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CHAPTER TWO

Automated bus systems in Europe: A systematic review of passenger experience and road user interaction

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Abstract

Automated driving systems promise a tremendous amount of benefits. Especially when applied in the domain of public transport, economic and passenger advantages are thought to be manifold. As technology rapidly advances, and projects involving automated buses appear throughout the world, investigating how its users and surrounding road traffic interact with these novel technologies need to advance with a similar pace. However, up to now, a reliable and up-to-date overview of performed, running, and planned projects is lacking. Moreover, little is known about human interaction with automated bus systems, and what is known is not always reported. By means of a systematic review, an overview of the current state-of-the-art knowledge on the interaction between automated bus systems and its interactors is presented. Results of these

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studies are described and discussed, and implications are being made regarding future policies to be applied in this domain to safeguard safe interaction with automated bus systems.

Keywords: Automated bus systems, Systematic review, Projects inventory, Passenger experience, Road user interaction, Policy implications

1. Introduction

From one vehicle showing its state-of-the-art technologies, to world-wide collaborations using a variety of vehicles differing in autonomy, location, and purpose, automated driving systems are becoming increasingly intelligent and commonplace. The benefits of automated driving systems are deemed plentiful, ranging from economic to environmental, such as reduced fuel consumption and carbon emission, and from personal to temporal benefits, such as having the freedom to read emails on your way to work and improved traffic flow. Public transport is generally regarded as one of the more suitable candidates to benefit from automating certain driving tasks (Shladover et al., 2016), hence this particular domain is receiving increasingly more attention from researchers, developers, and stakeholders alike. As a result, projects involving automated public transport systems are appearing with accelerating pace, and keeping up to date about their current developments is becoming increasingly cumbersome. A comprehensive overview of all these projects would provide valuable insights for researchers regarding what has been done in the past, and what is currently ongoing or planned in the domain of automated driving systems. Overviews like this do exist, but are not always (kept) up-to-date and often lack the detailed information needed for research purposes. For instance, the Bloomberg.org Group created an interactive map on current and planned projects involving autonomous vehicles (Bloomberg.org Group, 2018), and Connected and Automated Driving Europe's website gives an overview of European projects in the field of automated road transport (Connected and Automated Driving Europe, 2019), but these are not exhaustive and detailed information is often not provided. When narrowing down to automated bus systems, finding an exhaustive and up-to-date overview of completed, running, and planning projects becomes even more challenging. From a technological, energy efficiency, and legality perspective, a recent overview article investigated predominantly European completed and ongoing automated bus projects (Ainsalu et al., 2018). Although being exhaustive in their respective perspective, this overview does not provide an insight into the human perspective and their interaction with automated bus systems.

In terms of human interaction with automated driving systems in general, several issues have been raised several decades ago already, while still remaining relevant up to this day (see, e.g., Kyriakidis et al., 2019; Saffarian et al., 2012; Stanton and Marsden, 1996). Regarding the human interaction with automated bus systems, although being different in nature due to their subject, the issues are more or less as old and remain as relevant today as those in automated driving systems in general (see, e.g., Martens et al., 2008; Nordhoff et al., 2018; Warren and Kunczynski, 2000). It is therefore important to keep an even pace with technology, and, if we want to have the consumer (keep) using promising novel technology, maintain an up-to-date knowledge base of how humans (prefer to) interact with such technologies as automated bus systems.

In this chapter, we will seek answers to the following four research questions: (1) What is known about human interaction with automated bus systems? (2) Which methodologies are being used in research regarding the interaction between humans and automated bus systems? (3) What research gaps exist? and (4) which policy implications can be derived so far?

The chapter aims to answer these questions by performing a systematic review on the topic of automated bus systems and the interaction with its (direct or indirect) users. This will be done by starting off with a broad approach to ensure an as all-encompassing cover as possible, and then narrowing down by applying a series of pre-determined filtering steps. The results of this systematic review will consequently be interpreted and represented in a thematic overview. Ultimately, the implications of these results will be discussed, and policy recommendations will be suggested.

2. Method

The systematic review was performed by following a series of steps allowed for an objective analysis of the current literature. Fig. 1 displays the series of steps taken in this systematic review.

