports, and motorways – anonymous sites that nonetheless seem familiar due to their standardised nature, but that simultaneously elicit feelings of solitude and similitude (Augé, 1995: 106). They are transient places: they are measured in time, rather than located in space (Augé, 1995: 104). The kinetic elite is often presented as privileged due to the capacity of its members to move fluidly through and between spaces, whether they are social or geographical (i.e. mobility as capital, which is referred to as 'motility' by Kaufmann et al., 2004). However, such capacity to move often entails travelling through or staying in non-places, suggesting that the lived experiences of the kinetic elite are more ambiguous than the capacity to move fluidly might suggest (Costas, 2013). Hence, there is also reason to examine the affective landscapes which ostensibly are made possible by automated vehicles (Bissell et al., 2020; Mladenović et al., 2019). This includes examining what sensory experiences such vehicles might offer and to whom, and what experiences are left for others. For example, in the audiovisual material from Milton Keynes, the automated vehicles were able to flow uninterrupted through the urban environment (Wigley & Rose, 2020; for similar observations, see Hildebrand, 2019; R. Martin, 2021). While this might have been an idealised presentation, it still suggests that such vehicles are prioritised over other urban dwellers, meaning that to the pedestrian, the future city might still be characterised by stops and starts, rather than the uninterrupted flow experienced by those being chauffeured in automated vehicles.

assumption that technologies might be effortlessly adapted to quite differing environments (social, material, and regulatory) without requiring significant adaptations.

Julia Hildebrand's (2019) analysis of two concept car videos captures the overall proclivity in visual and audiovisual representations of automated vehicles. The sublime is at the centre of her analysis. As it was understood in the 18th and 19th centuries, the sublime referred to the simultaneous sense of astonishment and terror that humans experienced when faced with certain landscapes and natural phenomena, such as massive mountain ranges or hurricanes. The notion of the sublime has since been extended to include human-built structures and systems, including electricity (Carey & Quirk, 1989), digital technologies (Mosco, 2005) and automation (Kang, 2011). However, as opposed to the natural sublime, the technological sublime tends to emphasise the astonishing qualities of new technologies over their negative aspects (Marx, 1964; Nye, 1994).

In her analysis, Hildebrand shows how two concept car videos from Chevrolet and Nissan mobilise the technological sublime in order to present visions of automated vehicles that will electrify their audience without terrifying it (Hildebrand, 2019: 169; Hildebrand & Sheller, 2018). All the uncouth elements of automobility, such as accidents, congestion, and pollution, have been excised from the videos, and rather than drawing upon the dialectic of astonishment and terror that traditionally characterises the sublime, the videos depict 'a utopian, empowering, and exalting partnership between the human and machine' (Hildebrand, 2019: 168–169). The result is indeed utopian: by omitting all the negative aspects of automobility, automated vehicles are presented as part of a future characterised by ecological balance and social harmony, thus precluding a realistic assessment of the technology.

The strategy of presenting the exhilarating aspects of automated vehicles helps depoliticise them (Hildebrand, 2019: 169; on the depoliticising of automated vehicles see also Hopkins & Schwanen, 2018a; Legacy et al., 2019; R. Martin, 2021; McDowell-Naylor, 2018: 177; Mladenović, 2019; Reardon, 2018). It is not possible to engage sensibly with the technology without being aware of how most representations of automated vehicles often leave out contentious aspects. Fortunately, these are aspects that sometimes surface when automated vehicles are introduced to existing environments. Hence, I next turn attention towards recent attempts at deploying automated vehicles in the real world, and how these deployments, at least ideally, have complicated utopian and conflict-free representations of automated vehicles.

3.6 Automated vehicles and the 'real world'

Claims regarding the inevitable near-future arrival of automated vehicles have prompted the establishment of legislation pertaining to automated vehicles. Strategies for regulating automated vehicles have generally been similar, even across different governance cultures (Mladenović et al. 2020; Taeihagh & Lim, 2019). Rather than establish permanent legislation, most countries have opted for legislation that allows interested parties to test automated vehicles on public roads. In some countries, regulations have been lenient or non-existent (with regard to the UK, see Marres, 2020b: 121; with regard to the US, see Hess, 2020), while in others, project organisers are required to apply for a permit to conduct tests on public roads (e.g. in the case of Norway and Sweden, see Hansson, 2020). In the US, automated vehicle innovation has chiefly been undertaken by private companies (Stilgoe, 2018), while a series of countries have actively supported innovation efforts through government funding (with regard to Germany, see Schreurs & Steuwer, 2016: 163; with regard to Japan, see Hatani, 2020: 222; with regard to the UK, see Hopkins & Schwanen, 2018b: 73). Regardless of national goals, regulatory approaches, and funding sources, the interest in facilitating and conducting tests with automated vehicles suggests that such projects are considered to have an important function, both by the nation states that have facilitated testing and the various combinations of public and private actors that conduct them.

In 2014, legal scholar Bryant Walker Smith predicted that in the case of automated vehicles, 'the line between research and production will be blurred by novel deployments' (B. W. Smith, 2014: 86). Rather than being developed and tested in research departments before being introduced to consumers, as assumed both in the linear innovation model (Forlano, 2019; Godin, 2006) and in many regulatory frameworks (Leonardi, 2010; Stilgoe, 2018), Smith held the view that automated vehicles, whether research vehicles, low-speed shuttle buses, or other experimental configurations, would increasingly be deployed on public roads (B. W. Smith, 2014: 86–87). This turned out to be a prescient statement. Today, automated vehicles are often deployed in real-world settings, whether by technology developers or by institutions or organisations seeking to understand how they might make use of the technology. However, the exact configuration of these real-world settings (or, as I will shortly show, 'real-world' settings) differ with regard to their material configuration, the implicated actors, and the politics of the setting. After charting, categorising, and synthesising findings from 135 projects with automated vehicles, Dowling and McGuirk (2022) suggest that such projects are conducted at one of four distinct locales: either on existing roads, at purpose-built test beds, in dedicated urban precincts, or in living laboratories.

In *on-road trials*, automated vehicles are trialled on existing road networks. Such trials have generally been conducted by private companies, including incumbent automobile manufacturers (Nissan, Volvo) and entrant technology companies (Baidu, Tesla, Uber, Waymo). In terms of politics, the goal underpinning the trials appears to be the reproduction of individualised automobility (e.g. Urry, 2004): incumbents and newcomers alike use such trials to substantiate the prospect of the private car still being an important component of the transport system of the future, while simultaneously preparing their company for that future. As such, the trials reflect much of the same proclivities discussed in the preceding section (e.g. Hildebrand, 2019; R. Martin, 2021; for additional examples, see R. Braun & Randell, 2020; Hildebrand & Sheller, 2018).

At *purpose-built test beds*, organisers seek to replicate the heterogeneity of urban environments while retaining control. Some sites are bespoke and built from scratch, such as the Mcity facility run by the University of Michigan (Forlano, 2019), while other sites have been retrofitted to accommodate automated vehicle testing, such as the GoMentum Station at the disused Concord Naval Weapons Station in California and the former George Air Force Base used for DARPA's Urban Challenge in 2007 (Buehler et al., 2009). In terms of politics, test beds are ascribed a function similar to that of on-road trials: through the replication of urban environments, vehicles can safely learn how to operate in real-world environments, with the ultimate goal being the reproduction of automobility. Simultaneously, these sites often draw upon the same repertoire of economic opportunity and post-industrial growth that nations mobilise (e.g. Mladenović et al., 2020), although often applied at the regional level. For example, in Michigan, the test beds are seen as an opportunity to simultaneously revive and transform the state's largely defunct automotive industry (Dowling & McGuirk, 2022: 416; Forlano, 2019: 2821; Schreurs & Steuwer, 2016: 160).

Precinct trials have become increasingly common, especially in Europe. These trials eschew the perfectly controlled conditions characterising test beds. Rather than replicating urban environments at purpose-built sites, precinct trials turn bounded areas of cities into trial areas. Such trials turn attention beyond the technical performance of the vehicle: by deploying the vehicle in question – often an automated shuttle bus operating at low speeds – in a pre-existing urban environment, trial organisers can seek to assess the interaction between the vehicle and its surroundings. Such interaction encompasses both material aspects (e.g. road infrastructure, communications, digital platforms) and social aspects (e.g. interactions with motorists and/or pedestrians, public attitudes to the technology). In terms of organisation, precinct trials often reflect the triple helix interactions described by Etzkowitz and Leydesdorff (2000): they tend to be joint ventures that include technology suppliers, universities and/or specialised government agencies, and state authorities. Precinct trials also imply a different set of politics than the largely privatised technology development seen in on-road trials and at test beds: by combining a varied set of actors and a complex environment, there is a prospect of facilitating learning processes and institutional adaptations. In this regard, precinct trials may be likened to the niches in strategic niche management (Kemp et al., 1998).

In rare cases, automated vehicles are tested in *living labs*, which are akin to precinct trials but are more comprehensive in terms of complexity and size. Rather than being limited to a single precinct and/or a single technological configuration, living labs are used to test a variety of different configurations. As with precinct trials, living labs attract a series of different actors, often framed within an entrepreneurial rhetoric: while living lab initiatives originate from local or national governments, the environment is offered as a platform for companies to test novel technologies (for an example, see Hopkins & Schwanen, 2018b: 83). This also means that living labs tend to draw upon the rhetorical repertoire of regional development, in addition to emphasising the prospect of transforming mobility (Dowling & McGuirk, 2022: 418–419). As living labs are often accompanied by a lenient regulatory environment, they are also environments within which governance and public-private power relations may be transformed, possibly through 'side-stepping existing arrangements for the public accountability of new technology' (Marres, 2020b: 126–127). This holds particularly true if, like Winner (1980), one considers that the material changes enabled and/or precipitated by technology are an expression of politics. Hence, living labs tend to be characterised by a certain ambiguity with regard to their politics.

As the above discussion shows, there are crucial differences between the various types of test sites. On-road trials and test beds tend to be employed by private companies in an effort to reproduce automobility, albeit in a more palatable form. Precinct trials and living labs mobilise more diverse actor constellations in their attempts to challenge individualised mobility through the active modification of environments, predominantly urban ones. The implicated actors and environments at each site envision different futures and exhibit different politics, and thus imply different transition pathways (Fraedrich et al., 2015; R. Martin, 2021; Schippl & Truffer, 2020): some seek to develop technology that can be accommodated within the established transport system, whereas others seek to transform the urban fabric to accommodate automated transport (Dowling & McGuirk, 2022: 421–422; Stilgoe, 2017).

In conclusion, the various types of test sites exhibit specific politics: some sites tend to reproduce automobility, whereas others are better equipped for contesting it (Dowling & McGuirk, 2022). This is not inconsequential, because the urban environment does not merely contain the trial. Rather, trials are configured in relation to the urban environment, while they also constitute the urban (Dowling & McGuirk, 2022: 422; Hopkins & Schwanen, 2018b; Marres & Stark, 2020). In other words, the urban, as it currently exists, shapes the kind of trials that are conducted, which also relate to an envisioned future. At the same time, the trials reshape the urban: material adaptations are often made to facilitate automated vehicle trials, and simultaneously, the trials being conducted shape subsequent visions of what the urban might become.

The typology presented above offers useful insights into automated vehicle innovation by providing a comprehensive catalogue of implicated actors, motivations, practices, and visions (Dowling & McGuirk, 2022: 413). However, such an overview also runs the risk of flattening the empirical landscape. This risk is especially pertinent in the case of automated vehicles, where to date relatively few initiatives have been the subject of in-depth empirical inquiry (McDowell-Naylor, 2018: 290). Hence, to complement the above typology (Dowling & McGuirk, 2022), it is fruitful to consider insights generated from specific cases of automated vehicle innovation.

3.6.1 The nature of novel deployments

The introduction of automated vehicles on public roads represents an opportunity for social learning, which is the process whereby 'society and its institutions make sense of novelty' (Stilgoe, 2018: 26; for a further discussion, see Rip, 1986: 357–360). A generative example of social learning is the first fatality implicating Tesla's Autopilot (Stilgoe, 2018). In May 2016, a Tesla Model S hit a truck that had intersected its path, killing the Tesla driver in the process. The novelty of the crash prompted a sense-making process among US institutions. The resulting official investigations showed that the Tesla had employed an opaque software with technical capabilities that had been oversold by Tesla (on misleading advertising of automated vehicles, see Dixon, 2020). Still, human error was identified as the main cause of the crash: the driver had failed to use the software properly and within the limitations set by the manufacturer.

The Tesla crash pointed to a central difference between Tesla and traditional automotive manufacturers: where traditional manufacturers operate within a safety-focused culture, many of the companies that are currently developing automated vehicles, including Tesla, come from a software culture in which problems may be mitigated through on-the-fly updates (Stilgoe, 2018). When digital and physical infrastructures meet, as in the case of Tesla's Autopilot, this becomes a problem: while it is clear that software issues may cause damage in the digital realm, the damage caused by such issues appears different when it is located in the material world, such as on the road. Consequently, the fatality involving Tesla has prompted questions regarding regulation and governance of technologies that rely upon both digital and physical infrastructures.

The above line of inquiry may be interpreted as co-productionist: the way society chooses to frame a technology has consequences for how that technology is governed. The emergence of automated vehicles marks an opportunity for engaging with the question of how to govern technologies that straddle the line between physical and digital infrastructure. For example, it matters whether automated vehicles are governed as individual objects or as components in a sociotechnical system (Stilgoe, 2018: 44). By framing the fatal Tesla accident in 2016 as a case of human error, the governing of automated vehicles becomes a question of educating the public, rather than establishing, for example, data sharing mandates and procedures for pre-market approval. This means that responsibility is located with those using the technology, rather than those developing it (Stilgoe, 2018; for a discussion on the distribution of responsibility in automated transport, see JafariNaimi, 2018: 316).

In their study of two automated vehicle trials, one a precinct trial in Oxford and the other a living lab in Greenwich, London, Debbie Hopkins and Tim Schwanen (2018b) present findings which echo the proclivities described earlier in this chapter. The two trials were motivated by prospects of regional and national economic growth and were organised in a manner that facilitated triple helix interactions (Etzkowitz & Leydesdorff, 2000). However, when turning attention to the configuration of the actual trials and trial sites, it is notable that claims regarding the real-world nature of urban pilot projects underplay the extent to which the sites are carefully curated (Hopkins & Schwanen, 2018b). Rather than being chosen on a whim, the trial sites were chosen because they exhibited certain characteristics. On one hand, the sites were claimed to exhibit geographical and traffic-related characteristics that, according to the organisers, made them uniquely fit for trialling automated vehicles. On the other hand, the locations were chosen because they rendered public interaction unlikely (the Greenwich living lab) or offered specific audiences and interactions (the Oxford precinct trial).

Trial locations are chosen according to the priorities of the organisers, with regard both to the characteristics of the site and the intended audiences (Hopkins & Schwanen, 2018b: 90). This artifice leads to a certain ambiguity. On the one hand, the trials offer an opportunity to expose the public to automated vehicles. By reducing the complexity of interactions at the trial site, vehicles may showcase the flawless technical performance that the organisers consider to be key in fostering public acceptance. On the other hand, the segregated environment that allows for flawless technical performance also limits the prospect of second-order learning (Hopkins & Schwanen, 2018b: 87–88; Kemp et al., 1998; Hoogma et al., 2002). As such, the constructed nature of 'real-world' environments has the paradoxical effect of substantiating expectations regarding technical feasibility, and thus also commercial prospects and future profitability, while simultaneously precluding or limiting the learning processes that are necessary for such vehicles to function in heterogenous real-world environments. Although the trials grant credence to claims regarding the 'already-here-ness' or 'real-worldness' of automated vehicles (Forlano, 2019: 2812; Hopkins & Schwanen, 2018b: 91; B. W. Smith, 2014: 86), including their ability to function in urban environments, the credence may be more conducive to hype than to the actual future deployment of such vehicles.

The artifice that often surrounds trials with automated vehicle also represents a methodological challenge: if street trials are to facilitate interaction between vehicles and the people who navigate the same environment, as is often offered as justification for such trials (Marres, 2020a: 539), then the configuration of current trials is woefully inadequate. Drawing upon experiences from four different street trials in the UK, Marres (2020a) notes that the trials tended to be contained in order to reduce the social complexity that the vehicles might encounter. Each of the four trials included 'material, organizational, and regulatory operations upon the street environment' (Marres, 2020a: 546), operations that reduced the complexity of the environment in order to align better with the current technical capabilities of the vehicles being tested. Hence, rather than facilitate social interaction, understood here as the co-existence of and mutual adaptation between the vehicle and other road users (e.g. motorists, cyclists, pedestrians), the trials were configured to assess and enhance the vehicles' capability to navigate (artificial, curated) 'real-world' environments of rather low levels of social complexity.[7] This points to a crucial limitation of the UK street trials: rather than test the capabilities of humans and technologies to adapt to each other mutually, the environment was rendered passive – or made legible (Stilgoe, 2017) – in order to enable the testing of technology rather than society.

Due to their public nature, street trials may function as experiments in participation (Marres, 2020b). If properly configured, such trials may help to '[elicit] expressions or accounts of public issues that would otherwise remain underarticulated or exist only *in*

[7] This may also mean that the assumptions underpinning the engineer-led trials never are challenged. As Michel Callon (1987) has shown, engineers develop technologies based on expected societal developments as well as technical know-how, an insight that is also present within strategic niche management (e.g. Kemp et al., 1998: 177). Hence, if a technology, such as an automated vehicle, is never exposed to the environment in which it is expected to function, the validity of the engineers' assumptions cannot be assessed. This might mean that technology development continues in a specific direction without necessarily having to do so. For example, one might find that humans and automated vehicles are already capable of co-existing, even if the specific brand of co-existence might require humans to adapt both themselves and the built environment to the needs of the vehicles (Marres, 2020a: 552; Stilgoe, 2017).

potentia' (Lezaun et al., 2017: 195). Although current configurations of street trials often suspend or challenge established mechanisms for public accountability (Marres, 2020b: 127), this is not an inherent characteristic of such trials. Whereas current street trials tend to be envisioned and configured as instruments for eliciting public acceptance rather than issue articulation (Marres, 2020b: 122–123; for a similar argument, see Hopkins & Schwanen, 2018b: 87–88), the testing of novel sociotechnical objects and arrangements in public holds potential for participation.

The prospect of using automated vehicle trials as a means of public participation echoes, but does not imitate, concerns within strategic niche management. As discussed in Section 2.3, strategic niche management emphasises the importance of second-order learning (Hoogma et al., 2002: 29; Schot & Geels, 2008: 541), which is the questioning of established assumptions regarding, for example, the technology in question, the needs of users, and the regulatory requirements and barriers. In strategic niche management, second-order learning is considered crucial for the further development of niches. Due to the often implicit pro-innovation bias in strategic niche management (Ferreira et al., 2020; Godin & Vinck, 2017; Pel et al., 2016), public involvement tends to be of interest insofar as it might help to ascertain the functioning of the technology and hence help accelerate its development and diffusion (for an example of this proclivity, see Kemp et al., 1998: 191). However, this emphasis may be inverted. Rather than involving the public to produce a form of consensus, street trials (and public trials more generally) may be configured to elicit a full range of implicated actors, issues, and antagonisms (Marres, 2020b: 128; for relevant discussions, see also Callon et al., 2009; Eames et al., 2006; Lezaun et al., 2017; Marres, 2007; Mladenović, 2019) – in short, the politics of emerging technology.

The above discussion suggests that the curated nature of trial environments is not a problem in itself. Rather, the challenge is the specifics of their curation (Hopkins & Schwanen, 2018b; Marres, 2020a, 2020b). The formatting of participation in an automated vehicle trial conducted under the umbrella of the GATEway project offers an elucidating example (McDowell-Naylor, 2018). The trials in question took place over four weeks in March and April 2018 and consisted of a set of automated vehicles (referred to as 'driverless pods') being driven along a dedicated path on the Greenwich Peninsula. Insights from workshops conducted before the trials had suggested that the public had a complex view of automated vehicles, consisting of both hopes and fears. However, the insights did not make it into the trials. Rather than build upon the insights, the trial organisers employed a set of three digital tools that significantly limited the nature of public engagement.

The narrow conception of public engagement is best exemplified by the survey questionnaire that was distributed to participants after the GATEway project trials had ended. The questionnaire clearly preformatted the feedback by predominantly employing multiple-choice questions (McDowell-Naylor, 2018: 181). Based on insights and methods from social psychology, the questionnaire was designed with emphasis on the passengers' *experiences* with the driverless pods, and the combination of multiple-choice questions and experience as the central metric narrowed the kind of feedback passengers were able to give. For example, they were not able to give their views regarding the possible societal ramifications of automated transport, nor were they presented with the opportunity to reject automated vehicles altogether (McDowell-Naylor, 2018: 179). The other digital tools were simpler but exhibited the same characteristics as the survey: they allowed passengers (and people who observed the trial vehicles) to provide feedback regarding their experience, predominantly in the form of easily quantifiable metrics of low information quality (McDowell-Naylor, 2018: 178–179, 181–183). Rather than enabling a social decision about the development of automated vehicles, the public engagement surrounding the trials served the instrumental function of further justifying and lending legitimacy to strategic policies that had already been set in motion by the Government of the United Kingdom.[8]

Whether it is the modification of urban environments to facilitate automated vehicle trials (Hopkins & Schwanen, 2018b; Marres, 2020a), the use of trials to foster public acceptance (McDowell-Naylor, 2018), or government institutions' attempts to make sense of novelty (Stilgoe, 2018), the above examples show how a series of differentiated actors used novel deployments to understand, shape, and/or facilitate the emergence of

[8] Tom Cohen et al. (2018) describe a similar experience. Having produced a report with insights generated through stakeholder workshops, they found that their conclusions were subsequently 'massaged to make them more congruent with the general narrative that [automated vehicle] technology is a good thing and an opportunity to be grasped' (Cohen et al., 2018: 270).

automated vehicles. In this sense, the various deployments of automated vehicles may be considered examples of co-production, both the constitutive strand and the interactional strand (Jasanoff, 2004b). However, if the discursive representations and novel deployments discussed in the preceding two sections are any indication, this also suggests that the public is cast in a relatively marginal role in this process.

