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An attempt to determine the impact of the implementation of autonomous vehicles on a larger scale on the planning of city transport systems

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Abstract: *Purpose*: This paper aims to explore the potential impact of autonomous vehicles (AVs) on urban planning, sustainable urban development, and tourism. *Methodology*: The paper is a conceptual study that reviews and synthesizes existing literature on AVs, urban planning, and tourism. It also uses case studies to illustrate the potential effects of AVs. *Results*: The widespread adoption of AVs is likely to have significant implications for urban planning, including changes in land use, infrastructure design, and transportation patterns. AVs may also contribute to sustainable urban development by reducing traffic congestion and air pollution. In the tourism sector, AVs could lead to spatial changes, new social inequalities, and changes in the overnight visitor economy. *Theoretical contribution*: The paper contributes to the understanding of the complex interplay between AVs, urban planning, and tourism. It highlights the need for urban planners and tourism stakeholders to consider the potential impact of AVs in their decision-making processes. *Practical implications*: The paper provides practical insights for urban planners, tourism stakeholders, and policymakers on how to prepare for and adapt to the widespread use of AVs. It also emphasizes the importance of considering the potential benefits and challenges of AVs in the context of specific cities and tourism destinations.

Keywords: autonomous vehicles, urban security, urban planning, sustainable urban development, urban and highway environment

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1. Introduction

Modern urban planning had its originsoriginated as a reaction to the turmoil of the industrial period. Early urban planners sought to make cities more livable by providing sufficient sanitary facilities, lowering traffic, and addressing the problems of unsuitable structures in response to the rise in pollution and the consequent health problems. Urban planners' work nowadays is varied and multidisciplinary. They are a basis for business ventures, community expansion, and land development. Planners develop long-term ideas and strategies through this techno-political process, turning the objectives of citizens and municipal leaders into instruments for reshaping cities. The physical topography, particular climate, and economic conditions of the city frequently result in minor variations in these priorities (Pérez, Milanés & Penas, 2013). However, some goals in the political leadership landscape cut across all municipal lines at any particular moment. One of them is that transportation planners must constantly adapt to new technology.

Our current and subsequent transportation networks will change thanks to connected and autonomous vehicles. Since autonomous transportation immediately impacts the dynamics, control, analysis, and planning techniques of the tracking network, its effects should be adequately explored (Faid, Krahn & Krogman, 2021).

Intelligent vehicles can range in automation from human-driven to completely autonomous or autonomous vehicles. In its J3016 guideline, SAE International outlines five stages of autonomous vehicles (Litman, 2017). The driver is always necessary up to level 2. Delivery from the vehicle to the driver is achievable under challenging circumstances at levels 3 and 4. Level 5 is designed for completely autonomous vehicles that can operate everywhere (Litman, 2017). A traditional gradual method is used to bring advancements in intelligent cars. These developments raise the amount of automation in vehicles that assist the driver by, for instance, maintaining a consistent speed, staying in its lane, or performing handovers.

An autonomous vehicle (AV) is a vehicle that can navigate without human assistance and can identify its surroundings. The Society of Automotive Engineers (SAE) has divided autonomous driving into six levels based on how much driver involvement and attention it requires. The SAE J3016 taxonomy and definitions for the terms related to automated driving systems of on-road motor vehicles were produced by SAE International as part of a standardized categorization system for autonomous driving systems (ADS) (Faid, Krahn & Krogman, 2021). The availability and utilization of prior automotive technology can be used to forecast how AVs will be implemented. The adoption of driverless automobiles is dependent on both the technology's accessibility and user acceptance.

Although planning includes being aware of upcoming situations and demands, the future is ultimately unknowable. Many decision-makers and practitioners (planners, engineers, and analysts) are curious about how autonomous or robotic vehicles (also known as autonomous or robotic) will affect future travel demands and, consequently, the need for roads, parking lots, transport services, public transportation, and what public policies will have an impact on. They can minimize risks while enhancing rewards. (Lu, Tettamanti & Varga, 2018) These topics are surrounded by a lot of ambiguity. Optimists anticipate that autonomous vehicles will soon be trustworthy and affordable enough to replace the majority of human driving, giving numerous savings and advantages, based on the experience of earlier technical revolutions such as digital cameras, smartphones, and personal computers. However, there are compelling arguments against believing such assertions.

