Research Paper

Autonomous vehicles and smart cities: future directions of ownership vs shared mobility.

Logistic regression to predict future use of AVs based on current transportation mode used.

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Abstract

Over the last decade, there has been increasing discussions about self-driving cars and how most auto-makers are racing to launch these products. However, this discourse is not limited to transportation only, but how such vehicles will affect other industries and specific aspects of our daily lives as future users such as the concept of work while being driven and productivity, entertainment, travel speed, and deliveries. Although these technologies are beneficial, access to these potentials depends on the behaviour of their users. There is a lack of a conceptual model that elucidate the acceptance of people to Self-driving cars. Service on-demand and shared mobility are the most critical factors that will ensure the successful adoption of these cars. This paper presents an analysis of public opinions in Nottingham, UK, through a questionnaire about the future of Autonomous vehicles' ownership and the extent to which they accept the idea of vehicle sharing. Besides, this paper tests two hypotheses. Firstly, (a) people who usually use Public transportation like (taxi, bus, tram, train, carpooling) are likely to share an Autonomous Vehicle in the future. Secondly, (b) people who use Private cars are expected to own an Autonomous Vehicle in the future. To achieve this aim, a combination of statistical methods such as logistic regression has been utilised. Unexpectedly, the study findings suggested that AVs ownership will increase contrary to what is expected, that Autonomous vehicles will reduce ownership. Besides, participants have shown low interest in sharing AVs. Therefore, it is likely that ownership of AVs will increase for several reasons as expressed by the participants such as safety, privacy, personal space, suitability to children and availability. Actions must be taken to promote shared mobility to avoid AVs possession growth. The ownership diminution, in turn, will reduce traffic congestion, energy and transport efficiency, better air quality. That is why analysing the factors that influence the mindset and attitude of people will enable us to understand how to shift from private cars to transport-on-demand, which is a priority rather than promoting the technology.

Keywords

Autonomous Vehicles, Ownership, Shared Mobility, Smart Cities, Urban transformation

1. Introduction

The world is witnessing a rapid technological development which is affecting the way we live, work and interact with each other. Technologies such as quantum computing, fifth-generation wireless technologies (5G), artificial intelligence (AI), Robotics and Internet of Things (IoT), have led to the emergence of possibilities and perspectives that help to tackle social, economic, and environmental challenges that are facing our cities. This, in turn, aids in the delivery of smart city objectives (Tryfonas and Askoxylakis, 2014), including creating sustainable environments, smart infrastructure, facilitating planning and decision making. Amongst the initiatives on developing smart infrastructure and which has proliferated in the last decade is Automated driving. Several studies have shown that the adoption of Autonomous Vehicles will bring a wide range of benefits such as independent mobility (Fagnant and Kockelman, 2015), tourism extension (Cohen and Hopkins, 2019), Innovative freight delivery (Alessandrini *et al.*, 2015), Comfort and entertainment services (Atzori *et al.*, 2018; Panagiotopoulos and Dimitrakopoulos, 2018), and Reduced congestions and increased accessibility (The House of Lords Science and Technology Committee, 2017; Joiner, 2018). However, access to these potentials depends on the behaviour and the acceptance degree of the users.

On the other hand, The full adoption of AVs has the potential to change urbanisation patterns as well as urban design; this will have substantial implications on cities planning policies (Stead and Vaddadi, 2019). According to (Faisal *et al.*, 2019) some of these urban transformations are: millions of square kilometres presently utilised for parking may be freed, road space design can be different, and urban sprawl will increase. Adopting AVs will make City planning face a dilemma between the travelled distance and the city size, For example, a study by (Zakharenko, 2016) argues that in both cases whether AVs will increase or decrease cities size, the travel/commute distance will increase.

Although it is conjectured that AVs on-demand services will be the future mobility, it is still ambiguous what are the driving factors of public interest in SAVs (Nazari, Noruzoliaee and Mohammadian, 2018). (Grush and Niles, 2018b) argue that before transitioning to several types of shared mobility, AVs ownership would reach its high peak. For this, (Grush and Niles, 2018a) recommend to significantly concentrate on working how to reduce vehicle ownership by moving users to ride-buyers (which is a form of SAVs). A study by (Kim, Mokhtarian and Circella, 2020) using exploratory factor analysis to gauge the impact AVs could prompt specifically in terms of residential location and Vehicle ownership, found that most respondents expect "no change". Thus, between the expectation of Urban transformation and no change in the users' decision indeed in terms of vehicle ownership, it is crucial to study the factors that will drive public interest into SAVs.

