Social and economic impacts of Autonomous Shuttles for Collective Transport: an in- depth benchmark study

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Abstract: Most of current managerial studies on Autonomous Vehicles (AVs) focus on future social and economic impacts of privately-owned AVs. In contrast, the present study aimed on carrying out an in-depth benchmark on successful experimentations with Autonomous Shuttles for Collective Transport (ASCTs), identifying the most relevant social and economic findings as well as understanding how such results may contribute to future projects and trials. The research was designed as an in-depth qualitative benchmark of exploratory and descriptive nature on three selected European projects with ASCTs: CityMobil2, GATEway, SHOJOA. Results mainly focused on the trials' social aspects (e.g., user acceptance, trust, willingness to use and, shuttles' interactions with mixed-traffic). Economic impacts were not widely disclosed and/or explored (results were mainly centered on users' willingness to pay and potential to reduce fares). Thereby, we advocate that economic aspects shall not be considered as "*ceteris paribus*" while measuring user acceptance. From the perspective of social sciences, the study sheds light into what is currently being evaluated on ASCTs' trials. Results are relevant for future ASCTs projects to focus on neglected aspects and also to improve upon the trials' successful results in a sense that, to date, no current studies were found aiming to understand and evaluate the social and economic impacts of ASCTs deployments.

Keywords: Autonomous shuttles; Collective transport; Urban mobility; Social impacts; Economic impacts.

1. Introduction

With two-thirds of the world's population living in urban areas by 2050 (United Nations, 2018), this sheer number of inhabitants, together with economic growth, will lead to an increasing need for effective modes of urban transport (Ainsalu et al., 2018).

Consequently, cities worldwide are coming to terms with the numerous threats posed by urban growth, and are realizing that they may need to spearhead efforts to develop more sustainable transportation systems (Clausen, 2017; Pancost, 2016; Rosenzweig et al., 2010).

Densely-populated cities are strongly dependent on high capacity trunk lines to be able to sustain the necessary traffic flowrates required to meet travel demands (Ainsalu et al., 2018). For the authors, as trunk lines are not directly accessible by the whole population, additional more flexible first- and last-mile solutions are required to act as feeders and complementors.

As stated by Attias (2017), this revolution of urban areas will likely occur by the arrival of autonomous cars and shuttles, thus building a new paradigm of urban mobility and smart cities. If successfully deployed, automated minibusses and similar automated vehicles can provide flexible and cost-efficient solutions for serving both peak and off-peak demand, parallel and as feeders to trunk lines (Ainsalu et al., 2018, Merat, Madigan & Nordhoff, 2017).

As the implementation of more advanced, sensors, radars and navigation technologies in vehicles increases, there is now a potential for the mass-deployment of a new form of publicly available, electrically operated, driverless shuttle for urban environments (Merat, Madigan & Nordhoff, 2017). These driverless shuttles or hereinafter referred as Autonomous Shuttles for

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Collective Transport (ASCTs) belong to the emerging group of automated mobility solutions, that also encompasses the automated owned car and self-driving car-hail services (Smolnicki & Soltys, 2016).

The number of experimentations with ASCTs has rapidly increased over the last few years, with several pilot projects and test runs occurring in many developed countries across the globe, mainly in Europe and North America (Antonialli, 2019; Milakis et al., 2017), which has started to draw interest of various cities transport authorities, universities, companies and other stakeholders (Ainsalu et al., 2018).

Large urban centers could strongly benefit from the introduction of ASCTs (Ainsalu et al., 2018). For the authors, besides of being the first- and last-mile connection to mass transit, ASCTs could compete with automobiles by price and be more effective than traditional public transport buses (by taking 10 instead of 150 passengers), being on-demand instead of on-schedule, and moving on flexible routes instead of fixed ones.

Under the upright policy, vehicular automation could support public transit, provide accessibility for those who cannot or do not drive, as well as decrease housing development costs – by eliminating garages and space-wasting on-ground parking (Ainsalu et al., 2018). However, as stated by the authors, if regulations are depraved, the ubiquitous automated mobility could lead to numerous rebound effects, such as the growth of traffic congestion, obesity, urban sprawl and, reduced mass public transit use.

Until recently, much of the effort dedicated to the implementation of such vehicles has focused on improving their operational and technical aspects (Gandia et al., 2018). However, it is now time to consider the policy and behavioral factors that will allow successful deployment and user/societal uptake (Merat, Madigan & Nordhoff, 2017), since there is still much to learn about the operation of these vehicles from both policy and regulation perspective as well as regarding businesses models and consumer acceptance (Harris, 2018; Cavazza et al., 2019).

