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Adoption of Shared Automated Vehicles as Access and Egress Mode of Public Transport: A Research Agenda

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Abstract— **Shared Automated Vehicles (SAVs) are a new road-based means of transport, usually small in size and capacity, with a relatively low operating speed and no (regular) possibility for the user to engage in any of the driving tasks. Past research focused on the implication of fully Automated Vehicles (AVs) in the transport sector, especially automated cars, analysing travel behaviour, network design, costs and infrastructure development. Such an extensive research on SAVs cannot be found, and most results are based on predictions for AVs acceptance instead, next to simulation studies, assumption-based models or stated choice experiments. In this paper we conduct a meta-analysis of existing literature, analysing the underlying factors that determine the adoption of SAVs. We identify the factors that have a positive effect, the ones that have a negative effect and the ones for which the effect is still unknown. Subsequently, we propose a conceptual scheme to illustrate the links between the public transport network components and the implementation of SAVs, defining a set of research questions that can help integrate SAVs in the public transport system.**

I. Introduction

Automated Vehicles (AVs) are one of the largest innovations in transportation research, with automated cars envisioned as the future of passenger transport and promised to reduce traffic congestion [1] and increase traffic safety [2]. In the past decade, several studies have investigated the implication of fully AVs, analysing travel behaviour, network design, cost/benefit analysis and infrastructure development (examples can be found in [3], [4], [5] and [6]).

Among most recent studies, it is suggested to include automation in the vehicle fleet of Demand-Responsive Transport (DRT) systems, to increase cost efficiency and improve on-demand services. DRT provides a (more or less) flexible door-to-door service, often operated with minibus vehicles, that can be booked in advance or in real time through a dial-a-ride scheme [7]. In the scenario of making use of AVs for DRT systems, a new transport mode is emerging: Shared Automated Vehicles (SAVs), or self-driving minibuses. The term SAVs refers to a completely automated road-based means of transport, usually small in size and capacity, with a relatively low operating speed and with no (regular) possibility for the user to engage in any of the driving tasks [8]. Researchers started to investigate their potential application, with the aim of integrating shared mobility within transport network operations. Given the limited capacity and operational speed of the vehicles, a suitable function for SAVs was identified to be as access and egress complement of main public transport modes [9], to provide a door-to-door service [10], increase coverage and potentially encourage a mode shift towards public transport. This application is supported by the findings of Lane (2012), who identified one of the main challenges of public transport operators to be the provision of an adequate connection to high capacity commutes lines, such as train, metro or Bus Rapid Transit (BRT) systems, guaranteeing accessibility and coverage for all users [10]. This is especially challenging for low density areas, in which the combination of small demand and lack of infrastructure can lead to inadequate or non-existing public transport services [10]. Another reason to investigate first/last mile options is supported by the research from Yap et al. (2018), who analysed the egress component of multimodal trips. Results showed that once people get off the train, waiting time for last-mile vehicles is valued 1.6 times more negatively than in-vehicle time, while walking time to destination is even worse, perceived as 1.8 times more negatively than in-vehicle time [11]. In this context, DRT performed with SAVs could reduce waiting time as well as reduce access and egress walking distance. However, research on SAVs is still at its early stage. To pave the road for this new technology, it is important to collect the research done so far on SAVs and propose a future research plan, to understand the market potential of self-driving minibuses and how could they contribute to the existing operations once they will be fully available in the public transport network.

In this paper, the lessons learned from current literature and pilots are described, followed by a research agenda for the adoption of SAVs in public transport design. Section II contains an overview of the methodology used. In section III, the lessons learned from the literature and the current pilots are displayed through a meta-analysis, including the results of the most recent studies on SAVs. In section IV, a research agenda is proposed, as a guiding plan for future research on the adoption of SAVs. The paper concludes with the discussions and conclusions in Section V, adding some directions for future studies.

