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Acceptance of Automated Road Transport Systems (ARTS): an adaptation of the UTAUT model

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Abstract

As research into innovative forms of automated transportation systems gains momentum, it is important that we develop an understanding of the factors that will impact the adoption of these systems. In an effort to address this issue, the European project CityMobil2 is collecting data around large-scale demonstrations of Automated Road Transport Systems (ARTS) in a number of cities across Europe. For these systems to be successful, user acceptance is vital. The current study used the Unified Theory of Acceptance and Use of Technology (UTAUT) to investigate the factors which might influence acceptance of ARTS vehicles, which were operational in two locations in Europe. The results indicate that the UTAUT constructs of performance expectancy, effort expectancy and social influence were all useful predictors of behavioural intentions to use ARTS, with performance expectancy having the strongest impact. However, it would appear that other factors are also needed in order for the model to strongly predict behavioural intentions in an automated transport context. Based on these findings, a number of implications for developers and ideas for future research are suggested.

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1. Introduction

The last decade has seen an increasing interest in innovative transport systems, with projects such as NETMOBIL CyberMove, and EDICT exploring the potential uses of various types of automated vehicle systems (Delle Site, Filippi, & Giustiniani, 2011). Building on this work, the EU-funded project CityMobil2 is providing a large-scale demonstration of Automated Road Transport Systems (ARTS) in a number of cities across Europe. ARTS are made up of vehicles without a driver, operating in collective mode at SAE (2014) Level 4 of automation i.e. high automation. They are considered a useful form of transport as they can complement the main public transport network by supplying extra options (individual or collective) in areas of low or dispersed demand (Alessandrini, Campagna, Delle Site, Filippi, & Persia, 2015). CityMobil2 has worked with 12 city partners who were interested in the implementation of the ARTS systems, including 5 cities that have been selected for vehicle demonstrations. One of the main aims of the CityMobil2 project is to gain an understanding of the factors that might impact on people's use of ARTS vehicles. With this in mind, the current study focused on developing and assessing a model of user acceptance adapted for ARTS, based on data collected in two of the CityMobil2 demonstration cities – La Rochelle in France and Lausanne in Switzerland.

1.1. Research on Technology Acceptance

Alessandrini et al. (2015) have put forward a vision of how ARTS can enhance safety and improve the efficiency of current transport systems. However, in order for this vision to be realised, it is essential that the public actually uses the systems put in place. An examination of users' preferences towards innovative public transport using Stated Preference surveys (e.g. Delle Site et al., 2011) found that the attributes which have the highest potential to influence the choices of travellers between walking and motorised public transport include weather, illumination, on-board comfort, and distance travelled on foot. They also found that the preference for cybernetic transport systems increases with age. Research has found that an individual's decision to use any automated system is based on a number of attitudinal factors including trust (e.g. Ghazizadeh, Lee & Boyle, 2012), workload (e.g. Parasuraman & Manzey, 2010), perceived usefulness and ease of use (e.g. Davis, 1989), and social influence (e.g. Venkatesh, Morris, Davis & Davis, 2003). Thus, there are a variety of factors which can influence an individual's acceptance of these new automated transport systems.

A number of social-psychological models have been developed to explain and predict technology acceptance and use, with the most commonly used of these being the Technology Acceptance Model (TAM; Davis, 1989), and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003). TAM is based on the Theory of Reasoned Action of Fishbein and Ajzen (1975). It argues that perceived usefulness and perceived ease of use are the main determinants of behavioural intention to use, which in turn has an influence on actual system use. UTAUT builds on TAM by incorporating eight individual user acceptance models into a synthesised model of acceptance (Venkatesh et al, 2003). It proposes two direct determinants of system use – 'behavioural intentions' and 'facilitating conditions'. Behavioural intentions are in turn influenced by 'performance expectancy', 'effort expectancy', and 'social influence', which can be defined as follows (Venkatesh et al., 2003):

1. Performance Expectancy (PE) "*is the degree to which an individual believes that using the system will help him or her to attain gains in job performance*."(p.447)
2. Effort Expectancy (EE): "*is the degree of ease associated with use of the system.*"(p.450)
3. Social Influence (SI): "*is the degree to which an individual perceives that important others believe he or she should use the new system.*"(p.451)

Gender, age, and experience have all been hypothesised to act as moderators of this model (see Figure 1).

