Robomobility for collective transport: a prospective user centric view

Sylvie Mira Bonnardel

Ecole Centrale Lyon,
Lyon University,
36 avenue Guy de Collongue, 69134 Écully, France
Email: sylvie.mira-bonnardel@ec-lyon.fr

Abstract: Public transport may be undergoing an important transformation following the arrival of autonomous vehicles. Researchers, think thanks as well as consulting companies have designed many scenarios based on trend analysis of three main dimensions: technology, regulations and uses. The user level of acceptance for autonomous driving represents a key point for any prospective study. Therefore, this article aimed at proposing a use case daily scenario by focusing on the user. We analyse more specifically the implementation of autonomous vehicles for micro transit and commuting by studying user opinions via two field surveys. Discussion with users help us to build and test a use cases scenario and to picture personas whose characters will allow decision makers to better figure out the conditions to leverage the citizens level of acceptance for robomobility.

Keywords: autonomous vehicle; public transport transformation; use cases; scenario.

Reference to this paper should be made as follows: Mira Bonnardel, S. (2021) 'Robomobility for collective transport: a prospective user centric view', *Int. J. Automotive Technology and Management*, Vol. 21, Nos. 1/2, pp.99–120.

Biographical notes: Sylvie Mira Bonnardel teaches strategic management and corporate finance at the Centrale Lyon Engineering School. Her research mainly deals with innovation strategy linked with networking process leading to open innovation and entrepreneurial dynamics. She has addressed different mobility issue, developing an expertise on new forms of mobility, in particular robomobility. She is a member of the European AVENUE project.

1 Introduction

Are public transport systems going to be strongly disrupted by autonomous driving? This question raises many speculations and the answer can only be based on hypothesis and prospective scenarios. Mobility scenarios are not speculations, they are mandatory food for thought for policy makers for investment and infrastructure planning. These scenarios are being designed while taking into account three main change drivers: technology, regulations and uses.

This technology/regulation/uses (TRU) triad has been for years the cornerstone of profound mutations in the automotive industry, but we may expect in the next 20 years a genuine paradigm shift that may pave the way for a new mobility paradigm

(Mira-Bonnardel and Attias, 2018). Yet the current state of industrial and policy-making development provides evidence that significant progress has been achieved so far, but nonetheless a universal shift to a machine-led mobility paradigm seems not imminent any time soon (Nikitas et al., 2019).

A KPMG (2018) study proposes the autonomous vehicles readiness index assessing four key areas of preparedness for 20 nations: infrastructure, technology, regulatory and user acceptance. According to the results, the Netherlands are the most prepared with a score of 28 out of 40 ranking at the first place for infrastructure. Singapore has the most supporting legislation and is ranking number1 for user acceptance. The USA head the list for technology and innovation.

In fact, autonomous vehicles may be more likely used within collective transports as proved by the wide range of experimentations been conducted worldwide (Antonialli, 2019). Yet, the implementation of autonomous shuttles for collective transports (ASCT) represents a major cause of disruption, since it obliges stakeholders to think differently and build a new philosophical, theoretical and operational framework for urban mobility, giving birth to the picture of robomobility.

Stakeholders of the TRU triad are struggling to settle on a dominant design for robomobility, which is closely linked to the evaluation of economic and social impacts of ASCT's deployments. The shift towards robomobility is embedded in a systemic movement. A holistic view is needed to understand the strategy of each stakeholder of the ecosystem and the multiple interactions among them; the transport user acceptance being one of the most important key for the system's consolidation.

In this article we propose a prospective view of the implementation of ASCT for micro transit, first- and last mile trips and commuting with the user's perspective.

The article is composed with four sections. Besides this introduction, Section 2 presents the research question and the research methodology. Section 3 gives an overview of the theoretical framework of researches on ASCT focusing on the user-centred view of the new mobility paradigm. In Section 4, we propose a prospective scenario based on use cases built with users opinions gathered on two experimentations of autonomous shuttle in the city of Lyon. The scenario is discussed Section 5. We conclude the article Section 6.

2 Research question and methodology

Prospect the future is a mandatory process for industrial or political decision making; scenarios represent the fuel for strategic investment decision. Mobility models, and especially collective mobility models, are mostly built on proactive and transformative public strategies.

The design of scenarios aims at strengthening strategic thinking, opening mental models of decision makers and reducing the negative effect of cognitive biases (Meissner and Wulf, 2013). Scenario for urban mobility it is not simply a forecast of the most probable outcome, but rather it creates a set of the plausible futures challenging the prevailing mind-set and status quo (Amer et al., 2013).

Our research question targets the objective of building autonomous mobility scenarios by interacting with the users. We aimed at building a robomobility scenario by considering the needs of the users (or the customers). We frame the field of new possibilities by combining current users opinion with their expectation and vision.

Our research is descriptive and qualitative with the use of the mixed-methods approach for data collection, comprised of secondary data collection on academic and grey literature, as well as primary data collection based on in-depth interviews with customers and experts and data analysis from a panel survey.

In-depth interviews have been conducted within the ASCT experimentation in Lyon in January 2020. Details on the experimentation context are given Section 4.2. We interviewed 36 users of the service and the questionnaire is presented in Appendix. Besides general traditional questions, we tested the user's appetite for an autonomous demand-responsive transit service. The survey insights are presented in Section 4.2.

In addition to our own survey, we had the opportunity to analyse the results of a large panel survey conducted in 2018 by the public transport operator (PTO) in Lyon, the Keolis company. Given the confidentiality of the survey, we cannot present the questionnaire nor the entire results but we give an overview of the survey insights in Section 4.1.

We are currently working with 20 experts, members of the European Union project autonomous vehicles to evolve to a new urban experience (AVENUE[1]). The project started in May 2018 and targets the validation, via full scale trials in four European cities, of the usage of autonomous vehicles, complementing public transport in urban and sub-urban regions. The aim of the AVENUE project is to create disruptive public transport services based on on-demand, environmentally friendly, affordable and inclusive public transport. The project questions the main transport trends for the future, such as electric and autonomous collective vehicles, connectivity, digitalisation and individual needs for mobility. The AVENUE project proposes to test autonomous collective vehicles in different cities. At the beginning of the project, May 2018, the test sites for the autonomous e-minibuses have been located in four European cities: Lyon, Geneva, Luxembourg, Copenhagen. The project is running from May 2018 to April 2022. We spend time on-board within these experimentations to cross users' feedback with experts' views.

We combine four data sources, literature analysis, experts' opinions, survey, user's qualitative interviews, to propose a uses scenario for autonomous public transport in the next future. The next section presents an overview of theoretical framework based on literature review on current and foreseen mobility's transformation.

3 The new mobility paradigm: a user-centred ecosystem

The new mobility paradigm links companies, policy makers and a new type of customer called 'next-generation consumers' or 'next-gen consumers' (Firnkorn and Müller, 2011). These consumers demand more durable, efficient and cheap mobility; they are ready to play by the rules of the circular economy, replacing possession by use and, are expecting more offers of collective mobility on demand.

In this new mobility paradigm, autonomous vehicles play a major role (Buehler et al., 2009; Eskandarian, 2012; Attias, 2017), mainly for urban mobility. The researches show that autonomous driving offers some important advantages: for example, a greater safety, as automation reduces the effects of human errors, increased productivity, as humans can work instead of driving and more traffic efficiency by lowering congestion, as automated vehicles are able to platoon (i.e., precisely monitor one another's position and coordinate their motion).