II. Methodology

This paper aims to collect the most recent findings on SAVs as first and last mile solution for main public transport modes. The main methodology consists of a literature review through the most common searching websites such as Google Scholar and Scopus. Papers were selected according to the publication year and relevant keywords presented later.

The definition of Automated Driving System - Dedicated Vehicle (ADS-DV) provided by the Society of Automotive

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Engineers (SAE) fits perfectly in the definition of SAVs that is intended in this paper [12]. An SAV is a vehicle with a relatively low operating speed (between 15 and 25 km/h) and small passenger capacity (usually 8 to 12 passengers), characterised by driving automation levels 4 and 5, capable of driver-less operations and designed without users interfaces, such as braking, accelerating, steering and transmission gear selection input devices. Operations can be carried out within a corporate campus, within a geographically prescribed central business district or on all mapped roads, where passengers are picked up and discharged along a specific route. Therefore, publications focusing on automation level 4 and level 5 were selected, restricting to studies published between January 2016 and January 2020, peer-reviewed and published in English. The choice of the time span is based on the observation that in Europe the number of pilots and tests regarding SAVs has considerably increased starting from late 2015 and early 2016 [8]. The keywords to be included in the web search are derived from the main purpose of this research. As mentioned above, two means of transport are linked to SAVs: AVs and DRT systems. Research pertaining Travel Behaviour, Network Design, Cost Analysis, Willingness to Share and Willingness to Pay were investigated for the three different types of vehicle/operation configurations (AVs, DRT and SAVs). For this purpose, articles containing any combination of the following keywords in their title, abstract or keywords were considered for the review: shared automated vehicles, automated vehicles, self-driving vehicles, demand-responsive transport, on-demand transport. The words automated and autonomous were treated as synonyms, and searches were performed with British English spelling. To narrow down the review, the keywords travel behaviour, network design, cost analysis, willingness to share and willingness to pay were subsequently added. Additional searches were performed as a result of backward and forward snowballing, using Google and Google Scholar web pages, for which the search criteria were extended regarding the publication year and the peer-reviewed prerequisite. A total number of 28 articles were included in the analysis. Table I contains the list of selected articles. As can be seen from the table, the reviewed articles linked several explanatory variables (or predictors) to response variables. Based on the MAVA model proposed by Nordhoff et al. (2019), the authors decided to provide insights on SAVs acceptance and willingness to adopt self-driving shuttles based on socio-demographic characteristics, travel behaviour, personality characteristics and operational characteristics. Explanatory variables such as automation level, hedonic motivation, penetration rate, performance expectancy, previous accident experience and social influence are not included in this paper, for the authors consider them to be more applicable for the study of AVs in general and not particularly pertaining SAVs.

III. Meta-Analysis

Past research focused on the willingness of travellers to use AVs and the likelihood to switch to automation once the technology is ready (examples can be found in [3], [4], [5] and [6]). When talking about SAVs, the first important consideration concerns passengers preference between owning and sharing an automated vehicle. According to qualitative interviews conducted in 2019 by Zmud and Sener, 59% of respondents would prefer to own an AV, meaning that only 41% prefer to share one [13]. This distinction was made between owned and shared automated cars and not automated shuttles per se, so it is not fully representative of people preferences towards SAVs. A more positive percentage was found by Roche-Cerasi (2019), who investigated the likeliness of using driver-less buses amongst members of the Norwegian Automobile Federation. More than 56% stated that they are somewhat likely or very likely to use automated shuttles in the future, especially in combination with other public transport modes [14]. When asked what their expectations regarding benefits of driver-less buses are, 58% of respondents agreed that SAVs will increase mobility for elderly and people with disabilities, 50% agreed on less car in traffic and pollution and around 30% recognised possible fewer traffic accidents and shorter travel time [14]. This is in line with several studies linking the provision of automated shuttles as first/last mile solution with an increase in accessibility and inclusiveness [15], [16], [17].