According to (Kuhnimhof, Zumkeller and Chlond, 2013), since the turn of the millennium, in Great Britain vehicle ownership has shown signs of stagnation and even decrease. This is due to people shifting to other travel modes. Therefore, based on the former assumption and in the case of full AVs, if people travel is shifted to SAVs, vehicle ownership will decrease significantly. Many scholars have investigated the possible impact of AVs on private vehicle ownership and shareability. However, most of the research works have focused on examining how shared AVs (SAVs) models can reduce private vehicle ownership. (Narayanan, Chaniotakis and Antoniou, 2020) argue that the methodologies used for modelling SAVs impacts lack realistic indication for verification and validation because most of the studies are employing existing simulation models which these methods are believed to be debatable in determining the real SAVs impacts. For instance, research by (Zhang, Guhathakurta and Khalil, 2018) has shown that a 9.5% reduction in private vehicles can be achieved. Whereas (Milakis, van Arem and van Wee, 2017) stated that 67% to 90% conventional vehicle ownership could be replaced when implementing shared AVs conveying same mobility quality. Another study by (Fagnant and Kockelman, 2016) revealed that each shared AV could substitute roughly 11 private cars.

(Menon *et al.*, 2019) argue that, it is significant to take into account that people's perception of SAVs change and is affected by personal experience, information gathering and publicity. In our previous work (Bezai *et al.*, 2020) and in response to the lack of a conceptual model that elucidate the acceptance of people to AVs, we have identified the determinants of users' acceptance to AVs namely perception, vehicle usage, and cost. To attain successful adoption of AV in urban environments while diminishing congestions and pollution levels, scholars suggested that it is crucial to reduce AVs ownership by moving towards shared mobility. However, we argue that the implementation of this strategy might be difficult because it is related to factors that affect people acceptance of AVs such as privacy, safety, as well as users' mindset and attitude. Based on that, this paper aims to test whether the adoption of AVs will reduce vehicle ownership by studying the choice patterns between the current mobility modes used by people and their future Mobility choice. In other words, this study will test Two assumptions; Firstly, people who currently use public transportation are likely to share AVs in the future. Secondly, people who use private cars are likely to desire owning AVs. The former assumptions are studied considering Nottingham city as a case study and taking into account both types of mobility either in the city or between cities (long distances).

The remainder of the paper is structured as follows: Section 2 discusses the research methodology employed to address the aim of this research, which is a quantitative methodology using a survey. Section 3 presents the findings and hypotheses testing using logistic regression. Section 4 summarises the study aim, findings and suggests future research.

2. Methodology

This research embraces a quantitative research methodology with a survey questionnaire being the primary research method. The choice of this research method was motivated by the fact that it is possible to reach a wider audience efficiently within a short time. The online questionnaire survey was developed using our framework of users' acceptance of AVs (Bezai *et al.*, 2020). In particular, the current study revolves around the survey questions' part that addresses overall considerations and desires in owning or sharing AVs. Additionally, the survey encompasses socio-demographic questions to get insight into the sample characteristics and examine how answers may vary across different sub-groups (Gender, occupation, education, etc.). The survey contains a total of 10 questions which are close-ended in nature to help quantify the answers. The questionnaire was distributed using the Jisc online surveying platform, which in turn relies on social media and databases to recruit participants residing in Nottingham, UK.

2.1. Sample size

It is worth noting that this is an exploratory study which does not intend to generalise to the broader UK population but instead get an insight into Nottingham city residents' opinions about AVs ownership and shareability. Nevertheless, careful considerations were taken when calculating the sample size to fulfil the purpose of the study. First, we have used equation 1 by (Morse, 2000) to calculate the necessary sample size of this study. As discussed by (Conroy, 2015), a margin error of ±10% might be perfectly acceptable and hence why in this study, we opted for a 7% margin error. Secondly, since our case study (Nottingham city) had an estimated population of 332,900 (Nottinghamshire County Council, 2019), a Z-score of 1.65 was obtained. As shown in equation 1 the recommended sample size was 139. Thus, we opted to recruit 140 participants in the survey questionnaire.

