Understanding the Factors Influencing Consumers' Behaviour Towards Autonomous Vehicles Adoption

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Abstract. In this study, the key determinants or factors influencing consumers' behavioural intention to accept autonomous vehicles (AVs) have been explored and tested. Although, there is a plethora of studies in the literature evaluating various technologies, most of the models of technology acceptance and theories selected are applied on barriers of successful IT implementation in organisations or generally on technologies that have long been deployed. There are very few studies conducted on disruptive technologies such as AV. In this paper, this issue has been addressed with the identification of context-related constructs partly retrieved from existing literature, that describe a modelling process for a technology acceptance attempting to explain the main factors influencing people behavioural intention to adopt autonomous vehicle technology. Constructs such as trust, self-efficacy, anxiety, perceived safety and legal regulation have been considered. The main contribution of the study is the detailed exploration on the users' acceptance of AV. We propose a theoretical model called Autonomous Vehicle Technology Acceptance Model (AVTAM) that gives us a better understanding of what will eventually influence future AV customers. The main findings of this work suggest that users' safety on the road, the cost associated to the technology and the trust on car manufacturers will play a very important role for large scale AV adoption.

Keywords: Autonomous Vehicle adoption, TAM, UTAUT, UTAUT2, AVTAM, Safety, trust.

1 Introduction

For several years, IT users' acceptance has been a very important area of study by social scientists and management information system scholars. They have been analysing the behaviour of technology users at an individual level and within organisational settings [1]. With the fast pace of technological innovation in the transportation industry, vehicles are becoming more and more intelligent. Many are being equipped with advanced technologies allowing them to move commuters with no driving capabilities or with disabilities from one place to another. Autonomous Vehicles (AVs) will be here sooner than most people expect. These technologies are equipped with radar systems, camera, LiDAR, GPS systems and other smart devices, controlled by powerful AI programmes allowing these vehicles to sense their environment, navigate independently without the need of human intervention. These AVs also learn from their mistakes and improve their accuracy faster than any probable human driver. Today, it is recognised that more than 50% of innovations in vehicles are on electronic components [38]. Most cars are now equipped with some level of automation to assist drivers when parking their vehicles or following other vehicles. Indeed, latest generations of cars have the capabilities of detecting, anticipating and correcting drivers' maneuvers accurately and autonomously. Certainly, AV can be considered as a disruptive technology as it will completely change the way most people live their lives, it will affect parking spaces, insurance industry, the taxi industry and many other businesses. New car sharing schemes will be introduced and fewer people may own their private cars in the future.

Throughout history, not all innovative technologies predicted by the media have been immediately welcomed by the society and looking at all the changes this emerging technology may bring, AV may be rejected by a proportion of the population not ready to alter their habits. In the past few decades, several models and theories have been proposed to predict people use behaviour of technology. But in the literature, there is still a gap as most of the proposed models are still not able to fully capture the complexity brought by AVs. So, there is still a need to explore the key factors that will influence consumers' behavioural intention to adopt AV [1, 2, 3]. For several years, UTAUT (Unified Theory of Acceptance and Use of Technology) and later UTAUT2 were models that have been used extensively in the past to assist researchers in understanding the main factors influencing use behaviour of various technologies [4].When analysing most existing models and theories, including the latest car technology acceptance research model, it becomes evident that several factors not previously considered will have to be explored in this AV scenario. The rest of the paper is organised as follows: **section 2** gives a state of art review on AV acceptance, **section 3** discusses the main constructs identified for the proposed AVTAM model with the hypothesis, **section 4** provides the methods and techniques used to test the proposed research model, the results are presented in **section 5** followed by a brief conclusion with future work in **section 6**.

2 State of the art review

2.1 Brief History and background of Autonomous Vehicles

Since Norman Bel Geddes envisioned autonomous vehicles in the 1939 World's Fair General Motors exhibit Futurama, autonomous vehicle technology has come a long way. The idea of robotic vehicles and intelligent highways in the middle of the 20th century was mostly debated by futuristic and science fiction fanatics. The thought of automating the driver of the vehicle became a possibility only few decades after the first Model T Ford was introduced. During the subsequent decades, technology magazines predicted and documented the prospects of vehicles that could drive themselves becoming a reality [5]. The Defense Research Advanced Projects Agency (DARPA)

Grand Challenge that took place in 2004, 2005, and 2007 (Urban challenge), were some of the most prestigious developments in federal support for the industry. The prize for the winning team with the best AV technology was $1 million [6]. During the first competition in 2004, none of the robot vehicles finished the race, but during the second race, five vehicles successfully completed. The third competition of the DARPA Grand Challenge rules included obeying all traffic regulations while negotiating with other traffic and obstacles and merging into traffic. These activities brought several teams to the US coming from all over the world including Japanese and European car manufacturers and universities. Many of the participants are still working as AV engineers or researchers, committed at making the deployment of this technology a reality in their lifetime [7].

For decades, researchers claimed the breakthrough was imminent and now, it appears, it has finally arrived. Assuming the diversity of the main parties involved in the achievement of the same goal, it is evident that the names given to the technology are not the same. In some texts, it is referred to as self-driving car, driverless car, connected and autonomous vehicle (CAV), robot-car, robotic car or autonomous vehicle (AV) which is the choice selected for this paper. They all mean that the vehicle is capturing large amount of data from its environment, processing it and driving the passengers with a considerable level of autonomy. The advances made in the last 40 years can be understood in terms of three successive waves of development. **Phase 1**: Foundational research, from 1980 to 2003 dominated by university research centers, sometimes in partnership with transportation agencies and automotive companies, they undertook basic studies of autonomous transportation, **phase 2**: from 2003 to 2007, DARPA held three "Grand Challenges" that decidedly accelerated advancements in AV technology and reignited the public's imagination. **Phase 3**: from 2007 till now, commercial development. **Table 1** shows the chronological listing of some important events and projects in the history of autonomous vehicle systems.

Table 1. Important events and projects in the history of AVs

Date	Events and Projects	Info
1977	The first AV was built by Tsukuba Mechanical engineering lab.	This vehicle was able to reach 20 miles per hour by following some white street markers on a distance of up to 50 meters.
1980's	The work of the pioneer Ernst Dieter Dickmanns on dynamic computer vision and his team in Germany, equipped Mercedes -Benz van with camera and other sensors.	The 5-ton van was re-engineered in such a way that it was possible to control steering wheel, brakes and throttle, through computer commands based on real-time evaluation of image sequences. The van could achieve 60 miles per hour on streets without traffic.

