The Future of Mobility with Connected and Autonomous Vehicles in Smart Cities

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Abstract: Cities around the world are being wrecked by the ever-increasing burden of traffic. Smart cities are a recent innovation perceived as a winning strategy to cope with some severe urban problems such as traffic, pollution, energy consumption, waste treatment. This concept is attracting significant interest in the world of technology and sensors. Governments can streamline the way cities are run, saving money and making them more efficient as a result. Rapid urban developments, sustainable transportation solutions are required to meet the increasing demands for mobility whilst mitigating the potentially negative social, economic, and environmental impacts. This study analyses the smart mobility initiatives and the challenges for smart cities with connected and autonomous vehicles (CAVs), it also highlights the literature that supports why CAVs are essential for smart maintainable development as part of the intelligent transportation system (ITS).

Keywords: Smart cities; Smart mobility; ITS; IoT; Security; Connected and Autonomous Vehicles (CAVs)

1. Introduction

For the majority part of the 20th century, the concept of smart city was only science fiction pictured by the popular media. But very recently with considerable progress achieved in the development of computing and electronic devices, the vision that an entire city could be transform into a smart town is becoming a reality [1]. The idea of the smart city captured most people attention during the last decade as a blend of beliefs on how technology in general could be used to transform how cities around the world work, while improving their competitiveness, offering new ways of solving problems linked to poverty, social deprivation, pollution and poor environmental issues [2]. Smart cities are often seen as collections of intelligent devices installed across the city able to communicate with each other while providing constant data on the movement of people and objects. Over 50% of the world population now live in cities and it is expected that by 2050, cities will be home for about two-thirds of the world inhabitant [3]. As the population in cities continue to rise, the need for mobility as well as its burdens on the environment, social stability and the economy will grow rapidly [4]. People are attracted to cities mainly because of all the great opportunities they offer. In cities people are able to live and work, companies are able to settle, grow and recruit competitive staffs, young people able to go to schools and universities. However, cities are also places for diseases mainly because in cities there are high volumes of cars, traffic, CO_2 emission, high cost of living where waste production and pollution are worse. The possible applications of smart vehicles such as connected vehicles (Car2X technologies), autonomous vehicles (AVs) as well as connected and autonomous vehicles (CAVs) are wide-ranging, spanning on a variety of different sectors. CAVs appear to be a possible answer to contemporary transportation problems. Mass adoption of this emerging technology as a mode of transportation will reduce issues linked to emissions and energy consumption, while improving traffic flow, accessibility and efficiency of transportation systems, road safety, and city efficiency among other benefits [5, 6, 7, 8]. The deployment of CAVs will provide a time and space for other activities to take place from catching up on emails to watching TV. This chapter defines the concept of smart cities, it analyses connected autonomous vehicles (CAVs) as a prospective future mobility solution for smart and sustainable development. We will also identify challenges and security threats of CAVs as critical risks to the expansion of smart and sustainable cities around the world.

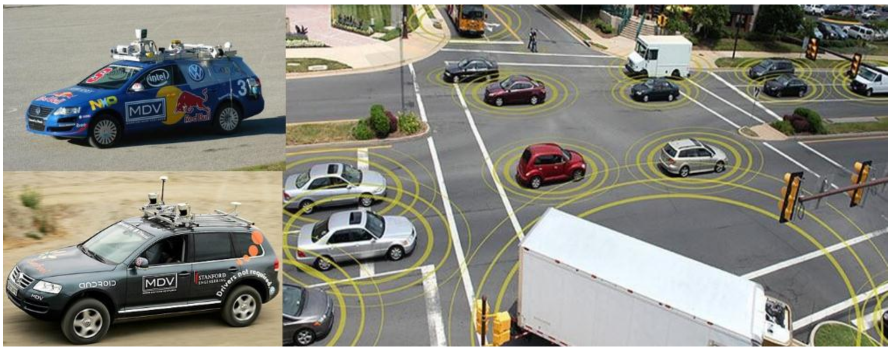

Figure 1 A graphical depiction of connected autonomous vehicles equipped with technologies such as Lidar, video camera, positioning estimator, distance sensors. These vehicles can “talk” to each other exchanging information such as vehicle size, position, speed, heading and turn signal status. (Image extracted from www.trucks.com and adapted).

