Transport Policy 136 (2023) 1–10

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Automated Vehicles: Changes in expert opinions over time

Maarten Kroesen [a,*], Dimitris Milakis [b], Bert van Wee [a]

[a] Delft University of Technology, Faculty of Technology, Policy and Management, P.O. Box 5015, 2600 GA, Delft, the Netherlands
[b] German Aerospace Center, Institute of Transport Research, Rudower Chaussee 7, 12489, Berlin, Germany

ARTICLE INFO

Keywords:
Automated vehicles
Panel survey
Expert judgement
Q-factor analysis

ABSTRACT

Innovations in transportation can contribute to reaching relevant societal objectives (e.g. reduce emissions, congestion levels and/or risks). To determine which innovations to stimulate (and which not) it is important for policy makers to assess their effects on beforehand. Expert judgement is an often-used method for this purpose. Although expert opinions can provide useful input for decision-making, these judgement are potentially subject to change, for example, due to new information becoming available or because the (academic) discussion about the innovation in question takes a new turn. Studies that explicitly study stability and change in expert judgements are rare, but highly relevant to determine the reliability of experts' assessments. To address this gap, this study assesses experts' judgments at multiple points in time focusing on the effects of a transport innovation with potentially widespread societal implications, namely Automated Vehicles (AVs). To this end a survey was administrated to a group of experts involved in the WISE-ACT project. The results indicate that expert opinions towards this innovation are generally favorable; AVs are believed to reduce congestion delays, greenhouse gas emissions and traffic accidents. Although the consulted experts are generally quite stable in their opinions, they are becoming less optimistic about these positive effects over time. A Q-factor analysis additionally reveals two clusters of experts, one with a positive and one a negative outlook on AVs. The latter group beliefs that AVs will lower the value of travel time, thereby increasing travel demand, and, in turn, emission and congestion levels. Overall, the changing and diverging opinions among experts indicate that the transition to AVs is not necessarily regarded as a desirable one.

1. Introduction

Transport systems continuously have to adapt to societal changes and preferences, including demographic, economic and spatial trends, and trends in accessibility, safety and environmental priorities and preferences. Transport innovations, both technical and non-technical (mainly: services) can play an important role in making transport systems fit for purposes. Many actors, including policy makers, interest groups and industry have an interest in understanding the societal effects of candidate future innovations, as well as options to influence such effects. Effects include travel behaviour impacts, accessibility, environmental, safety and health impacts, and economic impacts (such as for public transport or vehicle manufacturing companies). Travel behaviour effects are often an intermediate factor influencing the other factors listed (Milakis et al., 2017a). But there are more factors. For example, the environmental impact of hydrogen vehicles depends on the way hydrogen will be produced, more specifically the way electricity will be produced, assuming hydrogen will not be made by using fossil fuels, but by using electricity.

Empirical research on transport innovations based on real world implementation is often not possible (because transport innovations are not or not fully implemented yet). And even in case of innovations already introduced to the market but being in their early stages of adoption, the characteristics of innovators and early adopters can easily differ from the early and late majority of users (Rogers, 2003), and so can the impacts on travel behaviour and next on other societal effects.

An alternative for empirical research can be expert judgment. And indeed, forms of expert judgement can play a role in the complex mechanisms that lead to the adoption or not of candidate innovations (Feitelson and Salomon, 2004). Expert judgments can be the topic of research into the possible effects of candidate innovations, but experts sometimes also have direct contacts with policy makers and politicians, and are asked by media and via media they can have an impact on societal and policy debates.

These judgments can change over time, for example due to new research becoming available, debates amongst experts and others,

* Corresponding author.
E-mail addresses: m.kroesen@tudelft.nl (M. Kroesen), Dimitrios.Milakis@dlr.de (D. Milakis), g.p.vanwee@tudelft.nl (B. van Wee).

https://doi.org/10.1016/j.tranpol.2023.03.005
Received 12 January 2022; Received in revised form 20 January 2023; Accepted 6 March 2023
Available online 6 March 2023

societal debates on the candidate innovations as well as new personal experiences and changes in personal beliefs (Ralph and Delbosc 2017). To the best of our knowledge changing opinions on candidate transport innovations have hardly been the topic of research so far, the exception maybe being Delphi studies because in these studies the same experts are asked to answer research questions in two or more waves, and can update their answers based on the answers of others.

Fully Automated Vehicles (AVs) are a candidate innovation that has received a lot of attention of academics and society during the past decade or so. Fully AVs (for experts: SAE level 5; SAE-International 2021) are expected to perform all dynamic tasks of driving (e.g. steering, braking acceleration) under all conditions, either occupied or unoccupied. They could communicate and exchange information with other vehicles (V2V) and/or with the infrastructure (V2I).

AVs can have many societal impacts (Milakis et al., 2017a, 2021), including those mentioned above. In October 2017, the project WISE-ACT (Wider Impacts and Scenario Evaluation of Autonomous and Connected Transport) funded by the European Union within the framework of COST-Actions (European Cooperation in Science and Technology) was initiated (see section 2). WISE-ACT provided us a unique opportunity to explore to expert opinions on societal relevant effects of AVs, and to what extent expert opinions on expected societal impacts could change over time. We therefore initiated a study involving a three-wave questionnaire distributed to WISE-ACT experts in a period of three years. More specifically we aim to answer three questions: 1) What are the experts' expectations with respect to the societal relevant effects of automated vehicles? (2) To what extent do experts agree or not with respect to those effects? And (3) To what extent are expert judgments stable or not over time? This paper presents the results of this study, focusing on the first two waves. Because of the low response rate of wave 3 we could not include this wave analyzing trends with any statistical significance.

Section 2 briefly introduces the WISE-ACT project, followed by section 3 explaining the methodology and section 4 presenting the results. Section 5 discusses the results and presents the conclusions.

2. A brief introduction to wise-act

The four-year WISE-ACT project (13.10.2017–12.10.2021; extended to 12.4.2022) focuses on the wider impacts of AVs and how they can be evaluated. The project is funded by the European Unions' COST program that supports development of bottom-up research and innovation networks, through which research initiatives, researchers and innovators can connect and share knowledge. The key objectives of WISE-ACT refer to research coordination (e.g., development of common terminology, sharing of know-how across diverse localities, comparison of simulation results and end user preferences from diverse settings, creation of a roadmap about the wider impacts of AVs) and capacity building (e.g., build a scientific community on wider impacts of AVs, develop multidisciplinary training programs, bridge distinct scientific fields, act as a transnational stakeholder platform). The objectives are operationalized through five working groups (i.e. institutional and regulatory challenges, social challenges, business challenges, transport system, scenario development), semiannual coordination meetings of the management committee and the working group members, webinars, training schools, themed workshops, idea jam events and short-term academic visits. In total, 74 experts from 38 European and associated countries participate in the project with diverse professional backgrounds (e.g., universities, research institutes, consulting firms) and expertise (e.g., informatics, planning, geography, economics, engineering, law). WISE-ACT comprise leading academic experts (e.g. leading research groups, having produced multiple scientific papers including highly-cited ones) on specific aspects of AVs deployment and implications (e.g. traffic, road safety, travel behaviour, accessibility and spatial structures, planning, governance) as well as researchers and consultants being highly active in the field through participation in multiple relevant research projects and the production of science for policy reports.

