Overall synthesis and conclusions

van Wee, Bert; Milakis, Dimitris; Thomopoulos, Nikolas

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Policy Implications of Autonomous Vehicles

CHAPTER THIRTEEN

Overall synthesis and conclusions

Bert van Wee[a,*], Dimitris Milakis[b], Nikolas Thomopoulos[c]
[a]Faculty of Technology, Policy and Management, Delft University of Technology, Delft, The Netherlands
[b]Institute of Transport Research, German Aerospace Center (DLR), Berlin, Germany
[c]Department of Tourism and Transport, School of Hospitality and Tourism Management, University of Surrey, Guildford, United Kingdom
*Corresponding author: e-mail address: g.p.vanwee@tudelft.nl

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Abstract

This chapter first systematically summarizes the most important findings and policy implications of each of the chapters included in this book volume. Next it synthesizes the overall findings and policy implications, and discusses future avenues for policy making and research. A first conclusion is that the chapters make clear that the ranges in policy relevant implications of AVs, within the scope of each chapter/topic, are still relatively broad. Secondly we conclude that research that is conceptually rich is more valuable for policy making. Thirdly we hypothesize that context matters for the uptake, impacts, and specific system design characteristics of real world AV implementation. Fourth we conclude that research on the global south has been limited so far. Fifth we argue that AVs, shared vehicles and electric vehicles (EVs) might stimulate each other in a positive way, in all directions. Finally we conclude that AVs will have wider societal implications, such as in the area of land use, accessibility, social exclusion, governmental expenditures, the labor market, and the environment. The more indirect the effects of AVs are, the more difficult they are to understand. For policy making a first conclusion is that the issues of ethics, cyber security and data protection deserve way more attention than they currently get. We also conclude that future motorway network extensions might not be no-regret anymore, because of possible congestion reductions due to AVs, but also because of decreasing marginal values of time. Finally we argue that countries that introduce AVs later than other countries can learn a lot from the real world experiences elsewhere.

Keywords: Autonomous vehicles, Synthesis, Policy, Summary

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1. Introduction

This chapter first systematically summarizes the most important findings and policy implications of each of the chapters "Factors affecting traffic flow efficiency implications of connected and autonomous vehicles: A review and policy recommendations" by Narayanan et al.; "Automated bus systems in Europe: A systematic review of passenger experience and road user interaction" by Heikoop et al.; "Cyber security and its impact on CAV safety: Overview, policy needs and challenges" by Katrakazas et al.; "Cybersecurity certification and auditing of automotive industry" by Mateo Sanguino et al.; "The wider use of autonomous vehicles in non-commuting journeys" by Kimber et al.; "Policy implications of the potential carbon dioxide (CO_2) emission and energy impacts of highly automated vehicles" by Annema; "Potential health and well-being implications of autonomous vehicles" by Singleton et al.; "Data protection in a GDPR era: An international comparison of implications for autonomous vehicles" by Costantini et al.; "Ethical issues concerning automated vehicles and their implications for transport" by Dogan et al.; "Governance cultures and sociotechnical imaginaries of self-driving vehicle technology: Comparative analysis of Finland, UK and Germany" by Mladenović et al.; "Wider implications of autonomous vessels for the maritime industry: Mapping the unprecedented challenges" by Ghaderi; "The potential for automation to transform urban deliveries: Drivers, barriers and policy priorities" by Paddeu and Parkhurst. Next it synthesizes the overall findings and policy implications, and discusses future avenues for policy making and research. Table 1 gives an overview of the results and policy implications per chapter.

Table 1 shows that most chapters are based on systematic non-country specific literature reviews. In addition, all chapters do not only have clear conclusions, they also discuss policy implications. When we started the initiative to edit this book, we were a bit uncertain about the viability of all chapters we would like to include. Despite the fact that the attention paid to AVs started booming only about a decade ago (see, for example, the reference list of Milakis et al. (2017) or of the chapters in this book), we are very glad we now can conclude that the authors were able to review the literature on so many different aspects, and write a chapter that survived the review process.

Table 1 Overview of the results and policy implications per chapter.