As a first step, a Scopus search was performed on April 26, 2019. In Scopus, one can search in academic literature for specific words. One can narrow down the search by limiting their search field, for instance to title, abstract, and/or keyword only, to a specific domain like business, or to specific volumes or authors. In this systematic review, the search was limited to

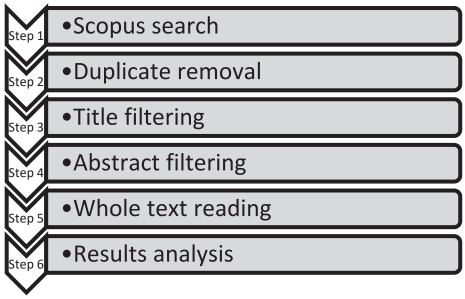

Fig. 1 Approach of the systematic review performed in this study.

Table 1 Search terms for the Scopus systematic review.

Domain	Automation	Subject
Bus(es)	Automated	Vulnerable road user(s)
Shuttle(s)	Autonomous	Cyclist(s)
Pod(s)	Driverless	Pedestrian(s)
Road transport system(s)	Self-driving	Passenger(s)
Personal rapid transit		User(s)
Transit network(s)		Public
People mover(s)		VRU(s)

title, abstract, and keyword only, but no other restrictions were applied. The systematic review queries were divided into three parts, namely domain, automation, and subject. In order to ensure an all-encompassing search, a broad scope was taken, meaning that several synonyms of the domain, the term "automation," and the subject were taken into account in the search. Determining appropriate search domains was done by investigating the titles and subjects of known literature in this domain. Regarding the domain of automated bus systems, this resulted in seven synonyms (see Table 1). For the "automation" term, four synonyms were used, and seven different subjects were determined. Also the plural versions of the terms were used, as it was noted during a piloting trial of the queries this otherwise would leave out valuable results. With these terms combined, a query was formed and submitted into the Scopus search field. An example of such a query would then be:

TITLE-ABS-KEY (cyclist OR cyclists) AND TITLE-ABS-KEY (autonomous AND (bus OR buses))

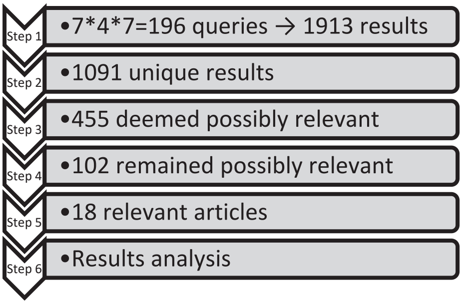

Fig. 2 Intermediate results per step of the systematic review.

This entailed a total of $7 \times 4 \times 7 = 196$ search queries, which provided 1913 results (Fig. 2). After filtering for duplicates as the second step in the systematic review, 1091 unique results were left. The third step in the process was an initial filtering procedure in which the titles of all unique articles were read, and selected or discarded based on whether it featured a user-automated bus interaction scope. This step entailed among others discarding results that were clearly technology-oriented, and involved automated systems other than buses, such as trains, while keeping titles that were either deemed relevant in any way, or found to have (an ambiguous) potential to be relevant. As a result, 455 articles were deemed relevant for this systematic review based on their title. Of the remaining articles, as a fourth step, their abstracts were read, to further filter out ultimately irrelevant articles.

With this step, 102 articles remained. Where there were any disputable (in terms of relevance) articles left, as a final step, the full article was read in order to determine its relevance, which ultimately lead to a total of 18 articles that were deemed relevant for this systematic review. Note, however, that of 5 articles out of the 102 their full papers could not be read, as they were not retrievable. It is nevertheless likely that, in line with the rest of the filtering procedure, these articles will have been irrelevant to this study as well. The relevant articles were consequently used for the analysis of this research and are presented in Section 3 (Table 2).

3. Results

3.1 Descriptive results of the systematic review

The first and most obvious result of the systematic review is that published research on this topic is still sparse. The 196 queries delivered little over a thousand results, which translates into less than 6 hits per query.

Table 2 Overview of the scientific literature that present empirical research on the interaction between automated buses and its users and/or interactors.