The most revolutionary impact of the autonomous vehicle will probably be on public transport; the introduction of on-demand mobility will transform collective transport uses and business models so profoundly that a genuine paradigm shift is inevitable.

The implementation of autonomous collective transport helps build the framework for the mobility revolution, because it involves numerous actors in very diverse fields, and because it forces policy makers to tackle huge problems as: complex as insurance regulations, personal data collection, energy and communication networks administration, fleet management, along with the emergence of new business models in the smart city context. Indeed, smart cities and the new mobility are not only related, they also share the same DNA, as they are both a combination of technology push and demand pull forces (Angelidou, 2015).

In the urban area, collective transport will be organised differently in the forthcoming mobility system, which is likely to be much more multi-modal than it used to. Collective transport will also be fully embedded in the smart city.

3.1 Autonomous mobility: an embeddedness in the smart city

Since the 1990s, the smart city concept has expanded, giving birth to a wide range of definitions and practices. We can distinguish two forms:

1 the data-based model in which the smart city is conceived as an information system, capturing data from its assets such as buildings, networks, transport, and instrumentalising the data to optimise flows of all kinds (Harrison and Eckman, 2010)

2 the social inclusive model in which modelling and optimising services are complemented by human assets and environment concerns (Leydesdorff and Deakin, 2011; Komninos et al., 2002).

With the analysis of 250 indicators between 2003 and 2006, Caragliu et al. (2011) showed that the relationship between transportation – normalised on the city area – and the level of wealth – measured with per capita GDP[2] – is strongly positive.

Although the concept of smart city is still to be universalised, the improvement of mobility for people and for goods has been, since the very first researches, a corner stone for smart city projects, together with smart energy, smart healthcare, smart infrastructure (Mohanty et al., 2016). Thereafter, smart city is the nest for smart mobility, which is characterised by a user-centred value proposition designed with a deep understanding of user preferences and behaviour, and an inclusive service available for all citizen.

The development of smart mobility is the key to the transformation that cities will have to perform by combining technology into specific local models, such as dynamic traffic management, and extended multi-modalities. Besides smart transport solutions are required to help the city's authorities to meet their biggest challenges: on the one hand traffic and congestion with high level of pollution as collateral effect; on the other hand, the necessity of inclusiveness, which is all the more requested as the urban area is expanding. Moreover, "the management of urban transport flows is part of a much larger issue in that it aims to reorganize the infrastructures that make up towns, enrich the services delivered to their inhabitants and, beyond that, involve those inhabitants in their co-production" (Geoffron, 2017). Thereby with the widespread population of two-sided business platforms (such as: Uber, Lyft, Airbnb), inhabitants are becoming prosumers, i.e., both producers and consumers.

In the near future, smart mobility will lean on the fourfold product-service-structure-market characterising new mobility technologies, and, on the societal shift towards the sharing economy, sustained by digital technologies. This evolution leads to responsible and sustainable mobility in adequation with the development of smart cities (Attias and Mira-Bonnardel, 2017). And pave the way for autonomous driving, i.e., robomobility.

Interactions between autonomous connected vehicles and smart cities are twofold: on the one hand, the automotive industry will influence the shape of mobility patterns, and on the other hand, public policies will organise the urban space within the new mobility paradigm, offering multi-modal mobility solutions (Kellerman, 2011). From an economic perspective, this multi-modal mobility will offer a wide range of new business models.

For now, “the technology itself is no longer the major hindrance” (Poorsartep, 2013). The main road blocks that robomobility is facing are consumer acceptance and regulatory frameworks (Attias, 2017): users need to be convinced and trust is a process that takes time to develop when it comes to transport interventions (Nikitas et al., 2018).

This is the reason why, as a first step, autonomous vehicles will surely be more successful for collective transport, mainly offering trips on micro transit and first- and last-mile settings with flexible shuttle services using small buses or vans, bigger than individual cars and smaller than traditional public transport buses.

Micro transit entails privately owned and operated shared transportation systems that can have fixed routes and schedules, as well as flexible routes and on-demand scheduling. This type of transport mainly provides transportation services that connect residential areas with urban and suburban working and commercial areas (Jin et al., 2018; Ganapati and Reddick, 2018; Cohen and Shaheen, 2016).

As stated by Mira-Bonnardel and Attias (2018), in cities that struggle to provide adequate public transport, autonomous shuttles could partially fill the gap by providing personal rapid transit and offering a personalised point-to-point service without the hassle, congestion, or potential crashes involved in driving.

To bring reliable solutions, several newcomer companies such as Navya, EasyMile, Auro Robotics and Local Motors are entering the domain of driverless shuttles and buses, with pilot projects being deployed in the USA, Europe, Singapore, Taiwan, Japan and the Middle East (Antonialli, 2019; Mira-Bonnardel and Attias, 2018).

The implementation of automated mobility-on-demand systems will undoubtedly help urban areas reduce congestion and pollution, as demonstrated by Spieser et al. (2014) with their case study in Singapore: “using actual transportation data, our analysis suggests that a shared-vehicle mobility solution can meet the personal mobility needs of the entire population with a fleet whose size is approximately 1/3 of the total number of passenger vehicles currently in operation” (Spieser et al., 2014).

Automated mobility-on-demand is based on the idea of shared fully-automated vehicles which might rapidly induce the shift from privately owned personal vehicles to fleet services by driverless, demand-responsive vehicles, shared among a mix of users (Fagnant and Kockelman, 2018).

Different experiments featuring autonomous collective transport are being conducted worldwide to collect data on their social and economic impact proving that the cornerstone of ASCT deployment is the citizens level of acceptance for this type of transport.

3.2 Are citizens and cities ready for robomobility?

For the past decade, ASCT have been pushed by technology rather than pulled by demand. Citizen, not only users, are expecting rather than demanding a new type of mobility, more sustainable but also more flexible than the everyday mobility they have been used to for a long time.

Citizens are mostly waiting for the technology to pave the way for this new mobility and are very much involved in the evolution of their city as proved by the review of 199 smart cities projects worldwide conducted by Crainic et al. (2019). The authors highlight the implication of five different stakeholders including city, citizens, administration, companies and universities and synthesise their results in the following figure.

Table 1 Which stakeholders are concerned by the efficient of city logistics

Stakeholders	*USA*	*Canada*	*Europe*	*Australia*	*Asia*	*Brazil*
City	76%	95%	80%	100%	100%	100%
Citizens	100%	87%	96%	100%	100%	100%
Administration	80%	76%	80%	62%	98%	100%
Companies	88%	80%	100%	83%	83%	100%
Universities	40%	33%	88%	27%	27%	85%

Source: Inspired from Crainic et al. (2019)

Table 1 show that all stakeholders are very much involved in the evolution of the transport system, especially citizens.

The future of mobility goes beyond seeing an autonomous vehicle simply as a new product, but rather as a new system, the product-service system (PSS), combining technological innovation with service and market innovation that will probably be sustained by new business models (Jittrapirom et al., 2017).

New business models are emerging from the transformation of the mobility ecosystem largely supported by digitalisation. "Digitalization is a sociotechnical process that leverages the technical process of the encoding of analog information in a digital format (digitizing) applied to broader social and institutional contexts, transforming their sociotechnical structures, thus rendering digital technologies infrastructural" (Kaiser et al., 2017).