While UTAUT is considered a robust tool for investigating individual level technology adoption, it has generally been applied to understand the use of Information Systems, often in an organisational context, such as online banking (Zhou, Lu, & Wang, 2010), e-portfolio systems (Shroff, Deneen & Ng., 2011), and e-government sources (AlAwadhi & Morris, 2008). However, to date, there has been limited research into the factors which might influence acceptance of automated vehicles such as ARTS. Osswald, Wurhofer, Trosterer, Beck and Tscheligi (2012) developed the Car Technology Acceptance Model (CTAM), which incorporated UTAUT along with a number of other attitudinal constructs, e.g. safety. They presented the reliability of their scales but did not investigate the impact of these factors on behavioural intentions towards driving information technology systems. Adell (2010) investigated driver acceptance of a "Safe Speed and Safe Distance" function. She found some support for the use of UTAUT within a driving context, with both performance expectancy and social influence affecting intentions to use the system, while effort expectancy did not. However, the model only accounted for 20% of the variance in behavioural intentions, which was quite low compared to the 70% variance in usage intention of IT models in an organisational context (Venkatesh et al., 2003).

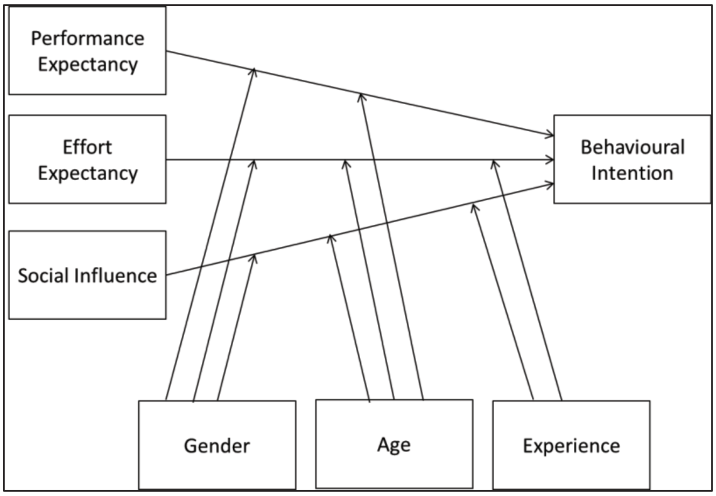

Fig. 1. Research Model based on UTAUT (Venkatesh et al., 2003).

1.2. Research Context

The purpose of the CityMobil2 project is to set up a pilot platform for ARTS which could be used to investigate the technical, financial, legal, cultural, and behavioural aspects that have an impact on how well new systems can fit into existing infrastructure in different cities (see www.citymobil2.eu for more information). As part of this project, the current study focuses on the users' expectancies which might influence behavioural intentions regarding use of ARTS, addressed at two locations – La Rochelle in France, and Lausanne in Switzerland.

The demonstration of ARTS took place in La Rochelle from November 2014 to April 2015, and in Lausanne from April to August 2015. The ARTS vehicles in La Rochelle provided a service along a popular tourist route in the Minimes district of the city. The total length of the route was 1,710 m, and it contained 7 station stops. In Lausanne, ARTS were situated in the West Region to provide a link between a metro station and key working sites/campuses in the district. The length of the route there was 1585 m and there were 6 fixed stops. Both vehicles could hold up to 12 persons per vehicle and both shared road space with pedestrians (see Figure 2). The ARTS in La Rochelle also shared space with vehicle traffic on part of its routes. The maximum speed of the ARTS vehicles was 45 kph, although they travelled at much slower speeds in reality (approx.12 kph). For legal and safety reasons, both vehicles had an operator on board who intervened in the operation and maneuvering of the vehicle when necessary.

CityMobil2 is the first project in Europe to investigate the interaction of the public with ARTS across a range of cities and countries. These demonstration vehicles allow the public to gain an understanding of what future forms of automated transport might look like, while also enabling designers, planners etc. to gain user input into the factors which might improve the usefulness/acceptance of these vehicles as an alternative mode of public transport. It is hoped that by increasing our knowledge of the factors which influence intentions to use ARTS, future implementations of innovative transport systems can be improved to maximise user uptake, and ensure a positive experience.