1987-1995	Pan-European PROMETHEUS Project also recognised as the largest ever funded project on autonomous vehicle	This project defined the state of the art of autonomous vehicles. The prototype car was able to exceed 110 miles per hour on the German Autobahn. Numerous universities and car manufacturers participated in this Pan-European project. Unlike the early AVs it drove in traffic and was capable of accomplishing maneuvers to pass other cars.
1995	CMU Navlab "No Hands Across America Project". The vehicle was semi-autonomous.	The vehicle was 98.2% autonomous and made almost 3000 miles. Brakes and throttle needed human input.
1997	AHS Demo'97 (Automated Highway System)	On a highway in San Diego, California, more than 20 fully automated vehicles were operated
2000-2002	CARSENSE	This prototype was equipped with a variety of sensors, lasers, radar system and camera vision. The project focused on more complex scenarios such as traffic jams.
2000	AHSRA Demo 2000 (Japan)	This was an automated system able to operate with magnetic sensors on the road. In this demo, 38 cars, trucks and buses showed the ideal system for reducing accidents on the road based on accurate information provided to drivers and control assist systems.
2000-2003	CHAMELEON	The system was made up of a processing module for crash prediction (control unit) and a sensor module for obstacle detection (vision system, medium range radar, laser scanner, laser, short range radar). Output was intended to be used by an advanced passive safety system on board.
2001	DARPA Demo III	This demo showed the ability of unmanned ground vehicles to navigate miles of tough off-road terrain, avoiding obstacles such as trees and rocks.
2001-2004	ARCOS (Research Action for Secure Driving) (France)	This project main objective was to reduce accidents by 30%. The key functions were: -controlling inter-vehicle distances; -avoiding lane departure; -avoiding collisions with fixed or slowly moving objects; -alerting other vehicles of accidents.

2001-2004	CarTALK 2000	This European project focused on the new driver assistance systems which are based upon vehicle to vehicle communication.
2001-2005	INVENT (Intelligent traffic and user-oriented technology) (Germany)	The prototypes were tried in the city of Magdeburg, Germany in April 2005. The main purpose of this project was to enhance the traffic flow and safety by using intelligent and user-friendly systems.
2004-2008	PREVENT (EU)	This project is aiming to develop and test safety-related applications, using existing devices that can be integrated into on-board systems for driver assistance. PREVENT will alert the car driver of hazard situations and take necessary measures if the driver is not reacting.
2004	DARPA (The Defense Advanced Research Projects Agency) Grand Challenge	The first competition of the DARPA Grand Challenge was held in March 2004 in the Mojave Desert region of the United States. No winner was declared, and the cash prize was not given.
2005	DARPA Grand Challenge II	It was designed to be a race in the dessert environment with no traffic. The course was predefined by GPS points and obstacle types were known in advance. Stanford University was the team that won the competition.
Nov. 2007	DARPA Grand Challenge III	The third DARPA Grand Challenge race featuring autonomous ground vehicles in an urban environment took place in November 2007, at the site of the now-closed George Air Force Base.
Jan. 2009	Google Car	The project was launched by Sebastian Thrun, the former director of the Stanford Artificial Intelligence Laboratory (SAIL) and Anthony Levandowski. Google's development of self-driving technology began on January 17, 2009, at the company's secretive X lab run by co-founder Sergey Brin.
2011	WildCat Project	Oxford University's WildCat Project created a modified Bowler Wildcat which is capable of autonomous operation using a flexible and diverse sensor suite

2013	RobotCar UK project	In February 2013, Oxford University unveiled the RobotCar UK project. An inexpensive autonomous car capable of quickly switching from manual driving to autopilot on learned routes.
2015	Project Titan	Apple Inc. developed an electric car prototype (iCar) as part of their autonomous vehicle scheme.
Dec. 2016	Waymo	In December 2016, the Google car unit was renamed Waymo and spun-off into a new division in Alphabet. The name Waymo was derived from its mission, "a new way forward in mobility."

2.2 Autonomous vehicles as a disruptive technology

Disruptive technology as coined by Christensen in [8] is an innovation that significantly changes the way that industries, businesses or consumers do things. It sweeps away or alters the systems or habits it replaces because it has characteristics that are observably superior. Christensen argues that when these technologies appear on the market, they may increase emerging market niches, get better very quickly with time and eventually overtake traditional products from established markets [8] [13]. Even a startup with restricted resources can aim at technology disruption by inventing an entirely new way of getting something done. There are supporting technologies with capability of improving the performance of existing products or services. Most markets appreciate, adopt and use them without delay [2]. At the same time, there are innovations that drastically challenge or change habits and the current state of affairs in the market. At the beginning, these products underachieve in the market, but after some time, few users value them, sooner or later the products become so convincing that all customers give up the old habits and flocks to the new way of doing things.

Globally, the transportation industry is inseparably connected to the energy industry and it is worth about $4 trillion [9]. The internal combustion engine technology is currently been disrupted and this will also provoke a massive reaction through the oil industry. The first level of disruption of the hundred years old car manufacturing industry would be electric vehicles (EVs) which is currently happening. The next wave of disruption will be AV technologies, and this will affect the market even before EV disruption has ended. Nothing will ever be the same again [2] [12] [15]. Indeed, societies as well as most cities in the western world and other parts of the globe will face massive transformation. Major technology giants and car manufacturers such as BMW, Mercedes-Benz, Tesla, Bosch, General Motors, Ford, Nissan, Waymo, Apple, Uber are already testing AV prototypes. Vehicles with some degree of autonomy are already been sold on the market. These innovations (EV, AV) are set to become a large part of our fleet. They will bring great opportunities such as new types of jobs, an increase in employees productivity, less accidents, cheaper and easier commute with fewer fatalities, less congestion, reduction in environmental emissions, therefore, reducing the billions of pounds the government spend on infrastructures etc. but in turn this will also create job losses, disruption in various industries which will have to reinvent themselves or disappear altogether and many other problems not currently identified. AV is a truly disruptive technology and we cannot predict the future by simply deducing from the past. All the above issues will change the forecasts for standard infrastructure and major transportation projects.