As analysed by Kaiser et al. (2017), in the automotive industry, the potential transformation enforced by digital innovation is inducing business model innovation that can widen horizons and business paths that may impact companies' strategies toward greater sustainability and more customer services. The path to mobility as a service (MaaS) is clearly being built up by all mobility stakeholders.

"MaaS predicts a paradigm with service providers offering travellers easy, flexible, reliable, well-priced, and environmentally sustainable everyday travel, mixing public transport, car-sharing, car leasing, and road use, with more efficient goods shipping and delivery possibilities" (Mulley, 2017). "It opens up opportunities for greater customer service and potential reductions in public subsidy for public transport service; it has the very real opportunity to match customer needs more closely to service supply" (Hensher, 2017).

MasS sits at the intersection of four macro trends: technology that offers autonomous vehicles, social demand for energy transition that pushes electrified vehicles, overall connectivity, and the sharing economy that transfers property to usage. It involves a shift away from ownership of modes of transport towards mobility solutions that are consumed as services.

As Mulley (2017) states: "one of the biggest hurdles for transition to a mobility as a service business model is the need for a cultural shift, away from personal car ownership and reliance, towards the multiple, often shared and public mobility offerings."

MaaS offers the better launch pad for autonomous mobility. RethinkX think tank report[3] warns adoption of rapid, self-driving collective vehicles could take many by surprise: "by 2030, within 10 years of regulatory approval of autonomous vehicles, 95% of passenger miles travelled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals, in a new business model called 'transport-as-a-service'."

Thus, the transition to autonomous driving may most likely be started within public transport system targeting specific customers, such as younger or older people, people with reduced mobility or disabled people. For these targets, MaaS should widely improve their mobility with 'mobility-on-demand', ensuring a completely new perspective in terms of mobility for people in need, reducing costs and time spent in transportation systems, and offering comfort to those who do not want to or cannot drive (Mutz et al., 2016).

In fact, the most remarkable asset for MaaS will undoubtedly be the portfolio of demand-responsive services, "using big data to innovate entirely new operations models to deliver new products and services based on a closer understanding of customers' on-going needs" (Graham et al., 2016).

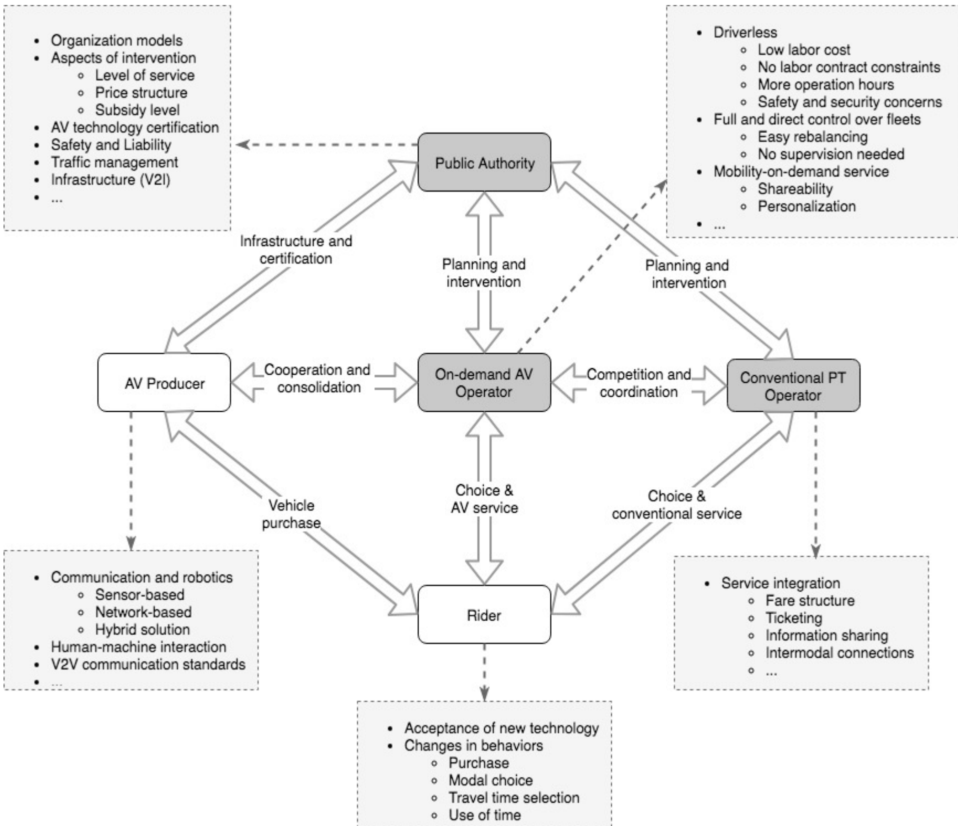
Consequently, autonomous buses fleet may be another important complementary asset for public transport and the investment strategy of their governance authorities.

3.3 Autonomous fleet for public transport

Many researches confirm that autonomous driving has reached a high degree of familiarity among the population. The acceptance rates for fully autonomous cars are reaching around 68% (Payre et al., 2014; Schoettle and Sivak, 2014), the willingness to use autonomous in the future even reaches 77.6% for public transport (Pakusch and Bossauer, 2017).

As stated by Antonialli (2019) on his worldwide benchmark on experimentations with ASCTs, 94% experimentations with autonomous collective transport have been conducted by PTOs. A few researches have been conducted considering the potential interaction between autonomous collective vehicles and public transport. Two ways of integrating autonomous shuttle into public transport network have been analysed: autonomous shuttles for first mile/last mile connection to mass public transport modes (Ainsalu et al., 2018) and autonomous shuttles for micro transit connecting residential areas with urban and suburban working and commercial areas (Jin et al., 2018).

Figure 1 Stakeholders around AV-PT operation and AV characteristics from the perspectives of operation, governance, technology, and consumption in Shen et al. (2018)



A few scenarios have been studied. Liang et al. (2016) proposed optimisation scenarios of an automated taxis fleet over the last mile to train service integrating it within the service provided by the human-driven taxis fleet. Lenz and Fraedrich (2016) discussed the opportunities and challenges resulting from the introduction of autonomously driving vehicles into car sharing and the possibilities of hybridising autonomous vehicles with public transport to improve inter-modality and individualisation of the transit service.

An interesting research from Shen et al. (2018) explored the opportunities that autonomous vehicles can provide when integrated into public transport systems. They worked on scenarios in which autonomous vehicles provide a complementary on-demand service to conventional fixed-schedule, fixed-route buses for the first/last mile and assess whether the new integrated service improves the performance of the overall system. This study is based on empirical travel demand and transit operation details derived from the smart card data in Singapore. The authors propose to preserve high demand bus routes while repurposing low-demand bus routes using shared autonomous vehicles as an alternative. They designed an agent-based supply-side simulation to assess the performance of the proposed service in 52 scenarios with different fleet sizes and ridesharing preferences. Under a set of assumptions on operation costs and dispatching algorithms, their results show that the integrated system has the potential of enhancing service quality, occupying fewer road resources, being financially sustainable, and utilising bus services more efficiently.

Shen et al (2018) analysed the ecosystem for autonomous mobility and each stakeholder perspective: autonomous and PTO (AV operator and PT operator), governance (public authority), technology (AV producer), and consumption (AV riders and PT riders). The authors proposed a detailed mapping of stakeholders points of view with Figure 1.