3.7 Automated vehicles and the public

Automotive manufacturers, technology developers, and governments direct considerable efforts towards enrolling the public, whether through visual or audiovisual discourse (e.g. Hildebrand, 2019; R. Martin, 2021; Wigley & Rose, 2020) or demonstrations of technological prowess (e.g. Hopkins & Schwanen, 2018b; Marres, 2020b; McDowell-Naylor, 2018). These efforts suggest that the public is ascribed some role in the development and/or implementation of automated vehicles. The question, then, is which role innovators and governments envision for the public in these processes.

There is reason to suggest that the public is narrowly conceived by innovators and governments alike. In an analysis of documents written by German stakeholders, Antonia Graf and Marco Sonnberger (2020) find a paradoxical image of the public: on the one hand, the public is thought to harbour an irrational opposition to automated vehicles, and on the other hand, the public is considered generally capable of making rational decisions regarding everyday mobility. That is, the public is generally able to find and assess the right information, except in the case of automated vehicles. Hence, the German stakeholders' documents suggest that the public's information deficit must be mended in order to enable the successful proliferation of automated vehicles (a sentiment that is echoed in some scholarly literature, e.g. Jelinski et al., 2021). The information deficit may be mended by educational means and/or by allowing the public to engage with the technology, for example, in living labs. Some of the analysed documents refer to such activities as public participation. However, this is at best a narrow understanding of the term: the documents conceive participation as activities that promote public acceptance of automated vehicles (Graf & Sonnberger, 2020; Mladenović et al., 2020: 251–252). Rather than discuss the technology's merits, the public is to be convinced of its excellence.

The emphasis on education rather than deliberation reflects a larger trend in which the public tends to be cast in roles such as users, customers, or consumers, rather than citizens (Milakis & Müller, 2021; for examples, see Hopkins & Schwanen, 2018a; Mladenović et al., 2020). This trend can also be seen in much social scientific research on automated vehicles (Cohen et al., 2020; Tennant et al., 2019), where a sizeable body of literature focuses on individualised aspects of automated vehicles such as user acceptance, barriers to adoption, and/or intention or willingness to buy (Milakis & Müller, 2021: 4; Stilgoe & Cohen, 2021: 852; for an overview of this literature, see Becker & Axhausen, 2017; Nordhoff, Kyriakidis et al., 2019). Often, public trials with automated vehicles have been combined with surveys that evaluate passengers' attitudes towards automated vehicles (Dowling & McGuirk, 2022: 417; Hopkins & Schwanen, 2018b; Marres, 2020b; McDowell-Naylor, 2018), resulting in a series of scholarly articles that claim to represent the public's attitudes or the determinants for behaviour or intent to use (e.g. Dennis et al., 2021; Feys et al., 2021; Harb et al., 2018; Hilgarter & Granig, 2020; Kassens-Noor et al., 2020; Liu & Xu, 2020; Liu et al., 2019; Nesheli et al., 2021; Nordhoff, de Winter et al., 2019; Nordhoff et al., 2018; Xu et al., 2018). This conception of the public is not inconsequential.

The prevalent focus on individual attitudes towards automated vehicles, which is discernible in street trials, stakeholder documents, and scholarly work, suggests that technology developers and governments alike conceive the public primarily as a barrier (Milakis & Müller, 2021: 2; Stilgoe & Cohen, 2021: 850). This is not uncommon and may be said to reflect the expert-based discourse surrounding automated vehicles (Hopkins & Schwanen, 2018a: 13; Mladenović, 2019: 111; Mladenović et al., 2020: 250–251): as experts, and stakeholders more generally, consider the societal benefits of technology to be self-evident, the public and its attitudes necessarily represent a barrier to the proliferation of that technology (Milakis & Müller, 2021: 2; McAslan et al., 2021: 8; Schot & Rip, 1997: 264; Stilgoe & Cohen, 2021: 850–851). Negative attitudes towards innovations are often imagined to be irrational (Bauer, 2017; for examples, see Graf & Sonnberger, 2020: 68; Stilgoe, 2021: 638), which is reflected in the emphasis on education: by providing the public with 'unbiased information', it will be easier to realise the benefits offered by the technology (Acheampong et al., 2021; Jelinski et al., 2021). This image of the public also suggests that the public is unfit to participate in the shaping of technological futures (Mladenović et al. 2020: 252; Stilgoe & Cohen, 2021: 850). Rather, the proper initiatives and incentives must be implemented in order to relieve the public of its irrational attitudes towards emerging technology, and thus foster public acceptance. However, the notion of acceptance is characterised by some shortcomings, which are especially applicable when discussing the relationship between emerging technologies and the public.

As I have emphasised throughout this chapter, automated vehicle technology is still in its foundational stage (Mladenović, 2019; Stilgoe, 2018), as opposed to, for example, renewable energy (Batel et al., 2013) or information technologies (Venkatesh & Bala, 2008). Accordingly, different subsets of the public may differ in what they envision when consulted about their opinions and attitudes regarding automated vehicles (Cohen et al., 2020: 3; Pigeon et al. 2021; Raats et al., 2020). Therefore, it is unclear exactly what technological proposition the public is asked to accept or reject when their attitudes towards automated vehicles are being surveyed (Stilgoe & Cohen, 2021: 853). It is also unclear whether the individual automated vehicle is the proper unit of analysis: when considering the extent to which transport shapes our lives, and the extent to which automated vehicles are claimed to disrupt this order, it seems reasonable to assume that a future full-scale deployment of automated vehicles will usher in changes that reach far beyond the transport sector (Milakis et al., 2017; Mladenović, 2019). Hence, analysing the public's acceptance of automated vehicles as a clearly delineated technological object may lose sight of the bigger picture, namely the emergence of a sociotechnical system with a configuration that is still characterised by considerable uncertainty.

Due to the uncertainty surrounding automated vehicles, it may be preferrable to use the term acceptability rather than the term acceptance to describe the relationship between technology and the public (Stilgoe & Cohen, 2021). There is a subtle but important difference between the two terms, a difference that applies regardless of whether they are applied to individual or collective decisions (Pigeon et al., 2021; Fournis & Fortin, 2017). With acceptance, the public is asked to adopt or reject the technology in question, as well as any additional demands it might place upon individuals and/or society (for a relevant example, see Stilgoe, 2017). With acceptability, the relationship between technology and the public is inverted, such that the question is how, and perhaps even whether, the technology in question might be shaped to fit the public's needs, requirements, and/or desires (Stilgoe & Cohen, 2021: 853). Shifting the burden of adaptation from the public to technology also serves to frame the public as partaking in the shaping of the future, as opposed to the binary acceptance or rejection of technology that is often implied in acceptance studies (Barben, 2010: 279; Stilgoe & Cohen, 2021).

The development of automated vehicles tends to be framed as a series of technical problems to be solved, which has resulted in the depoliticisation of the surrounding innovation processes (Hopkins & Schwanen, 2018a; Milakis & Müller, 2021; Stilgoe & Cohen, 2021). Both the public and national governments tend to be cast in instrumental roles (Mladenović, 2019: 108; Stilgoe & Cohen, 2021: 853, 856): the public is expected to adopt the technology, whether wholeheartedly or reluctantly, whereas national governments tend to be cast in the narrow role of mitigating risks, adapting infrastructures, and maintaining public trust (Borrás & Edler, 2020; Cohen et al., 2018: 271; Milakis & Müller, 2021). This results in a distribution of tasks that allows technology developers to define the desirable modes of future implementation. However, there have been attempts at moving beyond this allocation of roles.

One approach to eliciting the public's views is public dialogues, in which members of the public are invited to discuss a particular technology. In reporting the results from two public dialogues on automated vehicles, Cohen and Stilgoe (2021) find that such an approach, executed with care, may help societal institutions to make sense of novelty (cf. Stilgoe, 2018), not least by challenging how policymakers view the public, as well as by exposing policymakers to the public's opinions on emerging technology. Additionally, the dialogues highlighted how policy agendas tend to cluster around the facilitation of innovation, whether through support or by enabling testing, rather than the potential roles of automated vehicles in a future transport system (Stilgoe & Cohen, 2021: 855–856). On the latter point, Dimitris Milakis and Stephan Müller (2021) suggest that research on automated vehicles should be expanded to include 'anticipatory analysis of desirable urban and transport futures exploring the role and societal implications of [automated vehicles] within those futures' (Milakis & Müller, 2021: 8). The emphasis on urban and transport futures rather than automated vehicle futures echoes the work of Robert Martin (2021), who also emphasises the prospect of planning for futures that might or might not contain automated vehicles, rather than futures that are defined by them (Chacra & Hanson, 2018). These are but two examples of participatory and anticipatory approaches.

Still, they are illustrative examples of how the governance of technology, such as automated vehicles, may be pushed past narrow, primarily technical framings in which members of the public are cast as passive recipients of technology.

While participatory processes may impact policy (Stilgoe & Cohen, 2021), they may simultaneously be vulnerable for both preformatting (McDowell-Naylor, 2018) and co-option (Cohen et al., 2018; Hopkins & Schwanen, 2018a). However, despite their potential shortcomings, participatory processes may serve an important function: by circumventing narratives of inevitability, such processes may allow us to 'reclaim technological futures as plannable space' (Mladenović, 2019: 110). By asserting the undecidedness of the future, one may also steer towards one particular future among many possible ones, rather than simply set course for the one that is claimed to be inevitable. This also allows for a politicisation of the future: rather than seeking an acceptance-based consensus, the issues surrounding the development and future deployment of automated vehicles may be explored in detail, in order to gain a better understanding of who will be impacted by these processes, who stands to gain from them, and what societies these processes might possibly result in (Marres, 2020b: 128; Mladenović, 2019: 110; Mladenović et al., 2020: 257–258; Milakis & Müller, 2021: 8). However, such an exploratory approach may not seem viable as long as members of the public continue to be cast in the role of passive recipients, irrational opponents, and/or self-interested users, customers, or consumers of technology.

3.8 A summarising note

The purpose of this chapter is two-fold. The literature discussed in Sections 3.1–3.3 is meant to establish the fundamental understanding of automated vehicles that informs this thesis. Specifically, those three sections establish that automated vehicles are not, and have never been one specific sociotechnical artefact. Rather, automated vehicles are best understood as part of a sociotechnical system, a system whose characteristics, including both benefits and downsides, have yet to be ascertained. Furthermore, those characteristics cannot be ascertained beforehand, because they will be the outcome of current and future societal choices.

The literature discussed in Sections 3.4–3.7 summarises several important discussions relating to automated vehicles. Why do nations seek to facilitate the development and implementation of automated vehicles? How do representations of automated vehicles shape our expectations for such vehicles? How do innovation practices influence the shape of future automated vehicles and the surrounding system, and how do these innovation practices relate to society more generally? How can and should automated vehicles be governed, and what role should the public play in the development of automated vehicles? These are important questions that are addressed both in the articles that make up Part B and in the overarching discussion in Part C.

Chapter 4: Methods

In this chapter, I reflect upon the methods I have used to generate the data that this thesis and the three articles are built upon, and my strategies for analysing these data. First, I explain the research design and the reasoning behind deciding on the three case studies upon which this thesis is built. Second, I elaborate upon the interview as a method for data generation, including both practical and epistemological reflections. Third, I discuss observation as a method, including its usefulness in studying emerging sociotechnical arrangements. Fourth and finally, I elaborate upon my analytical strategies, including the analysis of interview data and documents, and the development of the cross-cutting analysis.

This thesis is firmly grounded in a constructivist view of knowledge and knowledge production. In my view, methods are generative tools: by describing reality in a certain manner, that reality is produced (Law, 2004: 143). Rather than a set of procedures used by researchers to access some deeper social truth underpinning everyday reality, methods are inevitably part of the same reality they describe (Silverman, 2014: 184). Reality is also a consequence of scientific description (Latour & Woolgar, 1986), meaning that researchers generate reality through the conclusions they draw (Voß & Simons, 2018). This suggests that methods are performative, and that this thesis cannot be separated from the methods that have helped to produce it. Hence, to justify conclusions set forth in this thesis, a closer look at the methods I have used is warranted.

4.1 Research design

The articles within this thesis were developed within the framework of a larger research project, 'Digitalization of the road sector and its consequences' (DRIVERS). As the name indicates, this project has sought to understand what consequences an increasing degree of digitalisation (here, taken to include automation) is expected to have for road transport. Within DRIVERS, I have participated in activities for which the output has not been directly employed in the three articles, including supplemental interviews, industry visits, and stakeholder workshops, but which nonetheless have informed my understanding of the overall field of road transport. During the course of the project, my research interest expanded slightly: from being primarily interested in the futures supposedly enabled by automation and digitalisation, I also became quite interested in alternative, non-technological visions for the future of transport. As a result, this thesis revolves around three quite different case studies.

4.1.1 Case studies

This thesis builds upon data collected in relation to three case studies: Forus Shuttle, Borealis, and Car-free City Life. The first case, Forus Shuttle, concerns the first test of an automated vehicle on a Norwegian public road following the implementation of newly developed regulations. The second case, Borealis, revolves around the testing of digital infrastructures along a stretch of public road in Northern Norway. The third and final case, Car-free City Life, concentrates on an attempt at establishing a car-free centre in Oslo, Norway's capital. In this section, I discuss the logic behind the choice of cases.

A case study may be defined as an attempt at studying real-life phenomena in their context, especially in cases where the boundaries between the phenomena and the context appear permeable and/or unclear (Creswell, 2007: 76; Yin, 2003: 13–14). As indicated in the preceding chapter, the increasing prevalence of pilot projects being conducted in public has helped to blur the lines between phenomena and their context (Engels et al., 2019; Marres & Stark, 2020; Ryghaug & Skjølsvold, 2021). This suggests that a case study approach is well-suited for studying such pilot projects (Schofield, 2000: 81f), whether they focus on automated buses, new technologies for intelligent transport systems, or car-free city centres. Due to their open-ended nature, case studies allow for the distinction between a phenomenon and its context, or the lack thereof, to become an empirical question, rather than a question of preconceived notions of, for example, scale or category.

When using multiple case studies, the researcher is faced with two options: choosing similar or disparate cases (Creswell, 2007: 74). By choosing similar case studies, one can facilitate comparability, for example by studying multiple pilot projects with automated buses (Lervåg, 2020). This may also allow for drawing conclusions that cut across the various cases, as well as for identifying what might be effective in particular situations

(Yin, 2003: 47f). By contrast, choosing disparate cases allows for illuminating a topic from different angles (Creswell, 2007: 74). Such an approach may be particularly beneficial when studying emergent phenomena, whether they are still mere prospects (Schofield, 2000: 81–84) or in the process of coming into being (Latour, 2005: 80f), as such phenomena often take on different guises, depending on their context (Schippl & Truffer, 2020). Hence, to study attempts at using new technologies to transform sociotechnical arrangements within road transport, I chose three disparate case studies.

To point out a case study is also to make a claim (Walton, 1992: 121). In general, a case study is chosen based on the presumption that it is in some manner appropriate for illuminating the topic at hand. This also applies to the three case studies treated in this thesis, which were all chosen for particular reasons. The first two case studies, Forus Shuttle and Borealis, were chosen due to ostensibly being rather different expressions of a digitalised and automated road transport sector. Forus Shuttle was chosen due to being the first pilot project with automated buses on Norwegian public roads. Borealis was chosen because of the emphasis on digital infrastructures, as well as its interesting choice of location. However, their connection to Car-free City Life might not be obvious and therefore some justification is necessary.

I chose Car-free City Life as a case study after having studied the two other cases. I found it fascinating that regardless of the problems in question, new technologies were posed as the solution. However, lurking at the edges of these cases were other means for addressing the same problems, whether currently available technologies or organisational principles. Therefore, I began searching for a case that would complement the two technology-centred cases. Car-free City Life soon stood out as a case of interest, due to the considerable controversy surrounding an effort to remove car traffic from the city centre of Oslo. I was curious as to why this project had aroused national interest, when the organisers were merely using traditional urban planning tools for transforming a rather small geographical area. Hence, I chose the case study to contrast with the technology-focused projects Forus Shuttle and Borealis.

Some scholars suggest that case studies are best chosen by first developing a theoretical framework that establishes where a phenomenon is most likely to be found (Yin, 2003: 48). However, as the projects used for my case studies revolve around emerging sociotechnical arrangements, the establishment of such a framework might mean imposing pre-established models of explanation onto phenomena for which the categories, connections, and causalities have yet to be established (Latour, 1996; Silverman, 2014: 245). Hence, my case studies were chosen using a bottom-up approach, in which the case studies reflected my research interest rather than a pre-established framework.

The purpose of this thesis and the accompanying articles has not been to generalise, understood here in the strict sense of finding universal laws that would apply to any comparable situation (Gubrium & Holstein, 1997: 12–13; Silverman, 2014: 58f), nor has it been to provide an objective, replicable view of the three cases I have studied. However, this is not to say that there is nothing to be gained from these three case studies beyond their immediate context. Rather, the findings presented in the articles and this thesis may still 'be used to speak to or help form a judgment about other situations' (Schofield, 2000: 76). The insights presented throughout this thesis (a) can illuminate the cases in question, (b) relate the cases to established dynamics within innovation policy and sociotechnical change, and (c) help to develop an analytical repertoire that may elucidate similar cases in the future (Schofield, 2000; Walton, 1992: 135; Yin, 2003: 38).

The reflections throughout this chapter are necessarily a retrospective account of my methods and analytical strategies. While I kept notes throughout the research process, the retelling of that process appears tidier than it really was. Throughout the research process, I was unable to enlist interviewees of interest (due to clashing schedules, lack of response, and lack of contact information), interviews were shorter than I would have preferred (again, due to schedules), and I spent less time doing observations than I would have preferred, to mention some limitations. Hence, the case studies presented throughout the three articles represent a partial view, as they are based on a limited set of interviews, observations, and documents. However, as discussed above, the cases were chosen for specific and thought-through reasons, and thus I contend that the data generated around the cases and the resulting analyses are a good fit for elucidating the topic at hand.

To summarise, this thesis is based on a multicase study approach in which the purpose has been to explore emerging sociotechnical arrangements within road transport. With the three case studies, I have sought to understand the potential emergence of new sociotechnical arrangements from the bottom-up: how do the three cases connect to broader developments and tendencies in Norwegian society, and how can they help us make sense of attempts at instigating sociotechnical change in the transport sector, and perhaps even beyond? In my attempt to answer these questions, I do not claim to describe some pre-existing reality in perfect detail (Law, 2004). To make such a claim would be hubris, considering that the thesis builds upon data material that is necessarily partial.

4.2 Interviews

The primary method used for generating data for this thesis and the associated articles was research interviews (for a full overview of the methods used in each case, see Table 4.1). In total, the thesis builds upon twenty-nine interviews conducted across the three case studies. I conducted twenty-five of the interviews, either alone or together with one or two colleagues (for a detailed overview, see Appendix A). The remaining four were conducted by a colleague without me present. Interviewees were sought in two ways: first by searching for actors who appeared central in the projects in question, and then by having those interviewees suggest other potential interviewees. For the case studies underpinning this thesis, this strategy worked relatively well. However, the strategy (i.e. the snowball method) is characterised by a certain shortcoming. By choosing such a method of recruitment, the range of interviewees may be limited to those deemed relevant by the initial interviewees, thus potentially excluding relevant actors or groups (Rapley, 2004: 17). To some extent, it is possible to counter this shortcoming by, for example, selecting initial interviewees from a diverse pool.

Table 4.1: List of method(s) by case

Case	Method(s)	Collection period
Forus Shuttle	Interviews (n=11) Documents (n=62) Observations	Nov.–Dec. 2018
Borealis	Interviews (n=8) Documents (n=7) Observations	Feb.–Jul. 2019
Car-free City Life	Interviews (n=10)	Jun.–Nov. 2020

The purpose of the interviews was to understand the dynamics of the pilot projects in question. Hence, there was not necessarily a diverse pool of interviewees to choose from, as such projects encompass a limited number of people. The first interviewees were recruited based on the assumption that they were important persons in the case at hand (Bogner & Menz, 2009). Subsequent interviewees were pointed out by the initial interviewees, suggesting that they were considered important and influential persons relative to the project. Hence, even if I was not able to recruit all of the interviewees that were suggested, this still indicates that the interviews I conducted focused on people who the initial interviewees *assumed* were able to influence social realities. As the main focus of my research was emerging technologies and associated practices, many of the selected interviewees held certain positions, in which they acted in a political or professional capacity. As such, many had been deeply involved in relevant processes and/or possessed certain technical know-how. In short, the interviewees might be termed experts.

The concepts of expert and expertise were long taken for granted in the methods literature. This caused a conflation of different conceptions of experts. The voluntaristic conception of the expert states that we are all experts, in the sense that we all possess specialised knowledge about *something*. In contrast to this flattened conception of the expert, the constructivist conception of the expert argues that expert status is relational. Experts are people who, within the social environment in which they operate, are considered to possess specialised knowledge. As such, they also tend to hold relatively important societal positions (Bogner & Menz, 2009; Grundmann, 2017). As opposed to the voluntaristic concept of the expert, the constructivist concept more clearly acknowledges the power associated with expertise. However, both conceptions tend to treat expertise in the same manner, as a special kind of knowledge that can be clearly discerned from subjective viewpoints.

Analytically, it is possible to discern expert knowledge from subjective views. For example, one might distinguish between technical knowledge, process knowledge, and interpretative knowledge (Bogner & Menz, 2009: 52). Such an analytical distinction may be useful when attempting to reconstruct the exact content of expert knowledge. However, when studying what experts *do*, the distinction between different kinds of knowledge break down. Experts seldom exert influence through professional knowledge alone. Rather, it is by combining different kinds of knowledge – technical, process, and interpretative knowledge – that the actions of experts have practical effects (Bogner & Menz, 2009: 52).

A prime example of how experts combine different kinds of knowledge can be seen in Callon's study of French automotive engineers (Callon, 1987). In the process of developing an electric vehicle, the engineers did not merely conceive a technical design for the vehicle, but by extrapolating from current developments in French society, they also envisioned the future society in which such a vehicle would be functional. Hence, Callon came to refer to them as 'engineer-sociologists': their concept of an electric vehicle relied as much upon sociological analysis as it did on engineering expertise, thus highlighting how various kinds of knowledge are combined in innovation processes.

In my interviews, I chose an approach similar to that of Callon's: rather than seeking to reconstruct expert knowledge or to establish an exact and incontrovertible timeline, I sought to understand the 'subjective action orientations and implicit decision making maxims of experts' (Bogner & Menz, 2009: 48). Hence, in my interviews and the subsequent analysis, I focused on how the interviewed experts acted, how they justified their actions, and how they imagined their actions to facilitate and/or produce change, regardless of whether the actions were based on technical, process, and/or interpretative knowledge.