2.3 Concept underlying user acceptance

Generally, the term "acceptance" refers to "agreeing, acknowledging or approving". This is the action of consenting to receive or use something [4]. For decades, IT acceptance has been an area of intense study by academics and practitioners investigating and proposing various models and theories attempting to explain and predict people behaviours towards various technologies [1]. In their struggle to clarify and give a rationale to system use, they developed a tool to measure computer user satisfaction. In order to do that, they first consulted the psychologists who have had a tracked record of studying user satisfaction [10]. In this paper, user acceptance will be defined as the demonstrable willingness within a group of users to employ a form of technology for the tasks it is intended to support. Thus, the term will not be employed in conditions consumers claimed to have used it in or for reasons unintended by the originators or creators. In reality, there are always possibilities that the actual usage deviates from the intended purpose. The main idea behind acceptance theory is that these types of deviation are not observed on a large scale, therefore not significant and that it can be modelled and predicted. In some instances, users are reluctant to use technologies in the event that their usage will result in massive performance gain. This is another reason why user acceptance is regarded as a pivotal factor when determining whether a new information technology or information system is a failure or a success on the market. Most technology acceptance models and theories proposed in the past follow a similar concept despite having their own specific attributes. **Fig.1** below illustrates the fundamental concept underlying user acceptance models.

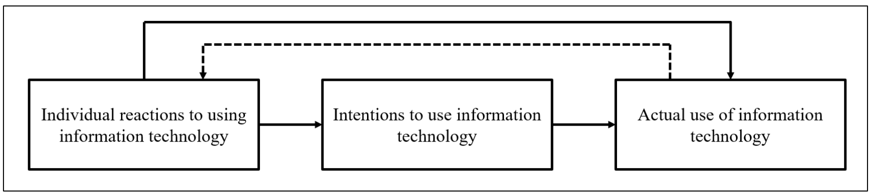

Fig. 1. Basic concept underlying user acceptance models [11].

In recent years, technologies linked to the automation of transportation systems has fascinated audiences around the world, from the stakeholders to the media. Car manufacturers and other stakeholders such as technology companies are joining forces to develop automated systems that will resolve the increasing demand of mobility around the world. On one hand, the recent deployment of electric vehicles by companies such as Tesla has exposed the public to a new form of energy powered vehicles, slowly gaining momentum and trust. Despite the problems related to the limited number of charging stations in major cities, several car manufacturers all over Europe and other parts of the world are currently running tests and pilot programs as prerequisites to make sure that such investments pay off in the future. On the other hand, many are convinced that consumer acceptance will be the most challenging problem for AV penetration [1] [2] [12]. A survey conducted in the UK and the US has identified that several passengers will be reluctant to have faith on robots by putting their lives in their hands. There is a split opinion whether people would like to have various levels of automation in their vehicles. Many car drivers enjoy the experience of driving, owning their own vehicles and believe that their independence and freedom to go where ever they please may be taken away from them once this technology is deployed all over the world. Citizens may only be able to go to places authorized by the government. In the past few decades, the world has experienced massive changes related to driving experiences. These rapid changes have been introduced by car manufacturers in terms of technological advancement. For instance, a typical middle-class classic vehicle has standard features such as electronic stability program, automatic gearbox, and power windows [4]. More expensive class of vehicles are equipped with more intelligent features such as self-parking technology, active lane assistance and automatic startup framework. These new features have made driving more comfortable, however, these vehicles still need human interaction to perform some other complex tasks [60]. More and more AV manufacturers are investing massively on these technologies to make them fully autonomous; able to operate without any human intervention; allowing the vehicle to control the acceleration, steering and braking while the passengers may be focusing their energies on other activities [13].

There is a variety of factors people must consider when thinking about purchasing a vehicle such as psychological factors, personal attitudes, situational factors including the regulatory environmental bodies or agencies. According to [4] environmentally conscious behaviours are influenced by several factors. These include personal values, environmental concerns depicting the fact that a difference can be made in the world and the environment by using the appropriate vehicles that generate less pollution. This contributes to individuals purchase decision for alternative eco-friendly forms of energy, reduction of air pollution, reduction of maintenance and better handling. It is evident that environmentalists and people who prefer cleaner energy sources will be more attracted to hybrid electric vehicles. According to [14], research shows that the most important attributes for car buyers are vehicles' price, reliability and the fuel economy. According to the unified theory of acceptance, different cultures around the world have distinct characteristics with regards to their behaviour towards AV technologies. For example, Hong Kong citizens give priority to the benefits related to the technology and the environment, followed by economic advantages and social benefits. In most developed societies, several limitations to AV and EV technologies have been identified.

These include the lack of AV and EV infrastructure, the limitations in terms of variety of EV technologies available and the possibility of electrical rates being increased as a result of EV and AV mass adoption. In [3] the researchers have identified four key factors influencing potential buyers purchase behaviour. These include short battery capacity, high buying costs, psychological factors and charge inconvenience. Other findings in China highlighted further issues such as overall cost of operations, and possible speeds. A study in [15] also demonstrates that personal norms, perceived behavioural control, attributes, as well as the planning abilities will influence consumers' decisions to purchase AV. It is evident that potential advantages such as safety benefits, time saving, and fuel savings will always be in peoples' minds.

2.4 Key challenges to autonomous vehicles acceptance

The century old car manufacturing industry used to be the area of mechanical engineering. Today, due to significant progress in computing and electronics achieved in the past few decades, more and more software and technology firms are joining the race. One of the main purposes of developing AV was to decrease the number of accidents on the road and increase safety [16]. It appears that over 90% of road accidents are somehow due to bad driving habits and human errors, whether it is dangerous driving or driving under the influence of alcohol [17]. Some initial studies conducted on car safety few decades ago produced the introduction of vehicles to vehicles communication (V2V) and Vehicles to Infrastructure (V2I) communication also referred to as VANET (Vehicular Ad-hoc NETwork) generated a lot of attraction in the past. Today, the goal of AV is making road accident be something of the past. Despite all the obvious positive reasons AV will bring to humanity, there are several challenges these technologies will also be facing. These vehicles will be developed with massive computing capabilities with internet connection, therefore very likely to be compromised by cyber criminals. Furthermore, in today digital world, our data is the new gold, the new oil, the new currency; these vehicles will generate large amount of data (passenger location, speed, record of the places it has been to) opening a whole pandora box for privacy concerns and ethical concerns. Other concerns will be legal, jobs losses. In the following sections, some of the key barriers to AV will be explored.

2.4.1 Safety

Most governments in the developed world are actively planning the deployment of AV technologies. At the beginning, people may be reluctant to hand over their lives to robots. There are surveys conducted in the past showing a split in opinion regarding making AV technology available in their vehicles [60]. It appears that mass adoption will surely take time, particularly there has been instances when these vehicles despite their technology superiority, have been involved in accident [18]. For example, in 2016, Google car (Waymo) was involved in several collisions, in March 2018, an autonomous car operated by Uber during real-world testing with a human emergency driver behind the wheel, struck and killed Elaine Herzberg in what is believed to be the first recorded pedestrian fatality involving an Autonomous car. This type of accident could generate fear from consumers particularly if they happen to take place early on in the adoption phase whether it is the vehicle system's fault or not.