In **Figure 1**, video cameras are mounted near the rear-view mirror, the camera detects traffic lights and any moving objects, the Lidar positioned on roof of the car as a rotating sensor scans the area in a radius of 60 metres for creation of a dynamic, three- dimensional map of the environment. A position estimator which is a sensor mounted on the left rear wheel measures lateral movements and determines the car's position on the map. Distance sensors made up of four radars, three in the front bumper and one in the rear bumper, measure distances to various obstacles and allow the system to reduce the speed of the car. CAVs will also be equipped with an event data recorder or EDR also referred to as automotive black box, recording information related to vehicle crashes or accidents.

The main contributions of this paper are as follow: (1) We present CAVs as the way forward and future for intelligent transportation system. (2) We analyse the capabilities of this technology to optimise network capacity, reduce congestion, make people's journeys stress free and increase safety and reduce pollution. (3) We explore the main challenges CAVs are facing while highlighting the key literature to encourage dialogue and engagement with national and local government, network operators, the automotive industry, technology providers, the logistics sector etc– as well as all the different stakeholders for who the road network is fundamental to connecting people and places.

The rest of the paper is organised as follows. In section 2, we explore the concept of smart city and its challenges. In section 3 we discuss how sustainable mobility could be reinvented for smart cities. Section 4 evaluate how transportation could become eco-friendly. Section 5 review the impact of CAVs on KPIs for smart cities. Section 6 explores the barriers to CAVs implementation and Section 7 presents our conclusion and future work.

2. Smart city concept and challenges

In the early 1990s the expression "smart city" was coined to indicate a city that has been transformed to a modern urban landscape with the effect of globalisation, extensive usage of technology and innovation [9]. In the past few years, this concept has attracted significant attention in the context of urban development policies and from various governments interested in collecting more and more data about their population. In this setting, security agencies, law enforcement organisations, secret services and other relevant bodies will be able to monitor, collect and analyse data about the movement of people going to school, work, libraries, hospital and other community services, goods, traffic information, power plants activities, waste management, water supply networks, energy facilities in real-time [10]. It is very important to recognise that infrastructure is a vital element for smart cities. Technology is one of the tools that make it possible but fundamental for the city to be truly smart, there should be a connection, combination and integration of all parts of the puzzle. For cities to gradually assume a critical role of leaders in innovation in sectors such as business, transportation, health in the digital economy, e-services enabled by internet and broadband network technologies are very important. Around the world, as cities continue to grow, more and more people are pursuing better lifestyle, challenges related to economic development, population growth and social progress seriously need to be considered carefully. In the reviewed literature, challenges have been identified and classified in six main city dimensions: Governance, Economy, Mobility, Environment, People and Living; see table 1. They represent the specific aspects of a city upon which smart initiatives impact to achieve the expected goals of a smart city strategy (sustainability, efficiency and high quality of life). Addressing the problems and development priorities of cities in a global and innovation-led world is the most important challenge of smart cities. Table 1. shows a possible classification of smart cities challenges:

Table 1. Challenges in European cities [11].

Governance	**Economy**	**Mobility**	**Environment**	**People**	**Living**
Flexible Governance	Unemployment	Sustainable mobility	Energy saving	Unemployment	Affordable housing
Shrinking cities	Shrinking cities	Inclusive mobility	Shrinking cities	Social cohesion	Social cohesion
Territorial cohesion	Economic decline	Multimodal transport system	Holistic approach to environmental and energy issues	Poverty	Health problems
Combination of formal and informal government	Territorial cohesion	Urban ecosystems under pressure	Urban ecosystems under pressure	Ageing population	Emergency management
	Mono-sectorial economy	Traffic congestion	Climate change effects	Diversity as source of innovation	Urban sprawl
	Sustainable Local economies	Non-car mobility	Urban sprawl	Cyber Security	Safety and Security

	Social diversity as source of innovation	ICT infrastructure deficit			Cyber Security
	ICT infrastructure deficit				

Governments around the world who aspire to develop smart cities really need to change their governance models. Reduction of greenhouse gases emission, sustainable development, improvement of the energy efficiency of urban infrastructures are some other societal issues that should be addressed. In smart mobility, the overall challenge is to accomplish an inclusive, sustainable and efficient transportation system of people and products. This could be achieved with the introduction of CAVs. On one hand, deploying a multimodal public transport system also known as combined transport system, making public transport accessible to all people and encouraging alternatives to car-based mobility are the three focus points that will allow improvement of connectivity, reduction of congestion and pollution in cities [11]. On the other hand, as a follow up to the Paris Agreement adopted by consensus in 2015 on the necessity for countries to deal with greenhouse-gas-emission and achieve a sustainable development, there is a rising ecological demand for cities around the world to find ways of reducing energy consumption, CO_2 emissions and pollution. Cities able to prioritise those crucial aspects and overcome the challenges listed above are crucial elements that set apart cities when it comes to good quality of life.