In the preceding paragraphs, I have used the term 'generating data' rather than 'gathering data' or 'collecting data' to imply my epistemological stance. I do not ascribe to 'the archaeological model of the interview' (Bogner & Menz, 2009: 55), in which the researcher is considered a neutral conduit for the collection of naturally occurring data. Rather, I consider the research interview is a process in which data are co-constructed (Dingwall, 1997; Holstein & Gubrium, 1997): interviewers and interviewees jointly produce an understanding of the topic at hand. This means that that the resulting data material is one among many possible representations of reality, rather than an accurate, indisputable retelling of events that have transpired (Rapley, 2004; Silverman, 2014).

4.2.1 Digitalisation of the interview and its consequences

In addition to in-person interviews, several of the interviews were conducted by phone or by using video conferencing software (i.e. Microsoft Teams, Zoom), for two reasons. The one phone interview in relation to Forus Shuttle was done for practical reasons: the interviewee was not able to meet me during my stay in Stavanger. All interviews in connection with the Car-free City Life were conducted using video conferencing software. As with the phone interview, this was also a pragmatic choice, albeit made for entirely different reasons: the COVID-19 pandemic was sweeping the globe, thus precluding travel and face-to-face interviews.

In general, phone interviews are considered an acceptable substitute for face-to-face interviews (Creswell, 2007: 132–133), insofar as they can provide access to interviewees who otherwise would not be available, whether because of spatial proximity or for other reasons. The prime interest in qualitative research lies in the interviewee's verbal responses, and barring an excessively poor phone connection, these are retained during a phone interview. However, communication does not depend exclusively on the words that are used. With phone interviews, one loses the non-verbal dimension of communication, such as facial expressions, eye contact, and body language (Gillham, 2000: 30f). Still, in general, phone interviews can be expected to yield results similar to those obtained through face-to-face interviews, even in qualitative settings (Sturges & Hanrahan, 2004). This, too, is my assessment of the one phone interview that I held.

As with the phone interview, the use of video conferencing software comes with particular benefits and challenges: whereas one might (and I indeed did) encounter technical issues, such as unstable Internet connections and poor sound quality, such software comes with the benefit of added access and, if needed, anonymity (V. Braun et al., 2017). In my case, the purpose of using video conferencing software was primarily to gain access to interviewees in an extraordinary situation, and then to mimic the characteristics of in-person interviews as far as possible. As an added bonus, the fact that most interviewees participated from their homes rather than their offices was sometimes generative in itself: for example, in one interview, the sudden entrance of a partner carrying a set of car keys sparked a conversation about the urban–rural divide with regard to car use. This points to the localised, collaborative, and sometimes contingent nature of the interview as a method (Rapley, 2004: 16).

The purpose of the above discussion is not to argue that phone or video conferencing interviews are an entirely satisfactory substitute for face-to-face interviews. Although they replicate the foundational aspect of the qualitative research interview – a verbal back-and-forth between interviewer and interviewee – some aspects are lost, even when discounting for the lack of non-verbal communication. When an in-person interview is conducted at the interviewee's workplace, it will also give the interviewer a glimpse of the physical organisation of the company or institution at hand. It also gives the interviewees the possibility of mobilising various materials to illustrate or substantiate the company's or institution's points of view. For example, during the interviews relating to Forus Shuttle, the interviewees drew upon materials such as maps, technology blueprints, and transport simulations.

Regardless of whether interviews are conducted in person, over the telephone, or via video conferencing software, they will be characterised by certain limitations. Whereas the interview produces a setting in which the interviewer (or interviewers) and interviewee (or interviewees) collectively attempt to make sense of the topic to be explored (Gubrium & Holstein, 1997: 53f; Rapley, 2004), the data co-constructed throughout the interview do not always coincide with observable reality. Hence, it may be useful to supplement interviews with additional methods, such as observations.

4.3 Observing emerging technologies

In two of the case studies, Forus Shuttle and Borealis, the interviews were supplemented with observational methods. These were not of such a nature or duration that they could be described as ethnographies. However, the use of observation was still important in shaping my understanding of the case studies and thus warrants discussion.

The purpose of using observation as a method is to explore the dynamics of particular social phenomena in the context in which they 'naturally' occur (Gubrium & Holstein, 1997b; Kawulich, 2005). This allows for studying what people do, rather than having them construct their actions (often internalised and routinised) from memory. From a constructivist point of view, this is not inconsequential. As established in Section 4.2, attitudes, interpretations, and narratives are meaningful because they guide action, regardless of whether they reflect reality. Actions are meaningful because they help to construct social realities (Gubrium & Holstein, 1997b: 38f; Silverman, 2014: 266), regardless of whether those actions repeat, reiterate, or rupture established social realities (Latour, 2005).

In the two cases in which interviews were supplemented with observational methods, Forus Shuttle and Borealis, my colleagues and I took on the role of partially participating observers (Ciesielska et al., 2018: 40). While we were not directly involved in the work that was ongoing at the two sites, we engaged in direct observation and were free to inquire about the project in question. This allowed us to pose clarifying questions, as well as to observe emerging sociotechnical arrangements in action. In combination with interviews, this approach resulted in inconsistent and even contradicting accounts of the project in question. This is not to say that the interviewees attempted to deceive us, but that the observations suggested that their accounts were unreliable. Rather, the different methods produced different views of reality, views that cannot necessarily be combined to form a unified narrative (Law, 2004). In the following paragraphs, I present two examples in which the information gained from observations and interviews combined in curious and surprising ways.

In the case of Forus Shuttle, I visited the public test site with a colleague. We chose to travel on the bus as passengers in order to (a) experience how it felt to be a passenger on a bus that ostensibly navigated the road without driver input, and (b) gain an impression of the nature of the interaction between the bus and other motorists. Our trips on the bus were combined with unstructured interviews with the bus operator (on conducting research in cars, see also Dahl & Tjora, 2021), which turned out to be productive.

In the interviews relating to Forus Shuttle, the interviewees tended to emphasise how the automated bus would operate on its own accord. However, our trips on the bus painted an entirely different picture. Whereas, in general, the bus was able to propel itself without any input, it soon became obvious that the bus operator played an important role in managing the bus, both in terms of ascertaining its technical functioning and in managing the relations between the bus, passengers, and motorists (for a similar example, see Both, 2020).

By choosing to ride the bus in addition to talking about it, my colleague and I saw more than the operations of a purportedly automated bus. We gained first-hand experience of the strange and slightly disquieting feeling of riding on a bus without a driver, a feeling that was also surprisingly transitory.[1] In addition, we had the opportunity to see the rag and detergent spray used by the operator to clean the bus's sensors, we experienced the bus's on-board computing system having to be entirely rebooted, and we saw the bus operator shifting to manual controls to circumvent an illegally parked vehicle. In short, the trips on the bus attuned us to the manual work necessary to keep the bus in operation.

The combination of fieldwork and interviews was productive also in relation to Borealis. Before my colleagues and I visited the test site, a video on the Norwegian Public Roads Administration's website had piqued our interest. The video showed three trucks driving across a changing landscape in Northern Norway. A narrator described how the foremost truck controlled the acceleration of all three trucks through digital coupling, termed platooning. Later in the video, images of the trucks were cross-cut with short interviews that described the expected benefits of the technology.

Upon visiting the Borealis test site, we were granted access to a control centre erected on the roadside. From there, we were able to watch the project partners survey the data gathered from a variety of sensors installed in and around the road. However, the platooning technology was nowhere to be seen. As the day drew to a close, we were invited to attend an internal project meeting, in our capacity as researchers, yet still there was no trace of platooning. The next day, we interviewed one of the NPRA engineers and inquired about the platooning, only to be told that it had been a promotional stunt (the implications of this exchange are discussed in more detail in Article 1). As with the Forus Shuttle example, our presence at the test site prompted us to ask questions we might not otherwise have asked.

The above-mentioned examples point to the potential usefulness of combining interviews with fieldwork when researching emerging technologies. Even rather short

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[1] In recounting his first experience with Tesla's Autopilot, Stilgoe (2017) describes the technology as 'magically exotic' while also noting 'how unnerving it is to sit, hands hovering above the wheel, foot floating next to the pedals, while [the] car steers itself at high speed' (Stilgoe, 2017: 2). His recollection seems to reflect the simultaneously electrifying and terrifying affects associated with the technological sublime (Hildebrand, 2019), affects that were aptly encapsulated in my initial experience with the automated shuttle bus.

field visits may be productive, as they may reveal details that might not have crossed the interviewees' minds in an interview setting, or they may prompt new lines of inquiry for later interviews. Although the actual functioning of emerging technologies is often stage-managed (Forlano, 2019; Marres, 2020a; McDowell-Naylor, 2018), a combination of methods may highlight the difference between frontstage and backstage presentations of the technology (Ciesielska et al., 2018: 35). In this manner, observation can offer a useful corrective or elicit an alternative view of the technology in question and the work necessary to make it function or appear to function.

In addition to site visits, I also attended three events organised by ITS Norway: the ITS Arena events in April 2019 and October 2020, and ITS Konferansen in December 2020. I attended the first event in person, the latter two were digital events due to the COVID-19 pandemic. ITS Norway is a member association with the goal of promoting and fostering the development of intelligent transport systems in Norway. The association has ca. 80 member organisations, and regularly organises meetings that convene members from public agencies, universities, and businesses. These meetings may be considered field-configuring events (Lampel & Meyer, 2008; for an analysis that fruitfully incorporates such events, see Liao, 2018), which are arenas where a varied set of actors can meet to discuss and coordinate the development and organisation of new technologies (in this case, intelligent transport systems). As such, the events provided further insights into the strategies, as well as the discussions on automated vehicles and related technologies in Norway.

4.4 Analysis

The article-based organisation of this thesis means that the thesis consists of two levels of analysis: the cross-cutting essay, which is spread across Part A and Part C, and the three articles making up Part B. The three articles represent the first level of analysis. When writing the articles, I conducted an analysis of the first-hand data material described above. The summarising essay represents the second level of analysis. In this essay, I use the three articles as a basis for analysis, and by doing so, synthesise findings to draw out more overarching insights regarding emerging sociotechnical configurations in the transport sector, and perhaps beyond. The two levels of analysis warranted different analytical strategies, which I elaborate upon in the remaining part of this subsection.

4.4.1 Analysis of interviews

When conducting interviews, I sought to elicit the interviewees' worldviews (Bogner & Menz, 2009). However, it would have been moot to co-construct rich data material if I then immediately turned to existing theories and/or models of explanation to describe the data (Silverman, 2014). Hence, when analysing the interview transcripts, I opted for an approach inspired by grounded theory (Charmaz, 2006).

I began my analysis by reading the transcribed interviews and assigning a code to every sentence. The codes were descriptive: they summarised the content of the coded segment, ideally phrased as an action (Charmaz, 2006: 47f). Codes can be applied word-by-word, line-by-line, segment-by-segment, among other ways, and the granularity of segments may vary. In general, I opted for line-by-line coding, whereby I ascribed a code to every sentence of the transcribed interviews. However, in some instances, increased granularity was warranted. For example, one sentence was first assigned the code 'argues that immature technologies are associated with irritation and frustration'. However, in the same sentence, a particular characteristic was ascribed to the technology in question ('immature'), a characteristic that was further connected to affective characteristics ('irritation', 'frustration'). Hence, to retain both the assessment of the technology and the affective characteristics ascribed to it, I supplemented sentence-by-sentence coding with word-by-word coding. However, such dual coding was generally reserved for instances in which interviewees used unorthodox words or phrases, or in which they made surprising connections.

After finishing the initial coding, I considered how the codes might be combined into more overarching categories. For example, the code 'argues that immature technologies are associated with irritation and frustration' became part of the more abstracted category, together with other codes, such as 'assumes that automated buses will follow the successful trajectory of the internet', 'argues that the company should engage actively with new technology', and 'describes the project as the first step in an inevitable success story'. The aforementioned four codes, and others like them, had a common theme: words such as 'trajectory' (including 'successful trajectory'), 'new', 'immature', and 'first step' all imply both temporality and expectations. As such, they were aggregated into the code 'expected developments'. The same strategy was used for all other initial codes, in order to aggregate a set of codes that would form the basis for subsequent theoretical coding (Holton, 2010).

Finally, I explored the connections between the aggregated codes, in order to conceptualise their interrelation. For example, the codes 'expected developments' and 'experience and attitudes' tended to turn up in relation to one another. When returning to the interview transcriptions, it seemed clear that the interviewees considered experiences an important aspect of sociotechnical change. Regardless of the exact experience described by the interviewees, whether they concerned pensioners testing automated buses, motorists being slowed down by the same bus, or citizens experiencing a car-free environment, they all connected experiential aspects to changes in attitude. By comparing the data contained under the aggregated codes, I arrived at the two differing approaches to sociotechnical change that are explored in Article 3. Hence, the strength of my analytical approach lay in the process of moving from the descriptive to the conceptual.

As should be apparent from reading the three articles in this thesis, they all draw upon established theoretical frameworks, such as sociotechnical imaginaries (Jasanoff & Kim, 2009, 2015) and the sociology of expectations (Borup et al., 2006). However, the point of my analytical strategy was never to avoid such frameworks entirely, but rather to avoid employing them prematurely. While I approached the data material with an open mind, I often saw similarities between codes, their interconnections, and existing theoretical frameworks. Hence, it made sense to draw upon those frameworks. However, this does not mean that they were adopted wholesale. In some instances, such frameworks ran counter to my findings. In those instances, I did not adapt the data to fit with the existing framework, but instead suggested an alternative interpretation or an extension of the framework. For example, in Article 1, I argue that sociotechnical imaginaries do not necessarily progress linearly throughout the phases sketched by Jasanoff (2015b).

4.4.2 Analysis of documents

For Articles 1 and 2, I analysed a series of documents in addition to interview material. The analytical strategies applied for the two sets of documents were similar. For Article 1, I first used the search engine on the Norwegian Government's website to find government documents that referred to automated vehicles (search terms: '*selvkjørende*' [self-driving], '*autonom**', [autonomous], '*automatisert**' [automated], and '*førerløs*' [driverless]). Additionally, I included documents that were either produced on behalf of the Government or developed by government agencies such as the Research Council of Norway and the Norwegian Public Roads Administration. As described in Article 1, most of the documents simply referenced automated vehicles in passing. Those documents were omitted from the analysis. I read the remaining documents in detail, focusing on the benefits ascribed to automated vehicles (in the transport system and beyond), and how the Government and underlying agencies had sought to facilitate their emergence.

For the analysis of consultation responses discussed in Article 2, my co-author Tomas Moe Skjølsvold and I read each of the 62 responses in detail. Thereafter, we noted the different arguments that were made regarding the question of whether testing of automated vehicles should be allowed on Norwegian public roads. We noted the argument or arguments in each of the responses, and subsequently sorted them into overarching categories, such as technology development, data protection, privacy, safety, and responsibility. This allowed us to observe how the responses clustered around certain issues while other, equally important issues remained marginal (Asdal, 2008; Marres, 2007). Hence, through the analytical strategy, we saw how particular subsets of the public helped to shape the legal framework for testing automated vehicles.

4.4.3 Cross-cutting analysis

For the cross-cutting analysis, I approached the three articles (i.e. that form the empirical basis of this thesis) anew, treating them as data material. I read all three articles in detail, combing through the findings and arguments to identify what the articles had in common, where they intersected, and how the insights presented in the individual articles might be combined into an overarching argument. I then turned my attention to what actors were present, what dynamics they described, how the various projects connected to other initiatives, how different scales and temporalities interacted, how the projects related to local and national contexts. The purpose of the cross-cutting analysis was to discuss the three articles in a larger context. Accordingly, the format of the summarising essay is more of a discussion. As my starting point, I take the arguments as they are formulated in the three articles and ask what further conclusions can be drawn from the articles.

Part B: Articles

Article 1:
Changing oil: self-driving vehicles and the Norwegian state

Published as:

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Abstract

Expectations regarding the imminent arrival of self-driving vehicles has prompted nations to embed such vehicles in policy and explore their potential through pilot projects. The article analyses interviews and document to explore the politics of self-driving vehicles in Norway. Using sociotechnical imaginaries as a theoretical starting point, the article finds that Norwegian policy and legislation frame self-driving vehicles in rather general terms, primarily citing expected economic gains and prospects of improving the transport sector. When these policies were operationalised in the transport innovation project Borealis, the Norwegian Public Roads Administration grafted the policies onto distinctively Norwegian use-cases: self-driving vehicles and associated infrastructures were envisioned to benefit the Norwegian fishing industry, have ramifications for standardisation work within the European Union, and possibly foster a Norwegian high-tech industry. The prospect of a high-tech industry links self-driving vehicles to the green shift, a collectively imagined future in which the Norwegian petroleum industry has been phased out and replaced by 'greener' industries. In sum, self-driving vehicles are mobilised both as a desirable transport innovation and as part of a national narrative: through innovation relating to such vehicles, Norway might be able to phase out a petroleum-reliant economy while remaining an affluent nation with high levels of social welfare.

1 Introduction

In May 2018, three freight trucks could be seen thundering across the snowy landscape of Northern Norway. The trucks navigated the winding roads while maintaining equal distances between them. While a driver was present in all three vehicles, the drivers in the two hindmost trucks were merely keeping their hands on the wheel. The three trucks were connected through 'advanced radar and camera technology', which allowed the driver in the lead truck to control the acceleration and braking of all three trucks.[1] The event marked Norway's first demonstration of *truck platooning*—the digital coupling of the acceleration and deceleration of multiple trucks in a convoy. The occasion for the demonstration was the opening ceremony of the Borealis project, which is funded by the Norwegian Public Roads Administration (NPRA). In this project, the NPRA has fashioned a 40 kilometre (km) stretch of public road (Fig. A1.1c) into a site for testing intelligent transport system (ITS) technologies in an arctic environment.

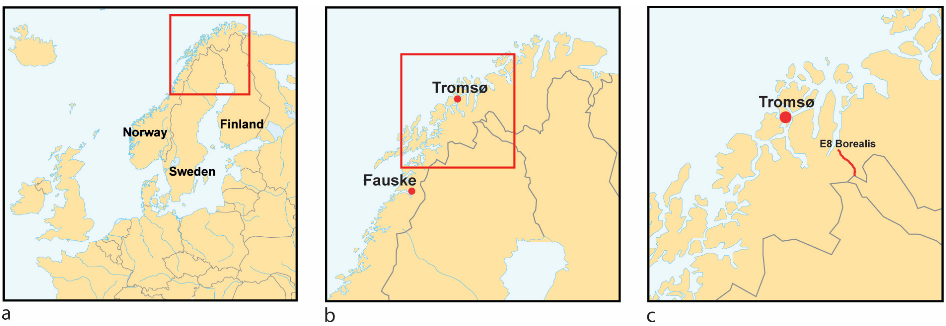

Figure A1.1*: Location of the Borealis project.* ***a*** *Norway's placement in Northern Europe.* ***b*** *The terminal points of the proposed Northern Norway railway line.* ***c*** *The location of the Borealis project (© Kartverket under a CC BY 4.0 license, modified by the author).*

In April 2019, Erna Solberg, Prime Minister of Norway and leader of the Norwegian Conservative Party, visited the city of Tromsø, where she was interviewed by a journalist from the local newspaper *iTromsø*. One of the predetermined topics for the interview was transportation, which was introduced with the question 'How's our railway coming

[1] My translation. The quote is from a video on the Norwegian Public Roads Administration's website at https://www.vegvesen.no/Europaveg/e8borealis/nyhetsarkiv/forste-test-pa-norske-veger (accessed 21 January 2020).

along?' The railway in question is a long-desired railway extension from Fauske to Tromsø (Fig. A1.1b), an extension that has been envisioned for nearly a century. Solberg responded by first referring to a committee investigating the possibility of extending the railway northwards, before making into the following statement:

> We are approaching a digitalised revolution, where we will have autonomous bus systems, cars, interconnected systems. [...] Fish, for example, will probably never be transported heavily along the railway in the future, which is one of the justifications people have offered [for building the railway]. Rather, [fish] will be transported in tightly interwoven trucks that are autonomous, trucks that employ systems where there is not even a driver and will drive twenty-four hours of the day within such a system. There is a high probability we will have this in twenty to twenty-five years. Any railway would take the same time to build.[2]

Solberg's statement is not unique. Expectations to self-driving vehicles have been growing since the late 2000s (Stilgoe, 2018). Whether due to the prospect of reduced emissions of climate gases, a safer road transport sector, or a reduction in automobile-related land use (car parks, roads), self-driving vehicles are commonly framed as an inevitable development (Legacy et al., 2019: 98) capable of ushering in dramatic changes within the road transport sector (Milakis et al., 2017; Duarte & Ratti, 2018). Still, there is considerable uncertainty associated with the development and implementation of self-driving vehicles. By steering toward this particular though uncertain future of road transport, other possible transport futures are given lower priority. As technological propositions are always value-laden (Winner, 1980), the prioritisation of one particular transport future also represents the subordination of alternative ways of envisioning and organising a future society.

Together, the two introductory vignettes outline visions for a future when advances in transport technology will allow for new ways of organising the freight and public transport sectors. In this article, I investigate the relationship between society and the emerging technology of self-driving vehicles through the lens of sociotechnical

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[2] My translation. The full video stream (in Norwegian) has been made available for *iTromsø* subscribers at: https://www.itromso.no/pluss/eksklusiv/2019/04/30/Her-kan-du-se-iTroms%C3%B8s-folkem%C3%B8te-med-Erna-Solberg-p%C3%A5-Skarven-18925419.ece (accessed 7 January 2020).

imaginaries (Jasanoff & Kim, 2009, 2015). This framework concerns the tight-knit relationship between politics and technoscience in contemporary societies and is thus a suitable tool for exploring the role envisioned for self-driving vehicles in Norwegian society and how innovation projects are configured to realise this role. In applying the framework to the case of self-driving vehicles, I address the following questions: What future is envisioned in Norwegian policy and legislation pertaining to self-driving vehicles? How is the envisioned future operationalised and/or altered by actors working in the field of transport automation? How does this future relate to Norwegian policy and society more broadly?