Author(s)	Year	Project	Location (type)	Length	Bus type	Speed	Steward	Service type	Method	No ppts	Ppt type	Categories			Measures		
Alessandrini et al.	2011	CityMobil	Verdun Square, La Rochelle, France (restricted access)	?	Many	?	Yes	Demo	Questionnaire	256	Users[a]	Acceptance	Quality of service		Importance ranking	Performance rating	
Boersma et al.	2018	STAD	Appelscha, The Netherlands (separate cycle lane)	2.5 km	EZ10	15 km/h[b]	Yes	Pilot	Questionnaire and observations	20 and 50	Users and VRUs[c]	*Undisclosed*			*Undisclosed*		
Distler et al.	2018	–	Lyon, France (public road with a.o. pedestrians)	15 min	Navya	20 km/h	Yes	Experiment	Questionnaire and observations	14	Users	Pre- and post-immersion	Automated vehicles		UTAUT[d]	CTAM[e]	
Eden et al.	2017	Smart Shuttle	Sion, Switzerland (public road with a.o. pedestrians)	1.5 km	Navya	20 km/h	Yes	Pilot	Interviews and observations	?	Users and VRUs	Attitudes and opinions	Interactions		Descriptive	Notes	Videos photos
Eden et al.	2017	Smart Shuttle	Sion, Switzerland (public road with a.o. pedestrians)	1.5 km	Navya	20 km/h	Yes	Pilot	Interviews and observations	17	Users	Attitudes and opinions			Descriptive		
Kim et al.	2017	–	Seoul National University Campus, Seoul, South Korea (campus)	4.5 km	?[f]	?	Yes	Regular service	Questionnaire	10	Users	Quality of service			Reliability	Accessibility	Safety
															Comfort	Convenience	Price
Madigan et al.	2016	CityMobil2	La Rochelle, France and Lausanne, Switzerland (public roads with a.o. pedestrians)	1.71 km and 1.585 km	? and EZ10	12 km/h[g]	Yes	Pilot	Questionnaire	349	Public[h] (users)	Performance expectancy	Behavioral intention		Adapted UTAUT		
												Social influence	Effort expectancy				
Madigan et al.	2017	CityMobil2	Trikala, Greece (public roads with a.o. pedestrians)	2.5 km	?	13 km/h	Yes	Demo	Questionnaire	315	Public (users)	Performance expectancy	Behavioral intention	Hedonic motivation	Adapted UTAUT		
												Social influence	Effort expectancy	Facilitating			

Merat et al.	2018	CityMobil2	La Rochelle, France, Lausanne, Switzerland, and Trikala, Greece (public roads with a.o. pedestrians)	2.6 km, ? and ?	?, EZ10 and ?	10 km/h	Yes[i]	Demo	Questionnaire	664	VRUs	Safety and priority	Type and mode of communication		Designated questions		
Moták et al.	2017	–	Estaing Hospital, Clermont-Ferrand, France (?)	?	?	?	?	?	Questionnaire	31[j]	Users	Intentions of re-use			Extensions	TAM[k]	TPB[l]
															Values		
Nordhoff et al.	2018	–	EUREF office campus, Berlin-Schöneberg, Germany (campus)	0.7 km	Olli	8 (avg) –10 (max) km/h	Yes	Regular service	Questionnaire	384	Users	Quality of service	Acceptance	Attitude[m]	Designated questions	Van der Laan	UTAUT
Oliveira et al.	2018	UK Autodrive	Urban Development Lab, Coventry, UK (fitted warehouse)	?	RDM	?	No	Experiment	Questionnaire	20	Users	Trust	Usability	Workload	SUS[n]	ATT[o]	NASA-TLX[p]
Portouli et al.	2017	CityMobil2	Trikala, Greece (public roads with a.o. pedestrians)	2.4 km	?	?	Yes	Demo	Questionnaire	200 and 498[q]	Users and public	Satisfaction	Safety and security	Usability	Designated questions		
												Intention of use and pay	Attractiveness	Attitudes and opinions			
Rehrl and Zankl	2018	Digibus	Koppl, Austria (public roads)	2.8 km	Navya	16 km/h[r]	Yes	Pilot and demo	Questionnaire	294	Users	Test purpose	Prior knowledge and experience	Driving pleasure	Designated questions		
												Safety	Usability				
Salonen	2018	CityMobil2	Vantaa, Finland (segregated lane [with tunnel])	0.95 km	EZ10	13 km/h	Yes	Demo	Questionnaire	197	Users	Emergency management	Safety	Security	Designated questions		

Continued

Table 2 Overview of the scientific literature that present empirical research on the interaction between automated buses and its users and/or interactors.—Cont'd

Author(s)	Year	Project	Location (type)	Length	Bus type	Speed	Steward	Service type	Method	No ppts	Ppt type	Categories			Measures		
Salonen and Haavisto	2019	–	Otaniemi, Espoo, Finland (campus)	0.7 km	EZ10	12 km/h	Yes	Pilot	Interview	44	Users	Attitude Affection	Imminent reactions	Social factors	TIB[s]	Descriptive	
Straub and Schaefer	2019	ARIBO	US Army installation, USA (army base (including roadways and sidewalks))	?	?	?	Yes	Simulation and pilot and regular service	Experiment and observation and video data and observation	24 and 20 and 86 and 91 and 3	Users and VRUs and road users[t]	Responsibility	Communication	Safety	Low-risk and high-risk	Descriptive	Videos
Wintersberger et al.	2018	–	Bavaria, Germany (public roads with a.o. pedestrians)	1 km	EZ10	?	Yes	Regular service	Interview	12[u]	Users	Opinion Trust	Usability Intention of use	Attitude	TAM2	Descriptive	