2.4.2 Legal implications

Countries introducing AVs technologies to their respective populations will also have to develop laws that allow these cars to be driven on the street with vulnerable people. At the moment, there are suitable laws that determine liability when there is an accident involving traditional vehicles and other vehicles with some level of autonomy. Although it is being debated in various countries, many countries around the world are still behind on laws regulating vehicle accidents where one of the parties is fully autonomous. The general vehicle safety rules that govern car design assume that a human sits behind the steering wheel of each vehicle. In fact, they assume each vehicle has a steering wheel. Now those rules may begin to change [31]. In this scenario, it is difficult to identify who to blame [38]. Is it the car owner, or the AV manufacturer? The adjusted standards would nix some rules related to rider safety for AVs that carry goods like groceries, but no people. They would address the protections needed when steering wheels and steering columns have gone the way of the dodo. They would reexamine how airbags might work in a car newly configured to drive itself and consider barring children from the front left seat of a vehicle, where the steering wheel traditionally lives [31]. The rules would also clarify the definition of "driver," which the agency has now decided it will not change within the standards. Instead, it will clarify within each mention whether "driver" refers to a fleshy human, or the advanced driver systems that might one day operate cars all on their own. There is a need for more clarity on civil and criminal laws [18] [19]. Some other implications of this would be when disable people or passengers unable to drive could "get behind the wheel" of an AV, or when these vehicles move from one location to another without passengers. What then happens if there is an accident? Who will be to blame in this instance. For semi-autonomous car, when there is a driver behind the wheel, the ultimate liability remains on the driver even if at this stage it may be intensely debatable. With Brexit underway, the UK Government has started consultation in allowing autonomous driving – self-driving – modes up to 70mph, with the potential for legislation as early as spring 2021, bringing UK law and standards in line with UNECE targets [32].

2.4.3 Social and Ethical Issues

Two kinds of ethical questions are raised by Autonomous vehicles.

(a) Large fleets of AV are being tested every day in roads all around the world. These technologies are equipped with advanced machine learning capabilities. When one vehicle makes an error, other vehicles with the same algorithm from a specific car manufacturer also learn from that mistake and avoid it next time around. Technology firm developing theses vehicles are spending huge sums on the development, therefore their programmes and source codes are secretly guarded. Now, is it possible to really programme these vehicles to respond to every conceivable road scenarios? Particularly in cases when the vehicle must disregard the law in order to save someone's life in a dangerous situation or break the law related to speed limit when taking someone to the hospital (A&E)? In some cases, the vehicle may have to choose between different options in a dangerous situation (either killing a young child crossing the road, a young adult, another old and disable person or heading towards a tree or a wall possibly killing the passengers of the vehicle). How would it make the selection?

(b) It is undeniable that AV introduction will deliver considerable social and economic benefits to the world, at the same time, it will make several existing jobs become obsolete. Today, when using your smartphone, you have the right to opt in or opt out when sharing your personal data. In the future, although that rule may still apply, it may be mandatory to share limited personal data by law, which will impact on people privacy right.

2.4.4 Technology

It appears that the mass adoption of AV technologies may face some practical technological hurdles. Vehicular Ad-hoc NETworks, (VANETs) were created by applying some of the key principles of Mobile Ad-hoc NETworks (MANETs). Although research on this technology remained mainly in the academic world, some of their principles are likely to be implemented soon where vehicles will be equipped with short-range radios capable of communicating with other vehicles or with highway infrastructures at distances of at least one kilometer [20]. The IEEE 802.11p was initially considered as the de facto standard that will support Intelligent Transportation Systems (ITS) applications in VANETs and connected autonomous vehicles (CAVs). This technology has scalability issues, unbounded delays, and lack of deterministic quality of service (QoS) guarantees. While many research partnerships have had this as a focus topic during Horizon 2020 [30], a problem with fragmentation has slowed progress. Although 5G is just getting started, and yet to be deployed nationwide in the UK, 6G network technologies is expected to bring autonomous vehicles to their full potential, more so than 5G could [22]. With AVs and CAVs connected to the web, they will also be a component of the Internet of Things (IoT), allowing vehicles to share data on the road. This will include the actual path, traffic information, and how to navigate around any obstacles. With the IoT, and big data, data privacy and security will also be a concern [21].

2.4.5 Infrastructure

Even though AV built today will have some level of autonomy with less dependence of dedicated infrastructure compared to early prototypes, a minimum level of infrastructure will still be necessary. These may include road markings and signage, GPS mapping, strong telecom networks [38] [39]. For V2X communication, the government and other dedicated transportation authority will still need to install important infrastructures such as Road side base stations and road side units (RSUs), intelligent traffic light systems particularly for smart cities allowing communication between vehicles (V2V) or with other infrastructures (V2I) [40]. The automaker might also facilitate delivery of some traffic-specific information through such infrastructure. The infrastructure is managed by infrastructure operators. The information is then used by the driver to generate situational awareness of the car and its surroundings and make appropriate decisions while driving [37]. Situational awareness will include an understanding of the cars own driving status (such as its velocity, acceleration, location, etc.) called the self-awareness, and an understanding of the car's surroundings (objects nearby, their state of motion, traffic signals and other road signs, etc.) called the contextual awareness [37] [38] [39].

2.4.6 Cost

The technologies to build this type of vehicle are very expensive. The cost of AVs will be the biggest barrier to their adoption [34]. Indeed, these vehicles will be equipped with advanced technologies such as sensors, camera, LiDAR which is a method for measuring distances (ranging) by illuminating the target with laser light and measuring the reflection with a sensor used to make digital 3-D representations of the target [38]. It is not only about the cost of AV, it is about the difference between the cost of traditional cars and AV [57]. In early adoption stages, possibly only wealthy people will be able to afford these vehicles but gradually, the cost of the components may be reduced later on with concepts such as the Moore's Law, the price of the vehicle components may become cheaper making vehicles affordable to the public. There would be cost related to maintenance and software updates. First cost estimates of future transport services with AVs were proposed by [34]. For three different cases (small to medium town, suburban and urban), they calculated the cost, per trip, of a centrally organized system of shared AVs (medium sedans with AV technology), which would replace existing transport services. Their estimates are based on different cost categories, which capture fixed and variable costs. They concluded that such systems could provide "better mobility experiences at radically [up to ten times] lower cost". In a second approach, [36] considered the external costs (e.g. crash or congestion cost) of today's private transport system to calculate AVs' potential benefits, which they found to be substantial. In a following paper, [35] focused on possible prices for users of a centrally organized, shared AV system. By assuming an investment cost of 70000 US$ and operating costs of 0.50 US$ per mile for AVs only, they found that a fare of 1.00 US$ per trip-mile for an AV taxi could still produce a profit for the operator. This is a higher price level than in [34] but still very competitive compared to today's transport options.