Figure 1 shows clearly that autonomous driving for public transport offers an opportunity to address challenges for all stakeholders. But the user acceptance represents an important key for the development of the ecosystem. The level of acceptance of the autonomous technology is the key point that will directly impact the user readiness for a new mobility as long as it proves to be a more adapted to its needs and expectations. One of the best ways to enhance their acceptance is to involve them in the development of new usages on robomobility. The next section gives a more precise user perspective and its integration in uses scenario.

4 The user level of acceptance for ASCT. An empirical analysis in Lyon, France

Designing scenarios for future transportation require to model the user's mobility behaviour and this is a big challenge. The user cannot be reduced to a simple constraint (as used to be for infrastructure optimisation), or to a physical flow (as it used to be for flow optimisation) but has to be integrated in the model as a much richer concept with diverse interactions with all other components of the mobility system.

Moreover, the user can be part of the scenario designing. This is the objective of our analysis. Firstly, we complement our knowledge on the user readiness towards autonomous public transport by the analysis of the results of two surveys: one large quantitative survey conducted in 2018 by Keolis, the Lyon PTO, concerning the first experimentation with autonomous shuttles at Lyon Confluence district and one qualitative survey we conducted in January 2020 at the second experimentation with autonomous shuttles at Decine Groupama Stadium in the suburbs of Lyon.

Secondly, based on the surveys results, we proposed a daily usage scenario to the second survey panel and analyse the users reaction.

The survey from Keolis, by being confidential, will not be presented extensively we will just highlight the more relevant insights. The second qualitative survey was conducted by our team, the questionnaire and results for each question are developed in Appendix.

4.1 Quantitative survey insights

A survey was conducted in May 2018, to better understand the opinions of users of an autonomous shuttle that has been running in the French city of Lyon since 2016. The shuttle, named Navly, is produced by Navya, one of the two French autonomous shuttle manufacturers founded in 2014 (the other one in France is Easy Mile).

Capable of transporting up to 15 people, Navly is operated by the company Keolis (Lyon's PTO). Navly's service has been as yet totally free of charge for passengers. The shuttle runs in a dynamic district in the city named Confluence. With a population of

11,000 residents and about 900 business employing 15,000 people, the area covers 150 hectares in the heart of Lyon, between the Rhone and Saone rivers. The ambition of this newly transformed neighbourhood is to double the city centre in accordance with the climate plan, i.e., positive energy construction, electro- and robomobility. The autonomous shuttle is fully part of this plan. It operates from Monday to Friday 7:30 to 19:30 serving five stops.

In 2018, when the autonomous shuttle had been running for two years, a survey was conducted to understand both users' behaviours and opinions about this robomobility.

300 people were interviewed including 150 employees working in the area and 150 people undertaking leisure activities in the area. The sample was balanced featured 50% men and 50% women, 50% of respondents were under 50 years old and 50% were over 50. 64% of those interviewed lived in Lyon and 60% regularly travelled on public transport, while 48% were used to moving around by car and 17% on a bicycle; most respondents were multi-mobile.

We synthesis hereafter the feedbacks of two different types of users: occasional users and regular users.

Occasional users mostly remain as is, but 46% of them said they had used the shuttle between 3 and 9 times in the last two years and 11% more than 10 times; 76% of Navly's occasional users usually travel with public transport in Lyon.

It took time for people to get used to the idea of moving without a driver, since 8 out of 10 passengers boarded the shuttle for the first time one year after its launch. It was mainly curiosity that prompted more than half of the users (57%) to take the shuttle, whereas one-third took it as part of a walk.

The respondents had a good knowledge of its characteristics before getting on board, i.e., mainly that it operates on electricity (90%) and aims at providing sustainable mobility (80%), a mobility that is planned to be generalised in the urban area (93%). For 99% of the users, the autonomous shuttle positively portrays public transport in Lyon and, as a side-effect it creates a good image for the city.

The occasional users expressed general satisfaction with the characteristics of the shuttle, in particular regarding comfort (95%) and security (92%), although 15% highlighted its very low operating speed.

No anxiety or fears were expressed by any of the interviewed users, who felt quite secure on board, with 90% claiming the driverless shuttle to be totally reliable.

Regular users are employees working in the Confluence area, and they expressed a more nuanced opinion on the shuttle. They claimed that safety, comfort and reliability were of a high level, but said that the shuttle did not meet their needs in terms of routes and timetables.

80% of employees in the area found the shuttle to be far too slow; they claimed its low speed was the reason why they did not systematically use the shuttle, although 60% thought it could be very useful to travel to their place of employment. 60% of employees said that an autonomous shuttle was highly suited to professional travelling, provided its speed could be increased to better match a professional pace.

20% of employees who travelled to work by car said that they would travel by public transport if a regular and more rapid autonomous shuttle service were available.

Almost 8 out of 10 employees saw autonomous transport as the solution for the future of mobility highly adapted to commuters.

4.2 Qualitative survey insights

A more qualitative survey was conducted in January 2020, to access the opinions of users of the autonomous shuttle that has been running since November 2019 in the Lyon, French city suburb of Decines. The shuttle named N1 is also produced by Navya and operated by Keolis; the service has also been of charge for passengers.

Two shuttles are being operated on a mixed road along with cars, trucks, bicycles and pedestrians from 8:30 AM to 7:30 PM for a round trip of 2.5 kilometres from the tramway T3 stop to the Groupama Stadium; the frequency is 15 minutes for peak hours and 30 minutes for off-peak hours. The shuttle service alternates with a bus service with the same frequency. This experimentation is an innovative mixed-traffic (including trucks, cars, bikes, pedestrians, ...) deployment of ASCTs that is so far one of the few in the world.

This route is part of the development of the area around the stadium. In fact, this area is a residential popular area in transformation: a large commercial area is being developed around the stadium, including a medical centre (30 doctors on 3,000 m^2 started in July 2019), an office building (opened in autumn 2019) and a recreation centre (delivery planned for fall 2020). Eventually, there will also be a concert hall, two swimming pools, as well as many bars and restaurants.

We interviewed 36 users in the autonomous shuttle in the wide timeslot from 8:30 AM till 1:30 PM to meet a large diversity of users (see Q7, Appendix) and mobility reasons (see Q1, Appendix); the panel presented an equipartition between the number of male and female respondents.

70% of the respondents are daily users of collective transport paying an annual or monthly pass. The large majority is confident with the autonomous driving (see Q3, Appendix). According to their answers, they consider the shuttle as an additional mobility mode mostly targeting the last-mile part of the journey; accordingly, the most important modal shift concerns pedestrians and much less personal car or bicycle (see Q4, Appendix).

However, 19% of the respondents claimed taking the shuttle instead of their personal car for this last kilometre, which should have a real impact on the local traffic.

For the respondents, the autonomous shuttle is seen like any other collective transport whose strengths are: sustainability (no noise or energy pollution), a widening of the service improving mobility in the suburb, a positive impact on the suburb image (see Q2, Appendix).

Although the respondents are confident with autonomous driving, their most pressing worry still concerns technology in terms of reliability and cybersecurity. 18% of the respondents were also quite concerned with the impact of the absence of drivers on the unemployment rate (see Q5, Appendix).