3. Methods

3.1. Data

To assess how experts' opinions towards AVs and how these have changed over time, data were collected at three points in time, namely in December 2018 (wave 1), December 2019 (wave 2) and May 2021 (wave 3), yielding respectively 61, 26 and 15 complete surveys. Nineteen respondents participated in waves 1 and 2, while 8 respondents participated in all three waves. The 19 respondents, who joined waves 1 and 2 formed the subset sample for our analysis of changes in experts' opinions towards AVs. All participants in WISE-ACT were invited to fill in the questionnaires.

The WISE-ACT members comprise leading experts on AVs, with a wide variety of expertise, coming for different geographies in Europe, and are therefore in the ideal position to assess the impacts of AVs. In particular, the 19 experts who participated in waves 1 and 2 were mainly academics (various professor levels and one PhD candidate; 10 participants), research scientists (mostly senior researchers; 7 participants) and professionals (consultant and planner; 2 participants). Their expertise was distributed as follows (number of participants in brackets): computer science (3), artificial intelligence and robotics (2), traffic engineering (2), urban and transport planning (2), transport policy (2), sustainable mobility (2), urban and regional planning (2), telecommunication engineering (1), transport planning (1), travel behaviour (1), transport geography (1). In addition, we expected a relatively high commitment to our study, resulting in high initial response and low attrition over time. Yet, there are also downsides to using this sample, which we will reflect upon in the concluding section.

Table 1 presents the number of respondents for each wave and each possible response pattern. In total, 61 respondents participated in the first wave.

Table 2 presents the characteristics of respondents in the sample (in wave 1). The majority of respondents were between 30 and 50 years old, probably reflecting that the majority of researchers in the area of AVs are in this age group. 70% were males, while a large share of respondents did not (wish to) answer the gender question. Not surprisingly, the majority of respondents had a PhD degree. Respondents come from a wide range of countries as expected given the geographical diversity of the WISE-ACT experts.

3.2. Survey measures: societal impacts and confidence ratings

Respondents were first asked to estimate the year in which they expected that a fully automated vehicle would be available for sale in the respective country of residence, and the respective years when 50% and 100% of the new sales would constitute AVs. In addition, they were asked to estimate the share of AVs that would constitute shared cars.

The questions on possible impacts of AVs were derived from the relevant conceptual model developed by Milakis et al. (2017a), and

Table 1
Number of respondents per wave and response patterns.

Wave	1	61
	2	26
	3	15
Response pattern: participation (1) or not (0) for each wave (e.g. 100 means that respondent participated only in wave 1)	001	1
	010	6
	011	1
	100	39
	101	3
	110	11
	111	8

Table 2
Sample characteristics of respondents in wave 1 (N = 61).

Variable	Category	%
Age	<30	2
	30–50	77
	>50	16
	Do not wish or disclose or missing	5
Gender	Female	21
	Male	70
	Do not wish or disclose or missing	8
Level of education	MA/MSc	16
	PhD	74
	Other or missing	10
Country of residence	Germany	10
	Slovenia	8
	Spain	8
	Israel	8
	Austria	5
	Netherlands	3
	UK	3
	Finland	3
	Turkey	3
	Ireland	3
	Portugal	3
	Serbia	3
	Other	38

include first-order (i.e., traffic, travel costs, travel demand), second-order (i.e., vehicle ownership, land use and location choices, transport infrastructure) and third-order impacts (i.e., energy consumption, climate change, traffic safety, social equity, economy, public health). Milakis et al. (2017a) identified the relevant impacts of AVs through analytical reasoning (i.e. by identifying possible mechanisms through which the introduction of AVs could have an effect on the respective factor) and subsequently performed an extensive literature review to search for available evidence on these impacts. Given the comprehensiveness of this study, it may be argued that the content validity of the survey instrument is high, i.e. it is likely that all possible relevant impacts of AVs are represented in the survey.

The impacts identified by Milakis et al. (2017a) are grouped into 12 main categories. Table 3 gives on overview of the possible mechanisms though which AVs may effect these (derived from Milakis et al., 2017a). For each category multiple indicators are identified to cover the category as a whole, yielding 38 indicators in total (see Table 5). For each indicator, the following question was included in the survey: As a result of the implementation of automated vehicles, I expect that … [impact] … will decrease greatly (1), will decrease slightly (2), will stay the same (3) will increase slightly (4) will increase greatly (5).

Finally, respondents were asked to rate their level of confidence in rating each of the 12 impact categories. This question was formulated as follows: Please state your confidence with rating this [impact category]: Not confident at all (1), somewhat confident (2), moderately confident (3), very confident (4), extremely confident (5).

3.3. Analysis strategy

To assess experts' baseline opinions on the impacts of AVs, we used the data of all respondents of wave 1 (61 in total). Next, to assess whether respondents changed their opinion over time, we used only respondents who stayed in the sample (otherwise changes may also be attributed to changes in the sample composition). Of the 61 respondents in wave 1, 19 again participated again in wave 2 (note that there were 7 new respondents, who did not participate in wave 1). Paired samples t-tests are used to assess the significance of the observed differences in sample means.

Secondly, to explore the heterogeneity in the sample we additionally conducted a Q-factor analysis. Hence, the data were transposed and subjected to a principal components analysis, thereby revealing clusters of respondents that have scored the 38 impacts in a similar fashion. Note

Table 3
Possible mechanisms underlying the impacts of AVs (Milakis et al., 2017a).

Category	Possible mechanism(s)
1. Traffic impacts	Enhanced free flow capacity and decreased capacity drops (i.e. fewer episodes of reduced queue discharge rate) could increase the road capacity and thus reduce congestion delays
2. Travel costs	The fixed costs of automated vehicles will very likely be higher than for conventional vehicles due to the advanced hardware and software technology involved
	The generalized transport cost (GTC), which comprises effort, travel time, and financial costs of a trip, on the other hand, is expected to decrease because of lower effort, time, and money needed to travel
3. Travel demand	The increase of road capacity, the subsequent congestion relief and the decrease in GTC could lead to an increase of vehicle travel demand
	The decrease of the GTC could enhance the accessibility of more distant locations, thus allowing people to choose such destinations to live, work, shop, recreate, and subsequently increase the amount of their daily vehicle use.
	The increase of AVs for ride-sharing and vehicle-sharing systems might negatively influence the use of public transport services and active modes, since automated shared vehicles could effectively serve short distance trips or feeder trips to public transportation.
4. Vehicle ownership	Automated vehicles could significantly reduce operational costs (e.g. no driver costs) for ride-sharing and vehicle-sharing services, and thereby reduce the need to personally own a car.
5. Land use and location choices	Due to self-parking capability of (fully) automated vehicles surface parking lots could be significantly reduced, enhancing infill development potential and leading to increased population/employment densities in central areas
	The decrease of the GTC could enhance the accessibility of more distant locations, leading to increased population/employment densities in rural areas
6. Transport infrastructure	Automated vehicles will also be likely to reduce demand for parking, but additional road capacity may be required to accommodate new travel demand.
	Travel demand for active modes and public transport may decline resulting in fewer investments in the related infrastructures
7. Energy consumption	The introduction of automated vehicles might result in energy benefits because of reduced congestion (more homogeneous traffic flows/lighter vehicles)
	The energy benefits of automated vehicles could be significantly mitigated by increased travel demand in the long term.
8. Climate change	The introduction of automated vehicles might result in emission benefits because of reduced congestion (more homogeneous traffic flows/lighter vehicles)
	The environmental benefits of automated vehicles could be significantly mitigated by increased travel demand in the long term.
9. Traffic safety	The advent of automated vehicles could significantly reduce traffic accidents attributed to the human driver by gradually removing the control from the driver's hands.
10. Social equity	Automated vehicles could offer the social groups that are currently unable to own or drive a car (e.g. younger, older and disabled people) the opportunity to overcome their current accessibility limitations.
	Automated vehicles are likely to be quite expensive (at least initially), thus limiting these benefits to only the wealthier members of these groups for certain time.
11. Economy	Full vehicle automation could lead to job losses for various professions such as taxi, delivery, and truck drivers.
12. Public health	Public health benefits might result from reduced congestion, lower traffic noise, increased traffic safety, and lower emissions from automated vehicles.
	An increase in vehicle use because of automated vehicles (either more or longer vehicle trips) could also have a negative impact on public health, since levels of physical activity is likely to decrease.