The remaining part of this section focuses on the relations between the selected explanatory and response variables. Results are clustered according to the conceptual model on AVs acceptance proposed by Nordhoff et al. (2019). This structure comprises the following categories [5]: socio-demographics of potential users (age, gender, income and education level), travel behaviour (travel purpose and mode choice), personality (trust and sharing with strangers). In addition, operational characteristics are included in the analysis, aggregating factors such as potential areas of usage, impact on traffic congestion, travel time and travel costs, presence of personnel in the vehicle and service type and driving context.

A. Socio-demographic of potential users

1) Age: Among the selected articles, age is the most studied predictor. All results are retrieved from stated preference choice experiments, of which the vast majority found a statistically significant link between age and intention to use SAVs. Young people have a higher interest in automation technologies and are more prone to adopt driver-less buses [18], [19], [20], [13], [21], although it seems to bring the highest benefit to the elderly population [16], by increasing the accessibility of main public transport modes. Age was also found to be relevant in the decision of which combination fits better the use of SAVs: elderly people are more interested in combining SAVs with regular buses whereas young population prefers to combine it with trains [22].

2) Gender: Gender appears to have a controversial influence on SAVs and AVs acceptance, and it seems mostly correlated with the year and geographical area in which the choice experiment took place. Earlier studies showed that men have a higher interested towards AVs [23] as well as a higher willingness to pay [24]. In 2018 and 2019

Article	Explanatory variables	Response variables
Gurumurthy and Kockelman (2020)	Age, Income, Built environment, Smart pricing, Travel time, Safety	Willingness to pay, Intention to use AVs or SAVs
Tirachini and Antoniou (2020)	Vehicle size, Frequency, Fare, Subsidies, Penetration rate, Level of automation	Effects of vehicle automation on PT
Vij, et al. (2020)	Age, Travel time, Cost, Shared space, Employment	Willingness to pay, Willingness to share, DRT and SAV adoption
Zhou, et al. (2020)	Number of trips, Education, Income, Age, Gender	Consumer preferences towards SAVs
Ben-Dor, et al. (2019)	Demand pattern, Geographical characteristics	Optimal fleet size
Jittrapirom, et al. (2019)	Gender, Age, Employment, Household, Mobility and smartphone proficiency, Preferences towards PT	Preference towards flex transport
Lavieri and Bhat (2019)	Residential location, Vehicle availability, Mode choice, Privacy concerns, Time sensitivity, Productive use of travel time	Willingness to share, Value of travel time
Liu, et al. (2019)	Familiarity with automation, Age, Gender, Education, Income, Perceived benefit, Perceived risk, Trust	Willingness to pay
Pöhler,et al. (2019)	Population distribution, Demand prediction, Policy	Costs
Roche-Cerasi (2019)	Age, Gender, Education, Residential location, Familiarity with driver-less shuttles	Likeliness to use, Perceived benefits, Worries, Trust
Snelder, et al. (2019)	Demand pattern, mobility choices	Shared mobility impact on PT
Soteropoulos, et al. (2019)	Vehicle Miles Travelled	Travel behaviour, Land use
van Soest, et al. (2019)	Gender, Age, Available vehicles, Income, Education, Ethnicity, PT mode, Station function and location, Walkability, Safety, Weather, Purpose, Time of day, Trip length, Number of transfers, Frequency of use	PT-related walking time (PTW)
Vosooghi, et al. (2019)	Demand patterns	Network performances
Wang,et al. (2019)	Waiting time, Service time, System capacity	Operation performances of SAVs
Winter, et al. (2019)	Travel time, Presence of steward, Interest in automation, Trust, Gender	Attitudes towards trust in self-driving vehicles, Interest in automation technology
Alonso-González, et al. (2018)	Generalized journey time, Shared of declined trips, Walkable and bikeable trips	DRT system characteristics, DRT operations, Accessibility indicators
Bansal and Daziano (2018)	Presence of steward on board	Willingness to pay
Millonig and Fröhlich (2018)	Journey satisfaction	Availability, Affordability, Accessibility, Acceptance
Panagiotopoulos, et al. (2018)	Perceived usefulness, Perceived ease to use, Perceived trust, Social influence, Age, Gender, Household income, Mode of daily commute	Consumer's intentions towards AVs
Shabanpour, et al. (2018)	Purchase price, Provision of exclusive lanes, Emission reduction, Income, Driving mileage, Accident past experiences, Age, Home location	Interest towards AV, Features that affect AV adoption
Pakusch and Bossauer (2017)	Previous experience and knowledge of automation technologies, Gender, Age, Current means of transport	Intention to use automated PT, Willingness to use different automated means of transport
Zmud and Sener (2017)	Age, Commute mode, Frequency of driving	AVs adoption, Owning VS sharing, Vehicle ownership, Vehicle miles travelled
Bansal and Kockelman (2016)	Presence of steward on board	Willingness to pay
Krueger, et al. (2016)	Cost, Accessibility, Inclusiveness, Trip purpose, Age	Mode share
Piao, et al. (2016)	Gender, Age, Level of education, Employment, Travel modes, Reduced fares, Steward on board	Awareness, General attitudes towards AVs, Attractiveness, Perceived safety
Yap, et al. (2016)	Main transport mode in multimodal trips, Age, Income, Gender, Trust, Travel time, Access time	Intention to use AVs as egress mode, Willingness to pay