The remaining part of this article is structured as follows. First, I expand upon the framework of sociotechnical imaginaries, which provides the theoretical basis for this article, before elaborating on some important 20th century developments in Norwegian society. Thereafter, I present my methods. In the analysis, I start by focusing on how self-driving vehicles are described in Norwegian government literature and then focus on the Borealis project as an operationalisation of the government policies. In the subsequent discussion, I explain how the Norwegian policies for self-driving vehicles relate to Norwegian society, and thereafter present my conclusions.

2 The pursuit of innovation

As this article investigates the relationship between Norwegian society and an emerging technology, I have chosen the framework of sociotechnical imaginaries (Jasanoff & Kim, 2009, 2015) as a theoretical starting point. Jasanoff (2015a: 4) defines sociotechnical imaginaries as 'collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology'. Put another way, this concept exhibits an interest in how individuals and/or organisations mobilise resources to establish support for a future they envision as possible through advances in science and technology. This includes an interest in the means that are mobilised to elicit support, such as the manner in which the institutionalisation and public performance of such a future helps to propagate and further consolidate an imaginary.

Jasanoff (2015b) suggests there are four phases in the life of a sociotechnical imaginary: origin, embedding, resistance, and extension. *Origin* describes from whom an imaginary originates, whether from individuals or groupings, political or otherwise. While imaginaries might originate in an individual's or group's vision of a possible world, an imaginary needs to be *embedded* within existing social, economic, and material infrastructures in order to gain traction. This might entail playing to a nation's collective memory or widely accepted models of innovation, as well as producing objects and infrastructures. In processes of embedding, *resistance* might arise. Whereas proponents of an imaginary see its merits, other groups might disagree and oppose the imaginary. Finally, a successfully embedded imaginary might be *extended*, for example by being supported over a protracted period or expanded through new institutional jurisdictions or spatially defined domains.

There is an increasingly common tendency for governments to view technological innovations as the pathway toward a desirable future. As evidenced by the recent increase in innovation strategies for cities, regions and nations, innovation appears to have become institutional shorthand for social progress and economic development (Pfotenhauer & Jasanoff, 2017a). This in turn has led nations to seek out or replicate more or less formalised models of innovation to enable a certain type of development (Pfotenhauer & Jasanoff, 2017b). However, until recently the success or failure of such models has often been attributed to how well (or not) the model has been implemented. Such a view ignores the fact that nations have pursued innovation for various reasons, for example to exhibit economic and scientific leadership, to elicit external aid, or to ensure national security (Pfotenhauer & Jasanoff, 2017a). These examples illustrate how innovation is tied to the past as well as the future: when articulating a desirable future, one also identifies contemporaneous challenges to be solved and the past causes of these challenges. Thus, to understand better the role of self-driving vehicles in Norwegian policy, let us examine Norway's past with respect to innovations and economic development and one collectively imagined future which relates to this past.

3 In a collaborative mood: Norwegian economy and innovation

Throughout the 20th century, Norway underwent a radical economic transformation. In 1870, Norway's gross domestic product (GDP) per capita was three-quarters of the Western European average, but by the early 2000s, the Norwegian GDP per capita had increased to 25% *above* this average (Fagerberg et al., 2009a). However, the Norwegian economy is distinguished from comparable Western European economies by primarily being resource-based. Historically, the Norwegian economy has relied upon maritime industries such as fisheries, refineries, and shipping, the hydropower-driven metallurgical and electrochemical industries, and the country's most recent resource-based enterprise, the petroleum industry. These industries have all emerged from Norway's geographical particularities: an extensive coastline, mountainous terrain, and offshore petroleum reservoirs.

Historically, Norway's industries have either been small-scale and decentralised (e.g. fisheries) or large-scale and centralised (e.g. fertiliser production). These industries have been supported in different ways by Norwegian authorities: small-scale industries have been supported by active regional policies (Teigen, 2012), while the large-scale development of hydropower and related industries was regulated through 'concession acts' intended to 'obtain national control over vital natural resources and to fulfil national development ambitions' (Sæther et al., 2011: 376). The concession acts implemented in the early 20th century ostensibly also influenced the organisation of the oil and gas industries more than half a century later (Engen, 2009: 181). Industry and technology have long been part of the Norwegian national narratives, as drivers of 'modernisation processes'. For example, the development of hydropower throughout the 20th century was part engineering feat, part state-making (Sørensen, 2016).

The Norwegian Government has also tried to foster industries that are not resource-based. This sector, described as 'knowledge-intensive [and] network-based' (Fagerberg et al., 2009a: 439), encompasses high-tech industries characterised by a relatively high research and development (R&D) expenditure. Examples include consumer electronics and ICT (Sørensen, 2016; Fagerberg et al., 2009a: 440), as well as the Norwegian attempt at establishing an electric vehicle (EV) industry (Ryghaug & Skjølsvold, 2019), all of which the Norwegian Government has supported in the past. Ultimately, none of these ventures succeeded, and the third industrial sector remains relatively small (Fagerberg et al., 2009a). Still, successful or not, the above-mentioned examples illustrate how the Norwegian Government has cast technology and industry in a central role in the nation's grand narratives, accompanied by both political and economic support.

However, the 1980s marked a change in Norwegian technology policy, characterised by a shift from public support for particular industrial ventures toward generalised support schemes meant to foster innovation (Sørensen, 2016). As a result, the current Norwegian innovation policy is characterised by an economic R&D-centred approach that often overlooks the importance of socialisation (e.g. developing regulations or infrastructures, shaping public attitudes) for successfully fostering new technologies and/or industries (Sørensen, 2013). This may be part of the reason why Norway continues to exhibit a characteristic lack of a major high-tech industry (e.g. ICT, biotechnology, pharmaceuticals) compared with other high-income Western European countries (Fagerberg et al., 2009a).

Although Norway lacks a high-tech industry, innovation has still been practised in relation to the resource-based industries. However, these industries have been characterised by low R&D expenditure. Innovation has often been problem-oriented, with the necessary competence for problem-solving being sourced outside companies. Often, intrafirm R&D was only pursued if the necessary expertise was not available elsewhere (Fagerberg et al., 2009a). Throughout the 20th century, such problem-oriented collaborations fostered both organisational and technological innovations, but these were often directed toward improving efficiency and increasing profitability within the resource-based industries, including the petroleum industry, rather than the development of new industries (Fagerberg et al., 2009a). As the recognition of problems relating to climate change have become mainstream, there has been an associated uncertainty regarding the future demand for petroleum and petroleum products. Accordingly, an economy that relies heavily upon petroleum production seems increasingly out of step, thus raising the by now idiomatic question: 'What will sustain Norway after the oil?'

Enter *the green shift*. This ill-defined term has seen a sharp increase in use over the last decade and is often invoked by Norwegian politicians and media. Although the term lacks a precise definition, it is often used to describe a desirable and supposedly ongoing process in which Norway is phasing out the petroleum industry and establishing new, sustainable industries (Haarstad & Rusten, 2018). The lack of an agreed-upon definition allows the term to be used to describe both a nationwide transition toward a sustainable low emission society and a general shift toward less carbon-intensive products and services. Paired with the question of a Norwegian society post-oil, this suggests that the green shift is not only about phasing out petroleum but also a question of retaining an established standard of living (Dale & Andersen, 2018). Thus, the green shift is not only a moral imperative but also a question of economy.

The origins of the green shift may be traced back to the *Our Common Future* report (World Commission on Environment and Development, 1987) and further to the deep ecology developed by Norwegian philosopher Arne Næss (e.g. Næss, 1973). These lines of thought echo through the Norwegian Government's websites, which describe a future society 'where growth and development happens within the planetary boundaries'.[3] Its frequent invocation suggests that the green shift has taken root in Norway's collective imagination, grounded in the characteristics of contemporary Norway and in the imagination of what Norway might become through advances in technoscience. Additionally, the green shift has been institutionalised through government initiatives such as Nysnø climate investments; Enova, a government enterprise promoting sustainable energy production and use; Innovasjon Norge's environmental technology scheme; and the digital platform The Explorer, which is dedicated to the international promotion of green technologies produced and developed in Norway.[4] As such, the green shift exhibits the defining characteristics of a sociotechnical imaginary (Jasanoff & Kim, 2015, 2009).

4 Method

To address my research questions, I have chosen a dual approach. With regard to the question of how self-driving vehicles have been taken up in politics, I use the findings from a document analysis. I started by checking 42 documents (White Papers, government commissioned reports, legislation, tender documentation) that contain references to self-driving vehicles. In many of the documents, the term self-driving

[3] https://www.regjeringen.no/no/tema/klima-og-miljo/klima/innsiktsartikler-klima/gront-skifte/id2076832 (accessed 3 September 2020). The translation of 'naturens tålegrenser' as 'planetary boundaries' is a matter of convention, rather than a precise translation. A literal translation of the term is 'nature's critical load', which connects the term more clearly to the principles underlying deep ecological thinking.

[4] These initiatives are the ones highlighted by the Norwegian Government's website regarding the green shift: https://www.regjeringen.no/no/tema/klima-og-miljo/klima/innsiktsartikler-klima/gront-skifte/id2076832/ (accessed 3 September 2020).

vehicles is merely used as shorthand for technological progress. Accordingly, my analysis focused on the seven documents that specify the Norwegian Government's policies relating to self-driving vehicles, constitute the knowledge base for those policies, or represent operationalisations of the policies (Table A1.1). First, I read the documents with an eye for the immediate benefits and challenges associated with self-driving vehicles. In subsequent readings, I focused on how self-driving vehicles were situated in the broader political milieu as well as how they were envisioned to influence societal aspects outside the transport sector. Through such an iterative reading, I gained a comprehensive overview of the visions and expectations associated with self-driving vehicles in Norwegian policy, as well as the actions that the government has since undertaken to support the policies.

Table A1.1: Analysed documents

Document title	Document type
Lov om utprøving av selvkjørende kjøretøy ('Act relating to testing of self-driving vehicles') (2017)	Legislation
Call for R&D proposals for E8—the Borealis Project (Statens vegvesen, 2017)	Tender documentation
National Transport Plan 2018–2029 (Meld St. 33 (2016–2017))	White paper
Smarter transport in Norway (Samferdselsdepartementet, 2017)	Tender documentation
Pilot-T (Forskningsrådet, 2019a)	Tender documentation
Technology for sustainable freedom of movement and mobility (Ekspertutvalget—teknologi og fremtidens transportinfrastruktur, 2019)	Report
Transport 21 (Forskningsrådet, 2019b)	Report

In addition to the policy documents, this article builds upon in-depth interviews conducted in 2019 in relation to the Borealis project. The project, which was instigated by the NPRA, has involved the NPRA and its partner companies testing ITS technologies in Arctic conditions. When researching Borealis, three colleagues and I conducted eight in-depth interviews: four with employees of the NPRA, three with employees of the NPRA's business partners, and one with a regional politician from the municipality where Borealis was conducted. The interviewees with the NPRA employees were chosen strategically: the interviewees were either project leaders or had otherwise worked closely toward the realisation of Borealis. Similarly, the interviewed NPRA business partners had been involved with Borealis since the project was announced, and thus had extensive knowledge of the project.

The interviews were conducted with the help of an interview guide (Rapley, 2004), with the purpose of investigating the provenance of the Borealis project, its relationship to policies and visions of self-driving vehicles, the benefits the project might have for the Northern Norway region, and the importance ascribed to testing in this region. All interviews were audio-recorded and subsequently professionally transcribed. All quotes in this article, whether from interview transcriptions or from documents, have been translated by me and pseudonyms are used for the quoted interviewees.

The transcribed interviews were subjected to an open coding process (Charmaz, 2006). In the course of that process, I became increasingly interested in the interplay between visions of technological futures and the testing activities being undertaken in Borealis. Through iterations of the coding process, the relationship between self-driving vehicles and politics became increasingly apparent. This prompted me to re-examine the seven government and government-commissioned documents in order to better understand the relationship between transport policy and technological pilot project activities, and the wider ramifications of these policies and activities.

In addition to the interviews, two colleagues and I visited the Borealis test site in March 2019, a visit that coincided with the first set of technology tests. Our visit took the form of participant observations, in which we were introduced to most of the NPRA's partners, sat in on troubleshooting exercises in the small control centre erected at the roadside, and generally observed and inquired about the project. At the end of the working day, the Borealis partners reconvened at a nearby hotel for a project meeting. We were invited to attend their meeting, during which their experiences and the challenges encountered that day were summarised. This allowed us to make further observations of the dynamics between the partners and to inquire further about the project.

Subsequent to the field visit, I attended the ITS Arena seminar held in Oslo in April 2019. The conference was arranged jointly by the NPRA and ITS Norge (ITS Norway). ITS Norge is a national membership association that acts as 'the contact point for

Norwegian expertise on ITS'.[5] The seminar in 2019 was a field configuring event (Lampel & Meyer, 2008). It attracted actors from different businesses and organisations, as well as from different geographical regions to an event that included both presentations from professionals and opportunities for informal face-to-face interaction. All presentations at the seminar, including those on Borealis, were held by NPRA employees. The overarching theme of the seminar was the current challenges associated with ITS. Through this focus, the NPRA implied the limitations that partners, both current and prospective, would have to work with or face, while simultaneously expounding what goals ITS should be mobilised toward. As such, the ITS Arena seminar was an event at which the NPRA contributed to configuring the field of ITS and its expression in the Norwegian context. In sum, the examined documents, interviews, and experiences provided the background for my understanding of the Borealis project and its internal dynamics, as well as how the project fits within the national context.

5 Analysis, part I: policy and legislation

While many Western European nations have expressed an interest in self-driving vehicles (Hopkins & Schwanen, 2018; Blyth, 2019; Mladenović et al., 2020), the motivations for engaging with such technology appear to differ. For example, Finland sees self-driving vehicles as an interesting opportunity for the country's comprehensive ICT industry (Blyth, 2019). By contrast, the UK interprets the technology in light of the country's past as automotive manufacturer and a perceived 'global race for supremacy in AV [autonomous vehicle] innovation' (Hopkins & Schwanen, 2018: 9). How, then, does the Norwegian Government conceive self-driving vehicles? To answer this question, I will explore how self-driving vehicles have been institutionalised in Norwegian policy documents and legislation.

Every 4 years, the Norwegian Government releases a new version of the National Transport Plan (NTP), a document that lays out the Government's transport strategy for the next 12 years, including funding priorities and expected technology trends. The 2017 NTP marked the first in-depth discussion of self-driving vehicles in Norwegian

[5] https://its-norway.no/category/english/ (accessed 1 September 2020)

government literature (Meld. St. 33 (2016–2017): 26–49). This NTP lists the benefits self-driving vehicles are expected to realise, which coincide entirely with the NTP's vision of a future 'transport system that is safe, facilitates value creation, and contributes to the transition towards a low emission society' (Meld. St. 33 (2016–2017): 27). The 2017 NTP proceeds to emphasise that trials and pilot projects are necessary to explore how self-driving vehicles might contribute to this overarching objective (Meld. St. 33 (2016–2017): 35). With the *Lov om utprøving av selvkjørende kjøretøy* (Lov om utprøving av selvkjørende kjøretøy, 2017), the Norwegian Parliament allowed for testing of self-driving vehicles on public roads. Since the Act's implementation in 2018, multiple companies (public and private) have conducted such tests, primarily with self-driving buses at low speeds (12–20 km per hour). Beyond creating a legal framework to facilitate testing, the Norwegian Government has also supported such trials through funding. This includes the allocation of NOK 100 million to the 2017 competition Smartere transport and NOK 60 million to the Research Council of Norway's 2019 funding scheme Pilot-T.

However, beyond the immediate objectives of the NTP Pilot-T, the institutionalisation of self-driving vehicles emphasises the economic importance of transport innovation other than mere value creation through a robust and reliable transport system. There is a prospect of economic gain (Meld. St. 33 (2016–2017): 38), whereby transport innovation can lead to 'increased welfare and economic growth' (Samferdselsdepartementet, 2017: 4). Beyond new business models and the elimination of human drivers, the prospect of socio-economic trade-offs is worth noting. In a report on technology for sustainable freedom of movement and mobility, written by an expert committee appointed by the Ministry of Transport and Communications, the authors argue that developments within the field of self-driving vehicles could render expensive, near-future developments of safety infrastructure obsolete (Ekspertutvalget—teknologi og fremtidens transportinfrastruktur, 2019: 40). Thus, self-driving vehicles appear not only as a boon for Norwegian businesses and industry clusters, but also for the socio-economic management of the nation itself.

The NTP for 2017 spells out the division of responsibility between government and businesses in no uncertain terms: 'Commercial companies will be important in the development of new technology and solutions. The role of the authorities is to develop and adapt legislation and policy framework, and to ascertain sufficiently safe solutions'

(Meld. St. 33 (2016–2017): 41). This is also reflected in the Norwegian legislation on testing, which is configured in a way that is beneficial for companies and businesses. Through public trials, companies develop interpretations of the social aspects of the technology. The companies' understandings of ideal modes of implementation are communicated to the Directorate of Public Roads through law-mandated final reports. These reports then enter processes of law-making and policymaking, potentially influencing the institutional understanding of self-driving vehicles (for an in-depth discussion, see Haugland & Skjølsvold, 2020).

The manner in which self-driving vehicles have been institutionalised in Norwegian policy and legislation is notable for two reasons. First, they are referred to in rather general terms. Rather than reflecting upon how Norwegian society might benefit from the implementation of self-driving vehicles, the Norwegian goals echo the benefits commonly cited in academic literature (Milakis et al., 2017; Duarte & Ratti, 2018; Legacy et al., 2019) and the expectations that have been documented in Finland, Germany and the UK (Hopkins & Schwanen, 2018a; Mladenović et al., 2020). Second, there is an obvious economic orientation, in which participation in an emergent field is framed as an economic opportunity for Norway in general (Meld. St. 33 (2016–2017): 38), and for technology and transport companies in particular. In sum, the Norwegian Government's efforts to support the realisation of self-driving vehicles appear to have been motivated as much by the prospect of economic gain from a transport sector that is considered to be on the brink of a rapid and radical transformation (Meld. St. 33 (2016–2017): 37; Ekspertutvalget—teknologi og fremtidens transportinfrastruktur, 2019: 40), as by such vehicles being able to fulfil the overarching goals of the NTP. The Norwegian Government frames self-driving vehicles primarily in economic terms, rather than connecting visions of self-driving vehicles with distinctively Norwegian conditions and challenges. However, through the innovation activities within the Borealis project, such connections were made.

6 Analysis, part II: the Borealis project

The Borealis project was the result of a Finnish-Norwegian collaboration. In 2017, the Finnish Transport Agency (FTA) conducted the Aurora project, in which a 10 km stretch of road was equipped with intelligent infrastructures.[6] At the same time, the NPRA had undergone a reorganisation that had freed up technical personnel for new projects. Combined with a NOK 30 million surplus from a previous road development, the NPRA's Region North office had the funding and personnel necessary to establish a collaboration with the FTA. Consequently, the NPRA designated the 40 km stretch of road from Skibotn to the Norwegian-Finnish border (Fig. A1.1c) as a test area. This stretch is part of the European route E8, which runs from Skibotn in Norway to Kilpisjärvi in Finland. There, the NPRA deliberately chose to test other technologies than the ones the FTA tested across the border, as that would allow the agencies to 'double the number of projects while halving the price and resource allocation' (Irene, former project leader, NPRA).

In preparation for Borealis, the NPRA made a needs assessment, asking local road users (from the fishing industry, customs office, road maintenance, and public transport companies) what challenges they experienced when travelling along the road. The results from the assessment informed the NPRA's subsequent call for partners for R&D projects, which in addition informed prospective partners about the types of data the NPRA would be able to provide. The call was distributed through both official channels for procurement and network organisations, such as ITS Norge, asking companies to submit project proposals. After assessing the proposals, the NPRA partnered with nine companies and institutions, funding 50% of the partners' project expenses. All but two of the chosen partners were based in Norway. Beyond the acquisition of competence that was not available internally at the time, the NPRA saw these partnerships as an opportunity to support industry: while the NPRA funded half of the partners' expenses, the NPRA 'did not place any limitations regarding what [the partners] might develop and commercialise. We leave that to the companies' (Vaughn, NPRA engineer). By choosing predominantly Norwegian partners and leaving them free to commercialise any concept they tested, the NPRA interviewees suggested that Borealis might help foster a new Norwegian industry.

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[6] In 2019 the Finnish Transport Agency changed its name to the Finnish Transport Infrastructure Agency (FTIA).

6.1 Testing infrastructures

At the start of this article, I referred to the platooning demonstration conducted within the Borealis project. The demonstration took place during the opening of the project, before an audience comprising the NPRA's project partners, the Regional Director of the NPRA's Region North office, and Norwegian media. However, when my two colleagues and I visited the Borealis test site the technology had disappeared from the project's portfolio of technologies. As the platooning demonstration was broadcast via the NPRA's website and different media channels, we were curious to understand what had happened to it. Upon enquiring, we were told that the technology was rather immature. It had malfunctioned when tested in sleet the day before the demonstration, and rather than actual platooning, the technology was 'really cruise control with something extra' (Vernon, NPRA engineer). The demonstration had something of a performative function: by 'drawing up these larger visions of self-driving and platooning', the NPRA could rally up some excitement for the project, while simultaneously giving 'politicians something large and nice to point to, as a way out of our current predicament' (Vernon, NPRA engineer). The only example of vehicle automation in Borealis had been more of a promotional stunt than a technology test.

Beyond platooning, the technologies tested at the Borealis site were out-of-the-box technologies. Some technologies were simply installed and used for their intended purposes, for example digital signs used to display weather conditions, and vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-infrastructure communications. Other technologies were used differently than intended. Examples included equipping an uphill slope with parking sensors that used a magnetic field to identify the type of vehicle passing, as well as its speed. The sensors were also able to identify a vehicle coming to a stop. Similarly, LIDAR technology was mounted on poles along the road and was used to identify trucks coming to a stop on slopes, with the aim of relaying the information to vehicles and/or to the aforementioned digital signs. Fibre-optic cables were set into the asphalt to monitor traffic through distributed acoustic sensing (DAS), a technique commonly used in the oil industry. Whether used for their intended purposes or repurposed, the tested technologies were intended to make the road more predictable (travel time, road conditions) and manageable (maintenance, accidents) for users and relevant agencies.