Table 4
Expectations regarding market share and fleet composition (percentage shared).

Please state the year that you expect.	Wave 1 participants (N = 61)	Wave 1 and 2 participants (n = 19)	
	Median wave 1	Median wave 1	Median wave 2
a fully automated vehicle to become available for sale in the country you live. I	2030	2030	2030
50% of the new vehicle sales to be fully automated vehicles in the country you live.	2040	2045	2050
100% of the new vehicle sales to be fully automated vehicles in the country you live.	2055	2060	2070
Please state (your belief regarding) the percentage of vehicles that will be shared when 100% of the new vehicle sales are fully automated.			
0%	3	0	5
25%	30	42	40
50%	39	47	40
75%	28	11	15
100%	0	0	0

that we used both respondents who participated in the first wave as well as those that participated in wave 1 and wave 2, in order to assess changes in factor membership over time. Unfortunately, only 8 respondents participated in all 3 waves, which we considered as too few to provide reliable estimates. Hence, the analyses of change are based on the subset of respondents who participated in wave 1 and 2.

4. Results

4.1. Changes in experts' opinions on AV market share and fleet composition

Table 4 presents the descriptive statistics regarding the questions in which years experts believe that AVs will become available on the market, when they constitute 50% and 100% of the new car sales and their expectation regarding the share of the AV fleet that will operate as shared cars. Note that medians were reported here, because of several outliers in the estimates. It can be observed that the median year that experts (in wave 1) believe AVs will become available is 2030 and that 10 and 25 years later (2040 and 2055) respectively 50% and 100% of the new cars sales will be AVs. The estimates of the participants that participated both in wave 1 and wave 2 do not substantially deviate from the wave 1 estimates. However, at wave 2, there is a tendency among these participants to expect that full market penetration will take longer (50% and 100% of the new sales at 2050 and 2070). Experts believe that substantial shares of the AV fleet will be shared cars. At each wave the majority opts for 50%, closely followed by the 25% option. Much less experts expect shared vehicles to ever represent 75% of the AVs fleet, while none believes that all AVs will be shared in the future.

4.2. Changes in experts' opinions on societal impacts of AVs

Moving on to the ratings of the impact criteria, Table 5 presents the descriptive statistics (means and standard deviations) of the 38 impacts for 'wave 1' participants (n = 61) at the first point in time and for participants that participated in both wave 1 and wave 2 (n = 19) at both points in time (Table 9 in the Appendix provides the complete frequency distributions for the 38 impacts). To ease the interpretation of the results, the means are color-coded, with green indicating that respondents believe that the particular impact criterion will increase and red indicating that the particular impact criterion will decrease.

The results indicate that -at the first point in time-there are no large differences between the means of all participants of wave 1 and those that also participated in wave 2, indicating that respondents that dropped out rated the impact criteria in a similar fashion (so no selective attrition). In addition, also for the wave 1 and wave 2 participants the means at both points in time remain largely the same, indicating that respondents were generally stable in their assessments over time. Only 3 differences reach statistical significance. Of course, this is also due to the small sample size.

Experts in wave 1 (strongly) believe that -as the result of the implementation of AVs-the motorway and urban capacity will increase (impact criterion 1 and 2), leading to less congestion (3 and 4), but also more demand for car travel (12 and 13). Assuming shared AVs will become the norm (see Table 3), respondents expect a decrease in vehicle ownership (16). Experts strongly believe that AVs will reduce the number of casualties (29 and 30). Overall, they expect positive effects on well-being (38), especially for older people (32) and those with disabilities (33). Yet, they also expect that obesity rates will further increase (37).

As mentioned above, respondents in wave 2 have not altered their beliefs to any great extent, yet the shift on most statements is consistently towards a position that is less favorable about the impacts of AVs (on e.g., travel time reliability: impact number 5, 6 (see Table 5); trip effort: 8; variable costs of a trip: 10; the level-of-service of active modes infrastructure: 23; the risk of serious and fatal casualties: 29, 30; the welfare of people on low incomes: 31; the disparities in welfare between vulnerable groups (low incomes, elderly, people with disabilities) and the rest of population: 34; the overall level of unemployment: 35; the premature mortality rates: 36; obesity rates; 37; satisfaction with life: 38) with the exception of the total vehicle kilometers traveled (12), the number of trips by car (13) the energy demand per vehicle kilometer (25), the greenhouse gas emissions per vehicle kilometer (27), and the wellbeing of older adults and people with physical and sensory disabilities (32, 33). It may be speculated that the less optimistic views on the safety benefits are due to reports of vehicles equipped with advanced driver assistance systems (e.g. Tesla's autopilot) being involved in (deadly) crashes. In quite a number of these accidents it has been claimed that the autopilot was indeed active. With respect to the positive effects on road capacity, respondents have become *significantly* less optimistic (2 and 3). In addition, whereas respondents in wave 1 believed trip travel times (of AVs) would decrease, in wave 2 respondents believe these will stay the same (9).

4.3. Changes in the level of confidence of experts' opinions

As explained in section 3.2 for each impact category experts also indicated their level of confidence with rating each impact category. Table 6 presents the results of these items again separately for the respondents that participated in wave 1 and those that participated in both wave 1 and wave 2. All mean scores are lower than the level of 'moderately confident' (3), indicating that overall experts are not very confident about assessing multiple impacts of AVs simultaneously. Experts are most confident about the travel cost and safety impacts and least confident about the land use, economic and public health impacts. Similar to the ratings of the impacts (Table 3) the confidence ratings at the first point in time do not deviate much between participants of wave 1 and participants that completed both wave 1 and wave 2. Over time experts generally become more confident in their ratings, which is an intuitively plausible result. With respect to the impacts on traffic, vehicle ownership and safety the mean scores significantly increase. Still, on a whole, the level of confidence remains at the below moderate level.