Finally, descriptive statistical techniques such as frequency analysis were used first to explore the responses and analyse the sample characteristics. After that, we used binary logistic regression to test the following hypotheses, see Table 1. The choice of this technique was attributed to the nature of the dependent variable, which is dichotomous (Peng and So, 2002; LaValley, 2008).

$$Necessary\ Sample\ Size = \frac{(Z - score)^2 * StdDev * (1 - StdDev)}{(\text{Margin of errors})^2}$$

$$Sample\ Size = \frac{(1.65)^2 * 0.5 * (1 - 0.5)}{(0.7)^2} = 138.90$$

Margin of Error: 7%, Confidence Level: 90%, Standard deviation: 0.5, Z-score: 1.645

Equation 1. The equation used to determine the sample size reproduced from (Morse, 2000).

Table 1. Summary of the hypotheses developed for this study.

TYPE OF MOBILITY	HYPOTHESES
IN THE CITY	**Hypothesis 1: Public transportation VS SAVs** **H0:** People who are using public transportation to move around the city do not significantly predict that people will share AVs. **H1:** People who are using public transportation to move around the city significantly predicts that people will share AVs. **Hypothesis 2: Private car VS AVs Ownership** **H0:** People who are using their private car to move around the city do not significantly predict that people will own AVs. **H1:** People who are using their private car to move around the city significantly predicts that people will own AVs.
BETWEEN CITIES (LONG DISTANCES)	**Hypothesis 1: Public transportation VS SAVs** **H0:** People who are using public transportation to move between cities (long-distance) do not significantly predict that people will share AVs. **H1:** People who are using public transportation to move between cities (long-distance) significantly predict that people will share AVs. **Hypothesis 2: Private car VS AVs Ownership** **H0:** People who are using their private car to move between cities (long-distance) do not significantly predict that people will own AVs. **H1:** People who are using their private car to move around the city significantly predicts that people will own AVs.

3. Results and discussions

3.1. Sample Characteristic

140 participants with various socio-demographic characteristics have filled the study survey, as shown in Table 2 and Figures 1-3. Overall, there was a fair distribution between male (54.30%) and female (45.70%) respondents. Similarly, 45% of respondents were married, whereas 44.30% were single. Although there was a fair age distribution in the sample, more than 57% were aged between 25 and 44

years which is 10% higher than the proportion of the ones in Nottingham city. This might be because the survey was diffused through social media and networks, which are used mostly by the younger population. As for the sample educational profile, 35.70% and 25% were educated at the postgraduate and undergraduate level, respectively. Conversely, 22.1% achieved a further education degree, whereas 15% obtained high school qualification (Figure2). Approximately 73.1% of the respondents were economically active, and 22.9% were students. This explains why 33.3% of the surveyees commute between 5 and up to 50 miles to work.

Table 2. Summary of the demographic details of the sample studied.

Variable	Minimum	Maximum	Mean	Standard deviation
Age	1	7	3.51	1.375
Gender	0	1	1.54	0.500
Occupation	1	6	1.99	0.877
Distance from home to work/study Place	1	6	3.01	1.360
Marital status	1	4	1.70	0.765
Level of education	1	5	2.84	1.140

1. Age:1=Under 21/ 2= 21-24/ 3= 25-34/ 4= 35-44/ 5= 45-54/ 6= 55-64/ 7= 65 Or Older; 2. Gender: 1= Female/ 0=Male; 3. Occupation: 1= Student/ 2= Employee/ 3= Self-employed/ 4= Retired/ 5= Unable to work/ 6= Other; 4. Distance from home to work/study Place: 1=0-1 miles/ 2= 1-3 miles/ 3= 3-5 miles/ 4= 5-10 miles/ 5= 10-25 6= Over 50 Miles; 5. Marital Status: 1= Single / 2= Married / 3= Divorced/ 4=Other; 6. Level of Education: 1= High school / 2= Bachelor / 3= College/ 4= Masters/PhD/ 5= Other.