2.4.7 Cyber Security

It is largely acknowledged that AVs as well as CAVs will be part of the internet of things (IoT) and the internet of Everything (IoE), therefore it will raise numerous cyber security concerns [38]. Indeed, these vehicles will be vulnerable and subject to cyber-attacks by hackers and cybercriminal with the objective of taking over the control of their target vehicles, thus undermining vehicle safety. Furthermore, personal data could also be harvested for malicious intent [23] particularly when sensitive data are transmitted when accessing the public network. As such, cybersecurity for AVs is important to win and maintain consumers' trust which will ultimately have a large influence on mass deployment and the rate of adoption [24].

2.5 Existing studies of user acceptance of AVs

Automation of vehicles and driverless technology has attracted a lot of people from the stakeholders to the media. Stakeholders have been yearning to develop and take the automated driving technology a notch higher and meet the increasing demands of consumers. Public exposure to the different forms of electric vehicles has slowly gained momentum in recent years with various manufacturers carrying out test runs and pilot programs in Europe [60]. Such programs help towards examining the user acceptance of these modern vehicles and act as prerequisites to ensure such investment pay off. Many authors believe that customer acceptance is likely to be the biggest obstacle to autonomous vehicle penetration [1] [2] [12]. According to [4], there are different factors that influence and motivate the environmentally conscious behaviours. The elements encompass the personal values; environmental concerns as well as the belief that one can make a difference in the use of such vehicles. Also, these factors contribute towards an individual's purchase intentions for the alternative fuel vehicles. Gas prices significantly impact the individual's interest in buying hybrid electric cars. There are other customer preferences such as reduced air pollution, reduced maintenance and better handling. There is no doubt that environmentalists and people that have strong preferences for energy security will automatically adopt the hybrid electric cars. Results of the study by [3] highlighted four determinant factors affecting purchasing behaviours of the potential buyers: high costs, charge inconvenience, psychological factors and short battery range. A study in China also revealed some deterministic factors or concerns when purchasing autonomous vehicles such as the cost of operations, overall buying cost, possible speeds and battery capacity. In the USA, the potential buyers considered the charge time and range as concerns other than the value of the hybrid vehicles. Findings by [15] also show that the attributes, personal norms, the perceived behavioural control as well as the planning abilities influenced the decision to buy an autonomous vehicle. Customers will always be concerned about the potential advantages as well as the promises as indicated below:

- **Safety Benefits**

According to the National Highway Traffic Safety Administration (NHTSA) annual reports, most car accidents are linked with human error as a result of distractions, sickness or fatigue [13] [61]. Thus, autonomous cars are capable of increasing traffic safety as all the critical functions of the driver are system oriented. Hence, a guarantee of safety for the users is a consideration when purchasing autonomous vehicles [59].

- **Time Savings**

Hybrid electric cars are considerate and time efficient. They can optimize the choice of routes based on their ability to collect updated traffic information and thus a person can reach their desired destination faster compared to human-driven vehicles. Automated vehicles also reduce congestion through minimized road accidents and shortened travel times for the users. The Internet of Things (IoT) will significantly influence the adoption of automated cars. Self-parking functionalities continue to be advanced with major improvements expected to be rolled out in the coming years to reduce damages because of parking accidents.

- **Fuel savings**

The V2V and V2I communication increases the fuel economy by a considerable percentage when automated vehicles are used. Fuel savings are also enhanced through high utilization of highways and the ability for the vehicles to travel closely together. The use of AVs significantly lessens the environmental degradation due to reduced greenhouse emissions. Additionally, the reduction of these pollutants also minimizes the social costs associated with human health [59] [60]. Autonomous technology will improve the productivity levels of the individuals. The passengers of the autonomous cars participate in other social activities such as resting (sleeping), reading, watching movies or working.

3 Formulating the Autonomous Vehicles Technology Acceptance Model (AVTAM)

This study was conducted in the UK using two surveys. The initial survey was developed to identify other important factors previously neglected by existing models and theories. The second survey was used to test the proposed model. Using a convenience sampling technique, a questionnaire (survey 1) was distributed to participant largely students and academic staffs from several British universities and other random users. The target population was any potential users of commercial AV and the sample size was 408 participants. In-dept interviews were also conducted with 25 experts including academics and practitioners in the fields of sociology, psychology and computer science. Data was collected from both sources together with extensive literature analysis to help generate the AVTAM model proposed in figure 2 below.

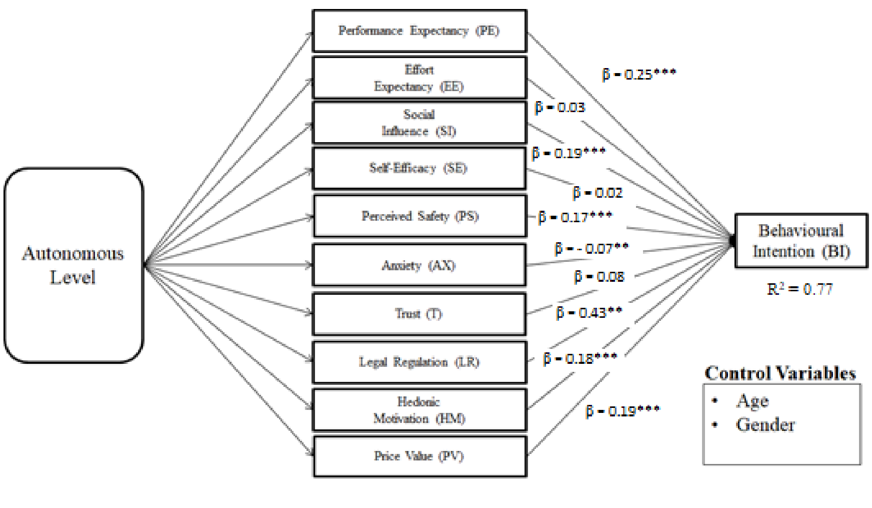

Fig. 2. Research model for Measuring consumers' behavioural intention to adopt Autonomous Vehicles: Autonomous Vehicle Technology Acceptance Model (AVTAM)

During the study, the following factors and hypotheses were identified as key to the mass adoption of this emerging technology.

Performance Expectancy (PE)

In this context, **PE** is the extent to which an AV user will have confidence that the technology meets his/her expectation and would be able to improve individual daily life activities, while increasing productivity, safety, trust, privacy protection and decreasing accidents on the road. In other words, doing what it is supposed to do. Gender and age are theorised to play a moderating role in this case, such that the effect will be stronger for men and specifically for younger men [41] [42] [43] [44] [45] [46].