This qualitative survey shows a more contrasted picture: although travellers did express a good opinion about autonomous collective transport, they actually need to be appeased as well on the technology reliability as on its social impact.

We asked the 36 respondents of our survey to help us design a usage scenario.

4.3 Daily scenario for robomobility

To design a prospective picture of robomobility as a usual transport mode, we decided to enable the users' proactivity by imposing no technological limit to their scenario creation, that is: freedom of choice regarding departure and arrival points, route selection and expression of specific needs, personalised journeys, etc. In that prospective vision featuring a totally autonomous shuttle with no driver or operator, mobility services operate non-stop (24/7) without additional costs. All users are connected to the shuttle's navigation system, which must be constantly updated to ensure the service quality.

We asked them to use the list of user requirements for traditional forms of transport in urban centres like: school journeys, home-to-work journeys, transport for disabled people, last-mile delivery, transport for medical care, sports and cultural activities, tours, goods deliveries, etc.

A daily usage scenario has emerged from the discussion with the users, alternating predetermined journeys with fixed stops supporting high passenger flows with request journeys characterised by mobile stops supporting shifting times and specific requests. The designed scenario is described in Table 2.

Table 2 Scenario for a typical week day for the autonomous fleet with alternating propositions

Time slots	*Use cases*
6 AM–9 AM predetermined journeys	Transportation with predetermined stops for regular, fixed time mobility (employees and schoolchildren).
9 AM–5 PM journeys on request	Transportation of goods (last mile) in city centres for retailers and individuals, with booking and connection to track the delivery process in real-time.
	Transportation for targeted needs (people with reduced mobility, leisure centres, care centres, specific goods, etc.).
	Transportation for disabled people at set times.
	Transportation for city tours and outings.
5 PM–8 PM predetermined journeys	Transportation with predetermined stops for regular, fixed time mobility (employees and schoolchildren).
8 PM–6 AM journeys on request	Night transportation for specific and emergency requests (like injured or sick people, delivery, deliveries for hospitals, tourist trips, etc.). Specific requests should be privately funded (individuals, travel agencies, retailer associations, etc.).

This scenario is coherent with the current daily uses of the autonomous shuttle expressed by the users we interviewed (see Q6, Appendix); it meets our panel requirements and received full support from the users we discussed with. Users themselves promote a robomobility based on daily uses segmentation to meet general and specific needs while supplying an efficient low cost public transport.

5 Discussion

The future of mobility has given rise to several prospective studies notably due to the growing interest for electrified and automated vehicles, most studies have been conducted by top consulting companies (KPMG, 2018; McKinsey, 2016; Little, 2018). These studies built scenarios-based mainly on trend analyses.

Unlike these studies, we built our scenario mainly with a user perspective by combining their current feeling and their vision on robomobility. Allowing users to express their vision on robomobility helps to reduce fears and uncertainties.

Indeed, to set up a new model of public transportation targeting also elderly people, people with disabilities and vulnerable users, a user centred design approach is essential. An innovative model will only be successful when the needs of the users are considered in the specifications and functionalities.

We enhanced users claims with experts' opinions, by working alongside the European Avenue project. According to experts, mobility on demand (for people or for goods) comes out as the cornerstone of autonomous fleet deployment that could easily be combined with conventional, regular transport management featuring predetermined stops and times.

The most consensual scenario for urban mobility involves designing shared and optimised mobility-on-demand based on a constant connection between the shuttle's navigation system and the users' digital interface (smartphone or computer) in a shared perspective.

Shared mobility on-demand will be designed with data mining technologies using personal data to create digital people-grouping pick-up stops and common travelling time slices that will optimise autonomous fleet management. Data management and machine learning should help integrate unanticipated requests into a global optimised system.

The scenario transforms the shuttle into a kind of 'Uber pool taxi', which would offer travellers a shared transport service on demand, operating 24/7 while being cheaper than conventional VTCs.

In fact, the scenario is designed with a uses segmentation model that distinguishes three different mobility options: mass transportation, customised transportation, inter-modal transportation.

Uses segmentation allows to craft personas that help to create value within robomobility by adapting the supply to their needs. A persona is a fictional character that communicates the primary characteristics of a group of users, identified and selected as a key target through use of segmentation data. This ultimately enables the design of the most suitable user experience for the customers at all touchpoints, which is a key success factor in today's business environment. Personas are increasingly used in policy making to help imagining more human-centred policies and services to the population (González de Heredia et al., 2018).

Inspired by the scenario *personarrative* method developed by Vallet et al. (2020), the discussion with users allow us to design the following four personas.

These personas help to highlight the limits of our daily uses scenarios. Like Paul, many travellers would prefer human contact during their travel, whereas others like Sophie would not mind walking the last mile rather than using the shuttle.

On the contrary Claire and Frank are ready to use the latest technologies for a new urban mobility with in- and out-of-vehicle services like personalisation of services, dynamic itinerary optimisation and in-vehicle entertainment. Frank will certainly appreciate the 'follow my kid' application.

As shown by the two surveys we presented, almost 20% of the interviewed persons are ready to shift from using their private car to using a collective autonomous vehicle provided that the autonomous service is regular and efficient. These customers are ready to integrate the robomobility into their everyday life. The percentage should increase if PTOs manage to provide services and solutions to accommodate specific needs, such as children and adults who have no direct special requirements; people with reduced mobility; young children and elderly people who require supervision for example services like 'follow my kid' or on-demand mobility.

Table 3 Examples of personas to describe the variety of uses and needs

Sophie 30 years old, commuter	Sophie goes to work every day on public transit. She lives in Lyon and has to go to the office building next to Groupama Stadium. The fastest and cheapest way is to take the tram and then the bus. When the shuttle is there in the morning, Sophie takes it: it has room to sit, and it is more friendly than the bus. She appreciates this last kilometre transit with a modern, well designed shuttle. Otherwise she walks, after all it is only 15 a minute walk. For the evening, it is the same routine: if the shuttle is there, she takes it, otherwise the walk will do her good after a sitting day.
Fanck 42 years old, resident	Franck lives in the neighbourhood served by the shuttle. He usually goes to work every day by car, to move around, go shopping, go to the centre park or to the cinema with his two sons. He appreciates taking the shuttle and teaches his children how to behave within modern autonomous buses. Very often his boys have too much energy and he would like to have some way to keep them busy during the travel with in-shuttle games. He is persuaded that the robomobility is the future for mobility. He dreams to share with his neighbourhood a more flexible mobility and hope the technology will improve quickly.
Claire 16 years old, resident	On the weekends, Claire usually joins her friends for leisure activities. Having no car or drivers license, she takes public transport. She prefers the autonomous shuttle, be being more modern than regular buses. She looks at her mobility application and follows the given instructions. The autonomous shuttle is usually on time. On the way back, she usually stops at the fast food restaurant on the road and visit another friend that lives nearby. Claire hopes that in a very near future she will be able to program the mobility app so that the shuttle would drive her right in front of her friend’s home.
Paul 85 years old, with reduced mobility, patient of the medical centre	Paul needs to go to the medical centre several times a month. When his children can, they accompany him but often he has to go alone. Paul can no longer drive, and taking taxis is too expensive. He manages to go by public transport. By often taking the bus, he became familiar to the drivers with whom he chats during the journey between the tram stop and the medical centre stop. Paul is afraid of losing that contact by taking the autonomous shuttle. In addition, he feels safer with a TCL agent on the bus.