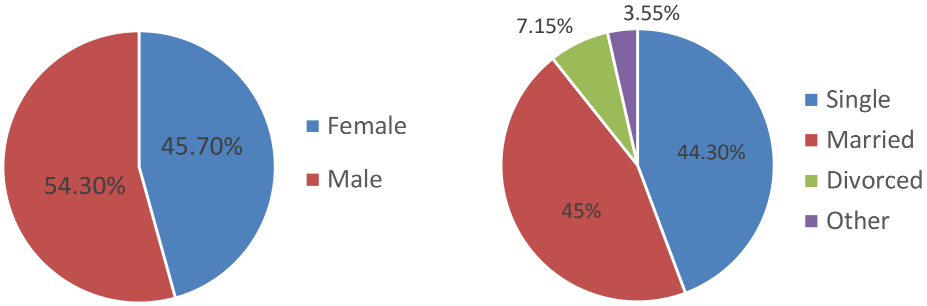

Figure 1. Gender and Marital status distribution of the survey's respondents

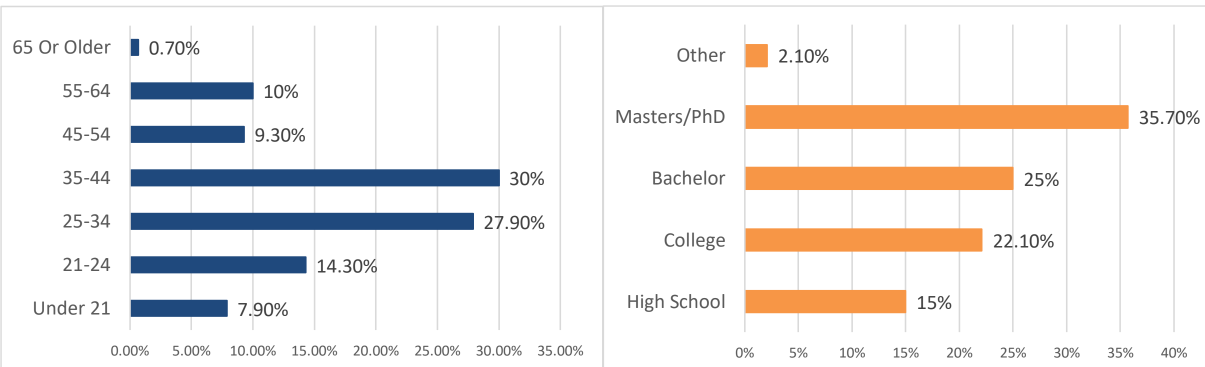

Figure 2. Age and education level of the survey's respondents

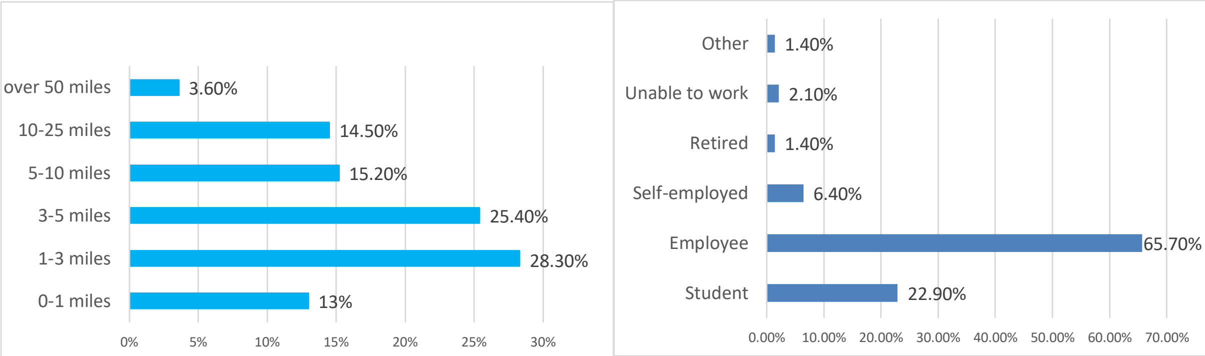

Figure 3. Occupation and distance from home to work/study place of the survey's respondents

3.2. Participants willingness to share/own AVs:

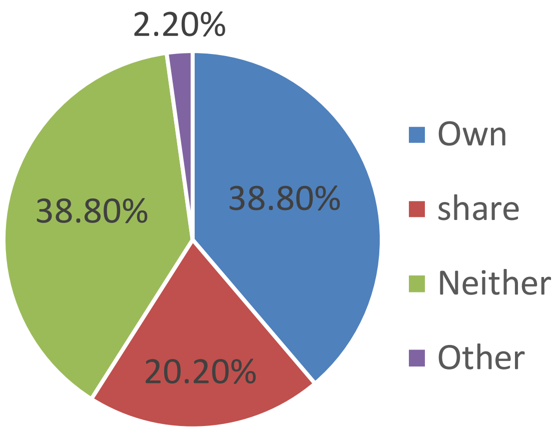

Figure 4. Participants' opinions about owning or sharing AVs.