Chapter	Topic	Review method	Country	Conclusions	Policy implications
Short-term implications of AVs					
1	Traffic flow efficiency	Systematic review of academic literature	Non-Specific	Four categories of factors influencing traffic flow are identified: (i) Vehicle characteristics, (ii) Travel behavior, (iii) Network characteristics and (iv) Policies. The expected impacts of AVs on the roadway capacity are found to be not at all unanimous, not only because of different assumptions with respect to these factors, but also because of differences in modeling conditions	Policy makers should enact laws to ensure connectivity between AVs to experience significant benefits, integrate CAVs with public transport to avoid mode shifts, incentivize ridesharing to reduce network load, develop suitable parking management policies to avoid empty relocations and introduce congestion pricing to curb induced demand
2	Humans-automated bus systems interaction	Systematic review of academic literature	Non-Specific	Public acceptance of automated bus systems is generally positive. People appear to have a high level of trust in the automated bus system. Questionnaires are the most used means of method for conducting experiments in relation to user acceptance or satisfaction. An important gap in literature is the lack of objective measures used for the assessment of human interaction with automated bus systems	AVs are not prepared and will not respond appropriately when other road users deviate from the formal rules. The general wait-and-see attitude of planners need to change into a more proactive approach from public planners and authorities when deploying AVs such as automated bus systems are implemented in real-life traffic
3	Cybersecurity and safety	Systematic review of academic literature	Non-Specific	Current solutions are solely concerned either with collisions and casualties or with the prevention of cyber-attacks with regards to both hardware and software issues. Thus, there is still not a reported strong correlation between cyber security breaches and the potential decrease in road safety levels	The evolution of an international collaborative directory linking cybersecurity liabilities with passenger and traffic safety concerns is suggested. A lot more AV miles need to be self-driven until such an international agreement is reached

Continued

Table 1 Overview of the results and policy implications per chapter.—cont'd

Chapter	Topic	Review method	Country	Conclusions	Policy implications
4	Cybersecurity Certification and Auditing	Systematic review of academic literature	Non-Specific	The risk of adding automation to vehicles has not been properly understood by car manufacturers in the past and it is a serious problem just as the insecure vehicular connectivity is being addressed nowadays. Most cars use components that are based on old hardware and software developed years ago and with basic flaws inherent to design, so errors and vulnerabilities are transferred to these new generation of vehicles	Cybercrime as a Service (CaaS) could generate millions in losses to the automotive industry, justifying new approaches of cybersecurity applied to the automobile industry, which must be flexible and adaptive along the production chain and the lifetime of CAVs. A collaborative approach in the automotive industry may be required to overcome the investments in time, money and broader organizational changes
5	Non-commuting journeys	PRISMA	Non-Specific	Public interest in AVs for leisure might exceed that for commuting while sharing might be less likely for AVs non-commuting journeys. Some non-commuting journeys will require a lower level of automation. Non-commuting journeys by AVs could involve spatial impacts	Increased policy attention to non-commuting journeys in the AVs context including Global South is required. Policy and regulation should focus on preserving equity, privacy and safety for shared AVs serving leisure travel and promoting infrastructure changes needed as a response to the spatio-temporal patterns of leisure activities
Long-term implications of AVs					
6	Carbon dioxide (CO2) emissions and energy	Review of academic literature	Non-Specific	The net energy and CO_2 emission balance for AVs seems, at its best, to be neutral, but is probably negative. However, the potentially accelerating role of AVs in relation to the uptake of electric vehicles could have the biggest impact on the CO_2 emissions per kilometer driven, but this accelerating role in the uptake of electric technology remains uncertain	Policies promoting alternative vehicle propulsion systems other than fossil fuel technologies seem most effective at the moment. Additional measures such as energy taxes, AV maximum speed limits as well as policies to curb the growth of VKTs could put in place to ensure further energy and emissions related benefits as soon as the adoption of electric AVs progresses