3. Smart sustainable mobility for smart cities

During the last 50 years, the sizes of cities have been growing considerably all over the world and it is predicted that city dimensions will increase even more in the future. In the past, to resolve the growing urban environment needs, most governments used to build more road and streets. Today, due to the lack of public funds and physical space, the transport network with a reduced capacity and the increased size of the population, is becoming overloaded, creating more congestion, CO_2 emissions and serious disruptions to citizens [12].

Mobility as we know it today must be carefully evaluated, considered and re-invented. At this moment in our development, we are at a junction for a paradigm shift that will encourage the increase use of smart mobility services with ultra-efficient vehicles, renewable energy, cooperative systems, innovation and optimization of cities resource allocation with ITS. In a bid to deliver better services to the citizens and increase the quality of life in urban spaces, smart cites are considered to be a winning strategy to enhance environmental quality [13]. Mobility is recognised as one of the most important elements to support the functioning of the urban area for a better quality of life. Yet, major issues such as traffic jam, the time it takes to cross the city, the bad state of work life balance, street congestion and the excessive price of public local transport services are only some of the negative impacts and problems it produces. Smart mobility with CAVs appears to be one of the most promising aspects of smart cities with the capability to substantially improve the quality of life of most city workers and the stakeholders [14]. The following six categories summarise the most important smart mobility objectives retrieved from existing literature [15, 16].

1. Reducing pollution;
2. Reducing traffic congestion;
3. Increasing people safety;
4. Reducing noise pollution;
5. Improving transfer speed;
6. Reducing transfer costs.

Additionally, smart mobility systems include a range of interventions with AVs and CAVs that must be viewed through a wide-angled lens as a technology involving several disciplines (psychologists, sociologists, computer scientist and engineers). These systems use all the paradigms comprising the smart city which includes digital city, green city and knowledge city. It also includes both actions concerning the mode of transport which affect the behaviours of residents and the introduction of vehicles with certain characteristics. [17] portrayed the AV emphasizing on key concepts such as “Connected” and “Big Data”. Indeed, in the future we will not only have connected vehicles better known in the research community as VANET (Vehicular Ad-hoc Network) able to talk with each other (V2V) and to infrastructures (V2I). These vehicles will be autonomous equipped with internet and communication capabilities as part of the internet of things, ensure communication between all contributing agents and stakeholders such as pedestrians, road infrastructure (road side base stations or intelligent traffic lights…), authorities, other vehicles. Figure 2 depicts a conceptual representation of a connected system.