However, if PTOs succeed in fully meeting social and economic expectations by providing an inclusive, flexible and shared mobility with sustainability footprint and value to all stakeholders, policy makers would still need to tackle the social burden of employment. Citizens have still to be convinced that robomobility would not induce high social cost by increasing unemployment of drivers. Transport operators have to prove that driverless mobility does not mean ‘humanless’ mobility. The human hand should still run the transport system, either as off-board (remote) supervisors or as intervention brigades.

6 Conclusions

Many scenarios are being developed for the future of mobility. We chose to focus the exercise on the customer perspective. Using the results of two different surveys conducted in Lyon we infer that travellers we interviewed are ready to integrate robomobility in their usual mobility practices. Deep discussion with the users helps us to propose a daily usage scenario for micro transit and first- and last-mile journeys by combining mass transportation with individualised customised transportation integrated in a multi-modal service offer.

The personarrative method allows us to provide insights on obstacles and drivers for general user acceptance of robomobility. These personas may help decision makers to better figure out the condition to leverage the citizens level of acceptance for robomobility.

Our conclusions are limited due to the specific context of our study and the research will be continued to bring further robustness and in-depth interpretations.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 769033 (AVENUE project).

References

Ainsalu, J. et al. (2018) 'State of the art of automated buses', *Sustainability*, Vol. 10, No. 3118, pp.2–34.

Amer, M., Daim, T.U. and Jetter, A. (2013) 'A review of scenario planning', *Futures*, Vol. 46, pp.23–40.

Angelidou, M., (2015) 'Smart cities: a conjuncture of four forces', *Cities*, Vol. 47, DOI: 10.1016/j.cities.2015.05.004.

Antonialli, F. (2019) 'International benchmark on experimentations with autonomous shuttles for collective transport', *27th International Colloquium of Gerpisa: the Automotive Industry in Transition*, Paris, June.

Attias, D. (2017) 'The automobile world in a state of change', in Attias, D. (Ed.): *The Automobile Revolution*, pp.7–19, Springer, Cham, Switzerland.

Attias, D. and Mira-Bonnardel, S. (2017) 'Extending the scope of partnerships in the automotive industry: between competition and cooperation', in Attias, D. (Ed.): *The Automobile Revolution*, pp.69–85, Springer, Cham, Switzerland.

Buehler, M., Iagnemma, K. and Singh, S. (2009) 'The DARPA urban challenge: autonomous vehicles in city traffic', *Springer Tracts in Advanced Robotics*, No. 56, Springer, Cham, Switzerland.

Caragliu, A., Del Bo, C. and Nijkamp, P. (2011) 'Smart cities in Europe', *Journal of Urban Technology*, Vol. 18, No. 2, pp.65–82.

Cohen, A. and Shaheen, S. (2016) *Planning for Shared Mobility*, pp.1–106, UC Berkeley [online] https://escholarship.org/uc/item/0dk3h89p.

Crainic, T.G., Perboli, G., Rosano, M. and Wei, Q.A. (2019) 'Transport for smart cities: a systematic review', *CIRRELT-2019-46*, pp.1–12.

Eskandarian, A. (2012) *Handbook of Intelligent Vehicles*, Springer, Cham, Switzerland.

Fagnant, D.J. and Kockelman, K.M. (2018) 'Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas', *Transportation*, Vol. 45, No. 1, pp.143–158.

Firnkorn, J. and Müller, M. (2011) 'What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm', *Ecological Economics*, Vol. 70, pp.1519–1528, DOI: 10.1016/j.ecolecon.2011.03.014.

Ganapati, S. and Reddick, C. (2018) 'Prospects and challenges of sharing economy for the public sector', *Government Information Quarterly*, Vol. 35, DOI: 10.1016/j.giq.2018.01.001.

Geoffron, P. (2017) 'Smart cities and smart mobilities', in Attias, D. (Ed.): *The Automobile Revolution*, pp.87–98, Springer, Cham, Switzerland.

González de Heredia, A., Goodman-Deane, J., Waller, S., Clarkson, P., Justel, D., Iriarte, I. and Hernández-Galán, J. (2018) *Personas for Policy-Making and Healthcare Design*, pp.2645–2656, 10.21278/idc.2018.0438.

Graham, G., Meriton, R., Tew, B. and Hennelly, P. (2016) 'How is big data transforming operations models in the automotive industry: a preliminary investigation', in *International Conference on Emerging Networks and Systems Intelligence*, University of Leeds, Venice, Vol. 8, pp.1–5.

Harrison, C. and Eckman B.A. (2010) 'Foundations for smarter cities', *IBM Journal of Research and Development*, Vol. 54, No. 4, pp.1–16, July–August, doi: 10.1147/JRD.2010.2048257.

Hensher, D.A. (2017) 'Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: are they likely to change?', *Transportation Research Part A: Police and Practice*, Vol. 98, pp.86–96, Amsterdam.

Jin, S.T., Kong, H., Wu, R. and Sui, D.Z. (2018) 'Ridesourcing, the sharing economy, and the future of cities', *Cities*, Vol. 76, pp.96–104.

Jittrapirom, P., Caiati, V., Feneri, A., Ebrahimigharehbaghi, S., Alonso-Gonzalez, M.J. and Narayan, J. (2017) 'Mobility as a service: a critical review of definitions, assessments of schemes, and key challenges', *Urban Planning*, Vol. 2, No. 2, pp.13–25, Lisbon.

Kaiser, C., Stocker, A. and Viscusi, G. (2017) 'Digital vehicle ecosystems and new business models: an overview of digitalization perspectives', *i-KNOW 2017*, Graz, Austria, 11–12 October.

Kellerman, A. (2011) 'Mobility or mobilities: terrestrial, virtual and aerial categories or entities?', *Journal of Transport Geography*, Vol. 19, pp.729–737.

Komninos, N., Pallot, M. and Schaffers, H. (2002) 'Smart cities and the future internet in Europe', *Journal of the Knowledge Economy*, Vol. 4, No. 2, pp.119–134.

KPMG (2018) *Autonomous Vehicles Readiness Index, Assessing Countries' Openness and Preparedness for Autonomous Vehicles*, January [online] KPMG International Cooperative, https://home.kpmg/xx/en/home/insights/2020/06/autonomous-vehicles-readiness-index.html,

Lenz, B. and Fraedrich, E. (2016) 'New mobility concepts and autonomous driving: the potential for change, in autonomous driving technical, legal and social aspects', in Maurer, M., Gerdes, J., Lenz, B. and Winner, H. (Eds.): pp.173–191, Springer.

Leydesdorff, L. and Deakin, M. (2011) 'The triple-helix model of smart cities: a neo-evolutionary perspective', *Journal of Urban Technology*, Vol. 18, No. 2, pp.53–63.

Liang, X., Correia, G. and van Arem, B. (2016) 'Optimizing the service area and trip selection of an electric automated taxi system used for the last mile of train trips', *Transp. Res. Part E Logist. Transp. Rev.*, Vol. 93, pp.115–129.

Little, A.D. (2018) *Capacity Effect of Autonomous Vehicles? Impact of Autonomous Vehicles on the Capacity of Traffic*, August.

McKinsey (2016) 'Automotive revolution – perspective towards 2030; how the convergence of disruptive technology-driven trends could transform the auto industry', *Advanced Industries*, January.