[a]Defined as those actively using/having used the bus.
[b]The max speed of the EZ10 was 40 km/h. Due to legal reasons, the max speed for this pilot was set at 15 km/h.
[c]Vulnerable road users; defined as those actively interacting with the bus from outside the bus.
[d]Unified theory of acceptance and use of technology.
[e]Car technology acceptance model.
[f]Technically, this was a taxi.
[g]The maximum speed of both vehicles was 45 km/h, but in reality not achieved.
[h]Defined as those not actively using/having used the bus, but at most merely having seen the bus.
[i]Not mentioned in-text, but deduced based on similar research.
[j]Total amount of participants in this research was over 500, but those were only used for study 1. Study 2 had 108 participants; wave 2 of study 2, the relevant part of the study for the systematic review, had 54 participants; only 80 and 31, respectively, were used in the analysis.
[k]Technology acceptance model.
[l]Theory of planned behavior.
[m]Among which were performance expectancy and effort expectancy (see Madigan et al., 2016, 2017).
[n]System usability scale.
[o]Advanced transport telematics survey.
[p]NASA task load index.
[q]519 Participants of which 21 indicated no knowledge of the autonomous mini bus.
[r]The max speed of the Navya was 45 km/h. Due to legal reasons, the max speed for this pilot was set at 20 km/h. Due to safety reasons, the max speed for this pilot was set at 16 km/h.
[s]Theory of interpersonal behavior.
[t]Defined as those actively interacting with the bus from outside the bus, who do not fall under the definition of VRUs.
[u]24, But only results of 12 described in this paper.
?, Unknown

Of those hits, a mere 1.6% were eventually found relevant to this study. Table 2 shows the details of the 18 articles that were relevant for this study. What is interesting, is that none but one (Alessandrini et al., 2011) predates 2016, which clearly indicates the relative novelty of this type of technology. Moreover, the 2011 CityMobil demonstration was a showcase placed at a relatively small market square, at which the first type of such vehicles from several different partners and manufacturers were shown, also demonstrating a range of different technologies, such as platooning and advanced (instead of the now fairly common adaptive) cruise control (ACC). This thus does not yet compare with the more recent projects which were predominantly aimed for (eventual) continuous use. Furthermore, CityMobil's successor, CityMobil2, appears to be the most prolific project in terms of scientific outreach, providing 5 of the 18 articles for this analysis.

In terms of geographic spread, it can be seen that the largest proportion of reported experiments on the interaction with automated bus systems are found in Europe, with only two articles being from outside of Europe: South Korea, and the USA (Kim et al., 2017; Straub and Schaefer, 2019). The South Korean article also reports the longest distance over which the automated bus system drove, namely 4.5 km, where the average reported distance among all articles is 1.9 km (13 articles reporting 14 distances). It should be noted, however, that this vehicle in the South Korean pilot had taxi characteristics (see also Table 2, footnote f). Furthermore, its speed was not mentioned in their paper. Assumedly, this was higher than average in Table 2, hence making it possible to drive longer distances than other vehicles listed in this paper who had more bus-like characteristics.

Navya and EZ10 are the two most prominent bus types reported in the articles, albeit noteworthy that eight of the articles did not provide any or all details of the bus types used. It is also worth noting that the buses' speed is equally underreported: in eight instances, no speeds were reported. Of particular interest is that some articles reported that the buses' maximum speed is (much) higher than that used in their pilots and/or demos. Due to legal and/or safety issues, the vehicle operators significantly reduced the maximum speed of the buses, to ensure a safe research or demonstration environment (see, e.g., Boersma et al., 2018; Madigan et al., 2016; Rehrl and Zankl, 2018). Moreover, for safety reasons, all but one (excluding those not reporting) had a safety driver/operator/steward on board of the automated bus system at all times. The one without a steward on board is that reported by Oliveira et al. (2018). Their experiment was performed under strictly secured circumstances, for instance without surrounding traffic and in a simulated city inside a laboratory. Direct communication with the research team was at all times possible, and an emergency stop button was inside the automated bus system.