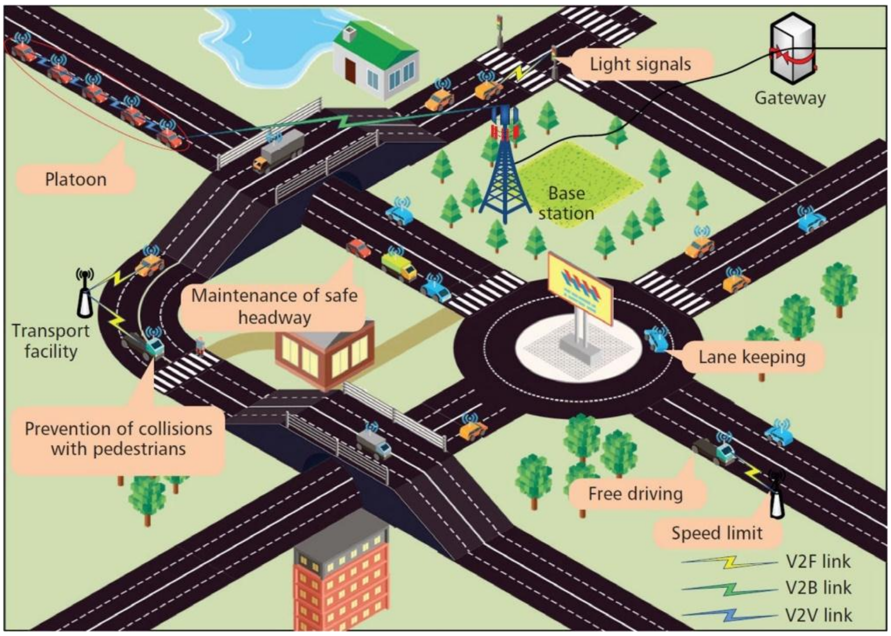

Figure 2. A representation of connected vehicles and infrastructure [18].

With ITS and the increased integration of information and communication technology, it is beyond doubt the question now is not whether the whole transportation system will be transformed and revolutionized, but how soon would this happen. Smart technologies will be introduced at all stages of the systems including vehicles, traffic light, surrounding infrastructure, systems management, energy supply and the delivery of services around the city. This trend continuing gradually will form a powerful intelligent ecosystem on one hand part of the internet of things (IoT) where objects and devices inevitably collect and share that data that they receive, and in another hand part of the internet of everything (IoE) where cities are able to bring together data collected from people, processes and things in a bid to make networked connections more relevant than ever before, turning eventual random data into information and knowledge to create richer experiences and unprecedented economic opportunities for individuals, businesses or even countries . Autonomous vehicles equipped with communication facilities will have the ability to monitor and collect valuable data about their surroundings and provide important information to other road users and infrastructure systems. The IoT and IoE will make communication between all pieces of the puzzle possible by enabling a whole range of service automation and optimization. As part of the solutions proposed in existing smart mobility literature, it appears that concepts such as car-sharing may become very popular. It is expected that CAVs will be electric. Car-sharing is a service that allows you to use a car reservation, picking it up and bringing it back to a parking lot and paying due to the use made. It allows reduction of urban congestion, reduction of polluting emissions (gas and noise), reduction in employment of public space and, in general, a new push towards the use of public transport [19]. TESLA company with their new business model is one of the leading car manufacturers developing electric vehicles (EVs) equipped with powerful, high performing, reliable and cost-effective batteries. These initiatives are part of the movement to combat climate change. Eventually, new vehicles producers will innovate and promote green and sustainable mobility. As a strategy to gradually migrate from conventional vehicles running on gasoline or diesel, car manufacturers may develop hybrid vehicles at the beginning and progressively move to electric vehicles powered with batteries. This move will ultimately disrupt several sectors and have a huge impact on the oil industry. On one hand, authorities should put in place infrastructure and policies supporting sustainable mobility such as the creation of bicycle lanes or interventions aimed at changing mobility as the creation of restricted traffic zones. The expansion or creation of bicycle lanes is an intervention that is closely linked to the use of the bicycle as a mean of private transport and could have positive effects on the spread of bike-sharing; On the other hand, a series of integrated policies that can be implemented to change the mobility system, in particular by the public decision maker (for example: incentives for the use of less polluting fuels, tax incentives or measures such as higher taxation on polluting fuels). One efficient way to achieve lower greenhouse gas emissions is by Intelligent Transport Systems and Services (ITS) that utilizes information and communications technologies. ITS helps achieve transport policy goals by shifting the focus from expensive transport infrastructure construction towards efficiency and fluency of mobility and logistics while creating and enabling new business. It must be noted that the introduction of ITS technologies will also significantly contribute to improved efficiency, safety, environmental impact and overall productivity of the transportation system.

4. Eco-conscious provisions for public transportation

Saying that we are connected to the World Wide Web (WWW) generally means to people that we are using our smart phones, smart watches, tablets or computers to access the internet. According to [20], in the year 2008 the number of things connected to the internet somehow surpassed the number of people on earth. By 2020 it is estimated that the number of items and things connected to the net around the world will be over 50 billion shaping a rich digital environment. These elements will be shaping the very fabric of our digital culture with numerous sensors embedded to our mobile devices storing and sharing data about our lives. In the future, smart cars will also be part of this ecosystem. South Korea is known as the most wired country on earth with fast internet connection and an impressive broadband connection even superior to the one currently in the UK. People spend a considerable amount of time on the internet. In some places, the internet is now classified as an addiction. More and more people are spending considerable part of their lives online. With Intelligent transportation systems in smart cities, vehicles will be mobile platforms more like computer on the road or rather computer network on the road together with huge scale cloud infrastructures and other network-enabled devices. Vehicles will have the ability to cooperate and interact with each other and road side base stations therefore creating value across numerous sectors in smart cities.

