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Public acceptance of driverless shuttles in Norway

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ABSTRACT

The main objective of the present study is to evaluate individuals' views on the usefulness of driverless shuttles and to examine if the provision of better access to public transit (thanks to the connection provided by shuttles) would make them consider public transit in the future. The survey was carried out amongst members of the Norwegian Automobile Federation ($n = 1419$). The results indicated that a large share of the sample (71.8%) did not evaluate driverless shuttles as useful. Cluster members who stated that it was unlikely that the implementation of driverless shuttles would make them use the public transit more were more worried concerning the safety and security issues, the greatest concern being traffic safety (accidents). Cluster members who stated that it was likely that they would use the public transit more had more trust in the ability of the authorities to reduce the risk of accidents, and they accepted having more automation in future buses. Developers of shuttles, city governments, transport operators, and other authorities should consider the findings of this study in order to develop specific measures to increase the acceptance of automation in the transport sector. We recommend better informing the general public about the procedures for implementing driverless shuttles in mixed traffic and the safety and security requirements for the vehicle automation system. It is crucial to explain the measures (e.g. comprehensive risk analysis, site inspection, laws and regulations) that will be set out to ensure that no incidents or accidents will occur. In the meantime, the actors should do their utmost to reassure passengers and other road users by demonstrating the effectiveness of the safety and security systems.

1. Introduction

With the increased use of automation in the transport sector, the public have become aware that new risks related to traffic accidents, violence, and data privacy will occur that are not yet identified and understood. Driverless vehicles are viewed with scepticism due to the uncertainties regarding failures or disengagements of the vehicle automation system and the complex interactions with other road users. Measures are needed to secure the implementation of fully automated modes and to investigate whether automation in the transport sector will be accepted and adopted by the general public.

Results from previous studies have illustrated the complexity and variety of factors influencing the public acceptance of vehicle automation. It is commonly related to perceived usefulness, usability, reliability, safety, comfort, trust, and depends on one's personal and cultural background (Alessandrini, Alfonsi, Delle, & Stam, 2014; Bazilinskyy, Kyriakidis, & De Winter, 2015; Becker & Axhausen, 2017; Gkartzonikas & Gkritza, 2017). Nevertheless, belonging to certain transport mode use groups may also play a role in how people accept driverless shuttles. Travellers using public transit may be more likely to accept driverless shuttles that might shorten their travel time. Car users, on the other hand, may be more reluctant since

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they consider flexibility and comfort most important for mode use (Rundmo, Sigurdson, & Roche Cerasi, 2011). Manual driving was also found to be the most enjoyable mode of driving (Kyriakidis, Happee, & De Winter, 2015), but it is likely doomed to disappear in the 10 or 20 next years, with drivers becoming 'passengers' in their own automated cars and driverless shuttles offering on-demand services with door-to-door trips, providing flexibility and 'shared' comfort (Khan, Bacchus, & Erwin, 2012).

2. Background

Most research studies in this area are related to automated vehicles in general. Little research has been conducted on the public's acceptance of driverless shuttles themselves (Jenssen & Roche Cerasi, 2017). There is a need to better examine how they can be integrated into the public transport network and how they can provide benefits for the environment and traffic safety based on viable business models and effective public-private partnerships.

2.1. Automated vehicles

Gkartzonikas and Gkritza (2017) and Becker and Axhausen (2017) have presented review studies on public opinion about automated vehicles. These reviews clearly demonstrate that the general public opinion is not unanimously positive, and general acceptance depends on many factors, e.g. perceived usefulness, usability, reliability, safety, comfort, trust, driving control, road types, traffic conditions, and cultural and personal background. Schoettle and Sivak (2014) examined the public opinion in Australia, the United Kingdom, and the United States regarding connected cars. The results revealed that most of the respondents had a positive opinion of the technology and thought that the expected benefits were likely to occur. However, Bansal, Kockelman, and Singh (2016), Brown, Drew, Erenguc, Hasegawa, Hill, Schmith, and Gangula (2014), and Payre, Cestac, and Delhomme (2014) hypothesise that the public are worried and question the reliability of the highest levels of automation. Zmud, Sener, and Wagner (2016) state that people are in a wait-and-see position. They are divided into four groups according to their acceptance of and intention to use automated vehicles: rejecters, traditionalists, pragmatists, and enthusiasts. The main reason that the rejecters and traditionalists are unwilling to use fully automated vehicles is their lack of trust in the technology. Liljamo, Liimatainen, and Pöllänen (2018) recommend that considering the concerns and attitude of the general public, all automated vehicles must still have the option of manual drive. Begg (2014) indicates that the public believe that the automation of the transport sector would make the road safer for all users. Bansal et al. (2016) found that respondents perceived fewer crashes to be the primary benefit of automation, with system failure being their top concern. Hulse, Xie, and Galea (2018) state that fully automated cars are perceived as a somewhat low-risk form of transport but perceived as riskier than a human-operated car for passengers and as less risky for pedestrians. Individuals are also concerned about vehicle software hacking/misuse (Kyriakidis et al., 2015), and reservations regarding data security are shared across generations (Owens, Antin, Doerzaph, & Willis, 2015). Hohenberger, Spörrle, and Welpe (2016) found an indirect effect of gender on the willingness to use automated cars through anxiety and pleasure. The negative effect of anxiety was strongest for young women and old men. Early adopters of automated vehicles in most studies are found to be younger adults and people with higher income, higher education levels, living in urban areas, and who drive most (Bansal et al., 2016; Haboucha, Ishaq, & Shiftan, 2017; Howard & Dai, 2013; Hulse et al., 2018; Liljamo et al., 2018). The oldest generation also exhibited the least interest in and comfort with this technology according to Owens et al. (2015). In conclusion, it has been found that individuals need clarification related to the liability of autonomous vehicles and the roles and responsibilities of the different parties (Casley, Jardim, & Quartulli, 2013; Howard & Dai, 2013; Kyriakidis et al., 2015).