As the technology behind automated bus systems is still fairly new, most of these systems are still being tested or demonstrated. This can also be seen in our results. Only 4 articles refer to (some sort of) regular service of their automated bus systems, whereas the other 13 are either demonstrations, pilots or experiments. The only article in which we were unable to explicitly identify the automated bus system's service type is that of Moták et al. (2017). As their main topic of investigation was the development of a model of acceptance, and they used an existing and already running automated bus system, elaborating on the details of that bus system may not have been their priority. They were also the only ones that did not elaborate on the trajectory length, bus type and speed, and steward presence.

The section that answers our second research question inventoried each research's methodology. Almost exclusively, the experiments performed in the articles were questionnaire-based. The works of Salonen and Haavisto (2019) and Wintersberger et al. (2018) were the only two not indicating having made use of a questionnaire. Instead, they took a (semi-structured) interview approach—which nevertheless somewhat resembles a questionnaire, but has the distinctive difference of having descriptive results, rather than ratings or rankings, which are common in questionnaires. Note that the two articles mentioned above were not the only two making use of descriptive measures. Five other articles indicated other methods, namely, observations (Boersma et al., 2018; Distler et al., 2018; Eden et al., 2017a,b) and an experimental setting and video analysis (Straub and Schaefer, 2019).

The number of participants was generally high but varied substantially between each study. The 18 articles together indicated performing 24 (sub)studies, for which only one article (Eden et al., 2017a) did not mention the number of participants recruited. The average amount of participants was 156 ($SD = 184$). The least amount of participants was 3, for sub-study 4 of Straub and Schaefer (2019), in which observations were made for the "second vehicle problem," meaning a situation where another driver who crosses the traffic behaves irregularly (i.e., against the rules of the road) or unexpectedly around the automated bus system, which eventually leads to a harmonica effect to the vehicles behind the automated bus system. The highest number of participants was 664 (Merat et al., 2018), which were recruited simultaneously in the three cities of La Rochelle, Lausanne, and Trikala, for a questionnaire-based experiment. Conducting experiments based on questionnaires usually allows for recruiting high amounts of participants. Seeing that the majority of the experiments performed in these articles are based on questionnaires, this would explain the high average amount of participants.

The nature of the participants were usually people who (just or recently) used the automated bus system. Four articles (Boersma et al., 2018; Eden et al., 2017a; Merat et al., 2018; Straub and Schaefer, 2019) indicated having conducted their research with vulnerable road users (or VRUs; i.e., pedestrians or cyclists; those who interacted with the automated bus system from *outside* of the automated bus system).

The main topic of interest of the articles was to investigate the users' acceptance of or attitude toward the automated bus systems. One of two commonly used measures to assess the users' level of acceptance of technology was the UTAUT (unified theory of acceptance and use of technology; Venkatesh et al., 2003) model, or a variation thereof (see, e.g., Madigan et al., 2016, 2017). The other is the technology acceptance model (TAM; Davis, 1986). A relatively large portion appeared to have specifically designed their questionnaire to fit their topic of interest. Five articles (Merat et al., 2018; Nordhoff et al., 2018; Portouli et al., 2017; Rehrl and Zankl, 2018; Salonen, 2018) have been found to not (only) use predesigned established questionnaires, but to also prefer aimed questions for their specific purpose. Another five articles (Eden et al., 2017a,b; Salonen and Haavisto, 2019; Straub and Schaefer, 2019; Wintersberger et al., 2018) used descriptions of their observations or interviews to make assessments of their topics of interest.

3.2 What is known about human experience and interaction with automated bus systems?

In essence, how much pleasure an automated bus system gives to its user predicts how much it will be used (Madigan et al., 2017; Moták et al., 2017; Nordhoff et al., 2016). Specifically, how an automated bus system performs, as well as how easy it is to use, are two of the main factors for (future) users (e.g., Alessandrini et al., 2011; Madigan et al., 2016; Nordhoff et al., 2018). But, interestingly, this finding is countered by Moták et al. (2017)'s results, who found ease of use to be the only *in*significant variable. Another interesting result is the impact of media and peer pressure on the public attitude toward the automated bus systems (e.g., Eden et al., 2017b; Madigan et al., 2017; Moták et al., 2017). News reports (for instance on autonomous vehicle crashes) as well as the beliefs of family and friends thus also weigh heavily on people's willingness to use an automated bus system.