H1: *Performance Expectancy will be positively related to behavioural intention of using autonomous vehicles.*

Effort Expectancy (EE)

In this scenario, EE is referred to as the degree of ease related to learning how to operate this type of technology safely. It appears that the influence of EE on people intention or use behaviour will be moderated by gender, age and previous experience of using the technology. The clarity of the instructions from AV manufacturers and the simplicity of the interaction with these vehicles. The influence of effort expectancy on behavioural intention will be moderated by gender, age and experience. It is suggested that effort expectancy is more salient for women than for men. The gender differences predicted here could be driven by cognitions related to gender roles. It has also been showed that the further someone is older, the harder it is to process complex information. Thus, the study proposes that effort expectancy will be most noticeable for women, particularly those who are older and with relatively little experience with autonomous vehicles. The influence of effort expectancy on behavioural intention will be moderated by gender, age and experience, such that the effect will be stronger for women, particularly younger women and mostly at early stages of experience [41, 44, 45].

H2: *Effort Expectancy will be positively related to behavioural intention of using autonomous vehicles.*

Social Influence (SI)

In this setting, SI could be understood as the degree to which someone would perceive that people who are important to him or her would appreciate him or her using the technology. Your friends, family members, Journalists, expert reviewers and the media have a strategic position to influence your opinions, emotions or behaviours. This construct can be seen taking several forms; socialisation, conformity, review of information, persuasion, peer pressure obedience, sales and marketing. The impact of social influence on behavioural intention will be moderated by gender, age and experience, such that the effect will be stronger for women, particularly older women, particularly older women in mandatory stages of experience [44].

H3: *Social Influence will be positively related to behavioural intention of using autonomous vehicles.*

Self-Efficacy (SE)

In this scenario, the construct self-efficacy is defined as someone's belief in his/her abilities and competence to use a piece of technology and accomplish a specific task. Generally, self-perception and external experiences play a key role on how someone approach a goal or a task. In the AV context, people with high self-efficacy - those who believe they can perform well are more likely to view a tough task as something to be learned rather that something to be avoided.

H4: *Self-Efficacy will be positively related to behavioural intention of using autonomous vehicles.*

Perceived Safety (PS)

PS in this scenario is defined as the degree to which an individual believes that using a specific technology will threaten his or her safety. Within AV, this also comprises the judgment of one's own driving capabilities and safety feeling in relation to other drivers. The impact of perceived safety is assumed as critical in the process of predicting the behavioural intention to use, as the user will evaluate the potential effect of safety-related consequences through using the technology on public road and dangerous surroundings. The following concepts are included in this factor: Vehicle security and safety, cyber security concerns.

H5: *Perceived Safety will be positively related to behavioural intention of using autonomous vehicles.*

Anxiety (AX)

In this scenario, AX is defined as the degree to which an individual reacts to a circumstance with uneasiness. The construct AX and Behavioural Anxiety differ as per their origin, as Anxiety was borrowed from the computer anxiety determinant proposed within the Social Cognitive Theory (SCT) and was also used in the Unified Theory of Acceptance and Use of Technology (UTAUT) validation. Behavioural Anxiety otherwise reflects anxiety in a more general understanding towards the autonomous vehicle or system behaviour which addresses e.g. the fear to lose control of the car [47,48].

***H6**: Anxiety will be negatively related to behavioural intention of using autonomous vehicles.*

Trust (T)

In the past few years, some car manufacturers have misled the public and some other government authorities about their real engine CO^2 emission. This kind of behaviours can largely damage consumer trust. Today, it may be difficult to accept statements from car manufacturers without evidence or proof. In this scenario, trust is defined as the belief in the reliability, truth, or ability of the car. The belief that consumers can trust the car and the system to function as presented while protecting users' personal data.

***H7**: Trust will be positively related to behavioural intention of using autonomous vehicles.*

Legal Regulation (LR)

In this AV scenario, LR is defined as the rule of order having the force of law made and maintained by an authority and transportation regulatory bodies. The following elements are included in this construct:
Effort by the government and car manufacturers to better support users, regulations, policies, legislation, liability, law.

***H8**: Legal Regulation will be positively related to behavioural intention of using autonomous vehicles.*

Hedonic Motivation (HM)

HM in this context refers to the influence of a person's pleasure and pain receptors on their willingness to move towards a goal or away from a threat. The fun or pleasure derived from using a technology, it has been shown to play an important role in determining the rate of technology acceptance and use. Therefore, the influence of HM on behavioural intention will be moderated by age, gender and experience.

***H9**: Hedonic Motivation will be positively related to behavioural intention of using autonomous vehicles.*

Price Value (PV)

Consumers' technology may be influenced largely by the cost of these technologies, and the pricing structure of their maintenance. In marketing studies, it is accepted that the quality of a product or service is also theoretically related to the price. PV is positive when the benefits of using a technology are perceived to be superior to the monetary cost and such price value has a good impact on behavioural intention. Thus, price value has been added as a predictor of BI to use AV [49]. The following elements are included in this factor: Cost of the vehicle, operational cost and maintenance cost, cost related to the network protocols and standards being used.

H10**: Price Value will be positively related to behavioural intention of using autonomous vehicles**.

Behavioural Intention (BI)

BI in this context can be defined as a person's aim to perform a given act which can predict corresponding behaviours when an individual acts voluntarily. Besides that, BI is the subjective probability of carrying out behaviour and also the cause of certain usage behaviour [26]. Thus, intentions show the motivational factors that influence behaviour and are indicators of how hard people are willing to try and the effort they put in to engage in a behaviour. Also, it was found that behavioural intention is to be the main factor of individual AV usage and that usage intentions are rational indicators of future system use.

4 Method

In this study, UTAUT2 has been used as a base model to better understand behavioural intention to accept AV. UTAUT2 [53] was expanded as illustrated in section 3 to develop the AVTAM. After creating the proposed research model, it was necessary to test and validate the constructs. For the second survey, the population selection was similar to the first survey, also conducted in the UK. The participants were people who used car as passengers or drivers and they didn't have to have had experience riding an AV in the past. Questions were developed using the free tool Google Forms and administered online and via email whenever possible using social media network. Indeed, by creating our questionnaire using Google Forms, the system generated a unique link that could be shared electronically. The questionnaire had an introductory paragraph included at the beginning explaining what self-driving cars were about. The introductory paragraph also clarified the purpose of the study and explaining to participants how all information collected would be anonymous and confidential. At the same time, participants had to confirm that they were at least 18 years of age. Before anyone could start answering the question there was a very short YouTube video demonstrating to participants how self-driving cars (Google Car) worked and what could be the benefits of this technology to future road users.