2.2. Driverless shuttles

In the framework of City Alternative Transport System (CATS), a FP7 (7th Framework Programme for Research and Technological Development) European project (2010–2014), Christie, Koymans, Chanard, Lasgouttes, and Kaufmann (2016) studied the public opinion on driverless shuttles in two modes, a self-service mode and a shared mode. The indicators of acceptance were found to be willingness to pay, waiting time, vehicle speed, distance, and time to the nearest stop. The users did not experience the absence of a driver as an issue. The respondents found autonomous vehicles to be particularly user-friendly, futuristic, functional, and aesthetic. However, they sometimes considered the vehicle speed to be too slow. For safety, security, and pedagogical reasons, the vehicles in trials run at a low speed during the first phases, and an operator must be on board until it is proven that there are no risks and passengers feel safe enough to travel with them (Smartfeeder, 2017; CityMobil2, 2016; SOHJOA, 2017). The respondents were in general positive but reactions at administrative and regulatory levels were less enthusiastic (Christie et al., 2016). Madigan et al. (2016) also studied the acceptance of driverless shuttles in the framework of the FP7 European project CityMobil2 (2016). The objective was to evaluate the users' expectations concerning the performance and usability of the vehicle automation system and their intention to use the vehicles. The results also showed that performance was the most important factor, but social influence, usability, safety, and comfort were also found to be relevant factors. Piao et al. (2016) also investigated public attitudes after demonstrations carried out in La Rochelle, France. More than half of the people surveyed stated that they would consider using driverless vehicles if they become available, with 75% being more interested in owning a driverless car, and 25% in sharing it through services such as car-sharing, car-pooling, or taxis. Nordhoff, Merat, Van Arem, and Madigan (2017) found during the Citymobil2 demonstration in Germany that people found the shuttles useful, but when comparing their mode use, the perceived usefulness and ease of use declined. The elderly found the shuttles less easy to use. The authors recommended having a safety button inside the vehicle to increase trust among users and discussed the consequences of misuses of such safety features that may hamper general acceptance. During trials of driverless shuttles in Finland, Salonen (2018) found that users assessed traffic safety to be better in the shuttles than in a conventional bus with a driver. They were mostly concerned about personal in-vehicle security. Krueger, Rashidi, and Rose (2016) investigated the characteristics of users who were likely to adopt and pay for shared vehicles with or without ride sharing. The results indicated that travel cost, travel time, and waiting time were the critical determinants for use and acceptance. Shared vehicles with ride sharing may be more likely to be adopted by young individuals and individuals who are used to multimodal mobility. Respondents who often travelled in private cars were relatively more likely to choose the option without ride sharing. During the SOHJOA project, a first trial of driverless buses was operated in traffic in Finland and a survey was conducted among the users. The results of the trial revealed that younger adults mostly found the ride pleasant and were more positive concerning the inclusion of driverless shuttles in the public transport network. However, the speed of 12 km/h was found to be too slow, and the acceptable distance for such trips was found to be around 400 m and over. Most of the users were willing to pay around €0.30–0.50 extra for the service (Pöllänen, 2017).

The number of pilot studies in open and mixed traffic has been quite limited, have lasted for very short periods of time, and were not able to demonstrate the usefulness of a flexible and fast transport service. Safe integration in real traffic remains quite theoretical, and the transport contexts in which driverless buses would or would not be found appealing by the public are not yet known.

3. Research study

This study is part of the Norwegian project Smartfeeder (2017), owned by the Norwegian Railway Administration and financed by the Research Council of Norway, in which four pilots demonstrating driverless shuttles have been evaluated. The shuttles are intended to provide links to public transit modes. They are available to operate at rush hour times over short distances. The general assumption for the present study was that if the public network becomes less fragmented with driverless shuttles, the public might be less reluctant to use public transit and there will be a mode change from private cars to shared modes, assuming that driverless shuttles would drive safely either from home or work to public transit or directly from home to work (a door-to-door service) and would allow users to save time.

The objective was to investigate the views of individuals who do not often use public modes of transit regarding the usefulness of driverless shuttles and to examine if the provision of better access to public transit (thanks to the connection provided by shuttles) would make them consider public transit in the future.

Table 1 below presents the research questions addressed in the survey. The survey is presented in the Appendix A.

Socio-demographic variables are addressed from question 20 to question 27.

3.1. Method

3.1.1. Procedure

The objective was to investigate the views of individuals who do not often use public transit modes. Men and individuals with a car at their disposal are therefore overrepresented. The results are therefore affected by the choice of the sample, in that they represent individuals who might be reluctant to use any form of shared transport. The respondents often use their cars and are representative of those who will be the most difficult to convince to adopt public modes of transit. The objective was to examine if better access to public transit will make them abandon their private car and use public transit.

An online questionnaire was distributed to the members of the Norwegian Automobile Federation (NAF). This association had approximately 500,000 members in 2018. The participants were informed about the online survey through the NAF's website.

Table 1
Research questions addressed in the survey.

Research questions	Survey questions
RQ1: Do respondents perceive the shuttles as useful?	Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13
RQ2: Do individuals intend to use public transit modes more often if shuttles provide better access to them?	Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14
RQ3: What kind of benefits do individuals expect from driverless shuttles?	Q11, Q12, Q15
RQ4: Are individuals willing to see more automation in future buses?	Q16
RQ5: Do individuals perceive the shuttles as a safe and secure transport mode?	Q15, Q16, Q17
RQ6: Do individuals trust the ability of authorities to reduce accident risks with driverless shuttles?	Q15, Q17, Q18

3.1.2. Sample

The sample is composed of individuals aged from 19 to 93 years old ($M = 60.9$, $SD = 13.6$); 0.6% did not provide information about their age. Of the 1419 respondents, 80.7% were males and 18.1% were females, with 1.2% preferring not to answer. Table 2 below illustrates the proportion of males and females and their educational level. The results showed that 99.7% of the sample ($n = 1415$) reported having a driving licence.

3.1.3. Limitations of the study

The members of the Norwegian Automobile Federation are individuals who use their cars to travel to work more often than the rest of the population. They are not representative of the whole population in terms of travel habits, gender, income, and age. The Norwegian population consists of nearly 5.3 million residents (Statistics Norway, 2018). About 51.4% are women, and the distribution between age groups is quite similar, with higher proportions for the age groups of 30–49 years old (27%) and 50–59 years old (13%). According to a survey carried out by Hjorthol & Engebretsen in 2014, about 73% of men and 66% of women over 18 years old had a driving license. About 82% of the Norwegian population live in areas with more than 200 inhabitants. Men in general and retired men in particular are overrepresented in the sample and might have a higher income than the average citizen. Differences between men and women should be interpreted with caution in this study, since the number of women in the sample is low and might affect the reliability of the comparison between genders.

The implementation of shuttles in Norway is not primarily planned for the current users of public transit or for people who already walk or cycle (Smartfeeder, 2017). As feeders to public transit, shuttles are intended to induce a modal shift from private cars to public transit by improving the access to public transit. One could argue that the members of NAF could be considered an appropriate target in the aim of understanding whether car users would be willing to change their habits if such connections to public transit were provided. However, the present study cannot investigate the differences between users of public transit and users of private modes.