Noteworthy is, supported by most of the literature selected in this study, although being relevant, the perceived usefulness of the automated bus system did not appear to be a primary determinant for its users. Following this, public acceptance of automated bus systems is generally positive (Portouli et al., 2017; Rehrl and Zankl, 2018; Salonen and Haavisto, 2019), but is influenced over time by its (reliable, consistent, or disappointing, etc.) performance (e.g., Boersma et al., 2018; Distler et al., 2018; Moták et al., 2017). Also, people appear to have a high level of trust in the automated bus system (either with a safety driver on board, e.g., Salonen and Haavisto, 2019; Straub and Schaefer, 2019, or without, e.g., Oliveira et al., 2018), although being dependent on the demographics of the user pool (Salonen and Haavisto, 2019; Wintersberger et al., 2018).

A steward on board was generally found to be important for information distribution to its users (e.g., Boersma et al., 2018), but also the surrounding traffic (Eden et al., 2017a), and the feeling of safety (Distler et al., 2018; Eden et al., 2017b; Rehrl and Zankl, 2018). This feeling of safety is generally considered to be one of people's main concerns regarding the automated bus system (e.g., Alessandrini et al., 2011; Portouli et al., 2017; Rehrl and Zankl, 2018). This concern is usually well caught, as it is usually perceived to be high (e.g., Eden et al., 2017b; Portouli et al., 2017; Salonen, 2018). Higher concerns remain about the automated bus systems' security (Distler et al., 2018; Oliveira et al., 2018; Salonen, 2018).

Interestingly, the results of Nordhoff et al. (2018) suggest that supervision from a control room rather than from inside the automated bus system is preferred, which seems out of balance with the other studies. This may be related to whether or not the automated bus system has an on-board information display which depicts its current status (see, e.g., Oliveira et al., 2018).

Communication from the automated bus system was found to be important (e.g., Boersma et al., 2018; Eden et al., 2017a; Kim et al., 2017). In terms of expectancy, for instance regarding priority, people need assurance about the automated bus systems' intent, which could also be provided by (the absence of) lane markings (Merat et al., 2018). Notifying its users and surrounding traffic about its speed and general behavior improves user acceptance (Boersma et al., 2018).

In general, people appear to be positive toward the implementation of (future) automated bus systems (e.g., Alessandrini et al., 2011; Distler et al., 2018; Eden et al., 2017b). Nevertheless, people generally appeared to have problems with the low speed of the automated bus systems. Cyclists had difficulty determining whether they should overtake (Boersma et al., 2018), while users found it ineffective (e.g., Distler et al., 2018; Kim et al., 2017; Nordhoff et al., 2018). What is more, quite often users found that the automated bus systems need some tweaking to improve smooth driving (e.g., Boersma et al., 2018; Eden et al., 2017b; Kim et al., 2017).

As a final result, specific adaptations for targeted groups appears not to be necessary for the development of automated bus systems. A one-size-fits-all approach is likely to be successful (Madigan et al., 2016, 2017; Nordhoff et al., 2018). As an exception, however, one finding that did provide a significant difference was the users' sense of in-vehicle security, where men rated it higher than women (Salonen, 2018).

4. Discussion and conclusions

With the systematic review presented in this chapter, we aimed to answer four research questions. The first questioned our current knowledge about human interaction with automated bus systems. From the scientific literature that we were able to find, a relatively small number of published articles have been found to be relevant for this study. Those that were relevant (18 articles in total), had some consensual findings as well as some conflicting results.

Consensual findings were the overall accepting attitude of the public toward the (implementation of) automated bus systems, as well as importance of the opinions of others (such as the media) for using them. This accepting nature of the public may be explained by the infrastructure of the transportation area automated bus systems are commonly aimed to be implemented in, namely the "last mile," which is commonly known as a caveat of the transportation area (see, e.g., Boyer et al., 2009). Furthermore, it was found that the automated bus systems' low speed was the most common factor that received a negative connotation. This is known to be due to people's concern about the time they have to spend traveling, which they prefer to be as low as possible (Hensher et al., 2003).

In terms of methodology (our second research question), it can be seen that questionnaires are the most used means of method for conducting experiments in relation to user acceptance or satisfaction. Established questionnaires, such as the technology acceptance model (TAM; Davis, 1986), or the unified theory of acceptance and use of technology

(UTAUT; Venkatesh et al., 2003) are frequently used. More objective measures have only been applied in a few studies (e.g., mental workload measured through, for example, heart rate variability; Shakouri et al., 2018). Also, behavioral observation, for instance by means of video registrations, has so far not been applied in many studies. The reason might be that this is a high-workload technique, requiring skilled analysts as well as a lot of time. However, there are pilots currently running where such methods have been adopted (Bjørnskau et al., 2019).