While being driven by autonomous technologies, people will be able to read, watch movies, play games, sleep or work and be more productive. As part of the process to realise the truly sustainable smart city vision technologies around the world should focus their energy in developing applications and devices with IoT capabilities. Enabling things and objects such as street cameras, traffic jam control systems, sensors for transportation times to be smarter. This will then give access to applications' developers access to these devices data through application programming interface (API) technologies.

In most advanced European cities, transportation is regarded as one of the main activities for daily living. Most commuters spend on average an hour or more per day travelling [21]. London is a multicultural city and many people work in London but live outside the city mainly because of the high prices of accommodation. The city aims at providing various modes of transportation (e.g. buses, trains, boat, trams, metros, "rentable" bikes and flying car in the future) while considering the environmental effects given that 12% of global CO_2 emissions are caused by transportation means [22]. In a sustainable global system, the three pillars of sustainable development are Environmental, Economic and Social [23]. According to a study of UK air quality [24] road pollution is more than twice as deadly as traffic accidents, while car pollution causes severe heath damage and risks in premature deaths [25]. On the other hand, one needs to take into consideration the emerging landscape: cities going digital by deploying various sensors and additional information is provided by individuals through their mobile devices. In this context, IoT as an underlying technology aims at creating smart environments / spaces for energy and mobility (as described by the European Research Cluster on the Internet of Things [26].

5. Green Mobility and the impact of CAVs on KPIs

There are multitude possible applications of CAVs across several sectors. This may include military to save soldiers in dangerous combat zones without risking more human lives, in the marine for example to search missing planes and other precious items in dangerous deep sea, aerial, this is already been used for example armed drones (remotely piloted aircraft) have been used by US and UK forces to carry out strikes in area such as Afghanistan to locate and eliminate terrorists [27]; space where unmanned spacecrafts could be launched in deep space to explore and seek new life in faraway locations where no man has gone before [28, 29] public roads, private and public transportation, to children and, elderly passengers, disabled people and the public in various location within the city. The technology can also be used in warehousing, in agriculture, with drones able to inspect and monitor crops and other resources, working in dangerous and unsafe environments such as nuclear facilities or locations with landmines. It can also be used to deliver humanitarian aid to populations in disaster zones around the world. The British government is actively considering the potential for UK to adopt this technology particularly in the roads sector [30]. As CAVs become a reality, they will have a growing impact on a range of Key Performance Indicators (KPIs) measured by cities and road authorities as indicated in the table 2 below:

Table 2. The impact of CAVs on KPIs (Adapted from [31]).

KPI	CAV impact on KPI
Journey time reliability	Due to CAVs ability to drive closer together, the impact caused by congestion will be reduced. The adoption of CAVs will increase roadway capacity without impacting on safety since machines can keep minimum distances and still drive safely when compared with human drivers. Journey time reliability will be expected to in-

	crease as incidents and accidents will be reduced.
Traffic volume	It is still not very clear what is going to be the impact of CAVs on traffic volumes, but it is believed that CAVs will lead to a huge reduction of vehicles on the road network because of the car share scheme. At the same time there may also be an increase in the traffic on the roads due the opportunity CAVs provides to children, elderly and disables passengers.
Road safety	It is believed that 90% of all accidents are caused by driver error, therefore, by handing driving duties over to computers and technologies, it is believed that the number of crashes will significantly decrease. And where collisions do occur, their severity rate is expected to be reduced as CAVs will be able to react quicker than the average human driver, thus mitigating the severity of the collision.
Safety of the most vulnerable road users	CAVs will be developed with advanced technology devices such as Lidar, sensors, camera and several processors able to predict vulnerable road users' actions, therefore it will improve safety of the most vulnerable road users (children, disables, elderly people…)
Ensuring the road network supports economic growth potential	By reducing congestion on the road network and improving journey time reliability, the road network will support the economic growth potential of an area by allowing efficient and reliable mobility.
Reduce carbon emissions associated with road traffic	On a per vehicle basis, carbon emissions will be expected to fall as CAVs are adopted as the technology which will improve driving efficiency (for example reducing stop/ start driving conditions). However, if there is an overall increase in traffic on roads then aggregated carbon emissions may remain static or increase.
Reduce the negative impact of road traffic on local air quality	As with carbon emissions, on a per vehicle basis, local air quality conditions will be expected to improve. As Connected and Autonomous Vehicles are adopted, the technology will improve driving efficiency. However, if there is an overall increase in traffic