3.1.4. Questionnaire

The questionnaire was divided into two main parts related to transport mode use and driverless shuttles. The first part concerned the accessibility of public transit near residential areas and workplaces. The respondents were asked how far away their workplace is from home and how often they used public (bus, train, subway, tramway, ferry) and private transit modes (car, motorcycle, bicycle, and walking) on a five-point evaluation scale ranging from 'never' to 'very often'. They were also asked, 'How often do you use the following transport modes to travel to your workplace/place of study?' In addition, the questionnaire contained an 11-factor measurement instrument intended to examine transport priorities. The respondents were asked how important the following aspects were for their choice of transit mode: punctuality, frequency, travel time, cost, comfort, flexibility, availability, safety, security, and environmental issues. A five-point evaluation scale ranging from 'not at all important' to 'very important' was used. The respondents were also asked to assess their own experience with public transit using the same criteria. The second part is related to driverless shuttles and their usefulness. First, the respondents were asked if they had had the opportunity to test shuttles before, or if they had heard of them. They were asked how likely they thought it was that they would use public transit modes more if driverless shuttles provided transport services to the public transit. In addition, the respondents were asked about the benefits they expect from the implementation of driverless shuttles. They were asked to select an answer on a five-point evaluation scale ranging from 'very unlikely' to 'very likely' for four items: fewer traffic accidents, less car traffic and pollution, shorter travel time, and increased mobility (opportunities to travel more) for the elderly and people with disabilities. Respondents were also asked to compare automated shuttles with traditional bus services in terms of whether they would be more worried about traffic safety (accidents); security regarding violence, robbery and harassment; security related to terrorism; and security related to data privacy, on a five-point scale evaluation ranging from 'lower' to 'higher'. Finally, they had to evaluate their own trust in authorities' ability to reduce

Table 2
Number of respondents in the sample by age, gender, and education. Basic level = high school or below, high level = completed university degree. Sparsely populated areas = under 2000 inhabitants, sparsely populated urban areas = between 2000 and 100,000 inhabitants, and densely populated areas = over 100,000 inhabitants.

Age groups	Gender			Education		Residential location			
	Males	Females	No answer	Basic	High	Sparsely populated areas	Sparsely urban areas	Densely populated areas	No answer
18–24	7	2	0	7	2	3	6	0	0
25–34	32	12	1	22	23	17	24	4	0
35–44	87	29	4	50	70	35	81	3	1
45–54	199	72	4	131	144	98	168	5	4
55–64	251	53	3	154	153	120	182	5	0
65–74	379	69	2	194	256	180	240	26	4
Over 75	185	18	2	84	121	70	97	36	2
No answer	5	2	1	2	6	4	3	0	1
Total	1145	257	17	644	775	527	801	79	12

the risks of accidents with driverless shuttles on a trust scale from 'no confidence at all' to 'very high confidence'. In addition, the respondents were asked about demographic variables including gender, age, income, and education.

3.2. Statistical analysis

Descriptive statistics were used to reveal the characteristics of the sample. The results were analysed with the IBM SPSS statistics 25 software. By convention, the cut-off point for the statistical results is a p-value of 0.05. The sample is composed of 99.7% members who own or have a car at their disposal ($n = 1415$). About 44.3% work full time and 44.4% are retired. The respondents were asked to give the number of kilometres between their home and work. For 2.2% of the respondents, the speed calculated was not realistic and the hypothesis was that they were super commuters who stay away from home a few days per week (e.g. working offshore or travelling to their office via other modes such as airplanes). Of the respondents who work or are students, 73.8% used their car to travel to work or to their study place often or very often ($n = 516$). Among those who work, 70.8% used their cars to travel to work the last time they did so ($n = 495$) and drove a mean distance of 19.6 km ($SD = 19.4$) in 22.6 min ($SD = 17.6$). The average distance is higher than the value found for the whole population in 2013/14, i.e. 14.5 km (Hjorthol & Engebretsen, 2014).

3.2.1. Familiarity with driverless shuttles

Driverless shuttles were defined to the respondents as follows: self-driving minibuses, also referred to as driverless (with no driver on board), that can drive automatically on short trips (<3 km). Respondents were asked if they had heard about driverless shuttles before this survey. The results showed that 91.8% of the respondents had heard of driverless shuttles before the survey ($n = 1302$), and 1.4% had even tried them. The results illustrate that the public is aware of the new technologies, and this study provides opportunity for authorities and other stakeholders to evaluate the current acceptance and the future intention to use the vehicles before making large investments in their implementation.

3.2.2. Usefulness of driverless shuttles

Table 3 below presents the results of the question about how the respondents thought driverless shuttles would be most useful for them. They could choose two options. Otherwise, they could choose to answer 'I do not think there is a need for such vehicles'.

A significant share of the respondents (48.9%) did not evaluate the driverless shuttles as useful. Half of the respondents who work or are students (50%, $n = 350$), or are retired (47.0%, $n = 296$) did not consider the shuttles useful. Only about of a fourth (28.8%) of the respondents thought that the vehicles would be useful between residential areas and public transit; about one-fifth (21.8%) thought that they would be useful between parking places and public transit, and a lower proportion (12.3%) between workplaces and public transit. A small share of the respondents (6.8%) proposed a door-to-door service with shuttles driving directly from home to work or other transport links (to the airport, to the shop, in the city centre).

3.2.3. Likeliness to use public transport modes more

Fig. 1 below shows the results of the question about the respondents' likeliness to use the driverless shuttles. The respondents were asked how likely they thought they were to use public transit more if driverless shuttles provided transport services between public transit and parking places, workplaces, and residential areas (if all the requirements are met regarding traffic safety and security issues). Slightly over half of those (56.2%) who evaluated them as useful stated that it is somewhat likely or likely that they will use public transit more. In this group, 55.6% of the respondents who work or are students ($n = 306$) and 56.4% of the retired people ($n = 296$) declared the same. Statistical tests (Mann-Whitney U and Kruskal-Wallis tests) demonstrated that there are no significant differences between gender and age groups.

3.2.4. Expected benefits of driverless shuttles

Fig. 2 below presents the results regarding the benefits the respondents thought would result from the implementation of driverless shuttles. Two expected benefits were believed to be somewhat likely or likely to occur with driverless shuttles: increased mobility (opportunities to travel more) for the elderly and people with disabilities and less car traffic and pollution. Of the respondents who answered the question about the mobility of the elderly and about pollution, 57.9% and 50.2% respectively found it to be somewhat likely or likely to occur. The majority were less confident about the third benefit (i.e.

Table 3
Respondents thoughts considering the usefulness of driverless shuttles ($n = 1419$). The respondents could choose maximum two options.