The relative lack of objective measures used for the assessment of human interaction with automated bus systems is consequently a research gap worth mentioning, answering our third research question. Another research gap is related to the low speed of the automated bus systems presented in these 18 articles. Either for legal- or safety-issues, speeds were low (max. 20 km/h), and therefore it remains to be seen how people would interact and experience automated bus systems when they would be driving at regular speeds (i.e., 50, 80, or perhaps even over 100 km/h when implemented on highways). Especially when combining several automated bus systems into platoons driving on highways, high speeds are beneficial to, among others, aerodynamic drag (see, e.g., Tsugawa, 2010); henceforth, the eventual increase of speed for these systems should be pursued.

Furthermore, most current projects involving automated buses use existing infrastructure, and risky situations have been found to occur when ordinary road users overtake the slow driving buses (Bjørnskau et al., 2019). The question then is whether infrastructural adjustments are needed (e.g., additional markings or cycle tracks), or whether under certain conditions a shared-space approach would be preferable (e.g., related to speed, position on the road; Vissers et al., 2016). The final research question, regarding policy implications, will be discussed below.

The performance of this systematic review proved to be a challenging endeavor, as it appeared that the research domain of human interaction with automated bus systems is still a niche area. Not much is known about this yet, and even less has been reported. By means of backward engineering—recalling search terms of relevant articles, and using those as search queries, to aim to be as all-encompassing as possible—another issue was elicited which is unfortunately not uncommon in the scientific domain, namely the issue of construct proliferation. This is a phenomenon where two or more different names are (mistakenly or deliberately) being coined for the same construct (see, e.g., Shaffer et al., 2016). In this systematic review, the majority of the false positives were due to this issue, as it was known that automated bus systems had at least six other domain names, and three other names for it being automated (see Table 1, left column). Because also domain names were used which are commonly used in a different domain (such as "automated people mover" which is commonly used in the airport domain), the majority of the results involved, for instance, airport rail/metro automated people movers on a guided track. More specifically, this entailed a larger domain, known as "automated guideway transit," which are driverless vehicles automatically guided along a guideway (Kittelson, and Associates, Inc., Parsons Brinckerhoff, KFH Group, Inc., Texam A&M Transportation Institute, and Arup, 2013), and include domains such as "group rapid transit," "people mover systems," "automated people movers," and "personal rapid transit." Since our domain of interest was automated bus systems *without* a guideway, the results gathered from these search queries were, apart from those proliferated, irrelevant for our study.

Other popular domains gathered by this systematic review are the technology-oriented, as well as the future-oriented domains, which either predominantly or completely focus on the technical aspects of creating, designing, and/or deploying current automated bus systems, or planning, philosophizing, and/or debating future automated bus systems. Within these articles, subjects such as users, passengers, or other vulnerable road users could be taken into account, but the interaction between topic and subject was not the focus of those articles.

A final portion of irrelevant articles within the results of the search queries involved articles that were not on empirical research, but presented, for instance, a report of a demonstration or planned projects and activities.

4.1 Limitations

Although the utmost care has been taken to be all-encompassing during the systematic review, certain existing empirical articles on automated bus systems interaction with humans may have been excluded from this analysis. Future studies could reproduce this systematic review with other focused search queries to encompass those missed out on in this study. A broader approach could be taken by, for instance, including other search terms or consulting search engines that include gray literature, although caution should be taken there in relation to the degree of freedom of these systems with respect to the interaction with its users and surrounding traffic.

During the filtering procedure, a cautious approach has been taken, to avoid mistakenly discarding a relevant article. Albeit unlikely, due to the cautious approach taken, as this was a manual process, mistakes could have been made. A replication study could be performed to acquire a form of inter-rater reliability.

5. Policy implications

The introduction of AVs as part of a transport system accentuates policy implications at different levels. At a general level there is the issue about how to introduce AVs in the transport system; should it be in the form of shared, public transport systems, as private automated cars and/or as self-driving taxis (Nenseth et al., 2019).

In this chapter we have focused on the research and the findings regarding automated bus systems. Although research results are still sparse and many questions remain, there are numerous pilots going on in cities all over the world, mostly operated by some public transport authority.[a] Simultaneously there is a rapid development of self-driving cars intended for the traditional individual car market, either for shared or private use, in the form of automated taxis (Waymo, Uber, etc.) and more or less self-driving traditional individual car use. Thus there is an ongoing race between the car/taxi industry (Volvo, Tesla, Waymo, Uber, etc.) and public transport companies about implementing automated transport services. Both real-life experience of cheaper and more flexible taxi solutions (Uber/Lyft in San Francisco) and model simulations reveal that promoting cheaper individual (i.e., private) transport solutions in the cities will increase traffic volumes. Furthermore, simulations and experiments reveal that such a development may lead to urban sprawl because living outside cities becomes more attractive with cheap and flexible transport (Milakis et al., 2018). Such developments are contrary to the widespread aims of achieving more sustainable and liveable cities. Thus it is vital that public authorities take the necessary steps to regulate the introduction of automated transport in cities in the form of shared transport solutions limiting traffic growth.