	on roads then local air quality conditions may remain static or worsen.
An accessible and integrated road network that provides equal opportunity for use	CAVs will open up the road network for equal opportunity use. This will increase mobility options and travel horizons for large sections of the population, resulting in increased economic, social and well being opportunities.
Freight optimisation	From connected platooning to automated and predictable last mile deliveries, CAVs will have a role to play in optimising and streamlining logistic movements. This in turn will help to improve the ability to both schedule and meet reduced delivery times, helping improve customer loyalty and satisfaction.
Increase the number and proportion of people using active modes of travel (walking and cycling)	The impact of CAVs on the number of people using active modes of travel is unknown. Persons currently using active travel modes because they cannot drive or do not have access to a vehicle may be able to use CAVs, thus reducing the proportion of people using active travel modes. Conversely, the improvements in road safety resulting from CAVs may lead to more people cycling or walking.

On average, today's cars are parked about 95% of the time [32] leaving huge transportation resources unused for a large portion of the day. With this technology being gradually introduced, we will have less parking in the city as most vehicles will be on the move. Furthermore, CAVs will be able to drive very closely from each other, without impacting on safety since machines required less time to react when a hazard occurs compered to normal human drivers. This will increase roadway capacity and allow more houses to be built, more business to settle and more commercial centres to open. We believe that these vehicles will be electric and possibly able to also charge themselves with limited or no human intervention. They will be using very powerful batteries. TESLA is one of the leading car manufacturers invested in car battery technology. This potential disruptive technology will create greener mobility with less CO2 emission.

6. Barriers to connected autonomous vehicles implementation

Although CAVs offer considerable benefits, applications and opportunities in transportation, it is undeniable that their implementation will also present huge challenges to governments, car manufacturers and other related industries around who will have to face and work together to overcome the challenges. The speed and the nature of CAVs mass adoption are far from guaranteed. This will depend largely on how the technology is introduced to the market, their cost, the transportation laws and regulations put in place to preserve safety and privacy of their users. The following sections outline some of the barriers to CAVs implementation. CAVs and AVs technologies are being tested in several cities across the world, global agreed standards and regulations are required and for the UK government to express their full confidence on the technology, the following challenges must be addressed.

6.1 Consumer acceptance

Since Norman Bel Geddes envisioned cars able to drive themselves without human intervention in the 1939 World's Fair General Motors exhibit Futurama, AV technologies has significantly improved. Connected Autonomous Vehicles (CAVs) will be here much sooner than most people expect and will lead to major changes to transportation, our cities and society. The car manufacturing industry used to be area of mechanical engineering. With advances in electronics, robotic and computer science, software companies such Google are somehow leading the race. More than 50% of innovations in vehicles today are electronic. In the early 2000s, several universities took part in the Defense Advanced Research Projects Agency (DARPA) challenges in (2004, 2005 & 2007), most car manufacturers (Mercedes, BMW and Tesla) and some other technology companies (Google, UBER) are actively developing and testing AVs but there are several barriers to the introduction of this disruptive technology. At first, many consumers may be reluctant to put their lives in the hands of a robot. Recent studies and surveys have shown a split in opinion on whether people would like autonomous capability to be available in their vehicles or not. Therefore, mass acceptance of this technology could take a long time. This could be the case particularly if there are accidents involving even semi-autonomous vehicles early in the adoption phase, whether it was the fault of the autonomous system or not [33, 34]. The transition from humans as drivers to humans as mere passengers in a car that drives itself is a major one. People generally have emotional connections with their vehicles. Therefore, are drivers willing to give up direct control over their vehicle and under what conditions? If automation of vehicles is not accepted by the users and users refrain from using the technology, the impact of automation on traffic flow efficiency, traffic safety and energy efficiency is mitigated. It is, however, not yet clear to what extent users accept automation and what the determinants of consumer acceptance of automation are [35]. Further, societal acceptance is pending with issues like safety, trust, security, privacy concerns, etc. Therefore, mass acceptance of this technology could take a long time.