To test the hypothesis and validate the proposed model, the researcher designed series of questions (Observable Variables) to help us measure our constructs (Independent Variables) (PE, EE, SI, SE, PS, AX, T, LR, HM, PV) which are variables that are not directly observed but are rather inferred [53]. The researcher has developed a series of Likert scale questions. All items of the model were measured using a seven-point Likert scale, [50] [51] [52] with the anchors being "strongly disagree" and "strongly agree." 482 valid responses were analysed using the Structured Equation Modelling (SEM) techniques with the R Studio and the Statistics Package for Social Science (SPSS) software. The following statistical tests were applied to the data.

Reliability analysis. Reliability analysis is a measure to define the degree to which measurements are free from error, that is how closely related a set of items are as a group and therefore yield consistent results [53]. In this study, Cronbach's Alpha was used to examine the internal consistency of each measure. As recommended by [29], a minimum cut off of 0.7 for Cronbach's Alpha reliability coefficients was employed. The result of this test is shown in **table 3**. Below, for conceptual purposes, (1) shows the formula for the Cronbach's Alpha [29]:

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \tag{1}$$

Here N is equal to the number of items, $\bar{c}$ is the average inter-item covariance among the items and $\bar{v}$ equals the average variance.

Correlation analysis. Correlation analysis is a measure of the degree to which a change in the independent variable will result in a change in the dependent variable. This test is a bivariate analysis that measures the strength of association between variables and the direction of the relationship. In terms of the strength of relationship, the value of the correlation coefficient varies between +1 and -1. A value of ± 1 indicates a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker. The result of this test is shown in **table 4**.

Regression analysis. Regression analysis includes any techniques for modelling and analysing several variables, with a focus on the relationship between a dependent variable and one or more independent variables.

Structure Equation Modelling (SEM). is a "multivariate technique combining aspects of factor analysis and multiple regression that enables the researcher to simultaneously examine a series of interrelated relationships among the measured variables and latent constructs as well as between latent constructs" [27] SEM examines interrelated relationships among multiple dependent and independent variables [27, 28]. In this study, Exploratory Factor Analysis (EFA) was used to summarise information from many variables in the proposed research model into a smaller number of factors. The

Confirmatory Factor Analysis (CFA) was also used to assess unidimensionality, reliability and validity of the constructs used in the model. In the process, this path analysis (SEM) was used to examine the hypothesized relationships between the latent constructs in the proposed model. According to [29], critical ratio (CR) estimates value >= 1.96 suggests significance of the causal path between latent constructs. The results of the original structural model are illustrated in **table 5**.

5 Results

Sample characteristics were analysed using frequency distributions (Table 2). The analysis of the data collected shows gender groups are evenly represented with 56.4% males and 43.6% females. The most represented age groups are 45 – 54 years (22%), 35 – 44 years (21.6%). With respect to levels of education, 78.8% of respondents had achieved a higher educational degree, with 13.7% PhD holders.

Table 2. Demographic breakdown of respondents

Demographic aspect		U.K. (N=482)	Percentage (%)
Age group	18 - 24	89	18.5%
	25 - 34	82	17%
	35 - 44	104	21.6%
	45 - 54	106	22%
	55 - 64	75	15.6%
	65 & Over	15	3.11%
	Prefer not to say	11	2.3%
Gender	Male	272	56.4%
	Female	210	43.6%
Level of driving Experience	No driving experience	51	10.6%
	Novice	42	8.7%
	Intermediate	80	16.6%
	Experienced	296	61.4%
	Expert	13	3.7%
Education	No formal qualifications	1	0.2%
	GCSE or equivalent	10	2.1%
	A level or equivalent	91	18.9%
	Bachelor's degree	148	30.7%
	Master's degree	151	31.3%
	PhD	66	13.7%
	Other	15	3.1%

In this section, we use Cronbach's Alpha (see Table 3.) to measure the internal consistency that is, how closely related set of items are as a group. All the values are greater than 0.7, which clearly shows the reliability of the scale/research instrument. Dillon-Goldstein rho should be higher than 0.8, as the minimum is 0.91 this is satisfactory.

Table 3. Cronbach's Alpha

#	Measure	Cronbach's Alpha
1	Performance Expectancy	0.91
2	Effort Expectancy	0.93
3	Social Influence	0.82
4	Self-Efficacy	0.86
5	Perceived Safety	0.80
6	Anxiety	0.88
7	Trust	0.85
8	Legal Regulation	0.90
9	Hedonic Motivation	0.96
10	Price Value	0.87
11	Behavioral Intention	0.92

Table 4. below presents the correlation matrix showing the correlation coefficients between different constructs part of the proposed model. The most correlated variables are PE & BI (0.81), so with the higher performance expectancy there is higher behavioural intentions, and PE & PS (0.73) and the least correlated variable is the Age. The anxiety is negatively correlated and that is good, the maximum is for Perceived safety (-0.74), which corresponds to what could be expected, as higher Perceived Safety implies less Anxiety.

Table 4. Correlations Matrix

Measure	PE	EE	SI	SE	PS	AX	T	LR	HM	PV	BI	Age	Gdr
PE	1												
EE	0.66	1											
SI	0.73	0.62	1										
SE	0.55	0.62	0.6	1									
PS	0.68	0.6	0.48	0.42	1								
AX	0.51	-0.5	0.38	0.33	0.74	1							
T	0.64	0.57	0.55	0.53	0.6	0.45	1						
LR	0.55	0.48	0.54	0.46	0.43	-0.3	0.72	1					
HM	0.58	0.45	0.53	0.42	0.36	-0.3	0.5	0.45	1				

PV	0.56	0.49	0.5	0.4	0.51	0.43	0.54	0.5	0.42	1			
BI	0.81	0.63	0.72	0.55	0.7	0.57	0.66	0.55	0.64	0.66	1		
Age	-.0.5	-0.4	-0.3	-0.2	-17	0.06	0.40	0.03	0.26	0.23	0.5	1	
Gender	0.08	-0.5	-0.4	0.22	0.12	0.11	0.18	0.21	0.02	0.13	0.29	0.29	1

Table 5. Results of the original structural model

Construct	Code Name	Hypotheses	Relationship (Positive)	Standardized regression weights (β)	Supported
Performance Expectancy	PE	H1	PE → BI	0.256	YES***
Effort Expectancy	EE	H2	EE → BI	0.038	YES
Social Influence	SI	H3	SI → BI	0.199	YES***
Self-Efficacy	SE	H4	SE → BI	0.020	YES
Perceived Safety	PS	H5	PS → BI	0.176	YES***
Anxiety	AX	H6	AX → BI	-0.077	YES**
Trust	T	H7	T → BI	0.084	YES
Legal Regulation	LR	H8	LR → BI	0.043	YES**
Hedonic Motivation	HM	H9	HM → BI	0.184	YES***
Price Value	PV	H10	PV → BI	0.193	YES***

*** Significant at 0.001 level (two tailed), **Significant at 0.01 level (two **tailed)**

Both the goodness of fit indices and parameter estimates coefficients were examined to check whether the hypothesised structural model fitted the data and to test the hypotheses. The fit indices indicated that the hypothesised structural model provided the good fit to the data. All hypotheses were supported (See Table 5.).