Figure 4 demonstrates that 38.8% of the respondents showed interest in owning an AV compared to 20.20% opt to share the upcoming technology. On the other hand, 38.80% of participants decided on neither share nor own an AV which makes it more than the third of the respondents. In this question, the option "Other" also is provided for participants to comment on the interest of owning or sharing an AV. 2.20% represents the respondents that selected "others". Therefore, the former group expressed opinions at owning or sharing technology depend on various reasons. For instance, it depends on the context where the person is living, rural or urban. "*…this would be in an urban context only? What if you live in a rural community…"* (participant 100). Besides, the same participant adds that it depends on the number of cars that could be owned "would you need to own two or more cars". Other reasons also are mentioned such as safety, personal experience and learning about them in advance.

3.3. Hypotheses testing

3.3.1. in the city

Hypothesis 1: Public transportation VS SAVs

H0: People who are using public transportation to move around the city do not significantly predict that people will share AVs.

H1: People who are using public transportation to move around the city significantly predicts that people will share AVs.

The analysis of hypothesis 1 focuses on the factor of "using public transportation" and whether it affects the consideration of "the desire of an individual to share an autonomous vehicle". In other words, whether people who currently use public transportation will be expected to share AVs in the future.

Table 3. Logistic regression results of Hypothesis 1 (in the City)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Public	0.481	0.023	1.617	0.359	1	5.700	0.017	56.6

Test value: alpha=0.05

As can be seen in Table 3, the logistic regression model is statistically significant, ($\chi 2$ = 5.700 and p = 0.017 < 0.05). The model explains 35.9% (Nagelkerke R2 = 0.359) of the variance in sharing an autonomous vehicle have classified 56.6% of cases.

The p-value of the predictor "using public transportation" Sig = 0.023 < 0.05, so we reject the null hypothesis and accept the alternative hypothesis. Therefore, the independent variable predicts the dependent variable significantly, and we can explain the positive relationship between the two variables. This is to say that for every one-level increase in using public transportation around the city, it is expected a 1.617 growth in the log-odds of sharing an autonomous vehicle

Hypothesis 2: Private car VS AVs Ownership

H0: People who are using their private car to move around the city do not significantly predict that people will own AVs.

H1: People who are using their private car to move around the city significantly predicts that people will own AVs.

The above assumptions will enable us to explain the relationship between the dependent binary variable "Own an Autonomous vehicle" and the nominal variable " Private car use " through performing a logistic regression test. This is to say that the hypothesis testing focuses on whether people who currently own private cars are likely wanting to possess an AV in the future.

Table 4. Logistic regression results of Hypothesis 2 (in the City)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Private car	0.993	0.007	2.700	0.072	1	7.426	0.006	64

Test value: alpha=0.05

Similarly, to hypothesis 1, the logistic regression model for hypothesis 2 is also statistically significant, ($\chi 2$= 7.426 and p = 0.006 < 0.05). The model explained only 7.2% (Nagelkerke R2 = 0.072) of the variance in own an autonomous vehicle and precisely classified 64% of cases Table 4.

The p-value of the predictor "using a private car" Sig = 0.007 < 0.05, so we reject the null hypothesis and accept the alternative hypothesis. Therefore, the independent variable predicts the dependent variable significantly, and we can explain the positive relationship between the two variables. In other words, for every one-level increase in using a private car in/around the city, a growth of 2.700 is expected in the log-odds of owning an autonomous vehicle in the future.

To see whether the participants' information influences this positive relationship or not, the logistic regression test is rerun taking into consideration the participant information (Age, Gender, Occupation, Distance between home and work or study place, Marital status and Level of education). Hence, Table 5 shows that the variables mentioned above are not statistically significant in the logistic regression except for the gender. The p-values of the variables: Age, Gender, Occupation, Distance between home and work or study place, Marital status and Level of education are all upper than 0.05. On the other hand, the gender variable is statistically significant (sig = 0.001). Therefore, the participants' gender has a positive relationship with the desire to share AVs. As per Table 5, the gender Female is codified by 1, which means that females are (1/0.197) 5.07 times more likely to share an AV than males.

Table 5. Logistic regression of the participants' information and sharing AVs Hypothesis 1; In the city.

Participants' information	B	S.E.	Wald	df	Sig.	Exp(B)
Age	-	-	6,24	6	0,397	-
Gender (1)	-1,626	0,5	10,601	1	0,001	0,197
Occupation	-	-	3,558	5	0,615	-
Distance between home and work or study place	-	-	8,294	5	0,141	-
Marital status	-	-	0,431	3	0,934	-
Level of education	-	-	5,415	4	0,247	-

3.3.2. Between cities

Similarly, to the hypotheses set for the assumptions "in the city" logistic regression will be applied to predict the AVs future use for long distances "between cities". Thus, Hypotheses 1 & 2 will analyse whether people who are using public transportation or private car to move for long distances will share or own AVs in the future.