Fig. 2. ARTS vehicles in (a) La Rochelle and (b) Lausanne.

The specific objective of the study reported here was to use an adapted version of UTAUT to learn more about the levels of importance placed by potential ARTS users on performance expectancy, effort expectancy, and social influence; along with gaining an understanding of the impact that demographic variables such as age, gender, and experience might have on these measures. Previous research has shown that the effect of facilitating conditions does not explain any variance in behavioural intentions (Venkatesh et al., 2003), and it is therefore out of the current research scope to include this measure. Figure 1 demonstrates the proposed model being investigated, including the proposed moderating effects of gender, age, and experience based on Venkatesh et al. (2003).

As it is anticipated that ARTS will eventually be implemented across a number of countries and cities, it is important to gain an understanding of any group differences which might emerge across locations. Therefore, this study also aimed to investigate whether or not there were any differences between La Rochelle and Lausanne users in terms of their response to the questionnaires.

2. Method

2.1. Apparatus

The questionnaire reported in this study was administered as part of a larger questionnaire study which formed part of the EU-funded project CityMobil2. The development of this questionnaire was based on the outputs of a series of interviews conducted with members of the public in Leeds and Braunschweig regarding perceptions of, and attitude towards, ARTS (Louw & Merat, 2014). The user acceptance items were included as part of a 42-item survey created to probe responses related to expectancies around the ARTS vehicles, and the influence of road markings on perceptions of safety and priority during interactions with ARTS vehicles in a mixed environment. In addition, respondents were asked to rate the importance and modality of communicating various ARTS vehicle behaviours and intentions, as well as how that information should be communicated to pedestrians and cyclists who might interact with them. However, only users' responses to the user acceptance questions are reported here.

2.1.1. Measure of User Acceptance

The first part of the questionnaire included questions about participant demographics along with aspects relating to previous experience with transport, including the number of times respondents had used or interacted with the ARTS vehicles, how many days a week they used a car, how many days a week they used any other form of public transport, and their general attitude towards new technologies.

Next, to understand whether respondents' expectancies around the ARTS vehicles were related to their intention to use it, we developed measures of Performance Expectancy, Effort Expectancy, Social Influence and Behavioural Intention, based on the relevant constructs identified by Davis (1989) and Venkatesh et al. (2003). To our knowledge, this is the first study which aims to investigate user acceptance of public ARTS, and has the additional strength of being administered on-site during the operation of such vehicles. The closest examples in the literature come from Adell (2010) and Osswald et al. (2012), who draw attention to the difficulties in adapting items developed to assess acceptance of IT systems to a driving context. The ARTS system differs substantially from the organisational and IT contexts investigated thus far by acceptance models such as TAM and UTAUT. It also differs from the two driver acceptance studies, as the focus of interest was on system performance rather than on how a system can be used to increase user performance of a task. It was, therefore, important to tailor the construct items to reflect the context of participant interaction with ARTS vehicles. It should be noted that there were some constraints in item development arising from the fact that the ARTS was temporarily on demonstration and thus items in the original UTAUT model such as "*I intend to use the system in the future*" could not be used. Therefore, behavioural intention was measured using only one item – "If it were affordable, I would use an ARTS". The final items developed to measure each of the UTAUT constructs are shown in Table 1.

Table 1. UTAUT Questionnaire Items.

Construct	Adapted Item
Performance Expectancy	1. I think an ARTS will become an important part of the existing public transport system
	2. I think using an ARTS in my day-to-day commuting is better and more convenient than using my existing form of travel
	3. I think an ARTS would be more efficient/faster than existing forms of public transport
Effort Expectancy	4. I think an ARTS would be easy to understand how to use
	5. It would not take me long to learn how to use an ARTS
Social Influence	6. The people around me think that I should use an ARTS
	7. I think I am more likely to use an ARTS if my friends and family used it
Behavioural Intention	8. If it were affordable, I would use an ARTS

2.2. Procedure

The questionnaire was administered on a tablet-based application using iSurvey (www.harvestyourdata.com). Data collection was conducted in the vicinity of the CityMobil2 vehicle demonstrations (see Figure 2), and carried out by students of L'Ecole d'Ingénieurs en Génie des Systémes Industriels (EIGSI) in La Rochelle, and École Polytechnique Fédérale de Lausanne (EPFL) in Lausanne. The questionnaire was translated into French by the La Rochelle team, and was independently checked by a bilingual colleague in Leeds to ensure that the meanings had been correctly translated. The Lausanne team also cross-checked this translation for accuracy. All respondents in La Rochelle responded in French, while participants in Lausanne were given a choice of responding in French or English.