Some of the technologies used in the Borealis project overlapped in terms of functionality. The parking sensors and poles used in the LIDAR scanning were intended to solve similar problems, allowing for A/B testing of functionality and cost. Similarly, cheap and expensive DAS cables were laid side by side to enable comparison of results. The sets of cables were also set into in different parts of the road surface (toward the edges, in the middle) to ascertain which combinations of cables and positions provided the best signal. These examples point to the experimental nature of Borealis. In addition to the aforementioned technologies, the stretch of road was provided with electricity to power the technologies and the broadband cables necessary to operate the technologies in an area in which phone coverage was not considered sufficiently reliable. Together, the infrastructural developments and the technologies that were tested point to attempts at making the road stretch in question more predictable and controllable. For example, trucks blocking a lane could be readily communicated to relevant agencies, other road users, and/ or infrastructures. Additionally, the need for road maintenance (salting, snow ploughing) could more easily be assessed. Rather than implementing technology for its own sake, the tested technologies were intended to solve certain preconceived problems. Interpreted in this manner, the technologies clearly addressed two of the central aims of the 2017 NTP: road safety and facilitation of value creation. The prospect of value creation is also discernible in the public–private partnerships characterising the organisation of Borealis: whilst the NPRA facilitated the tests, any future commercialisation was left to the commercial partners.

6.2 From Silicon Valley to Skibotn Valley

Both Borealis and Aurora were conducted in the northern reaches of the Nordic region, where snow and freezing temperatures are common. Fish are transported from Norwegian coastal islands and onward through Finland, entailing relatively rapid shifts from mild coastal climates to freezing inland temperatures for much of the year. By testing technologies in the region, their resilience and functionality can be ascertained, even in freezing conditions or heavy snow. In terms of self-driving, one NPRA engineer likened the stretch of road used in Borealis to the equivalent of master's level or doctoral level of difficulty, as opposed to the kindergarten level of difficulty experienced when driving in Arizona. As such, the engineer was alluding to the importance of transport innovation in the High North—whereas Norway might not be *leading* the development of self-driving vehicles, the Finnish–Norwegian collaboration still has a role to play in ensuring that new transport technologies work under all conditions, rather than merely in the flat and temperate deserts of Arizona. The perceived difficulty of the test site gave the tests credence (Gieryn, 2006). Testing under arctic conditions meant testing what engineers refer to as corner cases, meaning conditions under which multiple parameters are extreme (e.g. freezing temperatures, slippery roads, heavy snow, challenging topography; for the fishing industry, time constraints).

Whereas ensuring that technologies work under the above-mentioned conditions might appear as a niche concern for the Nordic countries, NPRA interviewees argued that such testing would benefit all of Europe. This points toward an envisioned division of labour between nations, as well as a focus on collaboration rather than competition. First, with regard to the Aurora-Borealis collaboration, the NPRA and the FTA actively chose to test different technologies in order to diversify. Rather than conducting the same trials, the promise of knowledge-transfer allowed the NPRA to wait for the FTA to 'narrow down their trials to something that looks exciting' (Vernon, NPRA engineer), and subsequently adopt the technologies that showed promise. Second, the NPRA interviewees argued that the conditions under which the tests were run represented an important contribution to standardisation work within the European Union (in which Norway participates through the European Economic Area Agreement). Whereas the weather conditions in Norway and Finland were acknowledged as distinctive, there was something to be gained from testing in the two countries: after all, if a future transport system encompassing self-driving vehicles is not able to handle snow or low temperatures, 'how many days of snow will the European economy be able to handle?' (Vernon, NPRA engineer). Rather than adopting the UK view of a race to the finish line (Hopkins & Schwanen, 2018a), the Aurora-Borealis project is characterised by a collaborative approach where the northern reaches of the Nordic countries act akin to a 'truth-spot' (Gieryn, 2006) with regard to the development of self-driving technology.

Barring a failed attempt at establishing a Norwegian EV industry (Ryghaug & Skjølsvold, 2019), Norway has little experience of car manufacturing. In light of this, the shift toward digital infrastructures rather than vehicle automation may be interpreted as a bet on a field where Norway might take the lead. By focusing on the conditions particular to Norway, the NPRA carved out a niche that might represent an opportunity for Norway. In the case of Borealis, the partners were also predominantly Norwegian, which points to how, in the future, the project might help foster a Norwegian industry relating to self-driving vehicles by producing reliable transportation innovations that will work everywhere, rather than merely in flat and temperate deserts.

7 Discussion

In my analysis I have shown how the manner in which self-driving vehicles have been institutionalised in Norwegian policy and legislation convey the benefits of such vehicles in rather general terms. The NTP cites the prospect of self-driving vehicles contributing to increased traffic safety, a more robust transport system, and a reduction in greenhouse gas emissions. These same benefits have been cited elsewhere in Western Europe (Hopkins & Schwanen, 2018a; Mladenović et al., 2020), suggesting that hitherto little concern has been paid to how self-driving vehicles might help to solve transport problems or enable new forms of social life that are particular to Norway. Thus, the Norwegian institutionalisation of self-driving vehicles is evidently not the origin of a sociotechnical imaginary. Rather, it is merely an institutionalisation of visions that circulate transnationally, visions that Norwegian policy and legislation fail to connect to the country's cultural and geographical particularities.

Still, the Norwegian Government has allocated funding to trial projects with self-driving technology, including competitions (Smartere transport), funding schemes (Pilot-T) and projects carried out by governmental agencies (Borealis). This reflects the long-running development in which the government has attempted to facilitate innovation through more or less generalised funding schemes, rather than by directly supporting a particular technology (Sørensen, 2016). I contend that self-driving vehicles were institutionalised as part of a sociotechnical imaginary, although not an imaginary centred on self-driving vehicles. However, to explore this point more fully, it is first necessary to discuss Borealis in more detail.

7.1 Northern provenance

In the second part of my analysis, I suggested that the motivations underlying Borealis were three-fold. The first and most immediate application of the technologies tested in the project simply relates to the road: What technologies can be used to improve predictability and control, and what configurations of technologies manage to do so in the most efficient manner? Herein lies also the prospect of transferring the technologies to other sites for similar or different purposes.

Second, the project was motivated by the need to solve challenges particularly associated with the E8. The NPRA's websites states that the road was chosen due to its 'significant economic importance'.[7] Since 2010, the road has seen a sharp increase in freight traffic, partially due to the road being the main route for transporting fish from the coast of Norway to Finnish airports, where the cargo is distributed to European or Asian markets by plane. Fish represents Norway's second largest export goods, surpassed only by petroleum products (oil and gas). As such, the Borealis project is also directed toward the resource-based industry of fishing and fish farming, and the prospect of facilitating a more efficient and predictable route for transporting fish. This resonates with Norwegian history, in which domestic innovations have predominantly been implemented in the resource-based industries in order to strengthen their long-term competitive advantage (Fagerberg et al., 2009a).

Third, and finally, there is the prospect of Borealis contributing to the standardisation of self-driving technologies with regard to the European Union, in particular V2V and V2I communications technologies. Historically, innovation in Norway has either been directed toward resource-based industries or, less successfully, toward establishing high-tech industries (Fagerberg et al., 2009a; Sørensen, 2016). However, the Borealis project exhibits a dual orientation: whereas one leg is firmly placed in the fishing industry, the prospect of standardisation lifts the project from being just another domestic innovation project to possibly becoming the beginning of a new industry. Thus, being grounded in the resource-based industry might be a strength, a form of support that might help to facilitate the emergence of a new high-tech industry (cf. Sørensen, 2013).

Borealis reflects Norway's historical bent toward the resource-based industries, yet it differs from the past in the project's dual orientation. On the one hand, its innovations are directed inwards, toward the domestic fishing industry and the prospect of increasing

[7] https://www.vegvesen.no/Europaveg/e8borealis (accessed 24 August 2020).

the efficiency and predictability of this industry. On the other hand, the focus on how Norway might become a central location for trans-European standardisation work suggests that the project's link to the resource-based economy might also facilitate the emergence of a new industry. As such, the Borealis project is both an extension of the traditional Norwegian mode of innovation, in which private–public collaboration is directed toward resource-based industries (Fagerberg et al., 2009a), and an example of a high-tech mode of innovation in which value-creation emerges from the development of products or patents.

7.2 Subcontracted politics

The policy and legislation discussed in the preceding section show how the Norwegian Government has pointed out the direction for technology development without establishing the purpose of the development beyond the most general of benefits (for another example, see Haugland & Skjølsvold, 2020). The same approach has characterised most of Norwegian technology and innovation policy since the 1980s: rather than promoting particular technologies, the Norwegian state has facilitated innovation through support schemes (Sørensen, 2016). Generally, most aspects of innovation have been left to commercial actors and the selection pressures of the market, suggesting a narrow conception of innovation (Sørensen, 2013). However, Borealis exhibits some particularities that set it apart. First, the project does not rely upon support schemes. Rather, it is a private–public partnership instigated by the NPRA. Second, the NPRA interviewees considered Norway to be in an exceptional position within Europe. While 'many European nations have exchanged their engineers for procurers' (Vernon, NPRA engineer), the NPRA has retained a number of professionals within the organisation. Together, these two aspects allowed the agency to take on the leading role in developing a prospective sociotechnical imaginary pertaining to self-driving. When preparing for Borealis, for example, the NPRA staked out a particular direction. NPRA professionals appraised the received proposals for feasibility and technological potential, while also considering how those technologies, if functional, might be applied to the NPRA's core operations beyond Borealis. Hence, the agency's professional judgements influenced the development of this sociotechnical imaginary.

The direction staked out by the NPRA is interesting for three reasons. First, it draws upon Norwegian expertise, including the ICT expertise pointed out in White Papers (e.g. Meld. St. 27 (2016–2017)). Second, the focus on digital infrastructures contrasts with the common narrative of autonomy. Peddled by prominent figures such as Tesla CEO Elon Musk, this narrative suggests that self-driving vehicles will have the capability to deal with the complexities of the real world in a manner superior to human drivers, and due to these capabilities there not be any need for governance or regulations (Stilgoe, 2017). By focusing on infrastructural requirements, the NPRA aligns with earlier conceptions of self-driving vehicles, in which the operation of such vehicles was expected to rely upon communication with smart infrastructures (Kröger, 2016; Wetmore, 2003). Third, and finally, both the NPRA interviewees and the interviewed partners considered the weather conditions in Northern Norway a boon to the development of reliable digital infrastructures, not only for Norway but also for the whole of Europe. Together, the three aspects show how the relatively non-descript visions from policy and legislation are being operationalised by the NPRA. This suggests that decision-making pertaining to self-driving vehicles has been subcontracted to a government agency, making it an administrative concern rather than a political one.

The mode of innovation characterising Borealis, in which the NPRA acted as a technological arbiter, shows how the lack of policy guidelines allowed the agency to steer technology development in its desired direction. The ITS Arena conference held in Oslo in 2019 may be considered another example of this steering, as it functioned as a field-configuring event (Lampel & Meyer, 2008) for self-driving vehicles in Norway, laying out current limitations and challenges pertaining to the field. Such institutional subcontracting of politics results from a hybrid mode of innovation, which draws upon elements from technology as nation-building (although promoted by the NPRA, rather than at a national level) and the more recent mode wherein the state acts as a facilitator for innovation. The institutional subcontracting of politics leaves the preferred direction for the development of self-driving vehicles to professionals. This exemplifies how decision-making in relation to self-driving vehicles happens outside traditional democratic politics, similar to how the Norwegian legislation on self-driving vehicles is configured in a manner that allows commercial actors to influence institutional understandings of the technology (Haugland & Skjølsvold, 2020).

The above discussion suggests that the Borealis project might represent the origin (Jasanoff, 2015b) of a distinctively Norwegian sociotechnical imaginary pertaining to self-driving vehicles. Nondescript visions from policy and legislation are grafted onto Norwegian conditions, namely the country's particular geography, its resource-based economy, its responsibility toward Europe, and its prospective future, as well as a specific, professionally informed conception of what technological future is viable. If Borealis represents the origin of a sociotechnical imaginary pertaining to self-driving, this would suggest that the embedding of an imaginary might happen before its articulation. For example, Borealis was accommodated through the institutional embedding of self-driving vehicles, but the project simultaneously represents the possible origin of a sociotechnical imaginary relating to such vehicles. This suggests that the development of sociotechnical imaginaries might sometimes be a non-linear process, where, for example, the embedding both precedes and is an integral part of a new imaginary's origin.

7.3 Infrastructure and socio-economics

At the start of this article, I described how Prime Minister of Norway Erna Solberg mobilised tightly interwoven trucks and autonomous systems to contrast with the rigid and expensive infrastructure of a railway extension. She suggested that technological progress would usher in a transport system characterised by an increased flexibility for both public and freight transport. Solberg clearly mobilised the narrative of autonomy described above, despite Borealis's focus on infrastructures. Similarly, the authors of the report *Technology for sustainable freedom of movement and mobility* argue that self-driving vehicles would be so safe that they might render the near-future development of infrastructure for road safety unnecessary (Ekspertutvalget—teknologi og fremtidens transportinfrastruktur, 2019: 40). Whether arguing against the railway extension or safety infrastructure, Solberg and the report by Ekspertutvalget—teknologi og fremtidens transportinfrastruktur (2019) both envision a future when costly investments in inflexible infrastructures will no longer be necessary. However, the systems tested in Borealis entail comprehensive infrastructural developments in which roads are fitted with the necessary technologies and associated electrical and communications infrastructure. As such, the socio-economic benefits of self-driving vehicles in relation to the transport sector are currently highly uncertain. However, I contend that socio-economic aspects are at the core of the Borealis project, as well as the Norwegian Government's push for self-driving vehicles.

Erna Solberg promoted an autonomous system hinging on the contingencies of 20–25 years of technology development over a currently possible infrastructure development. The above discussion might provide the key to understanding this prioritisation. At the start of the discussion, I stated that self-driving vehicles were institutionalised as part of a sociotechnical imaginary, though not an imaginary centred on such vehicles. Rather, Norwegian policy relating to self-driving vehicles appears to first have been an extension of the green shift imaginary into a new technological domain, a new opportunity for innovation and value creation. Only after Borealis did this extension come to represent the origin and embedding of a new sociotechnical imaginary which centres self-driving vehicles (cf. Jasanoff, 2015b). By exhibiting characteristics of both resource-based innovation and high-tech industry, Borealis represents a possible answer to what will sustain a post-oil Norwegian society, namely a more efficient and predictable resource-based sector and a prospective new industry. Prime Minister Solberg's measured response to the question of a railway extension is an extension of this belief: Rather than the railway being old-fashioned in itself, its relative undesirability arises from its lack of future orientation. Had the railway extension been developed subsequent to the 1992 official report on the Northern Norway railway line, there would have been a prospect of innovation. The report suggests that a development of the extension would have to make use of the most advanced technology currently available, and even then, the development of new technologies with more advanced capabilities might have been necessary (NSB, 1992: 126). However, in her statement, Solberg suggested that this prospect of innovation has now taken to the road—a road that might lead Norway to a green and prosperous future.

8 Conclusions

In this article, I have suggested that the Norwegian interest in self-driving vehicles should be interpreted in light of Norway's history as a resource-based economy and in particular the nation's petroleum industry, rather than as transport policy. In light of climate change, the future demand for oil is highly uncertain, meaning that the Norwegian state will need new means for sustenance. Domestically, this awareness is expressed in terms of the green shift, which describes a sustainability transition in which new, green industries are facilitated through market mechanisms, while the nation's current affluence is maintained. The Borealis project shows a dual orientation, in which it might simultaneously help establish a Norwegian high-tech industry and increase both efficiency and predictability for the fishing industry. The NPRA and its partners suggest that the weather-based challenges facing the fishing industry make Northern Norway a favourable region for establishing the reliability of new technology, suggesting that the combination of resource-based and high-tech innovation might be less clear-cut than it appears (Fagerberg et al., 2009a: 441). By drawing upon insights from literature on national innovation systems (e.g. Fagerberg et al., 2009b), this article shows the Norwegian interest in self-driving vehicles is both the result of and a reaction to established patterns of economic development and modes of innovation. This in turn shows how national innovation systems literature may fruitfully inform more agency-oriented and/or practice-oriented approaches to studying innovation (Pfotenhauer & Jasanoff, 2017a, 2017b).

In Norway, self-driving vehicles feature in two sociotechnical imaginaries, one established and one emergent. The institutionalisation of self-driving vehicles appears to have primarily been an extension of the green shift imaginary into a new technological domain (Jasanoff, 2015b). Accordingly, the manner in which the Norwegian Government has institutionalised self-driving vehicles is rather non-descript and often phrased in economic terms. However, through Borealis the NPRA has articulated some possible links between self-driving vehicles, intelligent infrastructures and Norwegian society, such as the role of these technologies for the NPRA's core operations, the Norwegian fishing industry, European standardisation, and the prospect of a Norwegian high-tech industry. As such, Borealis represents the possible origin of a new sociotechnical imaginary centred around self-driving vehicles.

The manner in which Borealis was facilitated by the extension of the green shift imaginary suggests that sociotechnical imaginaries might sometimes be nested, with established imaginaries facilitating the emergence of new ones. This in turn suggests that new imaginaries do not necessarily proceed in a linear fashion through the four phases in the life of a sociotechnical imaginary proposed by Jasanoff (2015b). Borealis was facilitated by the institutionalisation of self-driving vehicles, which was initially an extension of the green shift imaginary. Should the imaginary originating from Borealis take hold, it would already be embedded in policy and legislation. This suggests that the extension of the green shift imaginary through the institutionalisation of self-driving vehicles might have embedded a future self-driving vehicle imaginary before it was articulated through Borealis.

Whereas conventional wisdom suggests that links between technology development and state-making have become the exception rather than the norm, I argue that this link has merely been reconfigured. To the Norwegian Government, self-driving vehicles carry the promise of innovation and a domestic high-tech industry, and thus represents a possible path away from a petroleum-dependent economy. Further, the manner in which the government has facilitated the emergence of self-driving vehicles is grounded in a particular imaginary of innovation (Pfotenhauer & Jasanoff, 2017a) 40 years in the making (Sørensen, 2016), in which support schemes are considered the ideal mechanism for producing (or facilitating) the desirable future. By facilitating the emergence of self-driving vehicles through this mechanism, the technology is expected to contribute to the green shift, thus exemplifying how innovation is closely tied to state-making. In sum, the Norwegian Government's institutionalisation of self-driving vehicles and the NPRA's subsequent operationalisation of the Government's policies suggest a possible pathway toward a desirable future: through innovation relating to self-driving vehicles, Norway might retain its current levels of social welfare and GDP per capita while facilitating a comprehensive transition toward new industries and a greener society.

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Article 2:
Promise of the obsolete: expectations for and experiences with self-driving vehicles in Norway

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Abstract

This article explores the expectations associated with self-driving vehicles and the role of public trials in testing and upscaling this technology. Using a two-pronged empirical approach, we first analyse public responses to draft legislation circulated in preparation for Norway's 2017 Act Relating to Testing of Self-Driving Vehicles. Drawing on the sociology of expectations, we investigate the anticipated benefits of self-driving technology and identify a possible tension between calls for a flexible legal framework and concerns regarding the thoroughness and purpose of testing. Thereafter, the article analyses interviews with actors conducting the first public trial under the new law, drawing on literature on upscaling and public experimentation to investigate the effects of societally embedded testbeds. We argue that public testing influences the understanding of self-driving technology and its relation to traffic. Additionally, the analysis shows how these understandings enter processes of policymaking, lawmaking, and technology development, indicating that actors conducting testing have been granted significant influence over current institutional understandings and future technical requirements for self-driving vehicles. We conclude that as trial experiences mold current understandings of autonomous transport, companies conducting testing guide expectations toward specific self-driving futures, thus rendering these futures more probable than others.

1 Introduction

In this article, we explore visions and expectations for self-driving vehicles and the relationships between such visions and practical innovation aimed at materialising a self-driving future in Norway.[1] Ranging from car manufacturers, software companies, and tech startups to researchers, politicians, and lawmakers, a plethora of actors envision that autonomous transport will reshape transport systems in the years to come (Gandia et al., 2019; Hopkins & Schwanen, 2018; Stilgoe, 2018). Still, questions relating to the development and implementation of such technology remains. Examples of uncertainties include whether, when, and where self-driving vehicles will come into use; their effect on traffic safety, congestion problems, and climate change; their organisation in terms of ownership and business models; and the handling of the data that they gather and produce. Norway's most recent National Transport Plan (NTP) disregards such uncertainties and emphasises the prospective benefits of autonomous transport (Meld. St. 33 (2016–2017)). The NTP, which cites supporting international studies, lists benefits such as increased traffic safety and mobility to highlight the importance of launching trials and demonstration projects which explore current technological capabilities. The Norwegian Parliament passed an Act facilitating such testing in 2017 (Lov om utprøving av selvkjørende kjøretøy, 2017), and since its implementation in 2018, the country has seen a surge of projects to study self-driving buses on public roads.

Writing from a sociotechnical perspective rooted in science and technology studies, we consider a shift toward autonomous transport as entailing more than exchanging drivers for computers. Rather, we see the shift as a process that (1) necessitates systemic change, (2) encompasses the implementation of new materials, technologies, practices, roles, business models, and policies, and (3) represents a potential shift in what some call the system of automobility (Sheller & Urry, 2000; Urry, 2004). Our interest lies in how actors in and around the transport sector strategise and act to enable the emergence of a new transport system. Two key aspects of the process are the production of expectations and pilot projects. Expectations are often instrumental in providing direction for

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[1] The terms autonomous, driverless, and self-driving vehicles are used interchangeably. In this article the term self-driving vehicles is used consistently, reflecting the usage in the Norwegian legislative framework.

experimentation, whereas pilot projects facilitate learning about experimental technologies. This learning, in turn, may influence further expectations, but also facilitate the upscaling of niche technologies. In this article, we explore the interaction between expectations and pilot projects.

Empirically, our approach was twofold. First, we studied responses to the draft legislation on opening public roads for testing self-driving vehicles. The feedback from a broad range of actors highlighted both the issues at stake related to the testing of self-driving vehicles and existing visions of self-driving futures. Second, we conducted an in-depth case study of the first Norwegian pilot project to test a self-driving vehicle on a public road, allowing us to explore how autonomous transport is understood and performed today. This dual approach enabled us to probe the relationship between pilot-project activities and the potential future of self-driving vehicles. In this article, we address the following research questions: What expectations and visions do key actors within the Norwegian transport sector have for self-driving vehicles, and what issues do they anticipate? How do companies involved in pilot project activities currently understand and perform self-driving?