TABLE I

META-INFORMATION OF THE CONSIDERED ARTICLES

similar experiments showed that women started to reveal interest in automation as well, resulting to be more willing to try SAVs than men once the technology is available [25], showing that somehow the gender gap is closing. A higher interest in driving automation from women rather than man was also found in an earlier study from Yap, et al. (2016), in which choice experiments showed that female population attributes a higher utility in AVs rather than the male counterpart [11]. An interesting conclusion was drawn by van Soest, et al. (2019): given the contrasting results from different choice experiments, they stated that gender effect on willingness to adopt SAVs or driving automation technologies in general, is a cultural outcome depending on different norms and traditions and can be explained by geographical locations, travel purposes and car availability [26]. For example, women are found to be more worried than man about personal security when commuting on SAVs [14], but this is particularly the case in countries where women cannot walk freely without feeling a sense of threat, or where women are not allowed or encouraged to travel alone. The topic of personal security was also treated by Gurumurthy and Kockelman (2020), who found that women hold concerns about SAVs especially for night trips [18] and in case that the steward is not present on board [27]. Two more articles stressed the gender difference regarding trust in automation: SAVs acceptance for women was found to be highly related to trust effects [28], sometimes hampered by cautious opinions about self-driving capabilities [29].

3) Income and education level: The effect of income and education level was found to be consistent in almost all the reviewed articles. People (especially men [24]) with high income show a higher willingness to pay [19], which can be 26% more compared to the one of low or middle income population [18]. This is related to the fact that individuals with high incomes are usually not affected by changes in price, hence the low price elasticity of demand [21].

B. Travel behaviour

1) Travel purpose and mode choice: Travel purpose and mode choice are closely connected, since the choice of which transport mode to use is often made based on the travel activity [30]. According to the simulation analysis conducted by Vosooghi et al. (2019) on the origin and destination activities of trips performed with SAVs, the vast majority of trips (45%) have as origin or destination customer's home, followed by work activities (29%), study (8%) and leisure activities (7%). Shopping, escorting and personal tasks were the least popular activities for using SAVs [31].

C. Personality

1) Trust: Several studies suggested that previous knowledge of the system positively influences the trust that future users have on AVs [19], [25], [11] and this is especially true for women [28]. Trust can be expressed as faith in technology and positive expectations on the system reliability. A research conducted in Norway in 2019 studied the level of trust of potential users in the ability of authorities to reduce the risk of accidents with driver-less buses. Results were not positive, showing that only 16% reported a high level of trust, 33% were neutral on the subject and 51% admitted to have a low trust or no trust at all [14].