To ensure that respondents had some knowledge of the demonstrations, only members of the public who had come across the ARTS vehicle in operation at least once were asked to complete the questionnaire. Questionnaires were largely self-administered, apart from a few cases where respondents had difficulties operating the tablets, in which case the students captured responses. Data from La Rochelle were collected in blocks of 1.5–3 hours in two waves between 9th–20th February and 13th–24th April 2015, while in Lausanne the time blocks ranged from 2–10 hours on dates between the 20th May and the 3rd June 2015. The information was recorded anonymously and no compensation was offered to complete the questionnaire. Each questionnaire took between 8 and 10 minutes to complete.

3. Results

3.1. Group Characteristics in La Rochelle and Lausanne

A total of 349 valid responses were collected, of which 61.6% were male, and 38.4% were female. All respondents were residents of, or visitors to, La Rochelle, France (58.5%) or Lausanne, Switzerland (41.5%). Table 2 provides a breakdown of results for the two locations.

Table 2. Demographic and travel behavior information (N=349).

		La Rochelle (%)	Lausanne (%)
Gender	Male	59.8%	64.1%
	Female	40.2%	35.9%
Number of times using or interacting with the ARTS vehicles	<5 times	87.3%	82.1%
	>5 times	12.7%	17.9%
Days a week using a car	Less than 2	47.1%	64.1%
	Between 3 and 5	20.6%	22.1%
	Over 5	32.4%	13.8%
Days a week using any form of public transport (e.g. bus, taxi, train, tram etc.)	Less than 2	45.6%	30.3%
	Between 3 and 5	21.1%	26.9%
	Over 5	33.3%	42.8%
When it comes to trying a new technology product I am generally…	Among the last	20.6%	10.3%
	In the middle	56.4%	66.2%
	Among the first	23.0%	23.4%

The groups did not differ significantly in terms of their gender (χ^2=0.67, p=0.41) but they were significantly different in terms of age (t (341.37) =6.19, p<0.001, η_p^2=0.10), with users in La Rochelle tending to be older than those in Lausanne (see Figure 3).

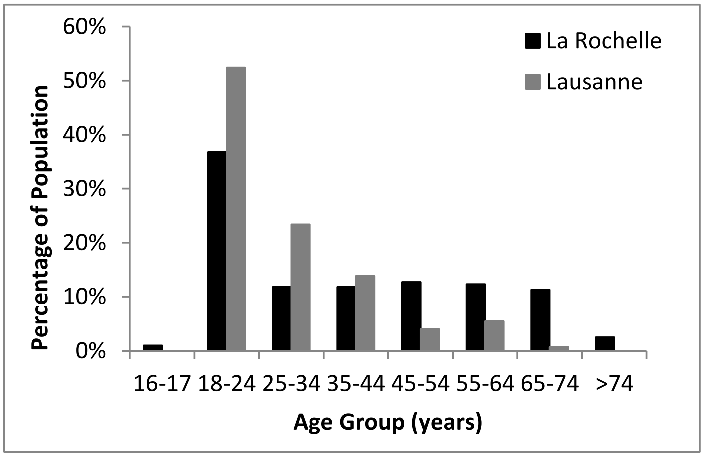

Fig. 3. Comparison of age groups across the two locations.

The groups also differed significantly in terms of how often they used a car (t (339.20) =4.13, p<0.01) and how often they used public transport (t (347) =2.62, p<0.01), with participants in Lausanne tending to use public transport more, and private cars less, than those in La Rochelle. Finally, there were no significant differences between the groups in terms of their experience of the ARTS vehicles (χ^2=1.79, p=0.18) or their attitude towards trying new technology (t (347) =1.57, p=0.12).