The present study emerged as a follow up to the international benchmark on experimentations with ASCTs carried out by Antonialli (2019), where 92 experimentations with ASCTs were identified and highlighted the countries with most deployments, the most prominent shuttles' manufacturers, the main typologies of uses, the prevailing business models, key-performance indicators as well as the main involved stakeholders and value flows.

With that, the guiding questions for the present study were as follows: what were the main social and economic results found in the experimentations? What were the main challenges and problems encountered? What were the key success factors? And ultimately, what can be learned from these existing experimentations that could be applied and/or avoided in future projects and deployments?

Thereby, this present study aimed at carrying out an in-depth benchmark on successful experimentations with Autonomous Shuttles for Collective Transport by identifying the most relevant social and economic findings as well as understanding how such results may contribute to future projects and trials.

The present benchmark study is part of AVENUE's project objective 5 (AVENUE, 2018). The Autonomous Vehicles to Evolve to a New Urban Experience project (AVENUE), is an EU funded project under Horizon 2020 (grant agreement No. 769033), the project started on May 1st 2018 and will last for 48 months. It aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of autonomous mini-buses on mixed-traffic conditions. Providing innovative services, like door-to-door and multimodal transportations, in low to medium demand areas of 4 European demonstrator cities: Geneva, Lyon, Copenhagen, and Luxembourg.

2. Methodology

The research design adopted in the present study was characterized as qualitative of exploratory and descriptive nature (Gil, 2008; Malhotra, 2001). As a starting point for the in-depth analysis, we took as reference the benchmark research carried out by Antonialli (2019).

Project's AVENUE scope was used as a criterion for selecting the research corpus (AVENUE, 2018). In this sense, in order to be considered into the research corpus the experimentations should have been: 1) finished/completed, 2) deployed in mixed-traffic conditions (not on exclusively dedicated roads); 3) mid- to long-term trials and/or regular services (short-time showcases were not considered due to their limited data-gathering potential) and 4) easy accessible (with public available final reports, academic papers, news, videos, blogs, and etc.).

As depicted in Figure 1, a total of eleven experimentations were considered for this in-depth benchmark and they were distributed within three main European projects: Citymobil2, GATEway, SOHJOA. It is worth highlighting that other successful experimentations such as WEPods and ParkShuttle in the Netherlands, Tallinkshuttle in Estonia, CATS EPFL in Lausanne (France), Postbus Smartshuttle in Sion (Switzerland), have all been considered to compose the research corpus, however, they were not analyzed due to the lack of robust online-available materials regarding the deployments.
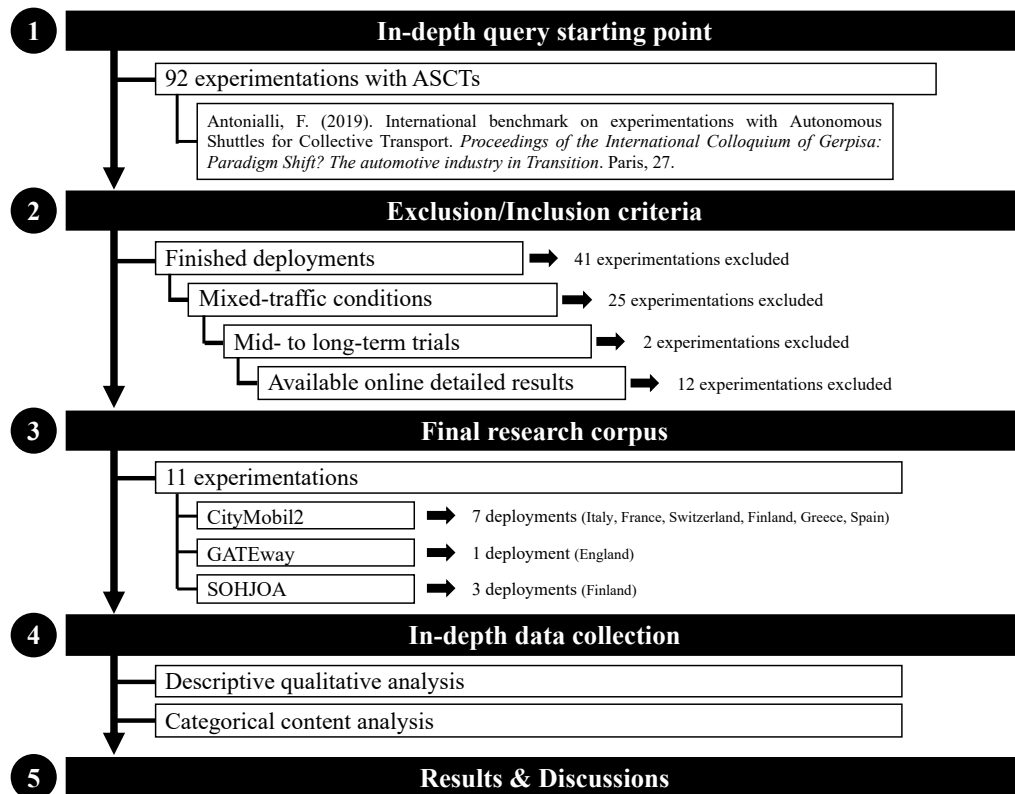