The remaining parts of this article are structured as follows. We start by establishing a framework for approaching the expectations and work underpinning attempts at systemic innovation and then outline our methods. Thereafter, we present our empirical findings, focusing first on responses to the draft *Lov om utprøving av selvkjørende kjøretøy* ('Act Relating to Testing of Self-Driving Vehicles') and second on our case study. Finally, we provide an analysis of our findings and our main conclusions.

2 Studying systemic innovation

We approach the potential introduction of self-driving vehicles as an attempt at systemic change, entailing the introduction of multiple technologies, practices, and cultural elements that will form a new sociotechnical transportation regime (Geels, 2012). The literature on large-scale sociotechnical change and transitions has long considered the production of visions and expectations as key to processes of systemic innovation, as emphasised by the importance ascribed to such activities within the fields of transition management and strategic niche management (Kemp et al., 1998; Rotmans et al., 2001; Berkhout, 2006). In this regard, the articulation of shared expectations has been considered central for providing directionality to processes of learning, attracting attention and enrolling new actors, providing legitimacy for new technologies, and establishing their competitiveness vis-à-vis other technologies (Geels & Raven, 2006; Schot & Geels, 2008).

The role of visions and expectations in technology development processes has been further explicated within the sociology of expectations (Borup et al., 2006; Brown & Michael, 2003; Brown et al., 2000; van Lente, 2012). This conceptual framework highlights the performativity of visions and how expectations for the future influence contemporary actions. This literature draws on classical insights from science and technology studies, such as how technology designers have envisioned future technology use and mobilised these visions in their design strategies (e.g. Akrich, 1995; Woolgar, 1991). Numerous studies have probed contemporary expectations with the goal of understanding the strategies of actors within fields such as transport (Wentland, 2016, 2017) and energy (e.g. Ballo, 2015; Skjølsvold & Lindkvist, 2015). This work has shown how innovators' visions of large-scale technological change tend to be accompanied by expectations of wider societal change (e.g. Skjølsvold, 2014). The effort to generate such visions and to engage in associated societal issues has been highlighted as key to establishing new pilot-project activities (Engels & Münch, 2015).

As visions of self-driving vehicles often include broader societal and systemic change, we also explore the strategies used in a pilot project to materialise one such vision and, by extension, to advance a transport system which includes this technology. We take inspiration from Naber and colleagues (2017), who have developed a typology describing four patterns of upscaling:

1. Growth: the continuation of an experiment with more actors involved, and/or an increase in experimental scale
2. Replication: the reproduction of the experiment's main concept at another site or in another context
3. Accumulation: the linking of an experiment to other initiatives, providing potential synergies
4. Transformation: the experiment prompts or shapes wider institutional change

Additionally, Naber and colleagues (2017) highlight three important aspects for successful upscaling. First, they describe the establishment of social networks consisting of a diverse set of actors (e.g. companies, scientists, users, policymakers). Second, they discuss involvement in learning processes that are broad (encompassing both technical and social learning) and reflexive (showing a willingness to change direction). Finally, they highlight the importance of articulating shared visions and expectations, with emphasis on the substantiation of these visions through experimental data.

Traditionally, pilot projects have been confined to research institutions and research and development departments, but in recent decades there has been an increase in real-world testing (Marvin et al., 2018). This has sparked a debate on whether public testbeds are a prerequisite for attaining urban sustainability or whether they represent a corporate colonisation of public spaces (Bulkeley et al., 2014). While societally embedded testbeds are well suited for facilitating broad learning processes, Engels and colleagues (2019) identify three prominent issues associated with such embeddedness. First, experimentation has traditionally entailed surveying the effect of changes on different variables, a controlled environment that is hard to reproduce in a real-world setting. Second, there is the question of whether testbeds are merely embellished test sites for companies, merely serving as public demonstrations of viability rather than scientific experimentation. Finally, there is the question of whether the knowledge produced in a specific context is scalable or transferrable to other sites. These issues are pertinent, as our second set of empirical materials relates to public testing.

3 Methods

In the study on which this article is based, our method was twofold. First, we analysed 62 consultation responses to a draft version of the Norwegian *Lov om utprøving av selvkjørende kjøretøy* (2017).[2] The responses were written by a variety of actors who self-identified as affected by the Act, thus providing us with an overview of key positions

[2] The draft legislation and all responses are available at https://www.regjeringen.no/no/dokumenter/horing–forslag-til-ny-lov-om-utproving-av-selvkjorende-kjoretoy-pa-veg/id2523663/?expand=horingssvar (accessed 7 February 2019).

regarding autonomous transport among actors associated with the Norwegian transport sector. The statements differed in length and character, ranging from a few lines expressing support for the legislation to several pages of discussion. Our reading of the statements focused on two matters. First, we searched for societal aspects that self-driving vehicles were expected to affect, with the aim of understanding the broad implications of systemic innovation within transport. Second, we identified statements concerning autonomous transport in the future, which opened up space for the inclusion of differing expectations in our analysis.

The second part of our analysis was based on interviews and observational data relating to a pilot project testing a self-driving shuttle bus outside of the city of Stavanger, located on the west coast of Norway. We conducted our interviews and made our observations during November and December 2018. As the pilot project ended in December 2018, it provided a good opportunity to engage with actors regarding their experiences and lessons learnt over the course of the project. Barring one interview carried out over the telephone, we conducted all of our interviews in person. The respondents were chosen strategically, initially by focusing on actors who were managing the project, and then by 'snowballing' to find new interviewees (Atkinson & Flint, 2004), in order to gain a broader understanding of regional approaches to the future of transport. An overview of the interviewed representatives of institutions and companies is provided in Table A2.1.

All but two interviews were semi-structured, conducted with an interview guide created to explore a set of pre-defined themes (e.g. Rapley, 2004). The exceptions were interviews held with the operator of the bus.[3] As we wanted to see the bus performing in its natural setting, we made four trips as ordinary passengers. During these excursions, we conducted open interviews with the operator while simultaneously paying attention to the operator's actions and the surrounding traffic. We audio-recorded all interviews and subsequently transcribed them verbatim. The quotes used in this article have been

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[3] Although it might seem counterintuitive to use the word 'operator' in relation to a self-driving bus, this term was used by the three companies that conducted the pilot study. During our four trips, we observed how the operator frequently chose to manually override the shuttle bus due to its defensive driving style, thus substantiating the logic behind the choice to use the term 'operator'.

translated from Norwegian by the authors, and the interviewees have been given pseudonyms. The transcriptions have since been analysed using an open coding process (Charmaz, 2006), during which certain themes and topics accumulated. Our subsequent analytical approach focused on the themes and topics as points of interest, both in terms of their potential for comparison and based on our assumption that they were important issues for the interviewees.

Table A2.1. Overview of interviewees' affiliations.

Institution/company	Function	Interviews
Kolumbus	Regional public transport company/'mobility provider' for Rogaland County	5
Forus PRT	Project leader for the project; interviewee also had experience in operating the self-driving shuttle bus	1
Forus næringspark	Manager of the properties in the business park; provided a stretch of road for testing	1
Department of Transport, Rogaland County	Authority over Kolumbus; shared their responsibilities with the Norwegian Public Roads Administration	1
Smart City Office, Stavanger Municipality	Produced Stavanger's smart city strategy, including elements for energy, climate, and environment	1 (2 interviewees)
Norgesbuss	Provided the bus drivers for Kolumbus in the Stavanger region; interviewee operated the self-driving bus	2 (1 interviewee)

4 Public hearing: expectations and issues of self-driving vehicles in a process of policymaking

Norway's National Transport Plan for 2018–2029 claims that self-driving vehicles have the potential to improve road safety, to enhance mobility, and to reduce the environmental impact of the road sector (Meld. St. 33 (2016–2017)). The plan presents multiple scenarios, ranging from options in which autonomous transport is 'clean and shared' to alternatives in which 'private autonomy' dominates. Rather than identify a preferable scenario, the plan emphasises that the realisation of any particular scenario depends on contemporary societal choices. Accordingly, it is necessary to 'investigate the potential of new technological solutions through trials and demonstration projects' (Meld. St. 33

(2016–2017): 35, authors' translation). Such investigations are facilitated by the Act *Lov om utprøving av selvkjørende kjøretøy* (2017).

When preparing the 2017 Act, the Ministry of Transport convened a public consultation on the draft legislation.[4] The draft version highlighted traffic safety and accident reduction as key societal benefits of self-driving vehicles. It also envisioned increased transport efficiency, improved access to mobility across society, and reduced need and demand for personal car ownership due to autonomous transport becoming integrated in ride-sharing services. These expectations resonate with the growing scholarly literature on self-driving (Duarte & Ratti, 2018; Milakis, van Arem, & van Wee, 2017), and were similarly echoed in the public's responses to the draft legislation.

While all of the commentators acknowledged the possible benefits of self-driving vehicles, some also addressed unintended consequences. Certain concerns were shared among nearly all commentators, such as issues relating to data and privacy. More often, unintended implications were framed in terms of specific interests. The Norwegian Association of the Blind, for example, argued that people with limited vision still would require special assistance, even if self-driving vehicles improved their mobility. Similarly, both the Union of Norwegian Transport Employees and the Norwegian Taxi Association emphasised how the automation of transport might lead to challenges for vulnerable social groups that currently rely upon assistance from professional drivers.

Many of the commentators were concerned with responsibility and safety, often conflating present and future issues. Addressing the draft legislation directly, the discussions frequently revolved around whether to hold the individual operator or a legal

[4] This section references multiple Norwegian companies and organizations whose designations differ from Norwegian to English. As not to clutter the main text, this footnote includes a legend for these companies and organizations. The list is alphabetical, sorted by the company or organization's English designation: the Confederation of Norwegian Enterprise = Næringslivets Hovedorganisasjon (NHO), the Federation of Norwegian Transport Companies = NHO Transport, Finance Norway = Finans Norge, the Norwegian Association of the Blind = Norges Blindeforbund, the Norwegian Cyclists' Association = Syklistforeningen, the Norwegian Logistics and Freight Association = NHO Logistikk og Transport, the Norwegian Motorcyclists' Union = Norsk Motorcykkel Union (NMCU), the Norwegian Taxi Association = Taxiforbundet, Public Transport Norway = Kollektivtrafikkforeningen, the Union of Norwegian Transport Employees = Yrkestrafikkforbundet (YTF).

body responsible for accidents during testing. With regard to the future, the actors' concern was expressed through comments regarding responsibility: In the absence of a driver, who would be responsible in case of an accident? Few actors explicated a position, but the prevalence of the question reflects a need to assign liability. Some commenters argued that the current testing conditions were closely linked to the future road safety of the technology. For instance, the responses from the Norwegian Motorcyclists' Union and the Norwegian Cyclists' Association emphasised the importance of establishing test sites where the reaction of self-driving vehicles to motorcyclists and cyclists would be assessed, thus raising the question of who would be responsible for ensuring the thoroughness of the testing.

4.1 Innovation roadblocks

Few of the commentators questioned the need for legal frameworks and technology development and testing. Business actors and public transport companies emphasised the need for a flexible framework. The former included Acando (a company developing self-driving mobility concepts), Finance Norway (a confederation of firms in the finance industry), Spekter (an employers association), and the Confederation of Norwegian Enterprise (consortium of employers' associations), including its associated suborganisations: Abelia (a trade and employers' association for companies in the knowledge and technology sector), the Federation of Norwegian Transport Companies, and the Norwegian Logistics and Freight Association. The latter incorporates the public transport companies Kolumbus and Ruter—the first two firms to test self-driving shuttle buses on public roads in Norway—and the trade organisation Public Transport Norway. The above-mentioned companies and organisations emphasised that the pre-Act conditions for testing were too limited and argued that neither the legal framework nor associated bureaucracy should 'hamper an approaching technological development'.[5] Characteristically, this quote references the temporal proximity (Michael, 2000) of self-driving technology.

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[5] As argued in the response from the Confederation of Norwegian Enterprise, available at: https://www.regjeringen.no/contentassets/d85eaf3bf13d4be7ac64a59d155ebe88/naringslivets-hovedorganisasjon.pdf?uid=Naeringslivets_Hovedorganisasjon.pdf (accessed 4 December 2019).

Business actors and public transport companies often stressed the importance of a permanent legal framework in order to ascertain predictability for business actors investing in self-driving mobility concepts. Finance Norway and Spekter argued that an act allowing for testing would help produce a valuable knowledge base for such a framework. The responses from Abelia and Ruter even outlined business models based on fleets of shared vehicles that would necessitate a framework allowing for larger-scale implementation. In the belief that access to data is an important enabler of innovation, the Confederation of Norwegian Enterprise called for public authorities to accommodate third-party access to data produced during trials. In this way, the experiments would represent a boon to business actors, as well as for establishing a future legislative framework.

The viewpoints expressed above were questioned by just two of the commenters. Both the Norwegian Motorcyclists' Union and a private respondent raised the following questions: What does society stand to gain from the testing? What is the aim and purpose of testing? Who carries the cost of testing? Who, other than society, has something to gain? We contend that these are highly appropriate concerns and raise similar inquiries later in this article.

5 Self-driving Stavanger

5.1 Phase one: learning at the test track

The pilot project we studied in Stavanger entailed the testing of a self-driving EasyMile EZ10 bus. This six-seater bus uses a combination of global positioning systems (GPS) and sensors to navigate the road. Although certified for 45 kilometers per hour (km/h), its speed during the pilot project ranged from 12 to 15 km/h. The bus was operated using a tablet-like panel located in the middle of the bus, with an operator present at all times, as required by law. The pilot project consisted of two phases. In Phase One (January–May 2017) the vehicle was tested at a closed test track and in Phase Two (June–November 2018) it serviced two bus stops along a 1.2 km stretch of public road. While not heavily trafficked, the road was frequently used by freight trucks and private cars. The route also had multiple pedestrian crossings. The pilot project was established by three companies, namely Forus Business Park, Forus PRT, and Kolumbus (see Table 1), which formed a partnership to assess whether a self-driving bus could service the areas of the business park that were without public transport coverage. As made explicit in Kolumbus's response to the draft legislation, the testing was also motivated by a shared belief in the viability and importance of autonomous transport in a future mobility system.[6]

The partnership acquired the EasyMile bus in anticipation of legislation allowing for public testing of self-driving vehicles. During Phase One, the bus was tested for 1800 hours at the closed track, where the partners simulated different situations, ranging from regular traffic interaction to a person running in front of the bus. The testing was instrumental in documenting the safety of the bus, thus laying the groundwork for the second test phase. When applying to the Directorate of Public Roads for Norway's first permit to publicly test a self-driving bus, the partnership was readily able to deliver its documentation alongside the application. This documentation also lowered the bar for similar initiatives, as subsequent applicants 'could take all [our] documentation, and really just deliver it alongside their application' (Vincent, Forus Business Park). Similar streamlining happened at the Directorate. After taking three months to approve the application of the Stavanger partnership, the turnover rate for subsequent similar applications was reduced to 2–4 weeks.[7] Thus, the original application can be considered a kind of *bureaucratic* pilot project which tested the legislative framework.

5.2 Phase two: learning on the road

In the second phase of the pilot project, the partnership shifted the EasyMile bus onto a public road. The purpose of this move was to bring social learning to the fore by exploring people's reaction to and interaction with a self-driving bus. This facilitated a broader learning process that encompassed social as well as technical learning. In terms of upscaling, Phase Two exemplified both experiment growth and replication, as the project

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[6] The response from Kolumbus is available at https://www.regjeringen.no/contentassets/d85eaf3bf13d4be7ac64a59d155ebe88/kolumbus.pdf?uid=Kolumbus.pdf (accessed 20 February 2020).

[7] Multiple such initiatives have been conducted in the wake of the project at Forus. These trials have tested either EasyMile buses or similar buses produced by the company Navya, driving routes similar to or less advanced than the one at Forus. At the time of writing, projects have been conducted in or near the cities of Oslo (areas Fornebu and Vippetangen), Kongsberg, Gjøvik, and Longyearbyen, in addition to Stavanger.

increased in both scale and difficulty while retaining the core concept from the experiment's first phase.

There were certain challenges associated with acquiring a realistic picture of people's interaction with a self-driving bus. Initially, the bus was allowed a maximum speed of 12 km/h, meaning it operated approximately 40 km/h below the speed of other traffic. During the initial stages of Phase Two, the speed limit for the road was lowered from 50 to 30 km/h, and speed bumps were installed to slow down other vehicles and prevent them from passing the bus. Following safety concerns voiced during the public hearing, these regulatory and material adaptations ensured safe operations. As a side-effect, the adaptations narrowed the gap between the different vehicles' maximum speeds, providing the opportunity for gaining valuable insights into motorist-machine interaction under conditions similar to those envisioned in the future. While the adaptations were intended to deter motorists from passing the slow-moving bus, hazardous situations arose continuously. To reduce risky overtaking and right-of-way infringements, the initial speed limit was reinstated and the speed bumps were removed. Whereas the bus managed to navigate 'make-believe cities and make-believe people' (Matthew, Norgesbuss) during Phase One, the tendency of human drivers to bend—or even break—traffic regulations represented a challenge for the bus's static and defensive driving practices.

While the abovementioned problems constituted a setback, the three companies agreed that interactions between drivers and the bus improved significantly during the first three months of Phase Two. This implies that social learning was a two-way process in which the firms involved in the pilot project learnt how motorists interacted with the self-driving bus, and that simultaneously the mobility culture was changed by the bus's presence. This implication also ties into expressions of regional and/or national mobility cultures (Sheller, 2012). At Forus, the companies saw that 'motorists were the cause of stops. In the Netherlands, it is the cyclists' (Jenny, Kolumbus), highlighting that social learning is somewhat site-specific and even culture-specific. This indicates that the challenges pertaining to the implementation of self-driving vehicles may differ depending on regional and/or national mobility cultures, thus emphasising the importance of experimental replication in different contexts. While the learning process encompassed social and technical aspects, some Kolumbus employees argued that the testing was too focused on technology. They suggested that rather than trial the technology, the pilot project should have simulated the *service(s)* that the bus was expected to provide. In the absence of self-driving technology capable of testing more advanced mobility concepts, the employees argued that these could be simulated using vehicles with human drivers. Such a proposal could be construed as a call to research the actual use of, or need for, such vehicles in the future.

While motorists soon adapted to the performance of the autonomous bus, the companies still emphasised that the vehicle's 'operating speed must be raised to ensure that self-driving buses interact properly with regular traffic' (Vincent, Forus Business Park). In terms of speed and site of operation, the partnership envisioned future self-driving vehicles to perform within the same infrastructures and at the same speeds as today's vehicles. With the bus's maximum speed raised from 12 to 15 km/h over the course of Phase Two, a small step was taken toward such a shared speed limit. Although this was not exactly an institutional *transformation* (Naber et al., 2017), the slight increase in speed was a gentle institutional *expansion* of the conditions under which the bus would be allowed to operate. Forus PRT has recently secured a permit allowing for testing at a maximum speed of 20 km/h (Norheim, 2019), thus representing a further expansion.

5.3 Shaping technology, striking preemptively

In addition to institutional expansions, the prospect of upscaling self-driving technology was substantiated through processes of accumulation (Naber et al., 2017). The first such process related to Kolumbus's involvement in the European Union project FABULOS (Future Automated Bus Urban Level Operation Systems). In that instance, Kolumbus was invited to join a larger innovation project due to the company's previous experience with self-driving vehicles. When defining the call for tenders, the partner cities of the FABULOS project sought Kolumbus's recommendations, simultaneously giving the company the opportunity to nudge the future of self-driving vehicles toward being able to meet the specificities of Norwegian weather and road conditions.

This reflects the pilot project companies' lived experiences that 'whatever [self-driving technology] works in France, in sunny weather and 15 degrees [Celsius], is not the same as works in Western Norway, in rainy and windy weather, and on these roads' (Olivia, Forus PRT). Through FABULOS, Kolumbus became involved in defining the specifications that future vehicles would need to fulfill in terms of battery capacity, top speed, and slope traversal, rather than having to adopt technologies matured in, for example, more temperate France. The partnership often emphasised this point as justification for testing the bus at Forus, as by engaging with immature technologies, it would be possible to adapt them to local contexts and needs. For example, in Stavanger this would mean ensuring that future buses could handle heavy downpours, wind, and fog.

Parallel to the pilot project at Forus, Kolumbus was conducting another experimental project in the small municipality of Sauda, located approximately 80 km northeast of Stavanger. The regular bus service in Sauda runs infrequently, carrying on average 1.5 passengers in a full-size diesel bus—hardly sustainable, either economically or environmentally. In addressing this challenge, Kolumbus developed a service with the Norwegian name *HentMeg* (*PickMeUp*), whereby people place a reservation on a website or by telephone, specifying the point and time of departure and their destination. If multiple bookings overlap with respect to time of departure and general direction, an algorithm computes an appropriate route for effectively picking up all the passengers and taking them to their destination(s).

As *HentMeg* is aimed at replacing the regular buses, the cost of any trip requested through the service is the same as the regular bus fare. The challenge is profitability. Given that more than half of the operational costs of running a bus service comprise the driver's salary, bus fares do not pay for a driver waiting in stand-by mode for reservations to be made. As explicitly stated by one interviewee, Kolumbus conducted *HentMeg* 'to understand how [the company] can use this kind of algorithm, with a view to using it for the autonomous bus in the long term' (Jenny, Kolumbus). The key to profitability lies in eliminating the driver, which is the anticipated outcome of self-driving vehicles in the future.

6 Discussion

Rather than prescribing a preferred transport future, Norway's current National Transport Plan stresses the work that is needed for any self-driving future to come to fruition, and how this necessitates exploration of the potential of new technologies through pilot projects (Meld. St. 33 (2016–2017)). This claim was almost unanimously supported in the responses to the draft legislation, and the widely recognised need for a policy framework was also present in our interviews, in which it was further emphasised by statements such as '[self-driving technology] is approaching, and it is approaching fast' (Vincent, Forus Business Park). In terms of the dimensions outlined by Michael (2000), our interviewees stressed self-driving vehicles' arrival in terms of temporal distance and speed (proximal and rapid, respectively)—they will arrive, and soon. In conveying a sense of urgency, such statements may serve to bypass or mitigate processes of deliberation, by hurrying the establishment of legislation without concern for the societal effects of such vehicles. To ascertain future competitiveness, for example, when responding to a call for tenders, mobility providers need know the benefits and limitations of the technology.