Usefulness of driverless shuttles	Frequency	Percent (%)
Between parking places and public transit	309	21.8
Between workplaces and public transit	179	12.3
Between residential areas and public transit	409	28.8
Other	97	6.8
I do not think there is a need for such vehicles	694	48.9

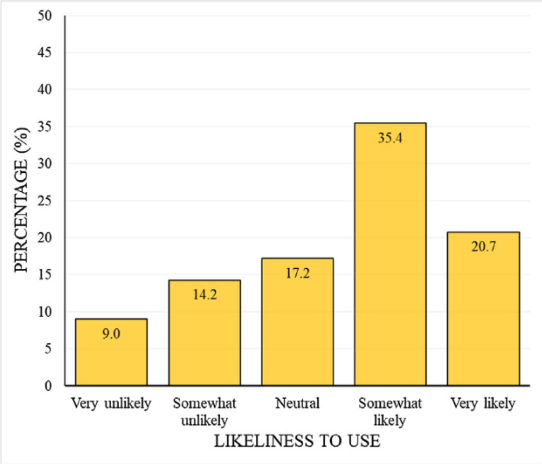

Fig. 1. Likeliness to use public transit more if driverless shuttles provide transport services between public transit and parking places, workplaces, and residential areas ($n = 624$).

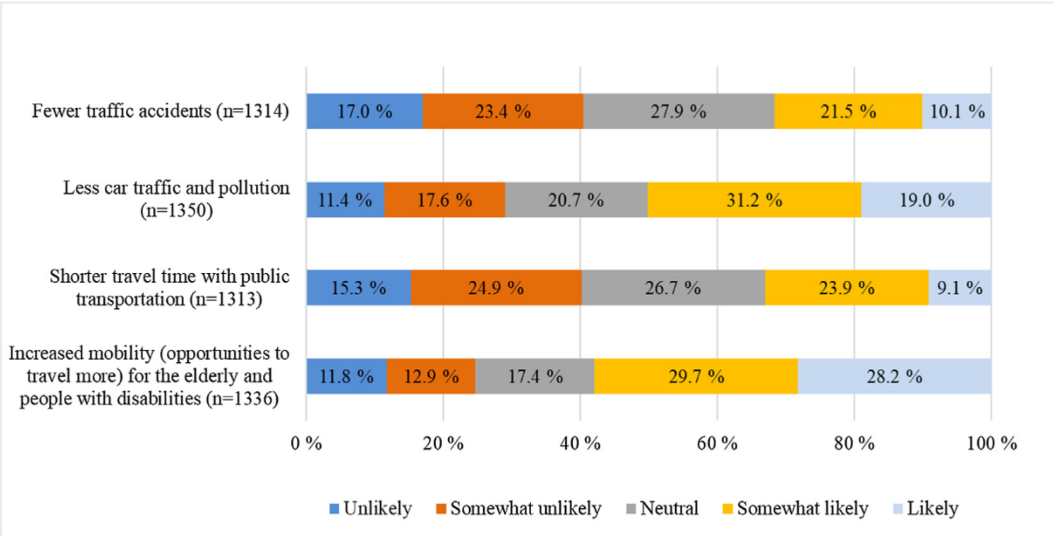

Fig. 2. Expected benefits of driverless shuttles.

shorter travel time with public transport). The results showed that 40.2% of the respondents who answered the question found it somewhat unlikely or unlikely. The respondents also felt that the benefit of fewer traffic accidents was somewhat unlikely or unlikely to occur. About 40.4% of the respondents who answered the question found it somewhat unlikely or unlikely to occur.

No differences were found related to gender assuming that the tests are significant for $p < 0.05$. Significant Kruskal-Wallis tests showed that the mean ranks increased among people with a higher education ($H = 22.670$, $df = 4$, $p < 0.001$) for the second benefit (i.e. less car traffic and pollution). Among respondents with the highest education level ($n = 232$), 57.7% thought that was very likely or somewhat likely that driverless shuttles would contribute to less car traffic and pollution. For the other benefits, the mean ranks from the Kruskal-Wallis tests did not increase with the education level. The Kruskal-Wallis tests revealed that the mean ranks increased for the fourth benefit (i.e. increased mobility for the elderly and people with disabilities) with people living in more populated areas ($H = 42.480$, $df = 16$, $p < 0.001$). The results showed that 48.6% of respondents living in densely populated areas ($n = 74$) thought that it was very likely or somewhat likely that driverless shuttles would contribute to increase mobility (opportunities to travel more) for the elderly and people with disabilities.

3.2.5. Trust in automation

Trust in automation is a key factor in the intention to use driverless shuttles. The respondents were asked to choose how automated they would prefer the buses to be in the future ($n = 1419$). They could choose between five scenarios.

The results presented in Fig. 3 shows that 54.9% of the respondents still preferred to have a driver in buses and 16.3% thought that buses should become self-driving, but they would like there to be a driver inside the bus to take over if necessary. About 9% thought that driverless buses should be allowed to drive only in bus lanes and 8.5% agreed that driverless buses controlled by an operator from a control room is the best scenario. Only 6.1% perceived that driverless buses with no human steering was the best option for the future.

A significant difference was found between men ($n = 1083$) and women ($n = 247$) with an independent t-test (t (1328) = 3.155, $p < 0.001$). The results showed that 83% of women thought that there should be a driver in the bus (scenarios 1 and 2) against 73.0% of men whereas 17.0% of men accepted the shuttles to be without human steering (scenarios 4 and 5) against 8.9% of women. The results should however be taken with precaution since the number of women in the sample is low and was not representative to population. Significant differences related to education, age and residential locations were also found. Kruskal-Wallis tests showed that people with higher education ($H = 50.097$, $df = 4$, $p < 0.001$), people living in highly populated areas ($H = 18.613$, $df = 4$, $p = 0.001 \leq 0.05$), and the younger generations ($H = 16.956$, $df = 6$, $p = 0.009 \leq 0.05$) were more willing to accept buses with no driver.

3.2.6. Worry about using driverless shuttles

Risk perception and worry for safety and security risks have been found to be an important variable for transit mode use in previous studies (Kummeneje & Rundmo, 2018; Nordfjærn, Simsekoglu, Lind, Jørgensen, & Rundmo, 2014; Roche Cerasi et al., 2011). The objective of this question was to measure the anticipatory worry which causes people to feel anxious when thinking about certain experiences and which results from the cognitive assessment of risk. Respondents were asked to evaluate which of four items related to safety and security they were most worried about when thinking about travelling via driverless shuttles (compared to traditional buses with a driver). About 52.5% of the sample were more worried about item 1, traffic safety (accidents), while 54.0% were more concerned about item 2, security related to violence, robbery, and harassment. About 50.5% were more concerned about item 4, security related to hacking and terrorism, whereas 38.0% of the sample were similarly worried concerning data privacy. In Norway, users of public transit pay with a smart card or an application on their mobile phone. It is likely that data privacy might not be considered as a new issue. Table 4 below depicts the significant difference related to gender as measured by Pearson chi-square tests ($p < 0.005$). The mean values on a scale from 1 (much less worried) to 5 (much more worried) indicate that women are more worried than men about the four items, which is similar to the results of previous studies examining differences in concerns about public and private transport modes (Nordfjærn et al., 2014; Roche Cerasi et al., 2011).