Figure 1. Research design

Therefore, based on the three selected projects, snowball sampling technique (Penrod et al., 2003) was used in order to continue collecting data on both academic and grey literature (both structured and non-structured data) and, saturation criteria (Guerra, 2006) was used as a stopping point for data collection.

At last, data was structured and analyzed via descriptive qualitative analysis (Kim, Sefick & Bradway, 2016; Sanderlowski, 2000; 2010) and categorical content analysis (Bardin, 2010; Vergara, 2005). The next session presents the results and discussion of this study, following, the order of our specific objectives.

3. Results and Discussion

The CityMobil2 project was carried out across six countries (Italy, France, Switzerland, Finland, Greece and, Spain), the GATEway project took place in London on the Greenwich peninsula and, the SOHJOA project in Finland (Espoo, Helsinki, and Tamper). All shuttles deployed in the three analyzed projects were in accordance with SAE Level 4 vehicles (SAE, 2016), which, for legal and safety reasons where only allowed to drive at slow speeds (no more than 15 km/h) and were required to have a human operator on board at all times – in case automation failed (DfT, 2015).

3.1. CityMobil 2

The CityMobil2 project was a European Commission funded project – with an overall budget of €15.286.789,52 – led by Universita Degli Studi di Firenze (Italy), carried out from September 2012 to August 2016.

The project aimed at fostering the implementation of ASCTs in seven European cities spread across six countries, the general objectives included the study of long term socio-economic impacts of automated mobility; and the definition of a legal framework that would finally allow ASCTs on urban roads (Alessandrini, 2016). As pointed out by some of the key people involved in the project:

> "The project demonstrates in real-life the implementation of this fully automated road vehicles in city centers." – Patrick Mercier-Handisyde (CityMobil2 Project Officer).

> "What we are really looking is how an automated transport system would really be integrated into the transportation system of a city (…) Citymobil2 is looking not just to automated vehicles but to the whole transport system. The reason for that is that is not enough just to look on vehicles, but you have to have a holistic approach on automation." – Angelos Amditis (Research Director ICCS).

With the seven demonstrators cities, CityMobil2 covered more than 25,000 km driven by the autonomous shuttles and carried over 60,000 passengers. The project is – to date – the most extensive trial with ASCTs worldwide (Ainsalu et al., 2018).

The autonomous shuttles were provided by two different manufacturers (both French-based start-up companies): Robosoft and EasyMile. The main difference among the shuttles is that the former was remotely controlled by a human in a central control room while the latter was fully autonomous-driven. Ainsalu et al. (2018) summarize the overall outcome of the project:

> "As the most important project carried out until then, CityMobil provided a comprehensive set of conclusions regarding the implementation of an Automated Road Transport System and the barriers to overcome: the lack of an implementation framework for cities, the absence of a specific legal framework, and the unknown wider economic effects." (Ainsalu et al., 2018, p.11).

3.2. GATEway

The Greenwich Automated Transport Environment project (GATEway), was a British founded consortium led by the consulting company TRL (Transport Research Laboratory) that took place from July 2014 to the end of 2017 in London at the Greenwich Peninsula. The project was jointly funded by government and industry, having received £5.5 million in funding from the Business, Energy, and Industrial Strategy (BEIS) and the British Department for Transport (DfT) and was further supported by an additional £2.5 million from the commercial organizations within the GATEway consortium.

GATEway was divided into three main experimentations with automated vehicles: 1) an autonomous shuttle service on the Greenwich peninsula (launched on April 4th 2017); 2) simulations and trials on how automation could support accessibility transport for disabled people; and simulations and trials with the delivery of goods (Cuerden, 2018). As elucidated by the project's organizers:

> "These trials are all about engaging members of the public and getting their feedback and their perceptions on how these vehicles are going to fit in with their lifestyles, how they're going to fit in with smart cities in the future."- Kristen Fernandez-Medina (TRL Technical Lead).