2) Sharing with strangers: Sharing a vehicle with strangers has proven to influence negatively the intention to adopt SAVs as first/last-mile option. Lavieri and Baht (2019) investigated the willingness to pay for a shared ride, showing that travellers are willing to pay 0.5 euros per commute trip in order to not share the ride with another person, value that increases to 0.9 euros per leisure trip [32]. This result suggests that people are willing to pay 84% more for a leisure trip than a commute trip in order not to have an additional passenger, therefore it might be easier to promote SAVs for commute trips rather than leisure trips. Other factors that influence the willingness to share a ride with other passengers are age, gender and the size of households. Young, full-time employed [20] males [28] are the category that is more likely to use SAVs, especially for commuting.

D. Operational characteristics

1) Potential areas of usage: Several combinations of potential origin-destination areas were already suggested in 2008 as part of the CityMobil project. The expected applications included: trips within the city centre, trips in the outer suburbs, feeder for major transport nodes (such as airports and central stations) and parking facilities, within major educational facilities (such as University campus) and to and from major leisure and shopping facilities [33]. Therefore, SAVs can be considered as a complement to traditional public transport when used as a first/last-mile solution for main services, but also as a threat to traditional urban public transport, providing a more convenient and flexible user experience [16].

2) Impact on traffic congestion: Studies on the effect of SAVs on congestion are still very limited. With an agent-based simulation study in Israel, it was found that the average daily decrease in congestion associated with SAVs is expected to be around 21%, with the highest decrease equal to 25% in case of inter-urban roads and the lowest about 14% for urban roads [34]. Although traffic congestion is predicted to be reduced, an increase in vehicle km travelled was found, due to empty trips [35], disadvantage that could be mitigated implementing an on-demand service [36].

3) Travel time and travel costs: Travel time and travel cost are two different acceptance factors. Nonetheless, they are usually interrelated by the value of time (VOT) [37]. VOT results are higher for work trips rather than for leisure trips: the willingness to pay is 14% more to reduce by one minute a commute trip compared to a leisure trip [32]. According to a choice experiment conducted among students and employees of the university campus in Aachen, Germany, the VOT for self-driving buses is equal to 10.59 euros, whereas for traditional buses is 5.13 euros [28]. This means that people are willing to spend more than twice to reduce time in SAVs compared to normal buses. A positive link between attractiveness and intention to adopt SAVs resides in the possibility to reduce fares due to the operational characteristics of the system (e.g. no driver needed) [27], [11]. Costs can also be reduced with an automated on-demand system, for which social costs were found to be two times lower than the one of a traditional on-demand system [38].

4) Presence of personnel in the vehicle: The definition of self-driving bus entails that the driver is not present in the vehicle. So far, pilots have been performed with a steward on board, helping out passengers understand how the vehicle works and performing safety measures in case of emergencies [8]. The presence of a steward on board has been studied to get insights on travellers' reaction, and to understand whether vehicles could be introduced without any personnel assisting passengers. So far, unpromising results have been achieved. New Yorkers were against having no personnel on board, being willing to pay on average $3 less per self-driving trip compared to traditional buses [39]. Of the same opinion were respondents from a survey in France, for whom the perceived safety decreased when the steward was not present, especially during night trips [27]. On the other hand, cost analyses have shown that the operational costs of self-driving buses are almost 4 times smaller than the operational costs of traditional buses [9]. These cost savings are only achieved in case that all human driving costs can be saved, otherwise if a steward is present on board, operational costs can be twice as high [9].