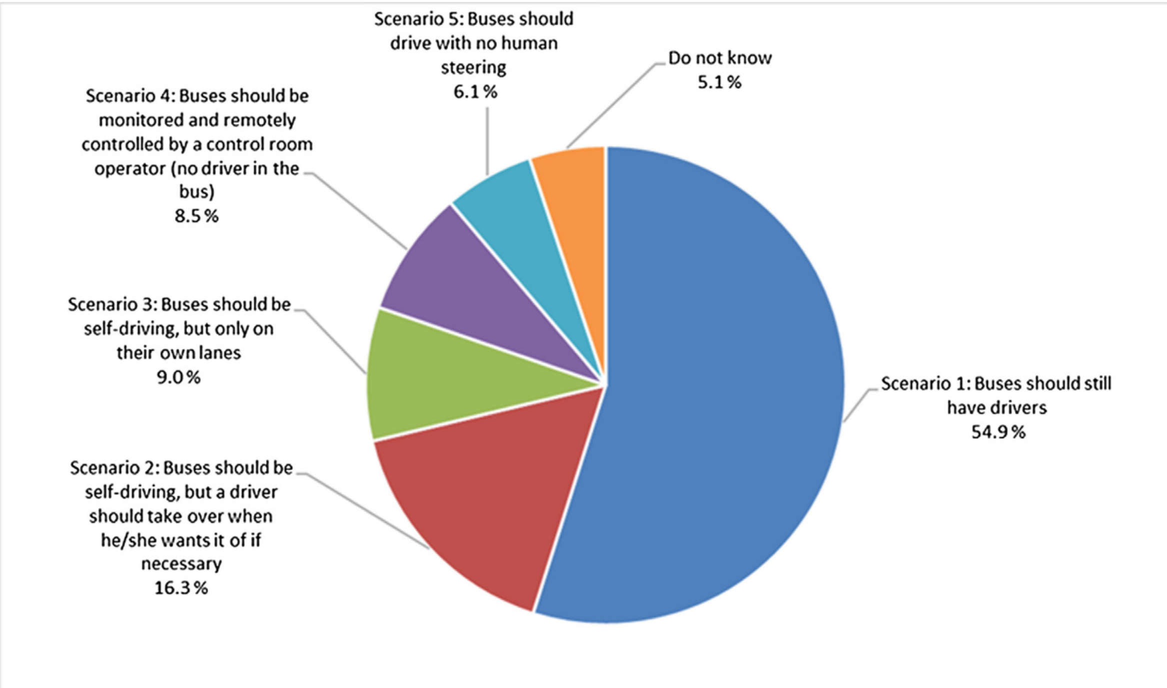

Fig. 3. Respondents' preferences considering five alternative scenarios ($n = 1419$).

Table 4
Pearson chi-square tests on differences in levels of worry about four items.

Variables	Items		N	Pearson Chi-square	Mean (SD)	df	p
Males	Traffic safety (accidents)	1	1055	41.818	3.54 (1.078)	4	<0.001*
	Security (violence, robbery, and harassment)	2	1039	38.282	3.64 (1.055)		<0.001*
	Security (hacking and terrorism)	3	1001	32.198	3.65 (1.040)		<0.001*
	Security (data privacy)	4	963	17.018	3.41 (0.996)		0.002*
Females	Traffic safety	1	238		3.97 (1.071)		
	Security (violence, robbery, and harassment)	2	232		4.09 (0.956)		
	Security (hacking and terrorism)	3	219		3.99 (1.049)		
	Security (data privacy)	4	204		3.71 (1.008)		

* $p < 0.05$.

Fig. 4 below presents the results for men and women. The results showed that 54% of men and 69.7% of women were worried about item 1, traffic safety. Concerning item 2, security issues regarding violence, robbery, and harassment, 56% of men and 73.7% of women were worried about it. About 55.9% of men and 66.2% of women were concerned about item 3, hacking and terrorism. Worry about item 4, data privacy, was not evaluated as highly as the others: 39.7% of men and 51.0% of women were worried about data privacy.

3.2.7. Trust in authorities

Fig. 5 below shows the results concerning the respondents' trust in the ability of the authorities to reduce the risk of accidents with driverless shuttles ($n = 1340$). The mean value is 2.50 ($SD = 0.992$) on a scale from 1 (very low trust) to 5 (very high trust). The results showed that 50.9% of the respondents had no trust or low trust in authorities and 16% had high or very high trust, while 33.1% had a neutral view. Significant differences related to education ($H = 28.869$, $df = 4$, $p < 0.001$) and residential locations ($H = 11.604$, $df = 4$, $p = 0.021$) were found with Kruskal-Wallis tests. The mean ranks indicate that people with higher education and people living in densely populated areas have greater trust in the authorities. No significant differences were found with statistical tests related to age, occupation, or gender.

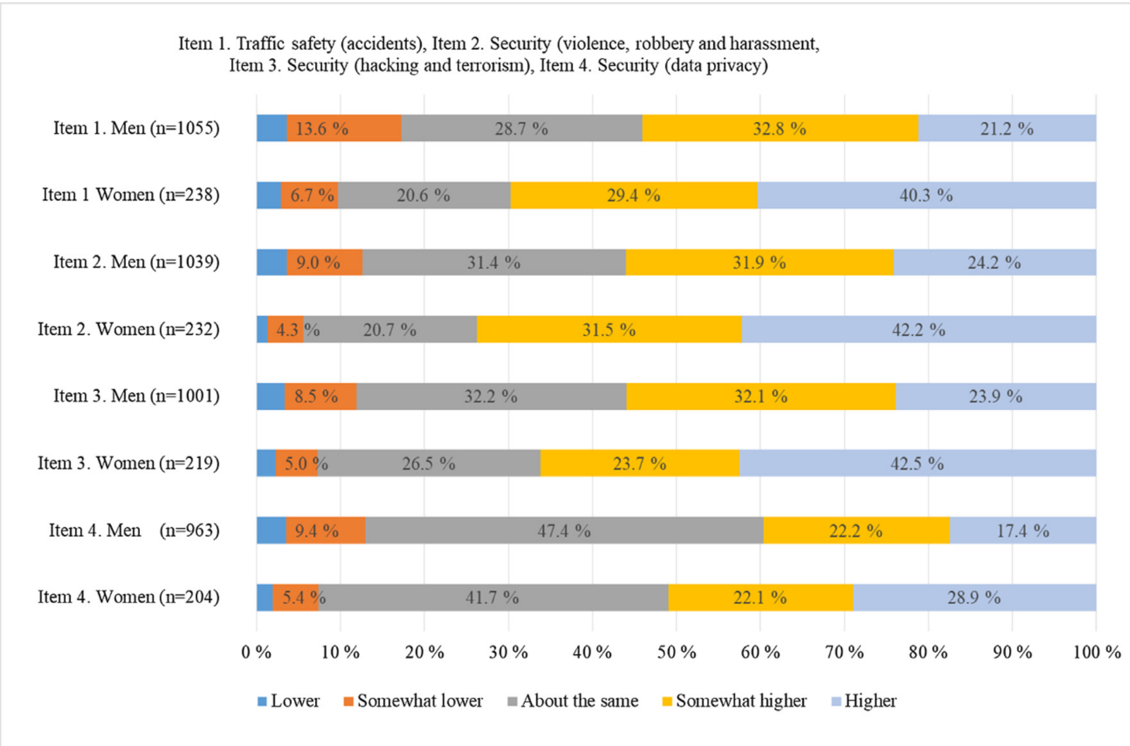

Fig. 4. Worry about driverless shuttles compared to traditional buses with a driver.