> "We're looking to learn more about how pedestrians interact with the vehicles, how the users interact with the vehicle and the level of acceptance they have from it." – Dr. Graeme Smith (Oxbotica CEO).

> "(…) GATEway is providing valuable sociological insight into mobility solutions and the part they could play in our cities of the future." - Richard Cuerden (TRL Academy director).

> "The results of the trial will be used to understand what are the use cases where these shuttle vehicles, these automated vehicles can really deliver value for the city. What is the way in which these vehicles could be used in cities around the world." – Prof. Nick Reed (TRL Academy Director).

The project ran during April 2017 in a 1.6 km mixed traffic route (among pedestrians and cyclists) on the Greenwich peninsula in London. A total of 2,310 trips were completed yielding in a total distance covered of 3,700 km and carrying a total of 320 passengers.

It is worth noting that different from the other two experimentations described in this study, the shuttles used in the GATEway project had a capacity of transporting a maximum of four passengers at a time, while the Shuttles on CityMobil2 and SOHJOA could carry two or three times more passengers.

The shuttle "Harry" utilized in the trials was the result of a partnership among Westfield, Heathrow Pods and Oxbotica (all British-based companies). Westfield is a car manufacturer specialized in delivering lightweight electric vehicles. Heathrow Pods is the company responsible for running the autonomous shuttles between the Heathrow Airport (terminal 5) and the parking lots, hence, it has experience and know-how on operating ASCTs (however on dedicated lanes). At last, Oxbotica is the software company responsible for the technology used for the pod's autonomous driving.

The overall outcome of the various trials carried out on the GATEway project was the creation of a research startup called "Smart Mobility Living Lab: London". Which has been designed to operate as an innovation hub where innovators in industry, service, commerce, government as well as on research bodies, can come together to exchange ideas and develop technical and business solutions for the future development of smart mobility solutions by facilitating working partnerships, sharing the cost of testing and development and therefore significantly reducing the timescales of bringing new technologies and services to market.

3.3. SOHJOA

The Physical and Virtual Innovation Platform of Autonomous Last Mile Urban Transportation project (SOHJOA project) was a Finnish consortium formed among the Metropolia University of Applied Sciences, Tampere University of Technology, Aalto University, Forum Virium Helsinki and the National Land Survey of Finland from June 2016 to May 2018 with a total budget of € 559,597 (of which 65% was funded by the European Regional Development Fund - ERDF).

The project was the first of its kind to introduce ASCTs in mixed traffic conditions on Finnish roads. The aim was to utilize an enterprise- and area-based approach to creating new innovations and understanding related to the use of autonomous minibusses in last-mile transportation for the benefit of both the public sector and companies specializing in IoT and transport services. It allowed participants (particularly innovation-focused transport companies) to increase their practical competence in utilizing autonomous vehicles.

Trials were carried out on three demonstrators cities (Espoo, Helsinki and, Tamper) carrying passengers on fleets of EasyMile's EZ10 shuttles over small mixed traffic looped routes (no longer than 1 km), in addition, the shuttles where able to face Finland's harsh weather conditions, as pointed out by SOHJOA's project director:

> "We have the weather which is quite challenging and we have the saying that 'if it works in Finland it works everywhere' (…) I think other countries in the European Union would be able to learn what we have been doing." – Oscar Nissin (SOHJOA project director).

The shuttles were offered as innovation platforms to companies (particularly smaller ones) for piloting their smart mobility products and services. According to professor Nissin:

> "We have been able to change small Finnish companies' way of thinking. Their product may not be directly connected to autonomous transport, but their technology can be utilized there (…) a good example of this is the affordable infrared sensor that can be used to calculate the number of passengers on a bus (…) or services intended for tourists, which one company has implemented." – Oscar Nissin (SOHJOA project director).

The SOHJOA project gave rise to a Finnish-based start-up that continues (to date) on developing robot-taxis technologies. In addition, Metropolia University was able to establish a new Smart Mobility Innovation Hub.

At last, the success achieved with the project enabled the creation of a spin-off project named "SOHJOA Baltic", which is a 3.8 million euros consortium (funded by Interreg – Baltic Sea Region programme) with partners in six Baltic regions that promises to bring ASCTs as part of the cities' transportation chain, especially for the first/last-mile connectivity. The project duration is from October 2017 to September 2020 and is expected to bring trials with ASCT to Helsinki (Finland), Tallinn (Estonia), Kongsberg (Norway), Vejle (Denmark), Gdansk (Poland) and Zemgale (Latvia).