4.4. Changes in the heterogeneity of experts' opinions

As can be seen from the standard deviations of the rated impacts in

Table 5
Evaluation of impacts of AVs by experts.

Impact category	Impact criteria	Wave 1 participants (N = 61)		Wave 1 and 2 participants (n = 19)		
	I expect that … [impact criterion] … will decrease greatly (1) will decrease slightly (2), will stay the same (3), will increase slightly (4), will increase greatly (5)	Mean wave 1	Std. Deviation	Mean wave 1	Mean wave 2	Mean diff. (wave 2- wave 1)
Traffic impacts	1 … the motorways capacity (vehicles per hour per lane)	3.7	1.1	4.0	3.7	−0.3
	2 … the urban roads capacity (vehicles per hour per lane)	3.3	1.2	3.4	2.9	−0.5[b]
	3 … motorways congestion delays (hours of extra travel time due to congestion)	2.4	1.2	2.5	2.9	0.4[a]
	4 … Urban roads congestion delays (hours of extra travel time due to congestion)	2.6	1.3	2.9	3.3	0.3
	5 … the travel time reliability in motorways	3.6	1.3	3.7	3.7	−0.1
	6 … the travel time reliability in urban roads	3.3	1.2	3.4	3.3	−0.1
Travel costs	7 … the fixed (capital) cost of owning an automated car	3.5	1.2	3.7	3.5	−0.3
	8 … the effort of a trip	2.0	0.9	2.0	2.3	0.3
	9 … the travel time of a trip	2.5	0.9	2.4	2.9	0.5[b]
	10 … the (variable) costs of a trip	2.6	0.8	2.7	2.9	0.2
	11 … the value of travel time	3.2	1.2	3.1	3.2	0.1
Travel demand	12 … the total vehicle kilometers traveled	3.9	1.1	4.2	4.0	−0.2
	13 … the number of trips by car	3.9	1.1	4.3	4.1	−0.2
	14 … the number of trips by public transport	2.9	1.1	2.6	2.5	−0.1
	15 … the number of trips by bicycle, foot	2.9	0.9	2.6	2.7	0.1
Vehicle ownership	16 … the number of owned vehicles per household	2.3	1.0	2.7	2.6	−0.1
Land use and location choices	17 … the population density in central areas (inhabitants/square kilometer)	2.9	0.8	2.9	2.9	0.0
	18 … the population density in suburban areas (inhabitants/square kilometer)	3.2	0.8	3.3	3.5	0.2
	19 … the employment density in central areas (employers/square kilometer)	3.1	0.6	3.2	3.1	−0.1
	20 … the employment density in suburban areas (employers/square kilometer)	3.0	0.8	3.2	3.5	0.3
Transport infrastructure	21 … the number of public parking spaces per square kilometer in central areas	2.1	0.9	2.2	2.5	0.3
	22 … the number of public parking spaces per square kilometer in suburban areas	3.0	1.1	3.3	3.6	0.4
	23 … the level-of-service of active modes infrastructure (i.e. length/square kilometer, maintenance)	3.4	0.9	3.3	3.0	−0.3
	24 … the level-of-service of public transport (i.e. frequency, capacity, route coverage)	3.3	1.2	3.0	2.9	−0.1
Energy consumption	25 … the energy demand per vehicle kilometer traveled	2.4	1.0	2.5	2.3	−0.2
	26 … the total vehicle energy demand	2.9	1.2	3.3	3.3	−0.1
Climate change	27 … the greenhouse gas emissions per vehicle kilometer traveled	2.2	0.9	2.3	2.1	−0.2
	28 … the total vehicle greenhouse gas emissions	2.5	1.1	2.9	2.8	−0.1
Traffic safety	29 … the risk of serious casualties (number of serious casualties per passenger kilometer, all modes)	1.6	0.7	1.7	1.9	0.2
	30 … the risk of fatal casualties (number of fatal casualties per passenger kilometer, all modes)	1.5	0.7	1.6	1.9	0.3
Social equity	31 … the welfare of people on low incomes	3.0	0.7	2.9	2.8	−0.2
	32 … the wellbeing of older adults	3.7	0.8	3.5	3.9	0.4
	33 … the wellbeing of people with physical and sensory (vision, hearing) disabilities	3.9	0.9	3.8	4.0	0.2
	34 … the disparities in welfare between vulnerable groups (low incomes. Elderly, people with disabilities etc.) and the rest of population	3.1	1.0	3.2	3.3	0.2
Economy	35 … overall level of unemployment	3.1	0.7	3.1	3.3	0.2
Public health	36 … premature mortality rate (deaths/100.000 due to cardiovascular diseases, cancer, diabetes and chronic respiratory diseases)	3.2	0.8	3.4	3.1	−0.3
	37 … obesity rates (% of people with body mass index≥30)	3.6	0.7	3.8	3.7	−0.2
	38 … satisfaction with life	3.4	0.7	3.3	3.1	−0.2

[a] Mean difference is significant at the 0.10 level (2-tailed).
[b] Mean difference is significant at the 0.05 level (2-tailed).

Table 5, there is quite some heterogeneity with respect to some of the impacts of AVs. To assess and understand this heterogeneity we ran a Q-factor analysis on the 38 impact criteria. A Q-factor analysis is a common analysis technique in studies that employ Q-methodology (see e.g. Watts and Stenner, 2005). The analysis is the same as a traditional principal component analysis, but is based on the transposed data matrix, thus the variables represent individuals' patterns of scores on the 38 impacts (of both wave 1 and wave 2 participants). As a result, instead of revealing clusters of variables that are correlated, the analysis reveals clusters of persons that are correlated, i.e. people with similar patterns of scores across the 38 indicators. A Q-factor analysis thus essentially works the same as other clustering techniques (like K-means). Its use here is primarily motivated by the relatively large number of indicators (38) which can be handled more easily by a Q-factor analysis than using traditional clustering techniques.

Based on the Scree plot (Fig. 1), it could be determined that most heterogeneity in the scores could be accounted for by extracting two factors, which could collectively account for 45% of the variance.

After extraction, Varimax rotation was applied to obtain simple structure (as is common practice in studies that apply Q-methodology, see e.g. Watts and Stenner, 2005). Based on the maximum factor loadings (after rotation) 46 respondents were identified to belong to the first factor and 15 to the second (in wave 1). Next, standardized factors scores were computed for each factor. These factor scores indicate how people belonging to a particular factor -on average-have rated each impact criterion. Note that, because the scores are standardized, they range from approximately −2 to +2.

We first describe the different clusters of respondents, followed by the changes between wave 1 and wave 2. Table 7 presents the standardized factor scores of both factors. Again, the results are color-coded to ease interpretation, with green indicating that respondents believe the respective impact criterion will increase and red indicating it will decrease.

While the factors show consensus with respect to some criteria, for example regarding the (positive) impacts on safety (29 and 30), there is generally quite some disagreement between the factors. Overall,

Table 6
Level of experts' confidence in each impact category.