3.2.8. Priorities for mode use

Table 5 below shows the dimensional structure with regard to the importance of factors relevant to prioritizing mode use (Rundmo et al., 2011). A dimensionality reduction factor analysis was performed on 11 factors after excluding the factor accessibility, based on reliability analysis (Cronbach's alpha = 0.906). Four dimensions were identified, and the result of the Bartlett's test is significant (KMO and Bartlett's test = 0.875, $p < 0.001$). Dimension 1 is composed of 4 factors related to transport convenience and efficiency (Frequency, punctuality, travel time, and cost), explaining 52.0% of the variance. Dimension 2 is composed of three factors related to safety and security, explaining 15.5% of the variance. Dimension 3 is related to health and environment, explaining 7.3% of the variance. Dimension 4 is composed of 2 factors related to comfort and flexibility, explaining 6.8% of variance.

Fig. 6 below shows the differences between the two clusters of likeliness to use public transit more thanks to the implementation of driverless shuttles with regard to factors that are important when choosing a mode ($n = 1286$). Cluster 1 members are those who stated that it was unlikely that they would use public transit more, and cluster 2 members are those who stated the opposite, that it was likely. Fig. 6 depicts the *z*-scores. The further to the positive side away from zero, the more important the dimension is reported to be, and vice versa.

There was an overall significant difference in the four dimensions for the two clusters (Wilk's $\lambda = 0.943$, $p < 0.001$). Tests of equality of group means revealed that two aspects were not significant (travel time and comfort). Fig. 6 shows that members of cluster 1 ($n = 923$) assigned lower priorities to all the aspects, whereas cluster 2 members ($n = 363$) assigned high priority to health and the environment and to the other aspects as well. The difference between the clusters in the dimension 'comfort and flexibility' is not very large; this dimension has been found in previous studies as an important aspect for car users (Rundmo et al., 2011), of whom the sample in this study is mostly composed.

There are significant differences between the clusters concerning their concerns in the four aspects (safety, violence, terrorism, and data privacy) and their trust in authorities, as well as the level of automation they would like to see in future buses. Cluster 1 members rated their worry about the four aspects ($p < 0.001$) more highly, while cluster 2 members were more willing to have higher autonomy in buses ($p < 0.001$) and have more trust in the authorities ($p < 0.001$). There is no significant difference related to gender between the clusters. Cluster 2 members have higher levels of education ($p = 0.005$) and live in more populated areas ($p = 0.029$).

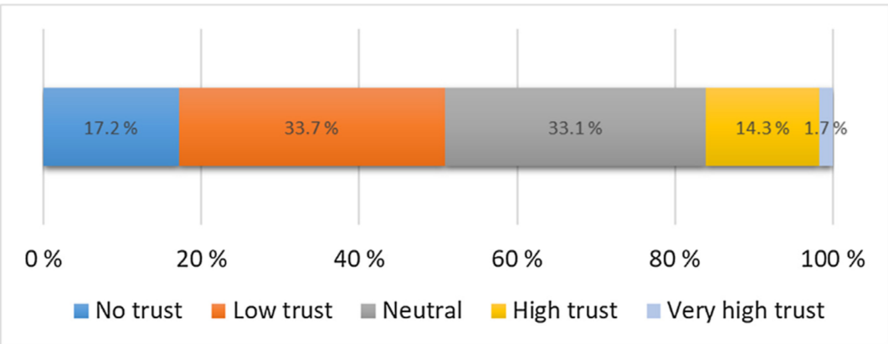

Fig. 5. Trust in the ability of the authorities to reduce the risk of accidents with driverless shuttles ($n = 1340$).

Table 5
Dimensional structure of factors relevant for prioritizing transport mode use.

Factors	Dimensions			
	1	2	3	4
Punctuality	**0.888**	−0.006	0.040	−0.014
Frequency	**0.941**	−0.073	0.051	−0.033
Travel time	**0.751**	−0.054	−0.045	0.210
Cost	**0.741**	0.198	−0.058	−0.031
Comfort	0.007	0.165	−0.095	**0.829**
Flexibility	0.045	−0.099	0.111	**0.874**
Safety (accidents)	0.150	**0.618**	0.253	0.092
Security (violence, robbery, and harassment)	0.022	**0.944**	0.009	0.015
Security (terrorism)	−0.025	**0.960**	−0.003	0.013
Health and environment	−0.003	0.060	**0.958**	0.013

The bold values indicate to which dimension the factor belongs.

Fig. 6. Cluster differences in priorities (mean value z-scores). Cluster 1 members ($n = 923$) are those who stated that it was unlikely that they would use public transit more and cluster 2 members ($n = 363$) are those who stated that it was likely.

There is no significant difference between the clusters concerning the use of a car. In all cases, cluster 2 members use public transit (bus, train, subway), cycle, and walk more often ($p < 0.05$). They are therefore more familiar with public transit than cluster 1 members.

Concerning the benefits, cluster 2 members thought that driverless shuttles would bring the four benefits in question: fewer traffic accidents ($p < 0.001$), less car traffic and pollution ($p < 0.001$), shorter travel time ($p < 0.001$), and increased mobility for the elderly ($p < 0.001$).

4. Results

The research questions were the followings:

RQ1: Do individuals perceive the shuttles as useful?

Previous studies have found a positive attitude towards automated vehicles (Liljamo et al., 2018). Bansal et al. (2016), Hulse et al. (2018), and Liljamo et al. (2018) showed that men, younger adults, highly educated individuals, and people living in densely areas had a more positive attitude towards automated vehicles. In addition, Liljamo et al. (2018) and Schoettle and Sivak (2014) found that men expressed a more positive attitude than women.

Nordhoff et al. (2017, 2018) also found that the respondents of a large survey in several countries rated driverless shuttles positively, while the elderly rated the shuttles less easy to use. Nordhoff, De Winter, Payre, Van Arem, and Happee (2019) conducted semi-structured interviews of 30 people who had experienced the shuttles in Germany and found that they were positive about the idea of using the shuttles as feeders to public transport, but the authors concluded that the participants also had idealized expectations about the technological capabilities of the shuttles.