Meissner, P. and Wulf, T. (2013) 'Cognitive benefits of scenario planning: its impact on biases and decision quality', *Technological Forecasting & Social Change*, Vol. 80, No. 4, pp.801–814.

Mira-Bonnardel, S. and Attias, D. (2018) 'The autonomous vehicle for urban collective transport: disrupting business models embedded in the smart city revolution', *Proceedings of the 26th Gerpisa International Colloquium: Who Drives the Change? New and Traditional Players in the Global Automotive Sector*, Sao Paulo, Brazil, June.

Mohanty, S.P., Choppali, U. and Kougianos, E. (2016) 'Everything you wanted to know about smart cities: the internet of thinks is the backbone', *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, pp.60–70.

Mulley, C. (2017) 'Mobility as a services – does it have critical mass?', *Transport Reviews*, Vol. 37, No. 3, pp.247–251, Oxfordshire.

Mutz, F., Veronese, L.P., Oliveira-Santos, T., de Aguiar, E., Cheein, F.A.A. and De Souza, A.F. (2016) 'Large-scale mapping in complex field scenarios using an autônomous car', *Expert Systems with Applications*, Vol. 46, pp.439–462.

Nikitas, A., Avineri, E. and Parkhurst, G. (2018) 'Understanding the public acceptability of road pricing and the roles of older age, social norms, pro-social values and trust for urban policy-making: the case of Bristol', *Cities*, Vol. 79, pp.78–91.

Nikitas, A., Njoya, E.T. and Dani, S. (2019) 'Examining the myths of connected and autonomous vehicles: analysing the pathway to a driverless mobility paradigm', *International Journal of Automotive Technology and Management*, Vol. 19, Nos. 1–2, pp.10–30.

Pakusch, C. and Bossauer, P. (2017) 'User acceptance of fully autonomous public transport', in *ICE-B*, pp.52–60.

Payre, W., Cestac, J. and Delhomme, P. (2014) 'Intention to use a fully automated car: attitudes and a priori acceptability', *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 2, No. 27, pp.252–253, Elsevier.

Poorsartep, M. (2013) *Self-Driving Cars: Radical Innovation in the Transportation Industry*, DOI: 10.4018/978-1-4666-4749-7.ch005.

Schoettle, B. and Sivak, M. (2014) *Public Opinion about Self-Driving Vehicles in China, India, Japan, the U.S., the U.K., and Australia*, Technical Report No. UMTRI-2014-30, The University of Michigan Transportation Research Institute.

Shen, Y., Zhang, H. and Zhao, J. (2018) 'Integrating shared autonomous vehicle in public transportation system: a supply-side simulation of the first-mile service in Singapore', *Transportation Research: Policy and Practice*, July, Vol. 113, pp.125–136.

Spieser, K., Ballantyne, K., Treleaven, R., Frazzoli, E., Morton, D. and Pavone, M. (2014) 'Toward a systematic approach to the design and evaluation of automated mobility on-demand systems a case study in Singapore', in Meyer, G. and Beiker, S. (Eds.): *Road Vehicle Automation*, Springer, Cham, Switzerland.

Vallet, F., Puchinger, J., Millonig, A., Lamé, G. and Nicolaï, I. (2020) 'Tangible futures: combining scenario thinking and personas – a pilot study on urban mobility', *Futures*, Vol. 117, DOI: 10.1016/j.futures.2020.102513, Elsevier.

Notes

1 https://h2020-avenue.eu/.

2 Gross domestic product.

3 https://spectrum.ieee.org/cars-that-think/transportation/self-driving/rethinkx-selfdriving-electric-cars-will-dominate-roads-by-2030.

Appendix

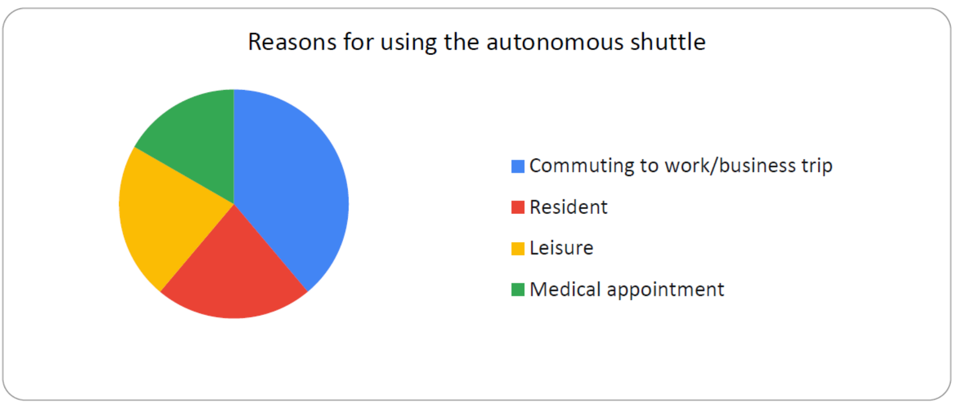
Qualitative questionnaire and results

Q1 – why are you moving with the autonomous shuttle

Table A1 Reason for using the autonomous shuttle

Reason	*Number*	*Percentage*
Commuting to work/business trip	14	38.89%
Resident	8	22.22%
Leisure	8	22.22%
Medical appointment	6	16.67%
Total	36	

Figure A1 Reasons for using the autonomous shuttle (see online version for colours)

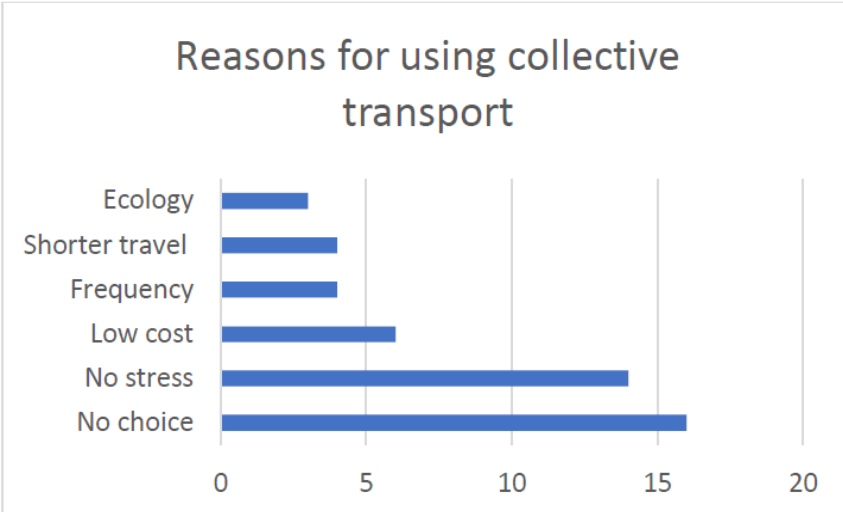


Q2 – in general why are you using collective transport? (Several answers possible)

Table A2 Reason for using collective transport

Reason	*Number*	*Percentage*
No choice	16	52%
No stress	14	45%
Low cost	6	19%
Frequency	4	13%
Shorter travel	4	13%
Ecology	3	10%
Total	47	

Figure A2 Reason for using collective transport (see online version for colours)