6.2 Vehicle costs

[36] highlights that the cost of most autonomous car technologies applications for military and civilians is about $100000. This is almost inaccessible for most people in the UK. Today the high-end automotive Lidar systems mounted on the roof of these cars is estimated to about $75,000. The hope is that with mass production and notions related to Moore's Law may also apply here to allow the prices of this technology to come closer to the conventional vehicles prices. J.D. Power and Associates' survey [37] found that 37% of persons would ''definitely'' or ''probably'' purchase a vehicle equipped with autonomous driving capabilities in their next vehicle. Nevertheless, costs remain high and is therefore a key implementation challenge, due to the current unaffordability of even some of the more basic technologies.

6.3 Legislation liability and litigation

In large cities, national and local authorities and law enforcement agencies will have to act swiftly in developing laws that allow cars to drive themselves on the streets without human intervention. Current legal systems have provision to deal with problems related to manufacturer defects. However, a framework for determining liability in a situation where an accident occur while the vehicle is handing full control over to the human driver of the semi-automated technology. In this situation there should be more clarity in the application of current civil and criminal law to shed a light on how to deal with the problem. When AVs and CAVs become certified for safe operation by the government, the regulatory bodies and other agencies responsible are to check that new technologies are of low risk, should new insurance and litigation issues arise. Such as the persuasion of insurance companies that they will work properly in all driving environments. The reality is that even with near-perfect autonomous driving, there may be instances where accidents are inevitable. Amongst the potential implications of this, people who otherwise are not able/allowed to drive could "get behind the wheel" of AVs or CAVs, and cars could technically drive from one place to another with no occupants. If there is an accident involving an autonomous vehicle, who is liable for the consequences as the driver is still behind the wheel? because the driver is still behind the wheel and therefore ultimately liable for the safety of the vehicle. But even this point may be intensely debatable [38, 34, 33]. It appears that with possible low number of accidents in fully connected smart cities, the insurance market will be disrupted. In general, most industries will have to re-invent themselves, change their business models or disappear altogether.

6.4 Social and Ethical Issues

Autonomous cars raise several kinds of ethical issues

(a) Is it possible to configure and program a CAV to react to every single imaginable situation on the road? For example, not obeying traffic light signals or speed limits when driving someone in an emergency to the hospital (A&E) or dangerous driving in order to escape from a life-threatening circumstance.

(b) Although it is certain that CAVs will bring substantial social and economic benefits to cities around the world, several industries will be disrupted, and many people will lose their jobs and surely must change career.

(c) If an animal such as a deer jumps in front of the vehicle from nowhere, does the CAV hit the animal or run off the road? How do actions change if, instead of a deer, there is another car, or a pedestrian, a cyclist, a motorcyclist or even a heavy-duty truck? How does the algorithm developed in these vehicles react in those situations? With a split second for decision-making, human drivers typically are not held at fault when responding to circumstances beyond their control, regardless of whether their decision was the best at the time. In contrast, CAVs have sensors, visual interpretation software, and carefully designed programmes that enable them to potentially make more informed decisions. In a court of law, CAVs behaviour in some scenario may be questioned even if they are theoretically not "at fault". Other ethical question may arise concerning the algorithm in these technologies. How do they make their decisions on who to protect most or kill in a binary situation, for example who should be protected between 5 adults and a kid crossing the road or between a disable person and an elderly pedestrian? Should the vehicle owners be allowed to adjust such settings?