The results of the present study indicate that a significant share of the respondents (48.9%) did not evaluate the driverless shuttles as useful, and higher educated individuals were more positive towards shuttles. The respondents also did not consider the shuttles a form of transport that could ease their travels, either as feeders to public transport or if providing door-to-door services. These findings are in line with Nordhoff et al. (2017, 2018), who showed that the perceived usefulness and ease of use declines when comparing the shuttles to current modes of transport.

RQ2: Do individuals intend to use public transit more if shuttles provide better access to it?

Both the frequency of the shuttles and the location of stops are important indicators of future implementation. However, the shuttles' potential to attract more public transit users and induce a modal shift from private to public transit is uncertain. Only a medium share of those (56.2%) who evaluated the shuttles as useful stated that with the provision of shuttles, they would use public transit more. As found in previous studies related to transport mode use and preferences (Roche Cerasi, Rundmo, Sigurdson, & Moe, 2013; Rundmo et al., 2011), improving access to public transit may be not enough to stimulate a modal shift from private cars to public transit. This should be accompanied with measures to reduce the dependency on private cars (e.g. tolls and parking fees at workplaces).

RQ3: What kind of benefits do individuals expect from driverless shuttles?

Shuttles can provide seamless transport by improving the accessibility of public transport stops. In the present study, the respondents found this new form of transport to have the potential to improve the mobility of seniors and to reduce car traffic and pollution, which is important in urban environments. It is important to anticipate the needs and examine tailored solutions that could facilitate the mobility of an ageing population and those with disabilities or medical conditions. These populations will become more frequent users of driverless shared transit (Harper, Hendrickson, Mangones, & Samaras, 2016).

RQ4: Are individuals willing to see more automation in future buses?

Slightly over half of the respondents (54.9%) in the present study preferred the presence of a driver and did not expect this form of transport to be relevant for them. The results are in accordance with previous studies on automated vehicles (Liljamo et al., 2018) including shuttles (Salonen, 2018), indicating that the presence of a driver and manual drive are important factors for the perception of safety and security risks.

RQ5: Do individuals perceive the shuttles as a safe and secure transport mode?

Similar to previous studies, the results illustrated that individuals are concerned about the safety and security of driverless shuttles (Merat, Louw, Madigan, Wilbrink, & Schieben, 2018; Nordhoff et al., 2017; Salonen, 2018), and that women are more worried than men in general regarding the safety and security of transport modes (Roche Cerasi et al., 2013; Rundmo et al., 2011).

RQ6: Do individuals trust the ability of authorities to reduce accident risks with driverless shuttles?

A substantial share of the respondents (48.1%) had no trust or low trust in the ability of the authorities to reduce the risks of accidents with shuttles. These results were found to be lower than the rate of confidence in the national government provided by the Trust, Policy, and Trust (2017), with 60% of Norwegian citizens trusting their government in 2015, Norway being one of the countries with the highest confidence value.

5. Discussion

5.1. Modal shift from private cars to driverless shuttles and public transit

Previous studies have demonstrated that most people have a positive attitude towards automated vehicles (Liljamo et al., 2018; Schoettle & Sivak, 2014). However, a positive attitude does not imply that people will be willing to adopt them. In the present study, the results were affected by the choice of the sample, in that the respondents represent individuals who might be reluctant to adopt any form of shared transport. They use their cars often and belong to one of the groups that will be the most difficult to convince to adopt public transit. The results indicated that better access to public transit is not enough to induce a modal shift, and the respondents did not evaluate driverless shuttles as useful. The restricted driving conditions and the maximum speed of 12 km/h were found to be important factors for the perceived usefulness of the shuttles (Liljamo et al., 2018; Madigan et al., 2016; Salonen, 2018). While shuttles provide greater flexibility, the ride-sharing option (i.e. travelling with other passengers) and the travel time with public transit remain barriers to adopting driverless shuttles (Krueger et al., 2016; Roche Cerasi et al., 2013; Rundmo et al., 2011). The respondents recognised that shuttles have the potential to facilitate the mobility of seniors. Other potential niches should be investigated.

5.2. A safe and secure new form of transport

The results of the present study indicate that transport mode use and worry about safety and security issues are key factors for the adoption of driverless shuttles. Integration of shuttles into mixed and open traffic at a low speed of 12 km/h is a major issue. They may be perceived as dangerous or having the potential to cause inconvenience to other vehicles (Piao et al., 2016). Accidents with driverless vehicles are widely reported in newspapers (Goggin, 2018; Lambert, 2018; Lee, 2018; McDermid, 2018), making individuals uncertain about the effectiveness of the vehicle automation system and the ability of the authorities to put measures in place to ensure a safe and successful implementation. If any incidents or accidents occur in the near future, it may then influence the general perception of automation and slow down the uptake of shuttles. Low speed and emergency stops are precautionary measures, but they might also alter the traffic environment of cars and drivers, increasing risks for all road users, and especially for pedestrians and cyclists. For example, drivers may lose patience and overtake slow-moving buses at high speed.

6. Conclusion

Distrust towards the driverless shuttles needs to be addressed. The question is how driverless shuttles should be perceived, and if they should be perceived as less risky compared to traditional buses. It is also important to make progress on the legislative framework and to clarify the responsibilities of all parties. Future studies should investigate the markets for driverless shuttles (e.g. in rural areas or for the elderly) and develop measures to increase their attractiveness and acceptance. In addition, to convince the population, it is important to prove the benefits for the environment and traffic safety and to develop viable business models and solid public-private partnerships. It is unlikely that driverless shuttles can be implemented free of charge without large public subsidies. Then, the question remains whether there is a reasonable ticket price that could support a viable operational model and cost structure with or without public subsidies.

Distrust towards the authorities in their ability to reduce the risks of accidents may be a major reason for not being willing to use automated shuttles. This concern should be addressed by the authorities and bus operators. We recommend that the authorities and cities communicate more about how they will protect road users and ensure the safe implementation of shuttles in mixed traffic. They can provide information on the safety and security requirements for the vehicle automation system, laws and regulations, and measures (e.g. infrastructure) that are put in place to avoid any unexpected events. They could, for example, explain the processes of how applications are submitted to the authorities concerned, the comprehensive risk analysis, the site inspection and route planning for the shuttles, and the requirements for shuttle staff. Allowing for dialogue between pilot partners and authorities and a process to put safe pilot studies in place are crucial for the population.

Appendix A. Questionnaire

Hi, we are conducting a survey on automated buses (also referred as driverless buses) for SINTEF. We hope that you can take 8–12 min to answer the following questionnaire.