Please state your confidence with rating this [impact category]: Not confident at all (1), somewhat confident (2), moderately confident (3), very confident (4), extremely confident (5)	Wave 1 participants (N = 61)		Wave 1 and 2 participants (n = 19)		
	Mean wave 1	Std. Deviation	Mean wave 1	Mean wave 2	Mean diff. (wave 2-wave 1)
Traffic impacts	2.7	0.8	2.5	3.0	0.5*
Travel costs	2.8	0.8	2.8	3.1	0.2
Travel demand	2.7	0.9	2.8	2.9	0.1
Vehicle ownership	2.7	0.9	2.5	2.8	0.3*
Land use and location choices	2.4	0.9	2.6	2.8	0.2
Transport infrastructure	2.6	0.8	2.7	2.7	0.0
Energy consumption	2.7	0.9	2.8	2.8	0.0
Climate change	2.6	0.8	2.9	2.9	0.0
Traffic safety	2.8	1.0	2.6	3.1	0.4*
Social equity	2.6	1.0	2.5	2.7	0.2
Economy	2.4	1.0	2.7	2.8	0.2
Public health	2.4	0.9	2.6	2.6	0.0

*Mean difference is significant at the 0.05 level (2-tailed).

respondents in factor 1 maintain a more positive outlook on the impacts of AVs, while respondents in factor 2 assume a more critical stance. In particular, respondents in factor 2 believe that the value of travel time will decline (11) thereby increasing the demand for car travel (12 and 13) and consequently also congestion levels (3 and 4). They also believe that AVs will result in a decline of public transport and active modes use (14 and 15), thereby increasing the total energy vehicle demand (26) and greenhouse gas emissions (28). In line with this, respondents believe that AVs will not lead to a strong reduction in car ownership (16) which is congruent with their expectation that fewer AVs will constitute shared cars compared to what members of factor 1 believe (presented in the last 5 rows). Overall, whereas respondents in factor 1 believe AVs will increase well-being of older adults and people with physical and sensory (vision, hearing) disabilities (32, 33), respondents in factor 2 believe that AVs will undermine public health (36, 37) and lead to lower satisfaction with life (38).

Given the panel nature of the data, we could assess whether respondents switched between the two factors over time. Based on the classification method described above respondents that participated in both wave 1 and wave 2 were assigned to one of the factors. Table 8 presents the factor membership of these (19) respondents at wave 1 and wave 2. Most respondents stayed in their respective factor, which is also in line with the small differences in the mean scores (Table 5). Two respondents switch from factor 1 to factor 2, while one respondent switched from factor 2 to factor 1. Hence, a tendency can be confirmed towards a more critical stance towards the impacts of AVs, but of course these figures are too small to draw firm conclusions (at the population level).

As a final analysis we looked at the association between the academic background of respondents, classified into "engineering" and "social sciences and humanities", and factor membership. We believed that experts with a social science background might be more inclined to assume a system-level perspective on AVs and, as such, also be more aware of the negative side-effects of AVs (e.g. increasing demand due to decreasing value of time), while those with an engineering background would more strongly or rather exclusively focus on the direct benefits of the AV technology. The results (Table 9) indeed show that this is the case, 63.6% of the experts with an engineering background belong to factor that has a positive view of AVs, while 62.5% of the experts with a social science background belong to the factor with a negative outlook. It should be mentioned though that the chi-squared test indicates that the association is not significant ($\chi^2 = 1.269$, df = 1, p = 0.260), which is also due to the small sample size.

Table 7
Standardized factor scores reflecting heterogeneity of experts' opinions on AV impacts (Factor 1: positive outlook, Factor 2: negative outlook).

Impact category	Impact		
	I expect that … [impact] … will decrease greatly (1), will decrease slightly (2), will stay the same (3) will increase slightly (4) will increase greatly (5)	Factor 1 (n = 46 in wave 1)	Factor 2 (N = 15 in wave 1)
Traffic impacts	1 … the motorways capacity (vehicles per hour per lane)	0.9	0.7
	2 … the urban roads capacity (vehicles per hour per lane)	1.0	−0.7
	3 … motorways congestion delays (hours of extra travel time due to congestion)	−1.3	0.5
	4 … Urban roads congestion delays (hours of extra travel time due to congestion)	−1.2	1.0
	5 … the travel time reliability in motorways	1.1	0.3
	6 … the travel time reliability in urban roads	1.1	−0.4
Travel costs	7 … the fixed (capital) cost of owning an automated car	0.3	1.3
	8 … the effort of a trip	−1.4	−0.9
	9 … the travel time of a trip	−1.0	0.3
	10 … the (variable) costs of a trip	−0.6	−0.1
	11 … the value of travel time	1.0	−1.1
Travel demand	12 … the total vehicle kilometers traveled	0.5	2.2
	13 … the number of trips by car	0.6	2.0
	14 … the number of trips by public transport	0.8	−1.9
	15 … the number of trips by bicycle, foot	0.7	−1.4
Vehicle ownership	16 … the number of owned vehicles per household	−1.1	−0.3
Land use and location choices	17 … the population density in central areas (inhabitants/ square kilometer)	0.1	−0.4
	18 … the population density in suburban areas (inhabitants/ square kilometer)	0.4	0.2
	19 … the employment density in central areas (employers/ square kilometer)	0.3	−0.2
	20 … the employment density in suburban areas (employers/ square kilometer)	0.4	−0.1
Transport infrastructure	21 … the number of public parking spaces per square kilometer in central areas	−0.9	−1.1
	22 … the number of public parking spaces per square kilometer in suburban areas	−0.1	0.5
	23 … the level-of-service of active modes infrastructure (i.e. length/square kilometer, maintenance)	1.0	−0.6
	24 … the level-of-service of public transport (i.e. frequency, capacity, route coverage)	1.3	−1.4
Energy consumption	25 … the energy demand per vehicle kilometer traveled	−1.2	0.2
	26 … the total vehicle energy demand	−1.1	1.8
Climate change	27 … the greenhouse gas emissions per vehicle kilometer traveled	−1.5	0.1
	28 … the total vehicle greenhouse gas emissions	−1.4	1.0
Traffic safety	29 … the risk of serious casualties (number of serious	−1.8	−1.6

(continued on next page)

Table 7 (*continued*)

Impact category	Impact: I expect that … [impact] … will decrease greatly (1), will decrease slightly (2), will stay the same (3) will increase slightly (4) will increase greatly (5)	Factor 1 (n = 46 in wave 1)	Factor 2 (N = 15 in wave 1)
	casualties per passenger kilometer, all modes)		
	30 … the risk of fatal casualties (number of fatal casualties per passenger kilometer, all modes)	−1.8	−1.6
Social equity	31 … the welfare of people on low incomes	0.5	−0.7
	32 … the wellbeing of older adults	1.2	0.5
	33 … the wellbeing of people with physical and sensory (vision, hearing) disabilities	1.6	0.5
	34 … the disparities in welfare between vulnerable groups (low incomes, elderly, people with disabilities etc.) and the rest of population	0.2	0.2
Economy	35 … overall level of unemployment	0.2	−0.1
Public health	36 … premature mortality rate (deaths/100,000 due to cardiovascular diseases, cancer, diabetes and chronic respiratory diseases)	−0.1	0.6
	37 … obesity rates (% of people with body mass index≥30)	0.4	1.1
	38 … satisfaction with life	1.0	−0.6
Please state (your belief regarding) the percentage of vehicles that will be shared when 100% of the new vehicle sales are fully automated.		%	%
0%		0	13
25%		24	47
50%		43	27
75%		33	13
100%		0	0

Table 8
Factor membership in wave 1 and wave 2.