Table 1 Overview of the results and policy implications per chapter.—cont'd

Chapter	Topic	Review method	Country	Conclusions	Policy implications
7	Health and well-being	Deductive approach	Non-Specific	AVs are likely to have overall positive impacts on some health and well-being aspects (safety, travel satisfaction, access to activities) and overall negative impacts on others (physical activity), while effects are more uncertain for other topics (urban built environments, air and noise pollution). An evolving systems approach to explore the multitude of potential impacts of AVs on health and well-being is proposed	Policy measures should try to limit the possible negative effects of AVs on health and well-being, such as reduced physically-active travel (e.g., through improved infrastructure for cyclists and pedestrians) and increased vehicle-distances traveled (e.g., focusing on provisions for active travel rather than placing high hopes on shared AVs which may also be associated with increased distances traveled) and urban sprawl (e.g., through compact and mixed-use neighborhoods)
8	Data protection	Mapping review of legal frameworks and regulations, experts survey	Austria, Brazil, Greece, Italy, New Zealand, Slovakia and Switzerland	Data management and protection of AV data is still at a nascent stage	Collaboration among stakeholders and countries (e.g., development of "regulatory sandboxes"). Regulatory attention to (a) the capability to "re-identify" originally anonymous data through AI or Big Data, (b) the legal status of such artificial agents
9	Ethics	Review of academic literature and policy reports	Non-Specific	Most research focuses on the decisions of AV in critical, forced-choice situations. Philosophical theories (e.g., consequentialism and utilitarianism, deontology, contractarianism and randomness theory) provide some answers but they raise others questions as well	Ordinary situations(e.g., following distance, brake strategies, lateral position within the lane, permitting violations)would require more guidelines and policy making, rather than highly improbable and uncertain unavoidable accidents. Policy makers should take into account ethical aspects of technology implementation, such as justice, autonomy, equity, and the democratic ideal of participation in the decision making about integration of the AV technology into the society

Continued

Table 1 Overview of the results and policy implications per chapter.—cont'd

Chapter	Topic	Review method	Country	Conclusions	Policy implications
10	Governance of AVs	Policy documents review	Finland, UK, and Germany	All three countries (Finland, UK, and Germany) think that AVs should contribute to the national economic growth. The UK and German positions AVs in the context of global leadership in technological development. Governance do not see citizens as equal partners in steering technological futures, but only as an actor that can potentially resist new technology. Consequently technological development is not based on the democratic enhancement of dialogue between state and society	The governance challenge centers around the understanding that technology is not a neutral and default-positive actant, and thus technological development is irreducibly a political and value-driven choice rather than an instrumental facilitation of what is an inevitable (automated) future. Three different types of technological determinism are identified: justificatory, methodological, and normative. Each of these types of technological determinism bring about a challenge for transparency, accountability, and responsiveness mechanisms in technological governance processes
Implications of AVs for the maritime and freight industry					
11	Maritime industry	Review of academic literature and overview of key maritime projects	Non-Specific	Autonomous ships will have vertical and horizontal effects on other supply chain players, such as ports, shipbuilding, and insurance. Existing research promises economic and financial benefits for shipping companies, yet some cost elements may transfer to upstream and/or downstream actors in the supply chain	There is a need to focus on the co-ordination of regulations and standards internationally, while supporting workforce training to develop new skills in demand. All stakeholders need to be taken into account when evaluating deployment of autonomous vessels, safeguarding that appropriate mechanisms exist to compensate losers through the gains of winners

Table 1 Overview of the results and policy implications per chapter.—cont'd

Chapter	Topic	Review method	Country	Conclusions	Policy implications
12	Urban deliveries	International overview of technologies, review of key stakeholders role, stakeholders workshops	Non-Specific	Despite the potential importance of automation for improving the efficiency and competitiveness of the urban freight sector, research evidence gaps exist related to the identification of competitive advantages for these new technologies, micro and macro-economic benefits, and the costs of those developments. Concerns related to introduction of automation technologies in urban freight also include low co-ordination levels among stakeholders, low load factors, short term cost increases, employment implications and urban planning issues such as sharing of public space, as well as privacy, safety and security	Policymakers should promote introduction of automated freight systems where they bring clear benefits, while at the same time ensuring equity in economic and social terms. Five specific priorities can be identified for policy makers: (1)To engage citizens and other "user group" stakeholders in urban revisioning, (2) To establish the extent to which relatively high and low technology solutions are appropriate, individually or in combination, (3) To develop the regulatory canvas, (4) To understand how the economic niche of urban freight deliveries fits in with wider emerging socioeconomic change, and (5) To promote responsible innovation and knowledge-sharing