3.2. Behavioral intentions towards ARTS

In this section the results of the UTAUT analysis will be outlined. To ensure that the four UTAUT dimensions being investigated were distinct, a factor analysis was conducted using principal components extraction and oblimin rotation. An examination of Cattell's scree plot, as recommended by Stevens (2009), showed four clear factors emerging, explaining 37.42%, 18.48%, 12.34% and 9.67% of the variance respectively. Factor loadings and scale reliabilities (Cronbach's alpha) are displayed in Table 3.

Table 3. Factor Loadings and Reliabilities for UTAUT measures.

Construct	Adapted Item	Factor Loading
Performance Expectancy (α = 0.66)	1. I think an ARTS will become an important part of the existing public transport system	0.650
	2. I think using an ARTS in my day-to-day commuting is better and more convenient than using my existing form of travel	0.553
	3. I think an ARTS would be more efficient/faster than existing forms of public transport	0.921
Effort Expectancy (α = 0.69)	4. I think an ARTS would be easy to understand how to use	0.895
	5. It would not take me long to learn how to use an ARTS	0.827
Social Influence (α = 0.55)	6. The people around me think that I should use an ARTS	0.914
	7. I think I am more likely to use an ARTS if my friends and family used it	0.268
Behavioural Intention	8. If it were affordable, I would use an ARTS	0.964

As Table 3 shows, item 7 did not load appropriately onto the Social Influence scale and the low value of the Cronbach's Alpha (α) coefficient suggests that the scale did not have high internal consistency. Therefore, this item was excluded from all further analyses. Neither the Performance Expectancy nor the Effort Expectancy scales reached the Cronbach's Alpha > 0.7 criteria recommended by Nunnally (1978). However, both scales were quite short (three and two items), which might provide an explanation for the low value. In addition, the content of the statements were considered valuable and, therefore, all items were maintained for the analysis. This is not uncommon in UTAUT literature (see AlAwadhi & Morris, 2008; Carlsson, Carlsson, Hyvönen, Puhakainen & Walden, 2006).

Prior to testing the research model, correlation analyses were conducted including all of the variables to check for multicollinearity (see Table 4). The highest correlation was 0.40, which is sufficiently low to rule out multicollinearity.

Table 4. Descriptive statistics and correlations between measures.

		M	SD	1.	2.	3.	4.	5.
1.	Behavioural Intention	3.59	1.18	1				
2.	Age	4.50	1.74	-0.01	1			
3.	Performance Expectancy	3.08	0.94	0.40**	0.15**	1		
4.	Effort Expectancy	3.89	0.77	0.24**	-0.08	0.27**	1	
5.	Social Influence	2.90	1.04	0.34**	0.13*	0.36**	0.14**	1

*p<0.05, **p<0.01

Hierarchical multiple regression was used to test the research model (see Figure 1), as recommended by Aiken (1991). The categorical variables of gender and number of times using ARTS (i.e. experience) were dummy coded, consistent with previous studies (Venkatesh et al., 2003, 2012). Variables were then entered in three steps (1) control variable (location: La Rochelle/Lausanne); (2) the predictor variables (performance expectancy, effort expectancy, social influence) and (3) a cross-product term between the centred UTAUT and demographic variables. The inclusion of the moderators did not affect the results in any way, and therefore only the main predictor variables are presented in Table 5.

Table 5. Regression analysis.

Step		Step 1 β	Step 2 β	R^2	ΔR^2
1	Location	0.03	0.04	0.001	0.001
2	Performance Expectancy (PE)		0.29**	0.22	0.22**
	Effort Expectancy (EE)		0.12*		
	Social Influence (SI)		0.23**		

*p<0.05, **p<0.01

The first step of the equation shows that there were no significant differences between the responses at the two locations. The second step shows that there were significant effects of performance expectancy, effort expectancy, and social influence, on behavioural intentions. The predictor variables accounted for 22% of variance in behavioural intention, with performance expectancy being the strongest predictor ($\beta=0.29$, $p<0.01$), followed by social influence ($\beta=0.23$, $p<0.01$) and effort expectancy ($\beta=0.12$, $p<0.05$).