Table 6. Illustrates that a total of 10 research hypotheses were tested to examine if the independent variables significantly explained the dependent variables.

Table 6. Summary of Research Hypotheses

HN	Research Hypotheses	Results
H1	Performance Expectancy will be positively related to behavioural intention of using autonomous vehicles.	Supported
H2	Effort Expectancy will be positively related to behavioural intention of using autonomous vehicles.	Supported
H3	Social Influence will be positively related to behavioural intention of using autonomous vehicles.	Supported
H4	Self-Efficacy will be positively related to behavioural intention of using autonomous vehicles.	Supported

H5	Perceived Safety will be positively related to behavioural intention of using autonomous vehicles.	Supported
H6	Anxiety will be negatively related to behavioural intention of using autonomous vehicles.	Supported
H7	Trust will be positively related to behavioural intention of using autonomous vehicles.	Supported
H8	Legal Regulation will be positively related to behavioural intention of using autonomous vehicles.	Supported
H9	Hedonic Motivation will be positively related to behavioural intention of using autonomous vehicles.	Supported
H10	Price Value will have a significant influence on behavioural intention of using autonomous vehicles.	Supported

The summary of the research hypotheses test; also, a reflection of the hypotheses relating to proposed conceptual model the performance of the said proposed model. It is possible to compare the predictability of the Autonomous Vehicle Technology Acceptance Model with previous study.

Table 7. Comparison of Intention and Behaviour in Terms of Adjusted R2

Study	**Theory**	**Adjusted R^2**	
		Behavioural Intention	**Actual Behaviour**
Davis et al (1989)	TAM	---	0.45
Davis et al (1989)	TRA	---	0.32
Davies (1989)	TAM	---	0.51
Taylor and Todd (1995)	DTP	0.57	0.34
Taylor and Todd (1995)	TBP	0.57	0.34
Taylor and Todd (1995)	TAM	0.52	0.34
Karahanna et al (1999)	TRA + TAM	0.38	---
Agarwal & Karahanna (2000)	TAM & Cognitive Absorption	0.50	---
Gefen & Straub (2000)	TAM	0.20	---
Brown et (2002)	TAM	0.52	---
Koufaris (2002)	TAM + Flow Theory	0.54	---
Current study	AVTAM	0.77	---
Recommended level (Straub et al, 2004)		0.40 or above	0.40 or above

Table 7 illustrates the comparison of previous studies for the adjusted R^2 obtained for both behavioural intention and actual behaviour. The comparison clearly demonstrates that the AVTAM performed as well as the previous studies. With regards to the behavioural intention value of adjusted R^2 varied between 0.20 [54] and 0.57, the adjusted $R^{2.}$ For this study is found to be 0.77, which suggests that the model has a very high predictability power [55, 56].

Living in the 21st century, technology often overtakes our ability as a civilization to come up with accepted rules of how it can be used. AV is one of these technologies that would disrupt the way how almost everything works in our society. Recent predictions that AVs will be here sooner than most people expect is progressively being acknowledged and becoming a reality. In the UK, the government's strategic policy plans are very favourable for research and investments in intelligent transportation systems. The following are some of the main recommendations surfaced and questions that still require answers:

- The impact AV deployment will have on the type of future road infrastructures should be investigated by researchers and professionals in the department of transport UK. Immediate studies will be required to reassure the public.

- The unpredictable and unknown element of future regulation subject to be imposed also appears to be one of the greatest barriers to innovation. In fact, despite all simulation and tests taking place now all around the world, it is difficult to know the rules that will be applied in their final forms. Therefore, questions remain about how fast tests can be endorsed and the length of the application process.

- Due to the life-threatening nature of this technology, it will be necessary to have policies, protocols and standards in place that would allow AV manufacturers to share their data with other car manufacturers to better understand each other mistake therefore reducing possible instance where these mistakes are duplicated.

- In a future world where AVs bring multiple travel advantages, it may be necessary to implement some form of road pricing that will play a crucial task in avoiding the rise of traffic volumes and congestion.

- It is predicted that AV deployment will provide more freedom and flexibility to people with disabilities such as passengers with mobility problems. This is likely to be available at a lower cost than the on-demand transport system which is presently offered.

- These vehicles may be supplementing bus services, so should the public transport authorities manage their operation? Tests conducted on existing prototypes demonstrate that AV will be generating large amount of data. Should the government own and manage people private information? Wouldn't it give considerable powers to authorities? Should it be administered by private parties? So, it is still unclear who will own the data generated and how it would be managed.

6 Conclusion and Future work

Throughout this study, technology acceptance literature shows the scarcity of empirical research of the determinants of the individuals' behavioural intention to use AV, especially in UK. This study examined the viability of the UTAUT2 model, which was established in developed economy settings for information systems, in explaining a similar behaviour within emerging technologies settings. Thus, the results of the present research contributions fill this important gap as AVTAM has been identified as a useful model to better understand consumers' behavioural intention to adopt AV. Most governments around the developed world are urgently working on sustainable transport policies and strategies to resolve key problems like environmental degradation, social inequity, congestion, road accidents and public health. In this paper, AV as a disruptive technology has been identified as a potential innovative transportation option for smart cities in an attempt to create a more sustainable productive development. It has been observed that consumers' acceptance is likely to be one of the most challenging aspect of AV deployment. Constructs influencing user behavioural intention to accept the technology have been identified and tested. The findings suggest that safety of these vehicles, trust, privacy protection and legal requirement and price value will play a crucial role and the proposed research model has a considerable predictive power. Findings of this research study have many marketing, managerial and customer service implications for different stakeholders such as car manufacturers and emerging technology designers. Future studies could focus in exploring the effect of factors such as cultural influence and socio-economic status on technology adoption, it is also important to evaluate various age groups behaviour such as senior citizens intention towards AV and the challenges they will face after the mass adoption.

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