2. Overall synthesis and conclusions

Looking at the conclusions and policy implications of Table 1 a few general lessons can be learned. Starting with the research findings, the chapters make clear that the ranges in policy relevant implications of AVs, within the scope of each chapter / topic, are still relatively broad. A first reason for the wide range is the differences in the scope and demarcation of the studies reviewed. Take the impact of AVs on CO_2 emissions and road capacity as examples: it really matters if studies only include the impact of AVs on speed and distances between vehicles, or also include induced demand and changes in mode choice (from public transport and active modes to AVs).But even if the scope and demarcation is equal, estimates on

impacts vary a lot, which is understandable because AVs at SAE levels 4 and 5 are not on the roads yet, so researchers cannot measure real world impacts, and have to rely on other methodologies to derive estimates. Research that is conceptually rich is more valuable for policy making. With "conceptually rich" we mean that it includes more relevant (clusters of) variables, and both direct and indirect relationships between (clusters of) variables. Policy makers need to be well informed about expected effects, including all factors and relationships influencing these effects. Future research aiming to estimate societally and policy relevant impacts of AVs therefore, preferably includes all dominant factors and interrelationships. Secondly, we hypothesize that context matters for the uptake, impacts, and specific system design characteristics of real world AV implementation. Take, for example, the more anti—government sentiments in the USA compared to most European countries. This could influence the support of the public for *cooperative* AV systems—such support probably is higher in European countries than in the USA. Another example: income levels influence the willingness to pay for travel time savings (e.g., Lam and Small, 2001) and probably also the willingness to pay for AVs: people with higher incomes are probably not only willing to pay more for travel time savings but also for AVs. So, in countries with lower incomes fewer people could be willing to pay for AVs. Such important concerns only started being addressed in 2019 via, e.g., the WISE-ACT multinational survey about AV user preferences and similar activities worldwide are essential to inform policy makers. The impacts of context factors on the design characteristics, implication options, and societally relevant effects therefore are a next promising research topic that deserves more attention. Third, and as a special case of topic 2, the chapters show that the focus in research on the global south has been limited so far. Especially because of the importance of context conclusions that hold for the global North do not necessarily apply for the global south (Thomopoulos and Nikitas, 2019).

Extending the scope from AVs only to their position in the transport system, there is an increasing awareness that AVs, shared vehicles and electric vehicles (EVs) might stimulate each other in a positive way, in all directions, as conceptualized in Fig. 1, at least as far as cars are concerned (e.g., Webb, 2019). Below we limit the discussion on these interactions to cars. Sharing can include both sharing cars as well as sharing rides. In the following discussion, we limit ourselves to sharing cars (or other small vehicles, like minibuses). AVs will make sharing vehicles more attractive and vice versa because AVs will likely be more expensive than conventional

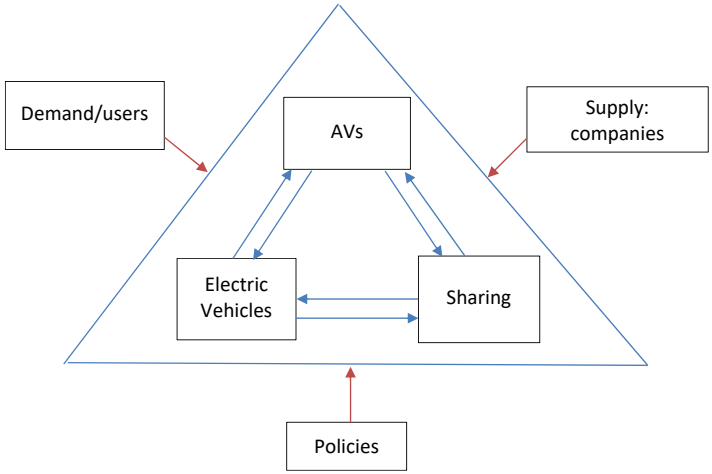

Fig. 1 Interactions between AVs, electric vehicles and sharing.