5) Service type and driving context: A study on public acceptance of SAVs conducted in Norway, showed that when respondents are asked about their preferences for future scenarios of first/last-mile, 55% are in favour of traditional bus services with human driver, 5% do not know their preference and 40% are interested and positive about self-driving buses [14]. Among the share of population in favour of self-driving buses, 40% would prefer a vehicle with emergency driver, 22.5% would opt for vehicles travelling on their own lanes, 22.5% wants the vehicle to be remotely controlled and only 15% have no problems with the lack of human steering [14]. One of the latest research on SAVs conducted by Tirachini and Antoniou showed that the best infrastructure for SAVs is on dedicated lanes or roads, so to minimise the interaction with other users and avoid potential points of conflicts [9]. They also argued that the presence of SAVs will anyhow constrain the presence of other users, leaving room for future research on the topic [9]. Based on the review articles, one of the topic that needs further research is whether to implement SAVs on an on-demand basis or with fixed routes and schedules. Contrasting results have been reached so far. On a passenger perspective, it was found that service decreases the perceived utility of self-driving buses, since it is more difficult and has a higher expected effort for the user [28]. On the other hand, simulations showed that implementing SAVs with dynamic ride-sharing reduces the average waiting time, vehicle km travelled and empty trips [36], resulting in a more efficient system.

IV. Research Agenda

What resulted from the literature study is an insufficient attention towards coverage area, operational characteristics and driving context and a consequent lack of research on the effect of SAVs on traffic congestion. Following the development of public transport networks, design dilemmas are changing to accommodate the integration of on-demand systems, first/last-mile options and the development of automation and electrification. Consequently, network design and infrastructure design should be adapted to allow for SAVs implementation.

In transportation modelling, public transport network design is represented using network lines as a set of connected links and nodes (stops) and associated frequencies [40]. To fully implement a new first/last-mile service, it is important to define the sets of nodes, links, and frequencies, to be able not only to simulate and optimise the system, but more importantly to operate it. In this context, it is relevant to distinguish between a door-to-door on-demand system and a fixed-route fixed-schedule system. So far, pilots have been performed on a fixed-route scheme, mostly connecting a bus stop/train station to a major facility. Operational requirements and passengers response (i.e. mode choice) could significantly change when a door-to-door on-demand system is introduced, hence the importance of answering questions such as whether an automated DRT system could help the realisation of an operative first/last-mile SAVs system.

Together with network design, infrastructure design plays an important role in the implementation of SAVs. So far, tests were carried out only on dedicated lanes and/or private areas. Simulation studies should focus on integrating SAVs operations in the existing infrastructure, identifying the potential technical issues regarding Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication. Moreover, behavioural studies on passenger acceptance should be added when simulating a mixed infrastructure configuration.

For what concerns the presence of personnel in the vehicle, choice experiments showed that passengers feel safer when there is a steward on board. On the other hand, cost analyses showed that operations are more profitable when no human is involved. On this subject, two questions arise: on a technology perspective, is it possible to operate SAVs without stewards? And more on the travellers' perspective, how would the SAV acceptance change if the steward is not present and SAVs are offered only without personnel on board? Existing pilots included a steward on board. This characteristic, together with the fact that tests run only on dedicated infrastructure and on a fixed-route fixed-schedule system, might render the experimental findings not fully representative for a long term implementation of SAVs.

According to recent studies, people who have knowledge on automation technologies are more willing to try AVs. This increase in acceptance is even more evident with individuals who already own a vehicle with automated components (e.g. Adaptive Cruise Control). This influence was found particularly for AVs, whereas for SAVs no research has been conducted yet. This opens up for questions on the link between technology knowledge and technology acceptance for the case of SAVs, such as whether or not market potential will keep increasing once people start using driver-less buses.

V. Conclusions

Existing literature shows that several factors can influence the use of SAVs. The effect of age, gender and income has already been studied, identifying target user group of medium/high income individuals between 26 and 65 years of age. Most common trip purposes have also been thoroughly investigated, being commute trips home-work and vice-versa the most popular use for an SAV. Studies regarding trust in technology, willingness to share, operational costs and presence of personnel on board have brought some insights on future adoption rates, identifying some marketing strategies (low fares and incentives for users) but mainly some drawbacks, such as lack of trust in vehicle technology and perceived safety, low willingness to share and fear of not having an operator on board. The review of existing articles helped to design a conceptual scheme for SAVs implementation, showing its links with public transport network components. Research gaps were found in the infrastructure and network design, as well as in the possibility of removing all human personnel from the vehicles. As a result, a set of questions is formulated, which can lead to understand why existing pilots are not moving forwards and have not been implemented into operational systems yet.