6.5. Cybersecurity, data security and privacy concerns

The idea that a car will be connected to the internet and able to drive itself without any human input raises several cybersecurity, data security, privacy, certification and licensing concerns as these vehicles may be subject to attack by criminals or terrorists and use for malicious purposes. These vehicles are just like computers on the road, therefore hackers may be able to take over control of the car either to kidnap someone or a group of people remotely, purposely create an accident, terrorists may be able to guide the stolen vehicle into a crowded area to kill people or load cars with explosives as a car bomb. Gang dealers may be able to deliver drugs or weapons including firearms to remote locations without being caught. It is clear that conventional cars are being used for some of the crimes listed above, but it is also obvious that with CAVs they will be achieved a lot more easily ([30]. All countries face the same dilemma of how to fight cybercrime and how to effectively promote security to their citizens and organizations. Cybercrime, unlike traditional crime which is committed in one geographic location, is committed online and it is often not clearly linked to any geographic location [39]. Large scale cyber security attacks by hostile nations, disgruntled employees, terrorist organisations can be mounted on the whole city transportation system, disrupting traffic and creating collisions and all kind of accidents. For example, a computer virus could be designed to first infect virtually the entire UK CAV fleet as a dormant program and later become active and create all kind of disaster on the road. Therefore, a coordinated global response to the problem of cybercrime is required. According to [40], vice president of software security firm Vínsula, current cyber-attacks are generally acts of espionage; most attackers gain unauthorized access to systems to gather information about their opponents rather than actual sabotage. Disrupting the vehicle electronic systems and sensors will require a more complex form of attack than the one used for data gathering which is generally harder. Regardless, the threat is real, and a security breach could have lasting repercussions [41]. Therefore, CAVs manufacturers, transportation policy makers and governments around the world should set security measures to handle these types of concerns. As CAV become mainstream and adopted around the world, privacy concerns will raise several questions: Who should own or control the vehicle's data? What types of data will be stored? With whom will these data sets be shared? In what ways will such data be made available? And, for what ends will they be used? In UK, particularly in London, there are literally thousands of cameras watching us, some call London a “big brother state”. From the moment you leave your home to the moment you get to work or school, you have an average of 300 cameras recording your movements. Our smart phones are equipped with location services. The reality is that privacy is almost a myth and these concepts are more likely to be transferred to CAV application. Someone involved in a car crash may not want his vehicles data to be shared with third parties, particularly if the person is at fault. Law enforcement could also benefit from such data. Risks such as losing privacy and/or integrity in public cloud may prevent many decision makers to authorise the implementation of digital services using cloud computing in a smart city [42]. In this situation, sharing traveler data may be balanced with privacy concerns.

6.6 Infrastructure

To get the full benefits of CAVs, new road and communication infrastructure will be required. Since CAVs are not yet completely deployed, it may be difficult to guess every single road equipment that would be required. Although AVs generally require less bespoke road infrastructure, CAV must interact with their environment, communicating with other vehicles and road side base stations in a Car2X context, they will be partially dependant on road infrastructures such as GPS mapping, road marking and strong telecom networks. The Transport Systems Catapult said that “infrastructure that is being imagined, designed, and built now, needs to have capability for future compatibility and functionality built-in from the get go” [30]. This is certainly true because they are very expensive to maintain and upgrade.

7. Conclusion and future research

In this article, CAVs was explored as a potential solution to several issues faced by large cities around the world including excessive traffic jams, road accidents, CO_2 emissions and public health deterioration. It is undeniable that transportation has a massive impact on social welfare, urban sustainability. It can influence the growth of digital economies in large cities and CAVs offer potentially transformative benefits that can alleviate some of these concerns and lead the way to a greater level of sustainability. Transportation has immense implications for social welfare, economic development, and environmental sustainability. Congestion, environmental degradation, social inequity, and public health issues are problems that sustainable transport policies urgently need to resolve. Some of the challenges mainly related to security, privacy, cyber security, ethical, legal and infrastructure have also been explored. Amidst the growth of ICTs and the sharing economy, the protection of personal data and the security of communication networks are vital to ensure society capitalises on the gains from increased connectivity. This study serves to inform policy-makers, scholars, and various stakeholders in the automotive industry of privacy and cybersecurity challenges of CAVs for achieving smart and sustainable cities. There are several smart city projects all over the world. These projects must be multidimensional and integrate the different action fields of the city, interacting with human and social capital. Technological solutions must be understood as the tool to achieve the smart city goals and to tackle the challenges these cities will face. The main objectives of these Smart City projects must be to solve urban problems in an efficient way to improve sustainability of the city and quality of life of its inhabitants. Furthermore, governments around the world should have strategies to deal with privacy and cybersecurity concerns. Possible future research on Autonomous vehicles and connected autonomous vehicles could be to develop a model to measure people behavioural intention to use AVs and CAVs.

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