Hypothesis 1: Public transportation VS SAVs

H0: People who are using public transportation to move between cities (long-distance) do not significantly predict that people will share AVs.

H1: People who are using public transportation to move between cities (long-distance) significantly predict that people will share AVs.

Table 6. Logistic regression's results of Hypothesis 1 (Long distances: between the cities)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Public	0.060	0.781	1.062	0.001	1	0.077	0.781	59.0

Test value: alpha = 0.05

As can be seen in Table 6, the logistic regression model is not statistically significant, (χ^2 = 0.077 and p = 0.781 > 0.05). Besides, the model explained only 0.1% (Nagelkerke R^2 = 0.001) of the variance in sharing an autonomous vehicle and correctly classified 59% of cases. We also notice that the p-value of the predictor « using public transportation » Sig = 0.781 > 0.05, so we accept the null hypothesis that the independent variable does not significantly predict the dependent variable.

Consequently, based on the logistic regression analysis, there is no significant positive relationship between using public transportation between the cities or long distances and the willingness to share AVs in the future.

Hypothesis 2: Private car VS AVs Ownership

H0: People who are using their private car to move between cities (long-distance) do not significantly predict that people will own AVs.

H1: People who are using their private car to move between cities (long-distance) significantly predicts that people will own AVs.

Table 7. Logistic regression's results of Hypothesis 2 (Long distances: between the cities)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Private car	0.018	0.960	1.018	0.000	1	0.003	0.960	61.4

Test value: alpha=0.05

Table 7 depicts the logistic regression results and the model statistically found is not significant, (χ^2 = 0.003 and p = 0.960 > 0.05). The model explains 0% (Nagelkerke R^2 = 0.000) in the amount of the variance in own an autonomous vehicle and correctly classified 61.4% of cases. Besides, we notice that the p-value of the predictor "using private cars" Sig = 0.960 > 0.05, so we accept the null hypothesis that the independent variable does not significantly predict the dependent variable.

Therefore, the results from the logistic regression demonstrate that there is no significant positive relationship between using private cars between the cities or long distances and the possibility to own an autonomous vehicle in the future.

4. Conclusion

This study examined two relevant hypotheses to find out whether the current mode of transportation used by Nottingham city residents, either in the city or between cities, is a determinant of future AVs usage and ownership. At first, we argued that cars will change many aspects of our lives and that their benefits are achieved when they are shared. Secondly, we reviewed the recent literature; a good deal of research has been done on the potential on how SAVs can reduce ownership. However, these studies focused on the ability of SAVs to minimise vehicle ownership, and how one shared AV can replace many current vehicle ownerships. Many studies, nevertheless, did not take into account the factors that will make people shift to using SAVs. Thirdly, since there is a lack of a conceptual framework that identifies the real motives that attract people interest to SAVs, we argued that it is vital to start to know the trend of AVs ownership based on the current usage patterns of the transportation/travel mode. To achieve this aim, we have conducted a survey questionnaire where we utilised a combination of statistical techniques, including binary logistic to test the hypotheses. In the city, the results demonstrate that based on the current mobility choice a growth in the vehicle ownership is expected; a 2.7 increase is predicted in the log-odd of willing to own AV in the future. Interestingly, it has been found that females are 5.07 times more likely to share an AV than males. On the other hand, prediction results regarding moving between cities or long distances did not show any variance either increase or decrease in shareability or ownership expectations; this is maybe due to the size of the sample.

The literature has discussed several factors that determine people's desire to own AVs, such as Knowledge gap; people are not familiar with the technology, AVs are not yet commercialised, machine distrust, Portraying AVs, personal space enjoyment, suitability to children and many more. Nevertheless, there is a lack of knowledge that identifies the factors that will make people shift to share AVs.

To conclude, this paper examined potential prospects for car ownership based on the travel patterns people use today. Therefore, based on the outcomes, more accurate results can be obtained and generalised if we take into account the study of a larger sample that represents the population of the UK. In addition to the former, the next step is to include a section that examines the factors that make people drawn to SAVs. In the end, the potential benefits of AVs will be realised when they are shared, so identifying the factors that help to shift users from ownership to service-on-demand is a priority rather than promoting them.

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