With their EasyMile pilot project, the Stavanger partnership experienced some of the challenges of current self-driving technology. When testing the bus amid regular traffic, the operators were surprised by how regularly traffic regulations were broken. Although precautions were taken to ensure traffic safety (installation of speed bumps, lowered speed limit), risky overtaking and right-of-way infringements were frequent. As motorists perceived the bus as an impediment to traffic flow, the partnership responsible for the project emphasised the need for raising its operational speed. In our interpretation, this solution is emblematic of a certain dynamic of real-world testbeds for transportation innovations. As testing is legally prescribed to proceed with caution, emergent transport technologies often impede traffic flow through technical and/or regulatory restrictions. With the test bus operating (and causing disruptions) within the confines of a well-established system, the impulse is to adapt the bus to this system, rather than to envision separate infrastructures (as was the norm until recently, cf. Kröger, 2016). This explicates how the testbed's social embeddedness informs current understandings of self-driving vehicles, reproducing existing practices and systems such as the expected speed of traffic or, more broadly, the current characteristics of the road-based transport system.

In the case of Stavanger, the above dynamic may also shape technology. Through FABULOS's call for tenders, Kolumbus suggested certain technological requirements. In addition to aspects such as slope traversal and battery capacity, it suggested a required top speed of 50–60 km/h, matching the typical speed limit in Norway's densely populated areas. These adaptations highlight how the societal embeddedness of testbeds may lead technology development in specific directions. The partnership responsible for the pilot project envisioned a raise in operational speed to solve the messy motorist-machine interactions in Phase Two. This prescribed solution may enter processes of technology development through the call for tenders. By extension, having self-driving technology imitate the characteristics of the current system in terms of speed and flexibility (Steg, 2005) can help uphold or reinforce certain forms of urban spatiality and temporality (Ziljstra & Avelino, 2012). It follows that adapting to current traffic practices can be considered a positioning in relation to collectively held expectations regarding the characteristics of a (good) transport system.

At the end of Phase Two, the three companies concluded that the EasyMile bus was unfit for its intended function due to its low speed and weather-based problems. However, both Kolumbus and Forus PRT are still involved in new projects on self-driving buses. This echoes the claim of Engels and colleagues (2019) that the conditions of failure in this kind of experimentation are often unclear. Even as the partnership judged the bus to be an unviable option for transport within the business park, none of the companies appear to be disillusioned. Social theorist Niklas Luhmann has argued that 'modern society produces its own newness … by way of stigmatizing the old' (Luhmann, 1994: 10). An analogous strategy is used to rationalise the self-driving bus's performance and continued investment in self-driving technology. From being considered 'the best possible tool' (Jenny, Kolumbus) for testing self-driving buses, two years of testing turned the EZ10 model into 'an old fossil' (Olivia, Forus PRT), ripe for being 'placed in a science museum' (Jenny, Kolumbus). Emphasising the bus's obsolescence serves to rationalise 'past disappointments … such that they present a reduced threat to new and successive expectations' (Borup et al., 2006: 290). Thus, expectations are regenerated through belief in continuous technological progress.

A similar belief motivated the development of *HentMeg*. Shared expectations of the materialisation of self-driving vehicles were 'used to justify other statements and actions' (Borup et al., 2006: 289). With autonomous transport being anticipated to the point of being commonsensical, there is ample space to think two steps ahead: How can the possibilities presented by such vehicles be utilised appropriately? This incessant future-orientation may impede deliberative processes, as there is no question of whether such forms of transport should be implemented, only how their benefits can be properly reaped. Echoing expectations present in the draft legislation statements and the national transport strategy, Kolumbus envisioned a business model relying on the realisation of self-driving vehicles. *HentMeg* was a preemptive strike, thought to prove advantageous *when* the expected future materialises.

In shunning technical requirements that might hamper technological development, the current Act allows for testing any of the various technological configurations characterising today's self-driving vehicles (Van Brummelen et al., 2018) as long as the testing is conducted 'gradually, especially concerning the maturity of the technology' (Lov om utprøving av selvkjørende kjøretøy, 2017: §1). This intention clearly caters to the needs expressed by trade associations and public transport companies. Simultaneously, they are awarded more than a flexible framework. The Act (§9) requires companies conducting testing to provide the Directorate of Public Roads with a final report. In Stavanger, we observed how the embedded test site in Phase Two shaped how the partnership *understood* the self-driving bus, both in itself and in relation to traffic. This indicates that the reports being passed to the Directorate are not merely an 'accumulation of data and facts' (Naber et al., 2017: 343). Rather, the documentation appears to communicate understandings produced at the test site, allowing these understandings to enter policy- and law-making processes. Through this configuration, business and industry actors are granted significant power to influence the characteristics of future implementation. In the pilot project we studied, this means that the partnership's ideals concerning implementation might be institutionalised.

To counter the power currently wielded by business and industry actors, we suggest that policy-makers take up a more active role in pointing out desirable outcomes of transport automation. Is the 'clean and shared' or the 'private autonomy' scenario of the National Transport Plan more desirable, for example? A set of preferred outcomes might serve as a basis for developing an experimental protocol, which would be useful for (1) clearly articulating the conditions of success/failure and (2) locating responsibility and establishing the technology's safety.

Further, we suggest that public trials may be reconfigured to enable deliberative processes. Asdal (2008: 13) has suggested that public hearings may be understood as *political technologies*, 'as tools for public involvement, for democratisation or deliberation'. Public trials may be considered another such technology, as they can be (but often are not) configured to 'enable the elicitation of social, political and ethical aspects of new technology that are not already apparent' (Marres, 2020: 127). Public hearings and experiments may serve as complementary tools, providing both an initial articulation of public concerns and a subsequent broadening or transformation of them in light of test experiences, thus enabling the public(s) and authorities to collaborate in shaping a desirable future through an iterative back-and-forth approach. Our suggestion may enable self-driving technology to benefit the larger public (Martens, 2017), rather than merely benefitting commercial actors and/or exacerbating existing transport problems (as have, for example, Lyft and Uber, cf. Schaller, 2018).

7 Conclusion

In this article, we have probed the expectations and work associated with self-driving vehicles in a Norwegian context. In deploying a two-pronged empirical approach, we have studied expectations relating to autonomous transport, and the practices and understandings informed by these expectations. Reflecting our empirical approach, we have employed two distinct, though related theoretical approaches. First, we approached the role of visions and expectations as they have developed in Norway. Drawing on the sociology of expectations, we have demonstrated how expectations for self-driving vehicles have been instrumental in developing legislation allowing for their public testing. In analysing the responses to the proposed legal framework, we highlighted three issues: (1) issues relating to safety and responsibility, (2) concerns that legislation or bureaucracy might hamper technological development, and (3) questions regarding the purpose and beneficiaries of public testing.

Second, we drew on literature on experiment upscaling and public experimentation when analysing our case study. We observed the challenges of upscaling, namely moving from a controlled test circuit to a messy real-life setting. Under the latter circumstances, the test bus's low speed gave rise to tension in motorist–machine interactions. The pilot project partnership expected that this friction would be alleviated by raising the operational speed, a belief that soon entered processes of technology development through FABULOS's call for tenders, possibly shaping future self-driving technology. This explicates how current testing, inextricably linked to existing infrastructures, also produces an understanding of self-driving vehicles that is tightly interwoven with the (written and unwritten) practices and rules of these infrastructures. Hence, further upscaling will rely on future self-driving technology approaching the requirements of this transport system. Such a development was expected to happen soon, as expressed by Kolumbus's development of algorithms and business models for the future. Together, this highlights the power of expectations, seeing how they underpin actions conducted in preparation for a highly uncertain future.

In this article, we have also argued that trials produce understandings of both self-driving vehicles and their ideal relationship to general traffic. In our interpretation, these understandings have entered policymaking and lawmaking processes in Norway through reports to the Directorate of Public Roads and contributed to further shape the institutional understanding of such vehicles. Against this background, we offer the following insights for future public initiatives pertaining to autonomous transport. First, we want to emphasise the benefits of articulating desirable transport futures at the governmental level. In doing so, policymakers give innovation processes direction beyond the deployment of self-driving vehicles, for example by establishing a decrease in private car ownership as the intended outcome of the automation of transport. Second, we suggest that these desirable futures serve as the basis for developing an experimental protocol. Such a protocol would allow for (1) assessing currently available technology in relation to desirable futures and (2) ensuring the safety of the technology, for example, in relation to vulnerable road users. Finally, we suggest that public hearings and public experiments may serve as complementary political technologies for abating the influence of business and industry actors over future conditions of implementation. By facilitating a back-and-forth between the public (or publics) and the government, the scenario(s) of future implementation might be shaped to benefit the general public rather than chiefly being adapted to the needs and understandings of commercial interests.

As exemplified in this article by concerns regarding legislation and bureaucracy impeding testing, emergent technologies are often embroiled in narratives of legislation lagging behind technological development. Drawing upon the findings from our case study, such concerns seem misguided. Rather than technology running ahead of the legislation, the opposite appears closer to the truth, at least in this instance. An immature technology is tested publicly *because* of the associated high expectations. The test experiences then influence how the technology is understood in terms of mode(s) of implementation and necessary technological capabilities, which go on to shape further expectations. As succinctly summarised by one interviewee, the EasyMile bus served the dual function of showing 'how far the technological development has come, but how immature [self-driving technology] still is' (Jenny, Kolumbus). Existing in this paradoxical state, simultaneously obsolete and representing the (expected) possibilities of future autonomous transport, the self-driving bus comes to represent the proto-existence of a specific technological future, a conduit through which this future may flow into existence.

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Article 3:
A new system in the shell of the old: prefiguration in technology and policy experimentation

Article submitted to journal, review pending.

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Abstract

The article adds to the theorisation of temporality within sustainability transitions by introducing the concept of prefiguration. Through two transport-related case studies, one technology experiment and one policy experiment, the article shows how prefiguration might elucidate the temporal aspects of experimentation. By employing the conceptual pair of ends-guided and ends-effacing prefiguration, the article shows how the future-orientation characterising much technology experimentation allows for the indeterminate deferment of politics, whereas experiments focusing on present-day transformations must contend with politics from the outset. As such, technology experiments are characterised by a temporal buffer which allows them to elicit considerable support without engaging with possible issues or contestations. In conclusion, the article suggests that more attention should be paid to experiments that practice ends-effacing prefiguration, as to better understand their characteristics and their capability to successfully trigger meaningful sociotechnical change.

This article is awaiting publication and is therefore not included.

Part C: Cross-cutting analysis

Chapter 5: Discussion

In Chapter 1, I asked what role or roles innovations relating to automated vehicles are ascribed in and beyond the Norwegian transport sector. Embedded in this overarching question were three subquestions: (1) How do various actors shape expectations regarding automated vehicles? (2) How are pilot projects expected to instigate social and technological change? (3) What is the relationship between innovation efforts and the Norwegian state? Some tentative answers are given to these questions in the three articles presented in Part B. In this penultimate chapter, I use these questions as a starting point for drawing conclusions across the three articles. First, I discuss how place shapes automated vehicle innovation and then I show how the current organisation of innovation priorities some futures over others, which paves the way for the next two sections, in which I discuss the temporal politics of innovation and the ramifications of the actor constellations that are prescribed in Norwegian innovation policies. Finally, I focus on how the Norwegian state's organisation of automated vehicle innovation reflects a specific political order that complicates the transition towards more sustainable road transport.

As a point of practical information, throughout this chapter, I reference themes and topics that are discussed in the articles that make up Part B of this thesis. Whenever I refer to the articles, I will refer to them by the number they are assigned in Part B.

5.1 Where are we?

In many respects, the visions and expectations underpinning the Norwegian push for automated vehicles are reminiscent of those seen elsewhere: as stated in the National Transport Plan for 2018–2029, automated vehicles are thought to be able to contribute towards the overall goals of the NTP, which is to establish a transport system that is 'safe, facilitates value creation, and contributes to the transition towards a low emission society' (Meld. St. 33 (2016–2017): 27). This may be considered an adoption of collective expectations, which are expectations that are not readily traceable to one person or group, but rather arise from a series of distributed discourses and innovation activities (Konrad, 2006: 431–433). The same may be said for the emphasis on the economic prospects of automated vehicles: the idea of transport innovation as an opportunity to be seized and facilitated is commonly seen in national discourses, and the National Transport Plan for 2018–2029 even references international reports to substantiate this point (e.g. Meld. St. 33 (2016–2017): 38). Hence, in terms of performativity, collective expectations regarding automated vehicles motivated the Norwegian Government to establish both legislation and funding for automated vehicle innovation.

Norwegian proponents of automated vehicles position the development of such vehicles as an extension of existing industries. Norway's distinctive geography was instrumental in the development of hydropower and the associated electro-chemical industries in the early 1900s and the emergence of the petroleum industry in the late 1960s (Fagerberg et al., 2009: 434). With automated vehicles, Norway's distinctive geography once again represents an opportunity, as even the development of high-tech products such as automated vehicles and related technologies may benefit from being challenged by Norwegian weather conditions and road geometries. Rather than Norway simply *being* an attractive site for testing automated vehicles, Norwegian actors work actively to *shape* the country into such a site. The motivation appears twofold: to ensure that future technology can function in Norway, but also to attract business by positioning the country as an attractive testing ground for automated vehicles. Regardless of whether Norway is compared with the flat deserts of Arizona, as one NPRA engineer did (Article 1), or with the temperate weather of southern France, as did one of the Forus Shuttle organisers (Article 2), the challenging topography and weather conditions of Norway are posed as an important challenge to automated vehicle developers.

In the case of Borealis (the NPRA-initiated project conducted in Northern Norway), the NPRA and its collaborators emphasised some of the complications automated vehicles may encounter, including animals, cold weather, ice-covered roads, and GPS-disabling northern lights (Ryghaug et al., 2022). In contrast to the often nondescript visions of automated vehicles, these examples highlight some of the complexities that automated vehicles must be able to handle, both in terms of the road itself and in terms of weather-related resilience. Although solvability was still a key component of the approach in the Borealis project (Haugland et al., in press), the attention to place suggests an approach to innovation that differs from the libertarian, vehicle-centred innovation of the US (Hess, 2020; Stilgoe, 2018). The NPRA highlighted cross-border collaboration (e.g. the twin projects of Aurora and Borealis) and standardisation work (e.g. as pursued within the EU) as key for automated vehicles to be able to operate across a series of varied environments, and thus for achieving scalability and interoperability in the future.

Whereas place may highlight the challenges to be overcome through innovation, it may also shape expectations. The Forus Shuttle project was geared towards second-order learning (Article 2), meaning that the objective was to understand the possibilities and limitations of the technology beyond its technical capabilities (Kemp et al., 1998; Naber et al., 2017). However, despite the aim of understanding the social aspects of the technology, the technical capabilities of the bus were thematised, too. The bus operated at the low speed of 12–15 km/h, compared with the 30–50 km/h speed limit followed by normal motorists. The organisers considered the difference in speed limits a problem and argued that the regulations relating to automated vehicles were too strict. However, this also suggests that the place where the bus was tested formatted the trial. Rather than testing the viability of an alternative transport system, the organisers were judging the bus according to its compliance with the existing one (Schot & Geels, 2008: 541; Tennant, Neels et al., 2021). This proclivity to reproduce established systems and practices is discussed further in the next section.

5.2 Where are we going?

Both the Borealis project and the Forus Shuttle project showed how the project organisers shape projects, and how the projects shape subsequent expectations. The two projects were initiated and implemented, and indeed constructed (Hopkins & Schwanen, 2018b; Marres, 2020b), by specific actors for specific ends, and shaped how innovations and innovation trajectories were understood. Thus, both before and after conducting a pilot project, organisers – and, as I discuss in Section 5.3, other actors – use their project to construct claims regarding the future. According to a constructivist view of expectations, these claims cannot readily be described as true or false, but rather, they are constructed as such (van Lente, 2012: 776). Therefore, it is worth perusing the content of the claims that are being constructed by examining the stated motivations for testing and possibly adopting transport innovations.

As described in Article 1, the starting point of the Borealis project was the challenges faced by, for example, the fishing industry, freight companies, and public transport companies. As such, the project focused on relatively narrow problem framings, such as identifying vehicles coming to a stop and relaying the information through communications infrastructures, and identifying the need for maintenance (salting, snow clearance). After gaining an overview of common challenges along the road, the NPRA distributed a call for project proposals and subsequently selected and partially funded proposals that were deemed promising. This points towards the specific orientation of the Borealis project: the technologies that were tested were chosen because the NPRA believed they could help optimise road transport, first along the E8, and then at other locations if testing proved successful. Whereas the NPRA strongly emphasised that it was not interested in deploying technology solely for the sake of it, as reflected by its charting of local transport challenges, the Borealis project still appears to have been grounded in an engineering paradigm that ultimately saw road transport as a system to be optimised, controlled, and ultimately improved using technology (Haugland et al., in press).

The Forus Shuttle project exhibited a similar orientation towards technology-enabled improvements to road transport. As discussed in Article 2, the mobility provider Kolumbus ran two parallel innovation projects, one involving an automated bus (Forus Shuttle) and the other an algorithm for ride hailing and ride sharing (HentMeg). Kolumbus expected to combine the two projects in the future, in order to create automated on-demand transport. This suggests an imitation of the characteristics of the system of automobility (Urry, 2004): automated buses, possibly in combination with other modes of travel, might allow new groups such as youths or the elderly to experience and practice mobility akin to that offered by the automobile. Additionally, as put by one Kolumbus employee, that would also help to 'make sure people want to live where they currently live and continue to have the opportunity to live where they currently do, while also having access to as good mobility services as possible' (Article 3, p. 164 in the thesis). In combination, this suggests quite a preservative orientation. While the two innovation projects (Forus Shuttle and HentMeg) were motivated by the prospect of providing green mobility, in particular to underserved groups, the prospect was still grounded in existing car-based settlement and mobility patterns.

Although Borealis and Forus Shuttle differed considerably in terms of their organisation and general orientation, the two projects embodied a similar dynamic. Both projects exhibited an instrumental view of technology, in which technological innovation was sought out to ameliorate the problems plaguing road transport. However, this orientation simultaneously highlights a limitation of technological innovation. While the emphasis on improving efficiency, energy use, and accessibility might have been commendable, these motivations and the associated visions remained protective: rather than transforming existing systems, the purpose of technology development and implementation was seemingly *not* to have to reconfigure the systems but rather to preserve them. This observation is particularly pertinent considering claims regarding emerging technology, as I discuss in the next section. However, here, it is sufficient to note that the preservative proclivity echoes the discursive presentations of automated vehicles discussed in Section 3.5 (Hildebrand, 2019; R. Martin, 2021; Wigley & Rose, 2020): new transport technologies are claimed to ameliorate the current problems of road transport while seemingly having few, if any, downsides. Simultaneously, by ascribing such a function to technology, the public is also cast in a specific role.

In the case of Borealis, the public generally remained outside the project. Because the project's starting point was specific problems experienced by agencies and companies operating along the E8 road, public concerns – for example, regarding the road sharp's increase in freight traffic since 2010 – were externalised. The temporary and technology-oriented nature of the project narrowed down larger questions regarding the organisation of freight transport in the region to specific problems that implicated clearly delineated publics. This is not to say that the technologies would not benefit the local road users too. However, because the technologies tested in the Borealis project were directed towards ameliorating existing problems, they also represented extensions of established transport practices – practices with problems that had motivated the project in the first place. Therefore, the public was also asked to accept the continuation of the practices, as improved by technology, rather than to partake in discussions regarding alternative transport arrangements.

Compared with Borealis, the Forus Shuttle project had a more obvious interface with the public. One aspect is the strategy discussed in Section 5.1, in which the partnership envisioned automated vehicles to replicate car-based mobility. As described in Article 3, the vision was communicated to those who tested the bus, seemingly to enlist them – to have them accept the technology, as it were. Simultaneously, the bus operators actively managed how the automated bus interacted with other motorists and regularly yielded their right of way in order to appease occasionally antagonistic motorists. This may also be considered an attempt at fostering acceptance of a new sociotechnical object.

Additionally, test rides were organised for specific members of the public. As discussed in Article 3, certain groups – including schoolchildren, the Norwegian Association of Disabled, and the elderly – were specifically invited to test the automated bus at the test track. These groups were then allowed to ride the automated bus in a controlled environment, to enable them to overcome what the project organisers described as an unnatural feeling associated with a non-traditional vehicle, a strategy also seen in discursive representations of automated vehicles (Hildebrand, 2019).

In sum, the engagement strategies that characterised the Forus Shuttle project suggest a twofold view of the public. On the one hand, the public seems to be understood as users with pre-established preferences (Schot & Geels, 2008: 541), such as with regard to speed and flexibility. On the other hand, the public also appears to be conceived as irrationally opposed to new technology (Graf & Sonnberger, 2020; Stilgoe & Cohen, 2021), as evidenced by the attempt at having the public unlearn what the organisers described as an unnatural feeling.

The above-discussed dynamics, in which technology is positioned as an improved extension of established practices, may also reflect the emphasis on commercialisation seen in the NTP for 2018–2029 (e.g. Meld. St. 33 (2016–2017): 38) and in the Borealis and Forus Shuttle projects. Because funding is tentative and project-based (Torrens & von Wirth, 2021), there is little room for more adventurous innovations. Instead, focus must be directed towards technologies that may be upscaled and commercialised. Even if Borealis and Forus Shuttle were to be considered examples of niche activities, they appear to have been grounded in a set of collective expectations that did not tend to stray excessively far from the system of automobility (Dowling & McGuirk, 2022; R. Martin, 2021; Wigley & Rose, 2020).

The Norwegian emphasis on emerging transport technologies appears either to externalise all or most of the public or to cast the public in the role of users and/or consumers (cf. Milakis & Müller, 2021). However, there is reason to believe that attitudes, behaviour, and needs are all malleable (McCarthy et al., 2021; Mladenović, 2019: 110). Hence, one might argue that the preservative orientation within transport technologies underestimates the public's capacity to change its practices, as well as its capacity to envision more transformative uses of emerging technologies. One might also argue that these capacities are reflected in transport-related visions that do not centre on emerging technologies.

Technology-informed visions are not the only ones circulating in Norway. As shown in Articles 1 and 3, there is also an orientation towards past futures – that is, futures that were envisioned in the past but never realised (Suboticki & Sørensen, 2020). For example, the Northern Norway railway line discussed in Article 1 has been envisioned for almost a century and it would be possible to construct it today. Similarly, the purpose of the Car-free City Life project discussed in Article 3 was to improve urban transport and the quality of urban life by restricting the use of cars in Oslo's city centre. These alternative futures have one thing in common: in principle, development could start tomorrow or it has already begun. However, this orientation towards the present represents a practical and political challenge: because the projects are already possible, they are also subject to political and administrative processes and procedures, budgeting, and conflicting interests. Automated vehicles are seemingly unencumbered by such practical concerns. This raises questions regarding the temporal aspects of automated vehicle development.