Before getting into the social and economic findings of the selected projects, Figure 2 summarizes the main features of each of the eleven experimentations within the sampled projects in this benchmark study.

Project	City	Trial period	Route design	Number of trips	Distance covered	Number of passengers	Shuttle
CityMobil2	Oristano (Italy)	Jul/14 to Sep/14	1.3 km in mixed traffic	714	1,836 km	2,327	Robosoft
	La Rochelle (France)	Dec/14 to Apr/15	1.8 km in mixed traffic	2,100	3,778 km	14,660	Robosoft
	Lausanne (Switzerland)	Apr/15 to Aug/15	1.5 km in mixed traffic	4,647	6,970 km	7,000	EasyMile (EZ10)
	Vantaa (Finland)	Jul/15 to Dec/15	1 km in closed traffic	3,962	3,962 km	19,021	EasyMile (EZ10)
	Trikala (Greece)	Sep/15 to Feb/16	2.3 km in mixed traffic	3,580	3,580 km	12,138	Robosoft
	Shopia-Antipolis (France)	Jan/16 to Mar/16	1.0 km in closed traffic	3,100	3,100 km	3,700	EasyMile (EZ10)
	San Sebastian (Spain)	Apr/16 to Aug/16	1.2 km in mixed traffic	2,362	2,362 km	1,968	Robosoft
GATEway	London (England)	Apr/17	1.6 km in mixed traffic	2,310	3,700 km	320	Harry (Westfield, Heathrow Pods & Oxbotica)
SOHJOA	Espoo (Finland)	Sep/16 to Oct/16	0.8 km in mixed traffic	521	365 km	522	EasyMile (EZ10)
	Helsinki (Finland)	Jun/16 to Sep/16	1 km in mixed traffic	n/a	n/a	n/a	EasyMile (EZ10)
	Tamper (Finland)	Oct/16 to Nov/16	1km in mixed traffic	n/a	n/a	n/a	EasyMile (EZ10)

Figure 2. Summary of the eleven experimentations within the three selected projects.
Source: prepared by the author based on research data.

3.4. Social impacts

As evidenced by Nordhoof et al. (2017), over the past years there has been a large number of research studies aimed to investigate the acceptance of automated vehicles by gathering social-demographic, mobility, psychological, functional-utilitarian and symbolic-affective characteristics. However, as the authors stated, most of these studies have focused on AVs with steer and pedals. As a result, knowledge on the factors that drive the acceptance of ASCTs in real environmental conditions is still limited.

A possible reason for this, is that on a global level, there has been few pilot projects with ASCTs (Antonialli, 2019; Charlet & Chaufrein, 2017; Hottentot, Meines & Pinckaers, 2015), therefore, as highlighted by Nordhoof et al. (2017, p.3): "only a few people have ever experienced such vehicles in daily conditions in real and complex environments; for these reasons, there is a lack of knowledge of the factors which will affect whether or not people will use these vehicles".

Thereby, the three sampled projects were mainly focused on gathering such social insights from users, regarding: acceptance, trust, willingness to use, shuttles' interactions with pedestrians, cyclists and other vehicles, and so on. Similar results were found by Ainsalu et al. (2018) on their review paper regarding the state-of-the-art on automated buses.

Furthermore, all three projects were consistently safety-focused. Since as pointed out by Merat, Madigan, and Nordhoff (2017), in order to be socially accepted (and thereby used), ASCT will need to be reliable and safe. This was made explicit by the GATEway's project manager Richard Cuerden: "We've designed the whole GATEway program around safety. Safety first and foremost".

Citymobil2 has thrived on gathering insights on the social acceptance of ASCTs. Over 1,500 users and 2,000 local residents (distributed among the seven demonstrators cities), as well as 89 mobility experts, were surveyed to assess their perception of the services and to draw long-term scenarios impacts. Structured and semi-structured questionnaires were carried out, based on the Unified Theory of Acceptance and Use of Technology – UTAUT (Venkatesh et al., 2012; Davis 1989). Results are not only depicted on the project's final report (Alessandrini, 2016) but also on several publications derived from the project (Madigan et al., 2016; Piao et al., 2016; Sessa et al., 2016; Madigan et al., 2017, Merat, Madigan & Nordhoff, 2017).