4. Discussion

As research into automation gains momentum, and increasing amounts of money are invested into adopting innovative automated transportation solutions, it is very important that we gain an understanding of the factors that will impact their adoption. This is something which has rarely been explored in the literature to date. The purpose of this study was to use UTAUT to learn more about the levels of importance placed by potential ARTS customers on performance expectancy, effort expectancy, and social influence in two locations (La Rochelle in France, and Lausanne in Switzerland). This was the first study to explore how user acceptance variables might influence the use of a public automated transport system, and a particular strength of the study was that data was collected on-site during the demonstrations, thus ensuring that first-hand experience was measured.

The results indicate that all three UTAUT constructs impact on intention to use ARTS. Performance expectancy is the strongest predictor, suggesting that the most important factor that people will consider in deciding whether or not to use an ARTS is how well they believe it will perform in comparison to other public transport systems. Social Influence and Effort Expectancy also had an impact on behavioural intentions, indicating that the influence of other people, and perceptions of how difficult the system is to use will also both influence the decision to use an ARTS.

These results show that the UTAUT framework can be applied to increase understanding of user's behavioural intentions around automated vehicles. However, similar to Adell's (2010) investigation of a driver support system, the explanatory power of the research model was only 22% percent. This suggests that the current manifestation of UTAUT is not capturing all of the factors which influence individual's behavioural intentions to use automated transport systems. It is also possible that behavioural intentions to use an ARTS are strongly influenced by variables such as on-board comfort, and distance travelled (see Delle Site et al., 2011), and that the inclusion of such vehicle characteristic variables in future research models may increase the power of the model. Indeed, Venkatesh et al. (2012) suggest that hedonic motivation is a critical determinant of behavioural intention in consumer-based contexts. Another issue which is likely to be of particular relevance in the transport context is how safe consumers feel while using the ARTS, and this is something which could be considered in future research with automated vehicles.

While there was a difference between the two demonstration sites in terms of age distribution and car and public transport usage, these factors did not have any impact on the UTAUT variables. Previous research using the UTAUT model had found that gender, age, and experience all moderated the relationships between the predictor variables and behavioural intentions. However, this relationship did not emerge in the present study. Given all of the participants would have had limited experience with the ARTS vehicle, and there were no differences between the two groups in terms of the usage levels, this finding is perhaps unsurprising. Delle Site et al. (2011) found that the relevant preference for a cybernetic transport system increases with age (particularly over 65 years), and therefore it might have been expected that age would also influence the relationship between the three predictor variables and behavioural intentions. However, the current research focuses on experience of using ARTS rather than using system descriptions, suggesting that age is no longer a factor when people have actually interacted with ARTS.

It should be acknowledged that there were a number of limitations to this study. Unfortunately, only one item could be included to measure both behavioural intentions and social influence, thus decreasing the reliability and validity of these items. The poor loading of the second social influence item suggests that the two items did not adequately address the same topic, and therefore the scale items may need further adaptation in future studies of automated vehicles. Thus, caution should be taken in interpreting the effect of social influence, as only one element of the construct was being measured. In addition, it would be useful to investigate whether the same results would emerge when using a multi-item measure of behavioural intention. Finally, a larger sample size with a greater balance of age-groups would help to increase the generalizability of the results.

5. Conclusions and Implications

This is the first study which tries to gain an understanding of the public's acceptance of ARTS as a transport system. The results provide some initial insights into the factors that influence acceptance of the ARTS vehicles. Performance expectancy, effort expectancy, and social influence all appear to have an impact on behavioural intentions to use such a system, although from the amount of variance explained it would appear that other factors e.g. perceived safety or on-board comfort should also be considered in future work in this area. The lack of a difference between La Rochelle and Lausanne suggests that, regardless of location, developers of public automated road transport vehicles should place their primary focus on ensuring that that the vehicles perform to a high standard, providing an efficient and convenient mode of transport.

In terms of increasing our understanding of the use of UTAUT, the results of this research suggest that this model can be adapted for use in a transport context. More research is needed to understand how other constructs e.g. hedonistic motivation might fit into the model. In order to investigate this further, the findings of this study will be extended and refined in a future analysis using an ARTS demonstration in Trikala, Greece in 2016.

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