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REFERENCES

[1] D. Li and P. Wagner. Impacts of gradual automated vehicle penetration on motorway operation: a comprehensive evaluation. *European transport research review*, 11(1), 2019.

[2] S. Kitajima, K. Shimono, J. Tajima, J. Antona-Makoshi, and N. Uchida. Multi-agent traffic simulations to estimate the impact of automated technologies on safety. *Traffic injury prevention*, 20(sup1):S58–S64, 2019.

[3] F. Becker and K. Axhausen. Literature review on surveys investigating the acceptance of automated vehicles. *Transportation*, 44(6):1293–1306, 2017.

[4] M. Martínez-Díaz and F. Soriguera. Autonomous vehicles: theoretical and practical challenges. *Transportation Research Procedia*, 33:275–282, 2018.

[5] S. Nordhoff, M. Kyriakidis, B. Van Arem, and R. Happee. A multi-level model on automated vehicle acceptance (mava): a review-based study. *Theoretical Issues in Ergonomics Science*, 20(6):682–710, 2019.

[6] A.D. Beza and M.M. Zefreh. Potential effects of automated vehicles on road transportation: A literature review. *Transport and Telecommunication Journal*, 20(3):269–278, 2019.

[7] M. Alonso-González, T. Liu, O. Cats, N. Van Oort, and S. Hoogendoorn. The potential of demand-responsive transport as a complement to public transport: An assessment framework and an empirical evaluation. *Transportation Research Record*, 2672(8):879–889, 2018.

[8] M. Hagenzieker, D. Heikoop, R. Boersma, J.P. Nunez Velasco, I. Zubin, and M. Ozturker. Automated buses in europe: An inventory of pilots, 2020.

[9] A. Tirachini and C. Antoniou. The economics of automated public transport: Effects on operator cost, travel time, fare and subsidy. *Economics of Transportation*, 21, 2020.

[10] B. Lane. On the utility and challenges of high-speed rail in the united states. *Journal of Transport Geography*, 22:282–284, 2012.

[11] M. Yap, G. Correia, and B. Van Arem. Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips. *Transportation Research Part A: Policy and Practice*, 94:1–16, 2016.

[12] SAE International. Surface vehicle recommended practice: Taxonomy and definition for terms related to driving automation systems for on-road motor vehicles. Technical report, SAE International, June 2018.

[13] J. Zmud and I. Sener. Towards an understanding of the travel behavior impact of autonomous vehicles. *Transportation research procedia*, 25:2500–2519, 2017.

[14] I. Roche-Cerasi. Public acceptance of driverless shuttles in norway. *Transportation research part F: traffic psychology and behaviour*, 66:162–183, 2019.

[15] M. Snelder, I. Wilmink, J. van der Gun, H. Jan Bergveld, P. Hoseini, and B. van Arem. Mobility impacts of automated driving and shared mobility. *European Journal of Transport and Infrastructure Research*, 19(4), 2019.

[16] R. Krueger, T. Rashidi, and J. Rose. Preferences for shared autonomous vehicles. *Transportation research part C: emerging technologies*, 69:343–355, 2016.

[17] A. Millonig and P. Fröhlich. Where autonomous buses might and might not bridge the gaps in the 4 a's of public transport passenger needs: A review. In *Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pages 291–297, 2018.

[18] K.M. Gurumurthy and K.M. Kockelman. Modeling americans' autonomous vehicle preferences: A focus on dynamic ride-sharing, privacy & long-distance mode choices. *Technological Forecasting and Social Change*, 150:119792, 2020.

[19] P. Liu, Q. Guo, F. Ren, L. Wang, and Z. Xu. Willingness to pay for self-driving vehicles: Influences of demographic and psychological factors. *Transportation Research Part C: Emerging Technologies*, 100:306–317, 2019.