The ambition of many transport companies is to deploy automated buses in mixed traffic, and it is important to gain insight into how other road users respond. When AVs are introduced in mixed traffic, Straub and Schaefer (2019) timely point to the need for policy making at more detailed levels, i.e., about actual operations in the streets. Given the conservative and defensive driving style of the automated buses, the buses stop abruptly for any obstacle registered by the bus sensors, providing discomfort to the passengers. Some

[a] Preliminary results from the ongoing Autobus project show around 120 fairly well documented automated bus projects in 18 European countries that have been executed so far, and many more—less well documented—are being planned (Hagenzieker et al., 2020).

researchers predict that over time other road users, interacting with the bus, will be aware of this and take advantage of the bus' defensive driving style, and deny the bus the right of way in all situations. This will in turn severely reduce the buses' accessibility and eventually make it impossible for the buses to be able to operate in mixed traffic (Millard-Ball, 2018). It is therefore paramount to study empirically how normal road users respond and interact with the automated buses. Some studies are currently under way and will provide valuable insights into such issues, like the Norwegian Autobus project where normal road users' interaction with automated buses are observed over time (Bjørnskau et al., 2019).

Straub and Schaefer (2019) identify a number of policy issues that need to be addressed to successfully integrate AVs in real-life traffic: (1) Control allocation—when and in what situations must humans take over control; (2) communications with vulnerable road users—AVs follow the formal rules but are so far not able to communicate and negotiate in informal ways, which is an essential part of normal traffic. Thus, AVs can be unpredictable and create dangerous situations, precisely because they adhere 100% to the formal rules (Bjørnskau et al., 2019; Rothengatter, 1991). (3) The courtesy problem and communication with other drivers—other drivers may deviate from normal behavior when interacting with AVs, which may lead to dangerous situations. (4) The "second vehicle problem"—AVs are not prepared and will not respond appropriately when other road users deviate from the formal rules. The automated minibuses that have been in operation so far are all programmed to stop for any object close to the vehicle, resulting in numerous abrupt stops providing discomfort for the passengers. Straub and Schaefer (2019) emphasize the need to take social interaction into considerations when introducing AVs in real-life traffic and they suggest to consider AV-to-human communication guidelines, better communication/signaling systems, the role and operation of AV sensor systems and more vigorous enforcement of existing rules.

According to Milakis (2019), referring to Legacy et al. (2019), public sector planners have by and large adopted a "watch and wait" approach to the introduction of AVs, leaving the initiative very much to the providers of AV transport services. And policy-makers seem to conceive AVs more as a threat than as an opportunity (Taeihagh and Lim, 2019). Such a conservative approach is risky with respect to the general policy needs; i.e., how to introduce AVs in a way consistent with the goals of sustainable and livable cities. In some respects one may say that the introduction of automated transport accentuates an old issue—how to avoid queues and crowds in and out of the cities during rush hour. Already nearly 60 years ago, Downs (1962) pointed out that expanding road capacity was not the way to do it; it will quickly be filled up by more cars. To follow-up, making individual transport cheaper and more flexible will lead to more transport. In other words, the solution is to reduce the need for transport and smarter, shared transport. It can be achieved with shared autonomous vehicles. Thus, maybe the introduction of AVs will wake up public authorities to realize the necessity of regulating car driving in and out of our cities.

A more proactive approach from public planners and authorities may also be called for when deploying AVs such as automated bus systems in real-life traffic, following the arguments presented by Straub and Schaefer (2019), Millard-Ball (2018) and Bjørnskau et al. (2019). As shown in the overview presented above, most pilots only allow buses to travel at very low speeds, and the buses are programmed to drive extremely defensively. By the very slow speeds they deviate from normal road user behavior which may produce risky situations and which make them unattractive as a transport means. Hence, as pointed out by Straub and Schaefer (2019), there is a need for policy to make such AV transport systems more realistic in order to be considered a useful and relevant transport means integrated in the transport network, and in order to avoid risky situations in real-life traffic.

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