cars, and sharing reduces the (fixed) costs. And the combination of AVs and sharing will increase the market share of electric vehicles because people can use shared electric AVs for most of their trips at a lower cost because of the lower operation costs of such vehicles (Annema, 2020) and use internal combustion engine vehicles for only those trips for which the range limitations of EVs are problematic. EVs might stimulate sharing, at least as long as purchase costs of EVs (especially with a long range) are higher, again because sharing can decrease the fixed costs of cars. The links between AVs and EVs are a bit less obvious, but it could be that the status of cars becomes less important if people cannot drive their car anymore, so that for people who think AVs provide a lower status than a conventional car, that negative aspect of EVs might reduce. And vice versa: if people own an EV providing them less status, the barrier of being driven in an AV, and drive oneself might be reduced. In addition, speeding becomes impossible, while driving cycles and energy recovery is optimized in case of AVs (Annema, 2020), so the strong range penalty for EVs is diminished. Fig. 1 also makes clear that the way AVs, EVs, and sharing interact, depends on policies (fiscal incentives, infrastructure provision, regulations for vehicle types), on activities of companies (developing AVs, EVs, and sharing services) and on users/consumers who buy or share and use vehicles. Many research challenges relate to the complex relationships as conceptualized in Fig. 1.

Extending the scope to beyond the transport system, it is clear that AVs will have wider societal implications, such as in the area of land use, accessibility, social exclusion, governmental expenditures, the labor market, and the environment. The more indirect the effects of AVs are, the more difficult they are to understand. This because the impacts on the transport system need to be understood first, and these are already uncertain, and next the wider impacts need to be understood, adding more uncertainty. Yet, understanding the wider impacts of AVs on society is extremely relevant for policy making.

We now continue this chapter by focusing on policy making. Policy makers can guide the transport related developments and also these wider developments to some extent so that they work out in a societal desirable way. Although we cannot precisely predict which policies each government agency should implement in each geographical context and when, we briefly reflect subsequently on some of the roles of policy.

First, we argue that "wait and see" can be a good strategy for some possible implications of AVs, but not for all. We now reflect on what policy makers could or even should do in the short term (the coming few years), the medium term (up to 10 years) and the long term (>10 years). In the short term, the issues of cyber security and data protection deserve way more attention than they currently get, in case of cyber security at least of the automotive industry, probably also of public bodies, in case of data protection of public and next private bodies. Also ethical issues, particularly those focusing on ordinary situations, deserve attention before the (large scale) introduction of level 4 and 5 vehicles. Next, involving citizens in shaping the future of AVs deserves more attention than it currently gets, since this is the core of the demand side (Fig. 1). Regardless of the topic, for reasons of efficiency and avoiding border issues, interstate or international collaboration with respect to policy making is to be preferred in many cases. Regarding the global maritime industry, international public bodies should by default take the lead in the process of future automation because vessels travel between countries and world regions, thus highlighting the need for even intercontinental policy making collaboration.

Extending the time horizon a bit further, say the next decade, an important lesson is that in developed countries with more or less complete motorway networks, future motorway network extensions might not be no-regret anymore. Many regions and countries face a diminishing population growth, if not: a decline in population. Car ownership levels seem to be not very far from saturation. If there are no (major) missing links, future

extensions of motorways mainly aim to reduce congestion. But if car ownership does not increase substantially, and if more people can avoid the rush hours because they can work online as widely proven during the COVID-19 restrictions, the costs of motorway extensions may exceed the benefits. AVs could further strengthen this process, first of all because they may reduce congestion levels (despite induced demand) and secondly they will reduce peoples' willingness to pay for travel time reductions (Zhong et al., 2020) because of the possibilities for other categories of time use in AVs.

On the longer term, it is important to realize that the introduction of SAE level 4 and 5 vehicles will not happen at the same moment in time across the world and the transition to AVs will vary widely. So, countries that introduce AVs later than other countries can learn a lot from the real world experiences elsewhere. We expect research and business interest on the many effects of AVs to boom after their widespread real world introduction. Respecting the differences in context as addressed above, we do think that many lessons can be learned, in many areas, such as the process of decision making, acceptance and acceptability, the pros and cons of design alternatives, the societally relevant implications of AVs (accessibility, safety, security, the environment, land use, impacts on other modes), and the evaluation of policy alternatives (including all relevant effects, but also fairness issues). So, learning from real world experiences it is both a very important topic for research as well as for policy making and AV trials pave the way in this respect.

We conclude that it is still unclear how autonomous vehicles will shape the future of transport systems, and what the policy relevant effects of AVs will be. But it is clear that the role of AVs in the vehicle fleets will have many policy relevant implications, some of which did not receive a lot of attention by policy makers yet. On the other hand, policy makers can also influence the uptake of AV. With this book, we review the AV literature on a wide range of topics. We hope it provides a source of inspiration for researchers, policy makers, and planners.

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