		Wave 2		Total
		Factor 1	Factor 2	
Wave 1	Factor 1	9 81.8%	2 18.2%	11 100.0%
	Factor 2	1 12.5%	7 87.5%	8 100.0%
	Total	10 52.6%	9 47.4%	19 100.0%

Table 9
Expert background and factor membership (wave 2).

		Factor membership (wave 2)		Total
		Factor 1	Factor 2	
Expert background	Engineering	7 63.6%	4 36.4%	11 100.0%
	Social sciences and humanities	3 37.5%	5 62.5%	8 100.0%
	Total	10 52.6%	9 47.4%	19 100.0%

5. Conclusions and discussion

Important conclusions from our analyses are first that experts in wave 1 (strongly) believe that -as the result of the implementation of AVs-the motorway and urban capacity will increase, leading to less congestion, but also more demand for car travel consistently with earlier expert estimations (Milakis et al., 2017b) and relevant literature (Milakis et al., 2017a; Harb et al., 2021). To some extent, they believe that AVs will reduce the variable cost of a trip and increase the capital cost of owning a car, which, assuming shared AVs will become available, is associated with a decrease in vehicle ownership. This is consistent with the typical outcomes of simulation studies about the possible replacement of conventional vehicles with shared automated vehicles at a percentage rate of up to 90% (e.g. Fagnant and Kockelman 2014; Boesch et al., 2016). However, recent studies suggest that such high replacement rates are overly optimistic because people tend to prefer owned rather than shared AVs (Milakis et al., 2021) for instrumental (e.g., lower total cost of ownership and use, Wadud and Chintakayala 2021; Wadud and Mattioli 2021), affective (e.g., aversion of sharing, Jabbari and MacKenzie 2020; Wang et al., 2020) and symbolic factors (Mohammadzadeh, 2021). The experts strongly believe that AVs will reduce the number of casualties, in line with emerging literature on the possible positive safety impacts of AVs (e.g., Arvin et al., 2021; Tafidis et al., 2021). Overall, the experts expect positive effects on well-being, especially for older people and those with disabilities. Recent discussion papers also expect positive effects of AVs on well-being through higher travel satisfaction (e.g. lower stress, relaxation and mental transition) and greater access to opportunities (Singleton, 2019; Singleton et al., 2020). However, factors such as operation and learning difficulties, insecurity, distrust, and increased price because of custom design could compromise those benefits especially for older people and people with physical and sensory disabilities (Milakis and Van Wee, 2020). Yet, experts also expect that obesity and premature mortality rates associated with transport will further increase, which is in line with literature expectations about possible reduced physical activity (i.e. walking, cycling) in the AVs era (Rojas-Rueda et al., 2020; Sohrabi et al., 2020).

Secondly, even though most participants were not only interested in AVs, but also quite knowledgeable in the transport field, they overall were not quite confident with respect to their assessments of societal relevant impacts of AVs. Experts, especially those taking a specialist rather than a generalist approach (e.g. civil engineers vs planners or geographers), might not be confident in assessing multiple AV impacts simultaneously or assessing impacts that cross the boundaries of their expertise given the complexity and system-level uncertainty surrounding the deployment of AVs. And maybe even more surprising: despite participating in WISE-ACT they have only quite limitedly become more confident with respect to their answers. Obviously, more knowledge sharing, discussions, presentations within certain field-specific working groups do not necessarily lead to more confidence in assessing the societal impacts of AVs. More knowledge sharing within hard-defined scientific boundaries and respective working groups might not be sufficient to ensure knowledge advancement and subsequently more confidence of experts in assessing highly complex, uncertain or even "wicked" problems such as the deployment and implications of AVs. Also crucial in such problems is the collaborative model between generalist and specialist experts, ensuring that qualities of both approaches (i.e., breadth and depth of knowledge respectively) are adequately represented, mutually respected and successfully integrated towards knowledge advancement (Woo et al., 2021).

Thirdly, respondents are more confident about their assessments of expected traffic costs and safety impacts, than about their assessment of more indirect effects, in particular land use, economic and public health impacts. This could be attributed to the fact that research and consequently available knowledge has so far predominantly focused on first order impacts of AVs such as traffic and safety, while interest in long-

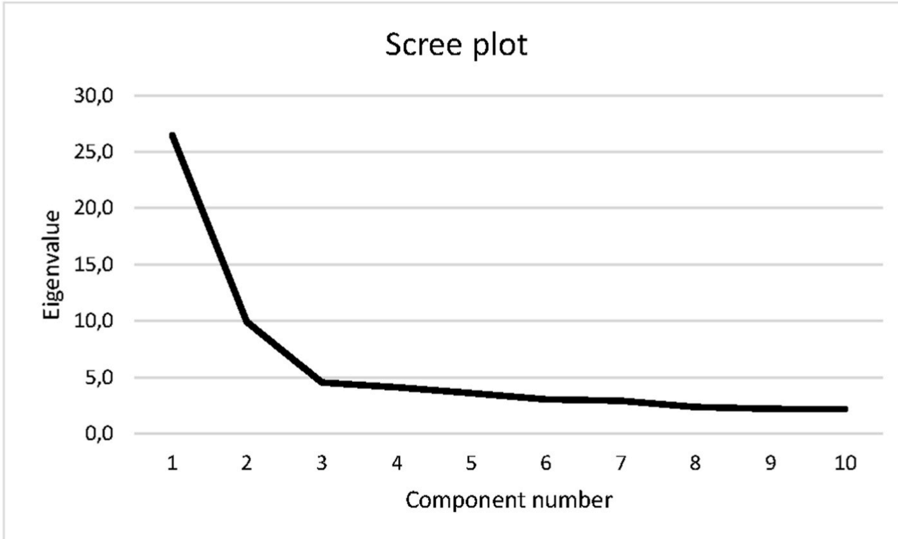

Fig. 1. Scree plot.

term implications has been gradually raised after 2015 (Gandia et al., 2019), but remain still relatively scarce and certainly inconclusive (Milakis et al., 2017a; Milakis and Müller, 2021). Thus, experts might feel less confident to express estimations for implications with limited background knowledge. Another explanation could be that indirect effects at least partly depend on direct effects, implying that uncertainties about indirect effects must be at least equal to, but likely larger than those about direct effects.