GATEway was also very successful in accessing social aspects of their trials. They have created detailed qualitative and quantitative surveys for participants to complete – after riding the driverless pods (Fernández-Medina & Jenkins, 2017; Fernández-Medina et al., 2018; Harrow et al., 2018,), as well as workshops to measure people's perceptions and attitudes towards AVs and how design influence on such perceptions (Phillips et al., 2016). They have also used Sentiment Mapping – as a way of monitoring social networks to identify how people feel about the trials (TRL Publish, 2018). At last – in partnership with the University of Greenwich – they have also carried out observational studies on how pedestrians and cyclists behaved around ASCTs (Holse, Xie & Galea, 2018), being this was the first in-depth study involving interactions with AVs. Further results are depicted on the project's final report (Cuerden, 2018) as well as a wide range of other white papers are available on the project's website (GATEway, 2018).

At last, Project SOHJOA was also very successful in reporting their findings via a wide array of reports, case descriptions, and guidelines made during the trials. All materials are available on the project's website (SOHJOA, 2018), however, the majority of the content was written in Finnish, therefore (due to language restriction) limiting the

scope of disclosure and replication of results. On the other hand, two peer-reviewed papers had been published. The first (Salonen, 2018) aimed at comparing passengers' subjective experiences on (a) traffic safety, (b) in-vehicle security, and (c) emergency management compared to the conventional bus. The second (Salonen & Haavisto, 2019), by applying the Theory of Interpersonal Behaviour – TIB, aimed at understanding what kind of perceptions and feelings people have when they travel in an ASCT.

In summary, the main social results obtained in the sampled trials have shown positive attitudes towards the implementation of ASCTs, with the general public perceiving the vehicles as convenient, accessible and safe. About two-thirds of the respondents stated that they would choose an automated bus if both automated and conventional buses were available in a route (Alessandrini, 2016).

Most participants were positive about the safety benefits, believing that ASCTs would be either safer than or as safe as human-driven vehicles, hence considering useful to implement ASCTs services on a permanent basis.

As reported by Alessandrini (2016), shuttles were mainly viewed as supplements to public transport, acting as first- and last-mile commute options – feeders. According to the results, the vehicles should enable integration with other modes to provide realistic modal choice alternatives. The offer of on-demand services on flexible routes was proven to be especially important (Salonen & Haavisto, 2019), once ASCTs could possibly decrease the use of private cars – if the services provided are better than conventional buses.

In this sense, quality of service was an indicator that clearly needs improvements: lower operational speeds, abrupt brakings, occasional localization problems, longer waiting times, better locations and routes, comfort complaints (limited seats), information availability, etc., are all issues that require urgent attention.

People's first impressions were a mix of curiosity, amusement and, an urge to try something new. As reported by Merat, Madigan and, Nordhoff (2017), most users made their trips to test the shuttles, that is, occasional trips were much more frequent than systematic ones. Thereby, the provided services will have to meet people's actual mobility needs in order for ASCTs to be accepted and used.

Furthermore, as people become more familiar with ASCTs, the excitement and enjoyment of using them may decrease (Madigan et al., 2017). Therefore, in order to maintain higher satisfaction levels, manufacturers and service providers will need to ensure that these systems perform to an optimum level and are reliable, along with optimizing their connectivity with other transport services (Sessa et al., 2016).

In addition, providing the correct infrastructure and increasing public engagement and awareness of the vehicle's capabilities is also likely to increase the acceptance of these AVs (Merat, Madigan & Nordhoff, 2017 p. 12).

Levels of distrust and fear have also been reported. According to GATEway's final report, building the public's confidence in the technology will be a critical factor in ASCTs successful adoption (Cuerden, 2018). However, as depicted by Ekman et al. (2017), trust formation is a dynamic process that starts long before a user's first contact with the system and continues long thereafter. One good experience already enhances the personal feeling of safety considerably (Salonen & Haavisto, 2019), but according to the authors, people still have hesitations about the general safety of ASCTs, in a sense that opposite to a human driver, mistakes will not likely be so easily accepted.

As depicted by Merat, Madigan and, Nordhoff (2017), there has been little actual research into users' trust or acceptance of shared AVs. Therefore, the public's awareness/understanding of ASCTs should be constantly monitored in order to assess

how attitudes change with increased levels of awareness/understanding of self-driving technology and their performances (Alessandrini, 2016).