5.3 When will we get there?

Despite the tentative and varied nature of automated vehicle technology (Schwarting et al., 2018; Van Brummelen et al., 2018), companies involved in such technologies have shown a notable proclivity to make official announcements regarding the timeline of automated vehicle deployment. The chief offender in this regard might be Tesla's CEO Elon Musk, who time and again has sketched out optimistic timeframes only to brush off the company's failure to meet them with statements such as 'punctuality is not my strong suit' (Musk, cited by Stilgoe, 2020: 39). However, Musk is simply an extreme case: his promises reflect a broader tendency for companies, both entrants (e.g. Comma.ai, Baidu) and incumbents (e.g. Volvo, Audi), to announce their target goals for automated vehicle deployment, only to fail to meet them (Nriagu, 2021). The consistent failure to meet target goals is not inconsequential, considering how automated vehicles are claimed to address urgent societal problems such as reducing greenhouse gas emissions from transport. Hence, it is worth exploring the temporal aspects of automated vehicles, particularly the role of automated vehicle trials.

Present-day trials with automated vehicles tend to be conducted in public (Dowling & McGuirk, 2022), with trial sites being chosen either because they already exhibit certain desirable qualities (Hopkins & Schwanen, 2018b) or because they may be modified to accommodate a particular technology despite its limitations (Marres, 2020b). By conducting flawless technical performances in public, the trials may act as technologies of persuasion (Jasanoff, 2004b: 29), meaning they may act as instruments for convincing an often-sceptical public about the claimed merits and desirability of the technology. For example, the platooning demonstration discussed in Article 1 played up to collective expectations regarding automated vehicles, rather than being useful in its own right. Similarly, as discussed in Article 3, the operators of the Forus Shuttle actively used the trial to promote a specific future. However, if demonstrations are conducted for performative reasons as well as practical ones, this raises the question of whether, and if so when, the gap between demonstration and implementation may be closed (Alderson & Doyle, 2010: 839; Both, 2020: 17; Engels et al., 2019; Woods, 2016).

Nevertheless, regardless of the above-mentioned stage dressing, automated vehicle trials communicate a sense of 'already-here-ness' or 'real-worldness' (Forlano, 2019: 2812; Hopkins & Schwanen, 2018b: 91; B. W. Smith, 2014: 86). This serves to substantiate the feasibility of a specific future, which means that the demonstration of automated vehicles may shape and/or ossify expectations regarding the future, as well as direct further funds towards the realisation of the specified future or futures. Despite automated vehicles being a technology with capabilities that have yet to be ascertained (Borup et al., 2006; van Lente, 2012), present-day trials allow such vehicles to be mobilised rhetorically, for example, to justify or defer certain directions and/or priorities in transport policy (e.g. Forlano, 2019: 2825; McAslan et al., 2021). The demonstration of automated vehicles allows actors to substantiate claims regarding feasibility, and thus mobilise further support for a specific innovation pathway.

Whereas many automated vehicle trials are one-off events that produce little in terms of policy learning (McAslan et al., 2021), the national and international proliferation of such trials may still substantiate expectations regarding a specific innovation pathway

(Haque & Brakewood, 2020; Hopkins & Schwanen, 2018b: 76). As discussed in Article 1, Erna Solberg, the former Norwegian Prime Minister, claimed that automated freight trucks might be realised within twenty to twenty-five years. Approximately four months later, the local newspaper *iTromsø* asked Solberg whether she still stood by her claim. She confirmed her stance, and further substantiated it by saying 'Remember, the first autonomous bus already runs in Kongsberg' (Solberg, cited by Lægland, 2019). In that respect, Solberg further justified her claim by referencing a pilot project with an automated shuttle bus in Kongsberg, a claim that she had initially substantiated with reference to the Borealis project.[1] This suggests that the aggregation of pilot projects with automated vehicles might also form an ecosystem that is either taken or being used to substantiate the probability of such vehicles being part of a future transport system.

While the above discussion clarifies how automated vehicles may be mobilised rhetorically and how trials may help to strengthen claims regarding the feasibility of the technology, it does not explain why technologies such as automated vehicles make useful rhetorical devices. Automated vehicles derive their rhetorical usefulness from their emergent nature. As exemplified in Articles 1, 2 and 3, it is possible to make a variety of claims regarding the future capacities of automated vehicles. Indeed, the use cases offered by automated vehicles appear almost endless. Because the capabilities of automated vehicles have yet to be ascertained, the technology is ascribed more potential than technologies with capabilities – and perhaps more crucially, limitations – that are well-documented. In reality, emerging technologies tend to be more limited in their capabilities than more mature technologies, a foundational observation in strategic niche management and associated frameworks (Kemp et al., 1998). However, because the limitations of emerging technologies are not yet *known*, they can more easily be discounted. This points to a paradox, in which high expectations for future technical capabilities counterbalance a technical performance that is currently inadequate.

The same indeterminacy that enables the rhetorical mobilisation of automated vehicles is also discernible in the relationship between trials and the public. While both

[1] Solberg was slightly incorrect in stating that the automated shuttle bus in Kongsberg was the first automated vehicle in Norway. The Kongsberg project began in October 2018, while Forus Shuttle began operations in June 2018.

of the projects discussed in Article 3 revolved around goals that in general are considered desirable, such as reducing emissions, improving urban life, and/or increasing accessibility, only one of them caused significant controversy: Car-free City Life. This points to the relative ease that comes with positing automated vehicles, or other emerging technologies, such as mobility-as-a-service (Pangbourne et al., 2020), as a solution to transport problems. Because the implementation of automated vehicles lies in the future, the rhetorical mobilisation of technology allows developers, manufacturers, and politicians to defer engagement with the potential problems of technology, such as increased traffic in residential streets through the implementation of on-demand automated shuttle buses, because they are future problems. If emerging technologies represent future solutions to present-day societal problems, there is no need for active intervention in the transport system through transport policy. The technological capabilities of automated vehicles must merely catch up with the expectations articulated today.

While the indeterminacy related to technical capabilities gives proponents of emerging technologies a rhetorical advantage, the same indeterminacy is a potential problem for society. Furthermore, while much attention has been paid to the assessment of technology and the anticipation of its possible effects, both with regard to automated vehicles and technology more generally, less attention has been paid to the consequences of its non-realisation.

5.4 Who's steering?

Emerging technologies such as automated vehicles often encounter an institutional void (Hajer, 2003). As emerging technologies often appear to be novel objects or are represented as such, there are no preestablished ways of making sense of them (Mladenović, 2019). Nevertheless, institutions and organisations ultimately employ some strategy for making sense of emerging technologies. The strategies for sensemaking and the resulting understandings of the technology are crucial to understand, as the way emerging technologies are understood also shapes how they may be governed (Stilgoe, 2018). In Norway, automated vehicles were surrounded by an institutional void until 2017, when the Norwegian Government developed legislation that allowed for such vehicles to be tested in public (Lov om utprøving av selvkjørende kjøretøy, 2017). The legislation was the subject of a public hearing and, as discussed in Article 2, a considerable number of participants emphasised that the resulting legislation should not hamper innovation through, for example, complicated bureaucracy. As a result, the final legislation exhibits considerable adjustment flexibility, as it can accommodate a wide variety of automated vehicles without requiring frequent updates (Hansson, 2020). The legislation was obviously important for companies and organisations seeking to test automated vehicles under Norwegian conditions. However, the development of the legislation must also be interpreted in light of the Norwegian Government's facilitation strategy for automated vehicles.

Social learning may be defined as 'the way society and its institutions make sense of novelty' (Stilgoe, 2018: 26; for relevant discussions on social learning, see Mladenović, 2019; Rip, 1986). In Norway, the legislation that allowed for testing automated vehicles on public roads also represents a mechanism for social learning. In the NTP for 2018–2029, the Norwegian Government lists a series of strategies for 'seizing the opportunities offered by new technology' (Meld. St. 33 (2016–2017): 26). Among other strategies, the Government (1) emphasises the importance of continuous and intensified knowledge collection and (2) prescribes the use of trials and pilot projects as instruments for producing knowledge about emerging technology (Meld. St. 33 (2016–2017): 26). As discussed in Chapter 1, trials with automated vehicles have been facilitated through two initiatives: the research funding scheme Pilot-T and the Smartere transport competition. Additional efforts, such as Borealis and Forus Shuttle, have been initiated outside these funding schemes. However, regardless of funding, projects relating to automated vehicles function as devices for social learning. Whether conducted by government agencies (Borealis) or public-private partnerships (Forus Shuttle), the knowledge produced through testing is fed back into government agencies such as the Directorate of Public Roads or the Ministry of Transport and thus also helps these institutions to make sense of novelty. Indeed, these trials make automated vehicles and related technologies knowable.

Both Borealis and Forus Shuttle were configured as public-private partnerships. This reflects the task distribution outlined in the NTP for 2018–2029, in which the Government prescribes that commercial companies should be tasked with developing new technologies, whereas authorities should mainly facilitate technology development (Meld. St. 33 (2016–2017): 38, 41). This suggests that the testing of automated vehicles may be interpreted as a kind of distributed governance in which a series of different actors – private, public, or some combination thereof – are tasked with making sense of new technologies. This in turn might be considered a mechanism for facilitating the co-evolution of technology and regulations, as prescribed by strategic niche management (Hoogma et al., 2002; Kemp et al., 1998). However, due to the preservative orientation discernible both in Borealis and Forus Shuttle, the task distribution prescribed in the NTP raises questions regarding the capability of these projects to trigger meaningful change.

The arrangements discussed above imply that the exact direction or directions of development has been left to the actors testing automated vehicles in public or at least has been strongly shaped by them. However, as discussed in Section 5.2, the preservation and improvement of established practices was the starting point both for the Borealis project and the Forus Shuttle project. The prospect of substituting one technology and its problems for another less problematic technology suggests something of a paradox. The NTP for 2018–2029 acknowledges that 'new technology is accompanied by new business models, new actors, and changes in user behaviour' (Meld. St. 33 (2016–2017): 38; for a similar argument, see Rip & Kemp, 1998). Considering this claim, the prospect of technology substitution looks very different: when project organisers seek to preserve established practices through technology, any change in social and/or societal practices rendered possible by the technology will be incidental and left to chance, rather than having been actively sought out or at least anticipated.

At the beginning of this subsection, I have suggested that automated vehicles were surrounded by an institutional void until the Norwegian Government established legislation in late 2017. However, the Norwegian state has long-honed strategies for dealing with novelty in the more general sense of innovations. As detailed in Chapter 1, the late 1970s marked a shift in Norwegian industrial strategy (Espeli, 1992; Sørensen, 2016). Rather than supporting specific industrial ventures, the Norwegian state shifted towards generalised support schemes, leaving commercialisation to industry and business actors. At first glance, automated vehicles appear to have been given the same treatment. However, because the testing acts as a mechanism for social learning for government institutions, this is not the whole story. As detailed throughout this chapter, test organisers do not simply test technology. Rather, they shape technology and, in doing so, possibly also society.

5.5 Preserving the present

Whereas pilot projects with automated vehicles or related technologies may offer opportunities for both first-order learning and second-order learning, as prescribed in strategic niche management (Kemp et al., 1998), the discussion in the preceding section suggests that these projects may not be as innocuous as they might first seem. However, the exact reasons for concern differ, depending on how the state is conceived. One possible way to analyse pilot projects with automated vehicles would be to assume that these represent ceding control from the state and into the hands of extra-governmental actors. Ceding control might be problematic if the goals of the state, the needs of its citizens, and the goals of the actors conducting the testing differ. However, this would mean treating the Norwegian state as a unity with clear and unidirectional goals, goals that are expressed through political documents and associated actions. In this analysis, pilot projects would represent the modulation and/or subversion of the state's goals and the circumvention of traditional forms of public accountability, as non-state actors are granted the power to steer technology development according to their own interests (for a similar discussion, see Marres, 2020b). However, this analysis is too simplistic and relies upon a false dichotomy between state and market (Mazzucato, 2013), in which the two are antagonistic towards each other. While actors such as Tesla level promote this view as part of a deregulatory agenda (Stilgoe, 2018), such a libertarian dynamic is not discernible in Norway.

Rather than consider the state an entity with unidirectional goals, one might consider the state as the sum of the activities it facilitates, regardless of whether the tasks are relegated to public or private actors. As discussed in Section 5.4, the current distribution of tasks with regard to automated vehicles (facilitation, funding, testing, and the associated knowledge production) is actively promoted by the state. Hence, the actors conducting pilot projects are simply following suit. This holds true regardless of whether the project organisers are motivated by the state's goal of establishing a safer, more efficient, and more green transport sector (Meld. St. 33 (2016–2017): 27) or its goal of having Norwegian companies seek out automated vehicle innovation to participate in an emerging market (Meld. St. 33 (2016–2017): 38). Rather than being an incidental ceding of control, the organisation of automated vehicle innovation appears to have been actively sought out by the Government, and thus reflects a specific political order.

The knowledge production taking place in pilot projects exemplifies constitutive co-production (Jasanoff, 2004b: 22–28). As exemplified through all three articles of this thesis, pilot projects either change or seek to change the constituent parts of the social, whether by modifying the physical environment (Articles 1–3), the attitudes of publics (Article 3), and/or institutional understandings of the technologies being tested (Articles 1–2). However, because the projects are linked to governmental institutions through specific institutional arrangements, they also exemplify interactional co-production (Jasanoff, 2004b: 28–36). There is a political order in which the Norwegian state facilitates pilot projects and, in turn, project organisers produce knowledge for the state (Meld. St. 33 (2016–2017): 41). Through this arrangement, the state acknowledges that pilot projects produce knowledge that may be regarded as a precise or sufficiently realistic description of the technologies being tested and their prospective use cases, despite the knowledge being produced by actors with vested interests (Voß & Simons, 2018; Weiland et al., 2017). This knowledge subsequently influences transport policies and regulations, with regard to automated vehicles specifically and the transport system more generally.

When pilot projects embody a combination of constitutive and interactional co-production, they may be powerful tools in shaping or directing change. However, the examples provided throughout this thesis also suggest an important shortcoming. When innovation is project-based and the prospect of commercialisation is left to the actors conducting pilot projects, there is little incentive to stray far from established practices. As described in Section 5.2, this results in preservative visions for the transport system, wherein the purpose of new technology is to ameliorate the car-based system but still provide car-like mobility, rather than, for example, to promote a transport system that is less dependent on motorised transport (Holden et al., 2020; Mattioli et al., 2020). This is not inconsequential: if pilot projects can simultaneously shape or attempt to shape the physical environment, public attitudes, and institutional understandings, this also means that the directions they make explicit might be pursued more rapidly than others. Depending on the direction, this may represent a challenge for transitioning towards a more sustainable transport system.

Chapter 6: Concluding remarks

The Norwegian approach to automated vehicle innovation is oriented towards problem-solving but is seldom directed towards the source or sources of a problem or a set of problems. Rather, the actors conducting testing direct their efforts towards optimising current practices and/or ameliorating the problems associated with those practices. This approach appears ill-equipped to instigate a radical transformation of the transport sector. One might argue that such a transformation would be outside the mandate of both the NPRA and the Forus Shuttle organisers, and would rather appear to be the responsibility of the state. However, because the actors that conduct testing are allowed to shape institutional understandings of emerging technologies, the modulation of ongoing dynamics – to put it in the parlance of strategic niche management (Kemp et al., 1998) – is directed towards incremental (and ostensibly commercially viable) improvements of established transport practices and the current transport system. As a result, niche actors, such as those testing automated vehicles or developing related infrastructures, pull in the same direction as regime actors – in this case, the Norwegian state – and thus ultimately sustain the regime under the promise of relieving the road transport sector of the problems currently plaguing it. I would argue that the dynamics I have described throughout this thesis apply more broadly. Hence, in this last section of the thesis, I will turn my gaze forward and ask how the insights I have presented might inform us about the role of emerging technologies in planning for the future.

Whereas one should be careful when using analogies for predicting the future (Borup et al., 2006; Schnaars, 2009), the past may still be instructive. In an article that traces the stops and starts of automated highway systems in the US, Jameson M. Wetmore notes that '[automated] highways have been "only 20 years away" for over 60 years' (Wetmore, 2003: 9). This points to the uncertainty of expectations (N. Brown & Michael, 2003). Whereas claims regarding the temporal proximity of emerging technologies are common (Michael, 2000), the realism of such claims is notoriously hard to assess (van Lente, 2012). As emphasised throughout this thesis, automated vehicles are characterised by considerable uncertainty with regard to the timeline of deployment (Nriagu, 2021), exact technological configurations (Ibañez-Guzmán et al., 2012; Schwarting et al., 2018; Van Brummelen et al., 2018), and social and societal effects (Duarte & Ratti, 2018; G. Martin, 2019b; Milakis et al., 2017; Taiebat et al., 2018). Regardless of this considerable uncertainty, claims regarding future developments may still exert considerable influence, both in terms of directing efforts and resources and in terms of present-day planning (e.g. Forlano, 2019; Hopkins & Schwanen, 2021; Legacy et al., 2019; G. Martin, 2020; McAslan et al., 2021; Srnicek, 2016). In the face of urgent problems such as climate change, it may be tempting to buy into claims regarding the disruptive and transformative capabilities of emerging technologies (Sperling, 2018). However, these technologies are of little use if they remain twenty years away for sixty years or forever. This points to the importance of planning for divergent futures.

Rather than envision and plan for a future in which automated vehicles are the quintessential transport technology, a more practical approach would be to use currently available technologies and regulatory tools to design a transport system that is safer, more sustainable, and more accessible (R. Martin, 2021). By making plans that do not centre on technology while simultaneously considering how emerging technology, *if realised*, might enhance society, one may be able to mitigate the risk of planning for a future that is never realised. Rather than believing in either the transformative or preservative capacities of future technologies, policy experimentation may be more conducive to near-future change (Kivimaa & Rogge, 2022). Whereas such an approach would still be associated with considerable uncertainty (Voß & Simons, 2018; Weiland et al., 2017), it would promote near-future action, rather than defer it. However, the approach would also come with the monetary and political cost of having to follow bureaucratic procedures, allocate funding, and make prioritisations in the present.

The prospect of addressing transport problems without considerable policy effort builds upon a conception of innovation in which innovations can *solve* problems (Mladenović, 2019). There is an assumption that, given sufficient time, there will be little need for contested and/or expensive policy measures, such as curbing car use, stopping the development of new roads, or developing railways. This points towards the temporal politics of innovation: neither the costs nor the benefits of these technologies can be reliably assessed *ex ante*. Because the changes resulting from innovation lie somewhere in the future, issues do not form in the same way as they do around contemporary initiatives and investments (Eames et al., 2006; Marres, 2007). However, the full-scale deployment of the technologies tested in the Borealis and Forus Shuttle projects would also require considerable political efforts, investments, and prioritisations. It is the nascent nature of the technologies in question, and of emerging technologies in general, which allows for the bracketing or marginalisation of the public and its various concerns, as well as the indefinite deferment of practical issues.

Automated vehicles *may* disrupt parts of the transport system, positively or negatively (Wadud et al., 2016; G. Martin, 2020), if realised on a large scale. Hence, it is crucial to assess claims regarding their benefits and downsides, in order to be able to govern them in the service of the public (Milakis & Müller, 2021; Mladenović et al., 2020). However, because of the uncertainty associated with emerging technologies (Borup et al., 2006), one should not plan for this future alone. As developers and manufacturers time and again fail to meet announced timelines for the deployment of automated vehicles (Nriagu, 2021), there is the distinct possibility that the technology might not be realised on a large scale any time soon. Hence, planning for a future in which automated vehicles are part of the transport system might entail planning for disappointment (R. Martin, 2021). Rather than plan for disappointment, we should plan for failure. If automated vehicles are not seen as inevitable, this will force us to think differently about the future. This would suggest that we should plan *against* new automobile-like dependencies and seek to facilitate mobility that is less reliant upon a comprehensive sociotechnical system to support it. Whereas the uncertainty associated with emerging technologies makes it important to assess their benefits and downsides, it is just as crucial to ask which society we would be left with, if automated vehicles and all the associated promises were not to come to fruition. Thus, in addition to posing the question *what if*, it is crucial to ask *what if not*, and plan accordingly.

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Appendix A: Overview of interviewees

Table A.1: Overview of interviewees' affiliations, Borealis

Institution/company	Function	Interviews
Norwegian Public Roads Administration	The government agency responsible for national and county roads; developed and organised the Borealis project	4
Q-Free	Developer, road-mounted parking sensors	1
Bouvet	Developer, intelligent road platform	1
Triona	Developer, digital signs	1
Storfjord Municipality	The municipality that hosted Borealis	1

Table A.2: Overview of interviewees' affiliations, Forus Shuttle

Institution/company	Function	Interviews
Kolumbus	Regional public transport company/'mobility provider' for Rogaland County	5
Forus PRT	Project leader for the project; interviewee also had experience in operating the automated shuttle bus	1
Forus business park	Manager of the properties in the business park; provided a stretch of road for testing	1
Department of Transport, Rogaland County	Authority over Kolumbus; shared their responsibilities with the Norwegian Public Roads Administration	1
Smart City Office, Stavanger Municipality	Produced Stavanger's smart city strategy, including elements for energy, climate, and environment	1 (2 interviewees)
Norgesbuss	Provided the bus drivers for Kolumbus in the Stavanger region; interviewee operated the automated bus	2 (1 interviewee)

Table A.3: Overview of interviewees' affiliations, Car-free City Life

Institution/company	Function	Interviews
City Development Committee	Organ at the uppermost level of Oslo City Government; responsible for approving changes to area zoning plans	1
Department of Urban Development	Oslo Municipality's overarching organisation for urban development	2
Agency for Planning and Building Services	Developed the new area zoning plan for the Car-free City Life project area	4
Agency for Real Estate and Urban Renewal	Responsible for Oslo Municipality's properties; involved in urban development initiatives	1
Agency for Urban Environment	Responsible for implementing physical and regulatory changes in the project area	1
Oslo Trade Association	Member organisation for businesses in the Oslo region, represented business interests within the project area	1

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