Fourth, over time the respondents who participated in both waves have become less favorable about the impacts of AVs. Especially with respect to the positive effects on road capacity, respondents have become significantly less optimistic. In addition, whereas respondents in wave 1 believed trip travel times (of AVs) would decrease, in wave 2 respondents believe these will stay the same. Evidence suggest that (top-rated) experts tend to be over-optimistic in their assessments (Tichy, 2004). Initial highly optimistic estimations leave room for more realistic assessments over time as more knowledge on a specific field becomes available. For example, evidence suggest today that the initially estimated positive impacts of AVs on road capacity (based on studies focusing on the supply side of the transport system and assuming stability in travel demand) might be significantly lower because of (a) expected increases in travel demand due to more and longer trips by AVs and (b) limited use of shared vehicles (Harb et al., 2021). Consequently, congestion levels and trip travel times in the AVs era are now more realistically assessed by taking into account potential impacts of AVs not only on the supply (e.g. capacity) but also on the demand side (i.e. travel behaviour) of the future transport system.

Fifth, there are two different clusters of participants, with considerable disagreement with respect to the societal relevant impacts of AVs. Cluster 1 is overall quite positive about the societal advantages of AVs, whereas cluster 2 is more skeptical. For example, cluster 2 considers that travel demand and the associated externalities will increase with a decrease in the value of travel time in the AVs era. Conflicting expert views naturally arise in this field given that deployment and implications of AVs are deeply uncertain and influenced by a multitude of factors. Most importantly they are influenced by the societal acceptance and the possible policies that will be introduced to anticipate integration of AVs and their implications in future transport systems. After all, AVs represent a socio-technical transition of the transport system that will not evolve in a political vacuum. For example, Cohen and Cavoli (2019) suggest that a “laissez-faire” compared to a more interventionist governance approach in fields such as planning/land-use, infrastructure/technology and service provision would result in less desirable societal implications of AVs. According to Lyons (2021), these conflicting views on “wicked” problems like AVs should be brought together through carefully designed and novel foresight methodologies (e.g. emulsion methodology). Such methodologies can promote deep constructive dialogue between actors with different perspectives to enrich understanding, promote shared learning, inform interpretation and co-create principles ensuring positive societal outcomes from the introduction of AVs into the future transport system.

Sixth, we were a bit disappointed to see the reduction in responses over time, even though we know most of the invited respondents personally, and even though we expected a positive ‘self-selection effects’, in the sense that the respondents must be above average interested in AVs and societal impacts, because they decided to join the WISE-ACT community. Although reminders were sent, other retention strategies could have been employed (Teague et al., 2018). Fortunately, the results did not indicate selective bias in the responses, as the opinions of the wave 1 only respondents did not differ strongly from those that stayed in the sample.

Finally, some limitations and future research directions may be identified. First, this study focused eliciting the expected impacts of AVs, in future research it would be interesting to also consider experts’ opinions regarding the mechanisms underlying these impacts (Table 2), and whether these change over time. As AV technologies are indeed penetrating the market, it is likely that experts also gain more knowledge about these mechanisms. Second, the present study only involved experts associated with the WISE-ACT program. While all participants can be considered experts on AVs and the associated impacts, for various reasons, it would be relevant to consider also experts outside this group. For one, all experts in this study are based in Europe, yet it may well be that experts from Asia or North America have very different views, considering, for example, the fact that the impacts of AVs may also be different due to demographic, spatial and/or geographic differences between countries. In addition, the members of the WISE-ACT group have collaborated with each other within a research project. This may have influenced their opinions in a particular direction. Finally, it would be interesting to explore whether the views of experts are similar or different from those of the general public. Since public support for AVs likely also influences political support, it seems important that possible negative side-effects of AVS (e.g. increased travel/energy demand) are adequately reflected in public discourses on AVs.

Overall, the changing and diverging opinions among experts indicate that the transition to AVs is not necessarily regarded as a desirable one by experts. Obviously, this has important implications for the (policy) practice, in particular the question whether policy makers should actively stimulate the development of AVs or not. In this regard, we believe it is important that AVs are not regarded as a cure for all problems associated with the car (as in fact, some experts believe some of these problems may even by aggravated.) As such, it is important that other solutions are (also) considered, for example, policies that internalize the external costs of car use (road pricing) and/or policies that stimulate the use of active modes and/or public transport. While being less technologically advanced, these modes also have an important role to play in the transition towards a sustainable and equitable transportation system.

Author statement

Maarten Kroesen: Methodology, Formal analysis, Writing - original draft, Dimitris Milakis: Methodology, Conceptualization, Writing - original draft, Bert van Wee: Methodology, Conceptualization, Writing - original draft.

Data availability

Data will be made available on request.

Acknowledgements

We thank (a) the experts of the WISE-ACT (Wider Impacts and Scenario Evaluation of Autonomous and Connected Transport) COST Action CA16222, who participated in our survey and (b) two anonymous reviewers for their useful suggestions on an earlier version of this paper.

Appendix A

Table 9
Frequency distributions of the 38 impacts of experts in the first wave (n = 61)

I expect that …	1. will decrease greatly (%)	2. will decrease slightly (%)	3. will stay the same (%)	4. will increase slightly (%)	5. will increase greatly (%)
1 … the motorways capacity (vehicles per hour per lane)	8	3	21	44	23
2 … the urban roads capacity (vehicles per hour per lane)	10	11	30	33	16
3 … motorways congestion delays (hours of extra travel time due to congestion)	26	31	23	15	5
4 … Urban roads congestion delays (hours of extra travel time due to congestion)	21	28	30	10	11
5 … the travel time reliability in motorways	11	8	20	33	28
6 … the travel time reliability in urban roads	10	13	26	36	15
7 … the fixed (capital) cost of owning an automated car	7	16	20	34	23
8 … the effort of a trip	33	46	11	10	0
9 … the travel time of a trip	13	39	33	13	2
10 … the (variable) costs of a trip	8	41	36	15	0
11 … the value of travel time	8	23	30	23	16
12 … the total vehicle kilometers traveled	2	11	21	25	41
13 … the number of trips by car	2	11	18	31	38
14 … the number of trips by public transport	10	31	30	21	8
15 … the number of trips by bicycle, foot	3	28	44	21	3
16 … the number of owned vehicles per household	20	46	25	5	5
17 … the population density in central areas (inhabitants/square kilometer)	2	30	48	21	0
18 … the population density in suburban areas (inhabitants/square kilometer)	2	16	41	38	3
19 … the employment density in central areas (employers/square kilometer)	0	15	62	23	0
20 … the employment density in suburban areas (employers/square kilometer)	3	18	51	26	2
21 … the number of public parking spaces per square kilometer in central areas	28	41	23	8	0
22 … the number of public parking spaces per square kilometer in suburban areas	8	26	33	26	7
23 … the level-of-service of active modes infrastructure (i.e. length/square kilometer. maintenance)	2	13	38	39	8
24 … the level-of-service of public transport (i.e. frequency, capacity, route coverage)	10	15	21	41	13
25 … the energy demand per vehicle kilometer traveled	13	52	15	16	3
26 … the total vehicle energy demand	13	33	20	25	10
27 … the greenhouse gas emissions per vehicle kilometer traveled	18	57	13	11	0
28 … the total vehicle greenhouse gas emissions	15	46	21	13	5
29 … the risk of serious casualties (number of serious casualties per passenger kilometer. all modes)	54	36	8	2	0
30 … the risk of fatal casualties (number of fatal casualties per passenger kilometer. all modes)	56	34	10	0	0
31 … the welfare of people on low incomes	5	10	67	16	2
32 … the wellbeing of older adults	2	3	30	51	15
33 … the wellbeing of people with physical and sensory (vision, hearing) disabilities	2	5	20	49	25
34 … the disparities in welfare between vulnerable groups (low incomes. elderly. people with disabilities etc.) and the rest of population	3	21	44	21	10
35 … overall level of unemployment	2	11	67	15	5
	0	15	61	18	7

(*continued on next page*)

Table 9 (*continued*)

I expect that …	1. will decrease greatly (%)	2. will decrease slightly (%)	3. will stay the same (%)	4. will increase slightly (%)	5. will increase greatly (%)
36 … premature mortality rate (deaths/100.000 due to cardiovascular diseases, cancer, diabetes and chronic respiratory diseases)					
37 … obesity rates (% of people with body mass index≥30)	0	0	51	38	11
38 … satisfaction with life	2	3	56	36	3

Note: the size of the relative frequency is reflected by the intensity of the color.