The pathway to adoption and social acceptance of ASCTs should be incremental and iterative, providing users with hands-on experience of the systems at every stage, thereby removing unrealistic and idealized expectations which can ultimately hamper acceptance (Merat, Madigan & Nordhoff, 2017). For the authors:

> "for ASCTs to be accepted and used, they will need to be: reliable and safe; available at any time; able go anywhere and everywhere, and; capable of operating in all weather conditions. They must also provide: a clean, comfortable and safe interior environment with enhanced privacy features; allow easy access for dependents (children, impaired and elderly) and their equipment (luggage, pushchairs, wheelchairs)." (Merat, Madigan &Nordhoff, 2017, p. 21).

The private semi-automated vehicle available today and in the near future provides a level of convenience and comfort which is perhaps superior to ASCTs (Steg, 2005). Therefore, for those kinds of vehicles to be considered a serious alternative to privately owned vehicles, city authorities will need to work with manufacturers and suppliers to enable the development of some – if not all – of the current features offered by privately owned vehicles (Merat, Madigan & Nordhoff, 2017).

3.5. Economic impacts

Results on economic impacts were not widely explored in the projects in the same way as social acceptance impacts were. Hence, robust results on economic aspects were not addressed or were not disclosed on the projects' publications.

The few results found were mainly concerned with users' willingness to pay for the services and the potential to reduce fares (due to the lack of a human driver). Such data were mainly gathered during the projects' data collection for their social acceptance studies, hence including a few variables on the questionnaires or on the interview scripts regarding these few economic aspects.

As depicted by Piao et al. (2016) and Alessandrini (2016) the majority of respondents on the CityMobil's trials were positive about ASCTs if the service was offered at a lower price (only a small percentage of users were willing to pay more than current public transport fares). Similar results were found by Merat, Madigan, and Nordhoff (2017) while analyzing the CATS project (EPFL campus in Switzerland with a Navya ARMA shuttle), where respondents were willing to pay about the same price for the autonomous service as conventional public transport offerings.

In addition, on a participatory appraisal exercise with 89 mobility experts carried out by Sessa et al. (2016), the authors drew long-term scenarios on the social-economic impacts of urban road automation within the scope of CityMobil2. According to the authors, the economic impacts would affect new jobs, employment rates, personal trip costs, fines, and impacts on insurance costs and services. Moreover, other economic impacts listed (but not detailed) by the authors (Sessa et al., 2016, p.176) included:

- Impact of travel comfort on personal productivity, during and after the trip;
- Impact of safety on human capital health and productive value;
- Impact of accessibility enabling economic development, in particular of more remote suburban areas where self-driving cars contribute to improving accessibility;
- Impact of fines not only on household budgets but also on public budgets that will suffer a loss;

- Impact for parking fees: their reduction is a benefit in terms of personal trip costs but would have a heavy negative impact on the local authorities budget, as parking charges are an important source of revenue.

On the GATEway project, participants stated that they would be willing to pay an average price of around £ 2 to use ASCTs (less than the average price of a single-journey ticket in London), also believing that the shuttles have the potential to be more economical (regarding fuel/energy consumption) and therefore better for the environment (Cuerden, 2018).

Results from SOHJOA also states the elimination of drivers' wages as a positive outcome. However interestingly, as highlighted by Salonen and Haavisto (2019), users were not hoping for a consequent reduction on fare costs; it was hoped that the funds saved would be used to improve the quality of the mobility services (e.g., more frequent lines, on-demand services, and operations around the clock). Thereby, the authors stated that reduced costs are not necessarily considered to improve customers' quality of life, but that better services are more likely to do that.

Taking into account all the aforementioned results, an interesting discussion arises. As elucidated by Ainsalu et al. (2018, p.8), in Europe, most of the autonomous shuttle pilots aimed mostly on: 1) integrating their services into the public transportation system; 2) testing the technology and circumstances and 3) looking at people's standpoint on autonomous vehicles – since one of the biggest concerns, along with the technical performance, is to see how the general public accepts autonomous shuttles.

According to Nordhoof et al. (2017), exposing commuters to the technology at very early stages on a small-scale and under controlled conditions makes it possible to gradually and slowly expose and familiarize them with ASCTs technology. In this way, Nees (2016) states that the introduction of automated vehicles can be linked to the creation of realistic expectations, which have been defined as a key-driver of acceptance.

We agree with the assertions made by the authors. However, we believe that the relevance of the economic impacts are not receiving the deserved attention and thereby are somewhat being neglected. We believe that it is indeed pivotal to understand social acceptance for proper implementation of ASCTs, however, we also advocate that economic aspects also comprises the concept of acceptance.