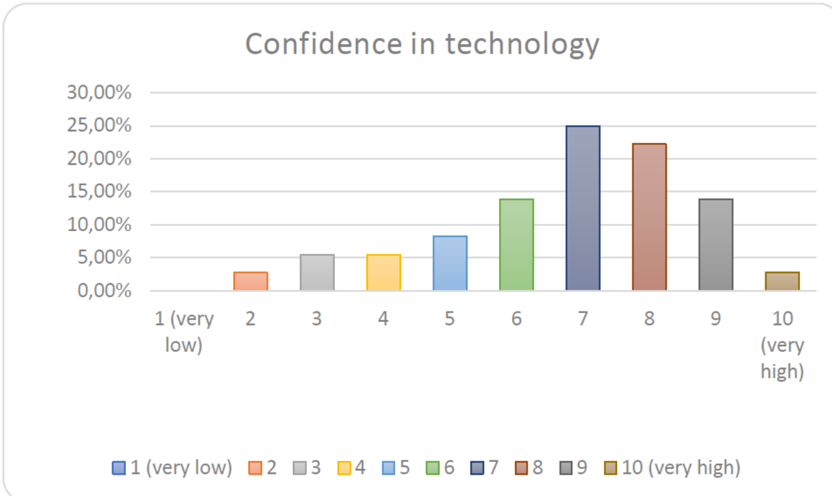


Q3 – how high is your confidence in autonomous driving technology

Table A3 Level f confidence for autonomous driving

Confidence level	*Number*	*Percentage*
1 (very low)	0	0.00%
2	1	2.78%
3	2	5.56%
4	2	5.56%
5	3	8.33%
6	5	13.89%
7	9	25.00%
8	8	22.22%
9	5	13.89%
10 (very high)	1	2.78%
Total	36	

Figure A3 Level f confidence for autonomous driving (see online version for colours)

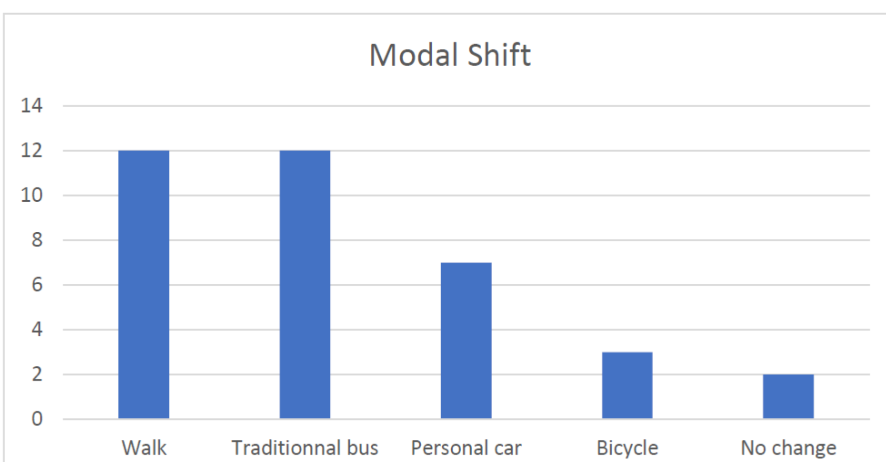


Q4 – which transport mode were you using before the shuttle settlement?

Table A4 Modal shift to the autonomous shuttle

Modal shift	*Number*	*Percentage*
Walk	12	33%
Traditional bus	12	33%
Personal car	7	19%
Bicycle	3	8%
No change	2	6%
Total	36	

Figure A4 Model shift to the autonomous shuttle (see online version for colours)

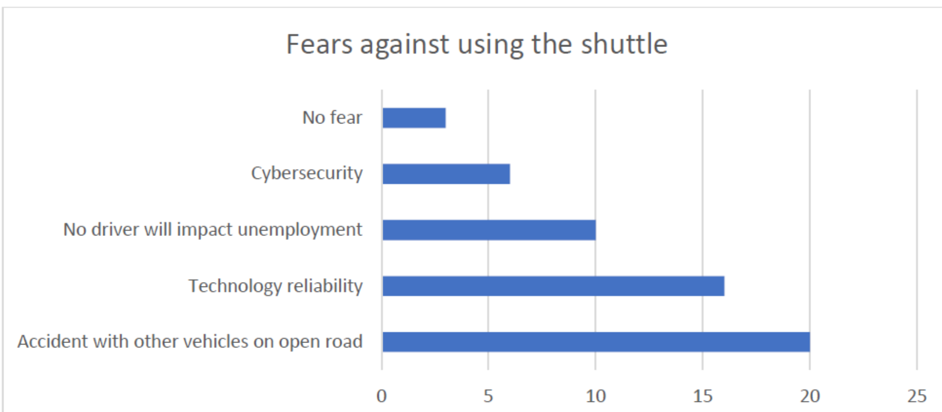


Q5 – what are you afraid of by using the autonomous shuttle? (Several answers possible)

Table A5 Fears

Fears	*Number*	*Percentage*
Accident with other vehicles on open road	20	36%
Technology reliability	16	29%
No driver will impact unemployment	10	18%
Cybersecurity	6	11%
No fear	3	5%
Total	55	

Figure A5 Fears (see online version for colours)

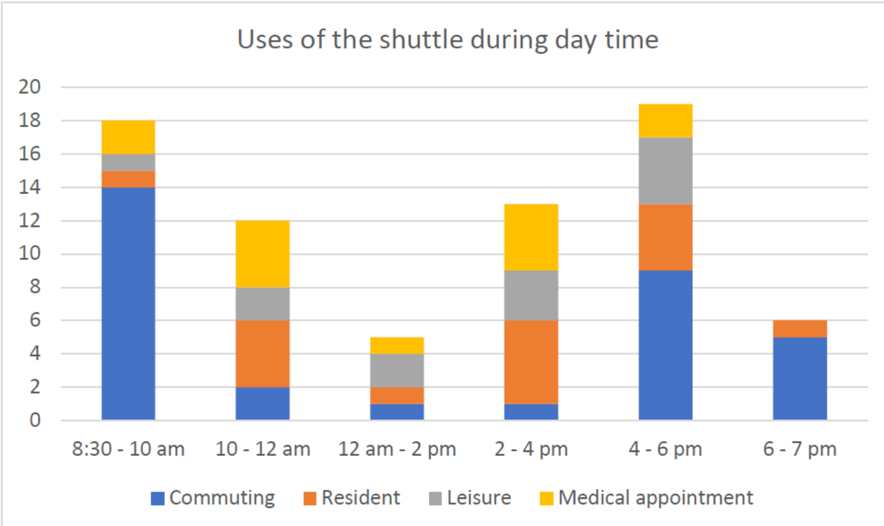


Q6 – indicate at what time you use the shuttle for which reason (several answers possible

Table A6 Usage per time slot in a day

Time slot	*Commuting*	*Resident*	*Leisure*	*Medical appointment*	*Total*
8:30–10 AM	14	1	1	2	18
10–12 AM	2	4	2	4	12
12 AM–2 PM	1	1	2	1	5
2–4 PM	1	5	3	4	13
4–6 PM	9	4	4	2	19
6–7 PM	5	1			6
Total	32	16	12	13	73

Figure A6 Usage per time slot in a day (see online version for colours)



Q7 – how old are you

Table A7 Age repartition of the respondents

Age	*Number*	*Percentage*
18–25	10	28%
26–45	9	25%
46–65	10	28%
Over 65	7	19%
Total	36	