Several academics, initiatives, competitions, and manufacturers have heavily pursued the creation of technologies to enhance driving in urban and highway situations over the past few decades. Recently, several prototypes were transferred from research institutions to commercial businesses. Some applications implemented and made commercially available in automobiles include emergency braking, adaptive cruise control, and parking aids. One of the short-term objectives pursued by the ITS (Intelligent Transportation Systems) group is the development of autonomous cars (Schwarting, Alonso-Mora & Rus, 2018). They use a variety of sensing, control, modeling, and communication approaches as their primary objective to increase driving comfort and safety.

ITS may interact with anything from a single car to the whole traffic network, depending on their level of complexity. Expressly stated objectives include enhancing traffic flow, lowering emissions, managing public transit networks, and enhancing urban and highway safety. Since there are so many issues that belong under the scope of ITS, research organizations all around the world concentrate their efforts on a select few. The EU project named HAVEit is one of the most notable projects to emerge in recent years (Schwarting, Alonso-Mora & Rus, 2018). It proposes an architecture for safe, effective, and enjoyable driving through a mobile virtual machine for both partial and complete car management in several high-risk circumstances.

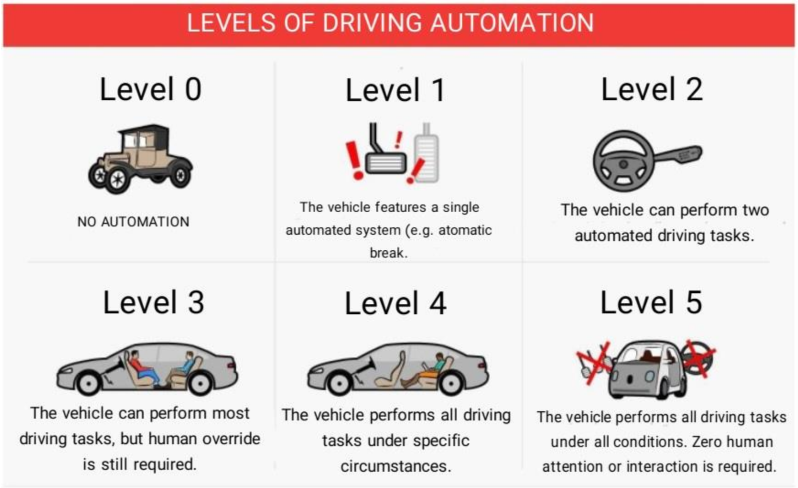
Fully autonomous vehicle development needs to overcome several technological, legal, and social obstacles. This survey focuses on technological methods for building Level 5 or completely autonomous vehicles. The Defense Advanced Technology Projects Competition, which ran from 2004 to 2007, brought autonomous driving research closer to use (Litman, 2017). These techniques were restricted to slow speeds and uncluttered and crowded settings with few moving impediments. Although current work on autonomous cars has achieved significant advancements, the complexity of the surroundings and/or the speed of movement are still some limitations.

Planners must attempt to foresee the advantages and disadvantages of AVs as automakers and technology companies continue to work toward completely autonomous vehicles to determine what role they will play in our communities. Improving road safety is a potential area in terms of positive outcomes. Furthermore, it is conceivable that AVs may promote car sharing and hasten the decline of private vehicle ownership, lowering greenhouse gas (GHG) emissions. If all goes as planned, it may redesign parking lots and roadways to provide more room for parks and pedestrians (Pérez, Milanés, & Penas, 2013). The first-mile-last-mile dilemma, which refers to difficult-to-serve areas for public transportation between a transit user's residence and the public transportation (first mile) and between the public transportation and their ultimate destination (last mile), may also be resolved with the help of AVs.