References

Arvin, R., Khattak, A.J., Kamrani, M., Rio-Torres, J., 2021. Safety evaluation of connected and automated vehicles in mixed traffic with conventional vehicles at intersections. Journal of Intelligent Transportation Systems 25, 170–187.

Boesch, P.M., Ciari, F., Axhausen, K.W., 2016. Autonomous vehicle fleet sizes required to serve different levels of demand. Transport. Res. Rec.: J. Transport. Res. Board 2542, 111–119.

Cohen, T., Cavoli, C., 2019. Automated vehicles: exploring possible consequences of government (non)intervention for congestion and accessibility. Transport Rev. 39, 129–151.

Fagnant, D.J., Kockelman, K.M., 2014. The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transport. Res. C Emerg. Technol. 40, 1–13.

Feitelson, Salomon, I., 2004. The political economy of transport innovations. In: Beuthe, M., Himanen, V., Reggiani, A., Zamparini, L. (Eds.), Transport Developments and Innovations in an Evolving World. Springer Verlag, Berlin Heidelberg, pp. 11–26.

Gandia, R.M., Antonialli, F., Cavazza, B.H., Neto, A.M., Lima, D.A.d., Sugano, J.Y., Nicolai, I., Zambalde, A.L., 2019. Autonomous vehicles: scientometric and bibliometric review. Transport Rev. 31, 9–28.

Harb, M., Stathopoulos, A., Shiftan, Y., Walker, J.L., 2021. What do we (Not) know about our future with automated vehicles? Transport. Res. C Emerg. Technol. 123, 102948.

Jabbari, P., MacKenzie, D., 2020. Ride Sharing Attitudes before and during the COVID-19 Pandemic in the United States. Findings.

Lyons, G., 2021. The Driverless Cars Emulsion: Using Participatory Foresight and Constructive Conflict to Address Transport's Wicked Problems (Futures).

Milakis, D., Van Wee, B., 2020. Implications of vehicle automation for accessibility and social inclusion of people on low income, people with physical and sensory disabilities, and older people. In: Antoniou, C., Efthymiou, D., Chaniotakis, E. (Eds.), Demand for Emerging Transportation Systems. Elsevier, The Netherlands, pp. 61–73.

Milakis, D., Müller, S., 2021. The societal dimension of the automated vehicles transition: towards a research agenda. Cities 113, 103144.

Milakis, D., van Arem, B., van Wee, B., 2017a. Policy and society related implications of automated driving: a review of literature and directions for future research. Journal of Intelligent Transportation Systems 21 (4), 324–348.

Milakis, D., Snelder, M., van Arem, B., van Wee, B., Correia, G., 2017b. Development and transport implications of automated vehicles in The Netherlands: scenarios for 2030 and 2050. Eur. J. Transport Infrastruct. Res. 17, 63–85.

Milakis, D., Müller, S., Seibert, D., 2021. Is the Strategy for Sustainable Transition of Automobility through Electric Shared Automated Vehicles Realistic? an Analysis of Key Actors' Purposes and Motivations. In: Paper Presented at the RGS-IBG Annual International Conference 2021. Virtual conference 31 August. (Accessed 3 September 2021).

Mohammadzadeh, M., 2021. Sharing or owning autonomous vehicles? Comprehending the role of ideology in the adoption of autonomous vehicles in the society of automobility. Transp. Res. Interdiscip. Perspect. 9, 100294.

Ralph, K., Delbosc, A., 2017. I'm multimodal, aren't you? How ego-centric anchoring biases experts' perceptions of travel patterns. Transport. Res. Pol. Pract. 100, 283–293.

Rogers, E., 2003. Diffusion of Innovations. Free Press, New York.

Rojas-Rueda, D., Nieuwenhuijsen, M.J., Khreis, H., Frumkin, H., 2020. Autonomous vehicles and public health. Annu. Rev. Publ. Health 41, 329–345.

SAE-International, 2021. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles [J3016 202104. SAE International, Warrendale, PA.

Singleton, P.A., 2019. Discussing the "positive utilities" of autonomous vehicles: will travellers really use their time productively? Transport Rev. 39, 50–65.

Singleton, P.A., De Vos, J., Heinen, E., Pudāne, B., 2020. Potential health and well-being implications of autonomous vehicles. In: Milakis, D., Thomopoulos, N., van Wee, B. (Eds.), Policy Implications of Autonomous Vehicles. Elsevier, The Netherlands.

Sohrabi, S., Khreis, H., Lord, D., 2020. Impacts of autonomous vehicles on public health: a conceptual model and policy recommendations. Sustain. Cities Soc. 63, 102457.

Tafidis, P., Farah, H., Brijs, T., Pirdavani, A., 2021. Safety implications of higher levels of automated vehicles: a scoping review. Transport Rev. 1–23.

Teague, S., Youssef, G.J., Macdonald, J.A., Sciberras, E., Shatte, A., Fuller-Tyszkiewicz, M., et al., 2018. Retention strategies in longitudinal cohort studies: a systematic review and meta-analysis. BMC Med. Res. Methodol. 18 (1), 1–22.

Tichy, G., 2004. The over-optimism among experts in assessment and foresight. Technol. Forecast. Soc. Change 71, 341–363.

Wadud, Z., Mattioli, G., 2021. Fully automated vehicles: a cost-based analysis of the share of ownership and mobility services, and its socio-economic determinants. Transport. Res. Pol. Pract. 151, 228–244.

Wadud, Z., Chintakayala, P.K., 2021. To own or not to own – that is the question: the value of owning a (fully automated) vehicle. Transport. Res. C Emerg. Technol. 123, 102978.

Wang, S., Jiang, Z., Noland, R.B., Mondschein, A.S., 2020. Attitudes towards privately-owned and shared autonomous vehicles. Transport. Res. F Traffic Psychol. Behav. 72, 297–306.

Watts, S., Stenner, P., 2005. Doing Q methodology: theory, method and interpretation. Qual. Res. Psychol. 2 (1), 67–91.

Woo, D., Pierce, C.S., Treem, J.W., 2021. Specialists over Generalists? Examining Discursive Closures and Openings in Expert Collaborations. Communication Monographs, pp. 1–26.