1 Do you have a driver's licence?	
Yes	○
No	○

2 Do you own or do you have at your disposal...?	
A car	☐
A motorcycle/Moped	☐
A bicycle	☐
No, none of these	☐

3 What is your main occupation?	
Full-time employment	○
Part-time employment	○
Working from home	○
School/student	○
Not employed/on disability	○
Retired	○
Other	○

4 How many kilometres is it approximately from your home to your workplace/place of study?	
Number of kilometres	☐☐☐

5 How many minutes does it take approximately to walk from your home to the nearest … if you would use public transport to travel to your workplace/place of study? Please choose the modes that you could use even if you choose other means yourself. Do not answer if it takes more than one hour or if it is not relevant.	
Bus stop	☐☐
Subway station	☐☐
Tram station	☐☐
Train station	☐☐
Ferry station	☐☐

6 How many minutes does it take approximately to walk from your workplace/place of study to the nearest ... if you would use public transport to travel back home? Please choose the modes that you could use even if you choose other means yourself. Do not answer if it takes more than one hour or if it is not relevant.	
Bus stop	☐☐
Subway station	☐☐
Tram station	☐☐
Train station	☐☐
Ferry station	☐☐

7 Which transport modes did you use the last time you travelled from home to your workplace/place of study? Please choose all the modes you used.	
Walked all the way	☐
Walked part of the way	☐
Car, as a driver	☐
Car, as a passenger	☐

7 Which transport modes did you use the last time you travelled from home to your workplace/place of study? Please choose all the modes you used.	
Bicycle	☐
Motorcycle/moped	☐
Bus	☐
Tram	☐
Subway	☐
Train	☐
Boat/ferry	☐
Other	☐

8 How many minutes did you spend from door to door to travel to your workplace/ place of study?	
Number of minutes	☐☐☐☐

9 How often did you use the following means of transport to travel to and from your workplace/place of study over the past year?

	Never	Rarely	Sometimes	Often	Very often
Bus	○	○	○	○	○
Train	○	○	○	○	○
Subway	○	○	○	○	○
Tram	○	○	○	○	○
Ferry	○	○	○	○	○
Car, as a driver or passenger	○	○	○	○	○

9 How often did you use the following means of transport to travel to and from your workplace/place of study over the past year?					
Motorcycle/moped	○	○	○	○	○
Cycle	○	○	○	○	○
Walked all the way (pedestrian)	○		○	○	○

10 To what extent are these conditions important to you when choosing means of transport?

	Not important at all	Not important	Neither/nor	Important	Very important
Punctuality	○	○	○	○	○
Frequency	○	○	○	○	○
Travel time	○	○	○	○	○
Cost	○	○	○	○	○
Comfort	○	○	○	○	○
Flexibility	○	○	○	○	○
Accessibility	○	○	○	○	○
Safety (accidents)	○	○	○	○	○
Security related to violence, robbery, and harassment	○	○	○	○	○
Security related to terrorism	○	○	○	○	○

10 To what extent are these conditions important to you when choosing means of transport?					
Environmental consideration	○	○	○	○	○

Automated minibuses, also referred to as driverless minibuses (with no driver on board) can drive in autonomous mode on short trips (< 3 km) (a picture is provided).

11 Have you heard of automated minibuses before?	
No, I have never heard of automated minibuses before.	○
Yes, I have heard of them, but have never tried them myself.	○
Yes, I have heard of them, and I have tried one or more automated minibuses.	○

12 Where did you try one or several automated minibuses?
Please specify:

13 Where do you think automated minibuses would be most useful to you? Choose max. 2 answers	
Between parking places and public transit	☐
Between workplaces and public transit	☐
Between residential areas and public transit	☐
Other. Please specify:	Open
None. I do not think there is a need for such vehicles.	○

14 If all the requirements are met and the automated minibuses drive (without a driver on board) between public transit and parking places, workplaces, and residential areas…						
	Very unlikely	unlikely	Neither/nor	Likely	Very likely	Do not know
How likely is it that you would use public transit more	○	○	○	○	○	○

14 If all the requirements are met and the automated minibuses drive (without a driver on board) between public transit and parking places, workplaces, and residential areas…
if you get such an opportunity?

15 What value do you think automated minibuses (with no driver on board) would provide?						
	Very unlikely	Unlikely	Neither/nor	Likely	Very likely	Do not know
Fewer traffic accidents	○	○	○	○	○	○
Less car traffic and pollution	○	○	○	○	○	○
Shorter travel time with public transit	○	○	○	○	○	○
Increased mobility (opportunities to travel more) for the elderly and people with disabilities	○	○	○	○	○	○

16 To what extent do you think traditional buses should also be automated in the future? Please choose only one answer.	
Buses should still have drivers	○
Buses should be automated, but a driver should take over if he/she wants to or if necessary	○
Buses should be automated but should only drive in their own lanes	○
Buses should be monitored and remotely controlled by a control room operator (no driver in the bus)	○
Buses should drive with no human steering	○
Do not know	○

17 Automated minibuses will be provided with both an automatic payment system and a surveillance system with cameras on board. If you compare a journey on an automated bus to a traditional bus with a driver, would you be (as a passenger) more or less worried about:

	Much less	Less	The same	More	Much more	Do not know
Traffic safety (accidents)	○	○	○	○	○	○
Security (violence, robbery, and harassment)	○	○	○	○	○	○
Security (hacking and terrorism)	○	○	○	○	○	○
Security (data privacy)	○	○	○	○	○	○

	No trust	Low trust	Neither/ nor	High trust	Very high trust	Do not know
18 How much do you trust the ability of the authorities to reduce the risks of accidents with automated minibuses?	○	○	○	○	○	○

19 Do you have any comments about the survey or automated minibuses?
Open

20 What is your civil status?	
Married/cohabiting	○
Single	○
Prefer not to answer	○

21 How many adults (over 18 years old) live in your household, including yourself?	
Please write the number:	☐☐

22 How many children (under 18 years old) live in your household?	
Please write the number:	☐☐

23 What is your household's total annual income?	
Less than NOK 299,999	○
NOK 300,000-499,999	○
NOK 500,000-699,999	○
NOK 700,000-899,999	○
NOK 900,000 or more	○
Do not know / prefer not to answer	○

24 In what kind of place do you live?	
Isolated place (fewer than 200 inhabitants)	○
Small town with 200-1,999 inhabitants	○
Small town/town with 2,000-19,999 inhabitants	○
Large town/town with 20,000-100,000 inhabitants	○
City with over 100,000 inhabitants	○
Prefer not to answer	○

25 What is the highest level of education you have completed?	
Primary school	○

25 What is the highest level of education you have completed?	
Secondary school, vocational studies	○
Secondary school, general studies	○
University - lower grades (Bachelor's or similar)	○
University - higher grades (Master's or similar)	○

26 Are you a man or a woman?	
Man	○
Woman	○
Prefer not to answer	○

27 What is your age?	
Age	☐☐

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2019.09.002.

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