A US-based association called SAE develops automotive standards. The forum uses a six-level methodology to categorize various stages of autonomous vehicle technology. Zero-level automobiles are those that have no automated systems and need the driver to do all control actions while driving, including using the brake, clutch, and steering wheel. The lowest of the six levels is this one. In level one, duties are carried out by a human and computer system, with the driver performing the majority parts of the labor. There are several vehicles at this classification now on the road. According to SAE, Level one systems include steering, acceleration, and deceleration as well as functions that use driving environment data. Lastly, most labor is performed by the person. The steering and speed of the vehicle are managed by one or more driver assistance systems in level two systems while people handle other functions. Autonomous driving systems of levels three and higher are regarded as include vehicles. In this case, the key distinction is that the cars may manage the surrounding driving environment.

Most importantly, these vehicles are autonomous. A level three automobile, for instance, can see the car in front of it before attempting to pass it. According to SAE, Level four is when an autonomous driving system handles all elements and activities associated with dynamic driving. Even when a person does not react adequately to an automatic system's request to take over the vehicle's operation, if a problem arises, the automobile will correct it on its own. Human control of the vehicle is not required at this level. Full automation at level five eliminates the need for pedals, a steering wheel, and human control (Khodabin et al., 2019). The many stages of autonomous automobiles are depicted in Figure 1.

Figure 1: Levels of driving automation



Source: SAE

This article is designed in three main parts. In order to understand the issue as deeply as possible. We first reviewed some obstacles in developing AVs, then studied the impact of this technology on city streets, and finally investigated the results.

2. Literature review. Development problems

Overly optimistic predictions can overlook essential expenses and barriers. Several technological issues must be resolved before autonomous vehicles function dependably in all typical circumstances. Before advancing the Technology Readiness Level (TRL) scale from a concept to full commercial availability and becoming inexpensive and appealing to consumers, they must undergo years of testing and regulatory authorization. New vehicle technology often takes decades to permeate the fleet since motor vehicles are costly, enduring, and subject to strict regulations. Autonomous driving may bring forth new issues. Although seldom dangerous, a faulty camera, phone, or computer can aggravate. Failure of a vehicle's systems can be upsetting and deadly for passengers and drivers. Therefore, it is likely that the development of autonomous cars will take longer and yield fewer net advantages than optimists anticipate (Litman, 2017). This results in some significant policy ramifications. Vehicles require more planning and control than other technologies since they depend on public infrastructure, can have significant external expenses, and are thus more dependent on it. For instance, many of the predicted advantages of autonomous vehicles, such as less traffic and pollution, need dedicated lanes to enable platooning (Vehicles traveling at quite high speeds near one another). In addition, autonomous cars can be configured to put the needs of the user first, e.g. by increasing travel and passenger speeds (Litman, 2017). To maximize advantages, policymakers must determine whether to construct autonomous car production lines, how much to charge for them and how to control their performance.

2.1. Lack of dedicated intelligent infrastructure

Self-driving technology is a new technology with many complexities. It is necessary to develop relative infrastructures to eliminate the complexity of new and immature technologies (Khodabin et al., 2019). The following are the more prominent infrastructures with significant roles in the implementation of self-driving technology:

1. Road infrastructure: Standard roads are necessary for some self-driving car systems to perform correctly. Some systems that require proper road infrastructure are lane departure warning systems and traffic sign detection systems (Khodabin et al., 2019). Some of the major challenges in road infrastructure relate to indistinct road markings, a lack of asphalt or low-quality asphalt with potholes, and the destruction of road signs and meaning charts.
2. Communicative infrastructures: For self-driving cars to perform safely, they must be connected to other vehicles and other sectors of transportation, such as fuel distribution, repair, and maintenance. In the current situation, data transfer should be conducted using 4G internet,

which is unreliable and does not have adequate coverage most of the time. In contrast, there is no platform for connecting self-driving cars and prodigy enterprises.