[20] A. Vij, S. Ryan, S. Sampson, and S. Harris. Consumer preferences for on-demand transport in australia. *Transportation Research Part A: Policy and Practice*, 132:823–839, 2020.

[21] R. Shabanpour, N. Golshani, A. Shamshiripour, and A.K. Mohammadian. Eliciting preferences for adoption of fully automated vehicles using best-worst analysis. *Transportation research part C: emerging technologies*, 93:463–478, 2018.

[22] P. Jittrapirom, W. van Neerven, K. Martens, D. Trampe, and H. Meurs. The dutch elderly's preferences toward a smart demand-responsive transport service. *Research in Transportation Business & Management*, 30:100383, 2019.

[23] C. Pakusch and P. Bossauer. User acceptance of fully autonomous public transport. In *ICE-B*, pages 52–60, 2017.

[24] P. Bansal, K. Kockelman, and A. Singh. Assessing public opinions of and interest in new vehicle technologies: An austin perspective. *Transportation Research Part C: Emerging Technologies*, 67:1–14, 2016.

[25] I. Panagiotopoulos and G. Dimitrakopoulos. An empirical investigation on consumers' intentions towards autonomous driving. *Transportation research part C: emerging technologies*, 95:773–784, 2018.

[26] D. van Soest, M. Tight, and C. Rogers. Exploring the distances people walk to access public transport. *Transport Reviews*, 40(2):160–182, 2020.

[27] J. Piao, M. McDonald, N. Hounsell, M. Graindorge, T. Graindorge, and N. Malhene. Public views towards implementation of automated vehicles in urban areas. *Transportation research procedia*, 14:2168–2177, 2016.

[28] K. Winter, J. Wien, E. Molin, O. Cats, P. Morsink, and B. van Arem. Taking the self-driving bus: A passenger choice experiment. In *2019 6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, pages 1–8. IEEE, 2019.

[29] F. Zhou, Z. Zheng, J. Whitehead, S. Washington, R. Perrons, and L. Page. Preference heterogeneity in mode choice for car-sharing and shared automated vehicles. *Transportation Research Part A: Policy and Practice*, 132:633–650, 2020.

[30] S. Stradling. Travel mode choice. In *Handbook of Traffic Psychology*, pages 485–502. Elsevier, 2011.

[31] R. Vosooghi, J. Puchinger, M. Jankovic, and A. Vouillon. Shared autonomous vehicle simulation and service design. *arXiv preprint arXiv:1906.07588*, 2019.

[32] P. Lavieri and C. Bhat. Modeling individuals' willingness to share trips with strangers in an autonomous vehicle future. *Transportation Research Part A: Policy and Practice*, 124:242–261, 2019.

[33] CityMobil. City application manual w.p. 2.2: Scenarios for automated road transport. Technical report, 2008.

[34] G. Ben-Dor, E. Ben-Elia, and I. Benenson. Determining an optimal fleet size for a reliable shared automated vehicle ride-sharing service. *Procedia Computer Science*, 151:878–883, 2019.

[35] A. Soteropoulos, M. Berger, and F. Ciari. Impacts of automated vehicles on travel behaviour and land use: an international review of modelling studies. 39:29–49, 2019.

[36] S. Wang, G. Correia, and H.X. Lin. Exploring the performance of different on-demand transit services provided by a fleet of shared automated vehicles: An agent-based model. *Journal of Advanced Transportation*, 2019, 2019.

[37] K. Small. Valuation of travel time. *Economics of transportation*, 1(1-2):2–14, 2012.

[38] L. Pöhler, Y. Asami, and T. Oguchi. Urban land use policies for efficient autonomous on-demand transportation–a case study on the japanese island of izu oshima. *International Journal of Transport Development and Integration*, 3(2):152–165, 2019.

[39] P. Bansal and R. Daziano. Influence of choice experiment designs on eliciting preferences for autonomous vehicles. *Transportation Research Procedia*, 32:474–481, 2018.

[40] R. van Nes. Design of multimodal transport networks: a hierarchical approach. 2002.