Nevertheless, we argue that economic aspects shall not be treated as "*ceteris paribus*" in the data collection of experimentations with ASCTs. As illustrated by Antonialli (2019), ASCTs' implementation requires synergy and alignment of value flows among multiple stakeholders (e.g., shuttle manufacturers, transport operators, client cities or firms, end-users, digital service providers, local transport bodies and, R&D centers). Thereby, understanding economic aspects such as: costs structures, revenue flows, taxes, subsidies, investments, etc., in this business ecosystem in fundamental for successfully implementing ASCTs.

Such an argument is made clear by Gandia et al. (2018) on their scientometric and bibliometric review of autonomous vehicles. For the authors, the technological evolution of the area is evident. However, it is still necessary to understand broader aspects of the industry, such as the market factors surrounding them and other economic and managerial issues.

Within this context, Cavazza et al. (2019) identified a possible gap between such technological advancements on vehicular automation and its eventual market insertion and consolidation as business models play an extremely important role in the events that precede AVs market introduction.

Hence, as evidenced by Merat, Madigan and, Nordhoff (2017, p.22), the ultimate success of ASCTs will only be achieved following an effective collaboration between

manufacturers, local and central government, to provide citizens with the most suitable options for each specific environment.

4. Concluding Remarks

The present study analyzed eleven experimentations with ASCTs across Europe inserted in three macro-projects: CityMobil2, GATEway and, SOHJOA with the aim of identifying the most relevant social and economic findings as well as understanding how such results may contribute to future projects and trials.

Results showed a predominance of studies on the social aspects of the experiments, especially regarding acceptance, trust, willingness to use and, shuttles' interactions with pedestrians, cyclists, other vehicles. A wide array of methods have been applied to collect this sort of data, varying from quantitative and qualitative surveys, in-depth interviews, focus groups, workshops, sentiment mapping, as well as *in-locus* observational studies. All three projects were safety-focused and thrived on gathering insights on social acceptance of ASCTs.

Users' first impressions were a mix of curiosity and amusement, distrust and fear, and the urge to try something new. In general, after getting acquainted with the technology, users showed positive attitudes towards the implementation of ASCTs, perceiving the shuttles as convenient, accessible and as safe as human-driven vehicles. However, findings pointed out that the quality of the services needs to be improved (with better and more complete routes, on-demand offerings, multi-modal integration, etc.), as well as the shuttles themselves that should be further developed in order to offer more comfort and privacy, provide more accessibility as well as to perform safely with full automation and at higher average speeds.

Economic impacts were not widely disclosed and/or explored in the projects. Most of the results were mainly centered on users' willingness to pay and the potential to reduce fares, with results showing that the overall service price should not vary much from the current prices of public transport in the respective cities.

Thus, we believe that economic impacts are somewhat being neglected in the projects. In our standpoint, aspects such as: costs structures, revenue flows, taxes, subsidies, investments, etc., are fundamental points that should be considered in order to correctly understand the implementation of ASCTs. Thereby, they shall not be considered as "*ceteris paribus*" while attempting to measure the overall user acceptance.

Hence, the business ecosystem of the deployments should be considered as a whole in order to accurately yield robust social and economic results for the trials. In this sense, different groups of stakeholders should be taken into account for analysis (e.g., shuttle manufacturer, transport operator, client city/firm, service providers, R&D centers, transport authorities, and so on.) and not exclusively the end-users. Accordingly, more comprehensive surveys and interviews are needed to improve the understandings of the economic impacts and consequently user's behavioral responses and interactions with the shuttles.

The main limitation of this study was the difficulty in obtaining data, mainly from primary sources. Contact attempts via e-mail were made with several people involved in the projects, however, we had no responses by the time this paper was written. By consequence data collection was restricted to secondary sources available online (e.g., projects' websites, final reports, academic papers, white papers, news, blogs and even YouTube videos), thus, besides the language barriers found (mainly on the SOHJOA project), in many cases the information was not structured (e.g., videos and photos) making it difficult (and sometimes not possible) to codify and analyze.

As for further future research, we agree with Alessandrini (2016) conclusions. With the support of city authorities, deployments should focus on large-scale field trials with more operations in real traffic situations – thereby getting a step closer to overcome the legal barriers for full-market implementation. Trials routes should also enable integration with other transport-modes in order to provide realistic commute choice alternatives. As a way of validating the reliability of the systems, applications covering a wide range of weather and context situations are also needed, as well as complete operational, security and emergency management systems must be designed and implemented.

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