3. Legal infrastructure: Considering that robots are making decisions instead of humans, a decision made by a robot that causes property and life losses cannot be legally justified (Khodabin et al., 2019).

According to experts, there is insufficient preparation to allow these cars on the streets. As an example, Google has contributed to the development of self-driving cars and, since a couple of years ago, smart vehicles without drivers have been used on the streets to develop Google Maps software. Moreover, Tesla has recently entered the competitive market, beating famous old automakers and launching AI-enhanced cars in some countries (Rostami, Ataiean, & Sharifpour, 2011). The world is preparing to host electric and self-driving cars daily in developed and developing countries. For example, many highways in Sweden are equipped with exclusive lanes. As of this writing, electric cars in this country can recharge their batteries on the go. Finland, Germany, Japan, South Korea, and other countries are also preparing for this technology (Almasinejad, Zahabi, & Nakhaie, 2014). In doing so, they hope to reduce their dependency on fossil fuels and save the environment from their harmful effects. Nevertheless, many countries are still not prepared to accept these vehicles on their roads.

The following report examined Iran as a country with an unprepared infrastructure.

While most countries are preparing their infrastructures for electric and smart vehicles, Iran has almost zero preparedness (Pourseif & Shirkani, 2020). Three years ago, the first electric vehicle charging station was established in the country. After that, a few of these stations operated throughout Iran, and currently, just a few are left (Pourseif & Shirkani, 2020). Recently, some electric and hybrid motorcycles have been imported into the country, and they seem to be well received (Pourseif & Shirkani, 2020). People regret their purchases because of a lack of infrastructure, and electric vehicles will not be readily accepted in the future as a result. Due to the current infrastructure in Iran, smart vehicles will not be able to operate on the streets for at least ten years. The design of self-driving car algorithms requires behavioral recognition of other drivers for some decisions (Pourseif & Shirkani, 2020). The vehicle's artificial intelligence knows that if it turns on the left-side flasher, other vehicles will move away from it and allow it to change directions. Even after turning on their flashers, Iranian drivers struggle to change direction. In addition, smart vehicles require a stable internet connection, a connected satellite router, and standard and accurate traffic signs for their decision. You know these conditions are unstable in Iran (Pourseif & Shirkani, 2020). For instance, GPS signals are interrupted by noise, or internet connections are lost sometimes. Self-driving vehicles cannot travel long distances in such an environment because they lose their decision-making ability.

2.2. Problems with sensors

Technologies inside and outside self-driving cars play the driver's role, allowing them to travel without a driver. The system makes a decision based on the conditions by processing the information it receives from the sensors on the vehicle.

Sensors types:

- Color Camera;
- Radar Sensor;
- Ultrasound Sensor;
- Lidar Sensor.

2.2.1. Camera

It specifies colored tools, such as road markings, traffic lights, and signs. In addition to not providing 3D information directly, cameras have problems receiving environmental information, including distance (Pourseif & Shirkani, 2020). In addition, they are heavily dependent upon environmental factors (darkness, pollution, fog).

Since self-driving cars involve human lives, it is important to be aware that some face detection systems have difficulties with dark skin. Researchers at Georgia Tech studied eight artificial intelligence models used in face recognition systems (Wilson, Hoffman, & Morgenstern, 2019). These systems enable self-driving cars to detect signs, pedestrians, and other items in the path. People with darker skin were found to be at higher risk (Wilson, Hoffman, & Morgenstern, 2019). When confronting dark-skinned pedestrians, the system's accuracy was reduced by 5%, and it had lower accuracy when confronting pedestrians with the darkest skin (Wilson, Hoffman, & Morgenstern, 2019). The results were obtained in both day and night scenarios and showed that people with darker skin had a lower level of safety when confronted with self-driving cars (Wilson, Hoffman, & Morgenstern, 2019).

2.2.2. Radar

The transmitter sends radio waves to the surroundings. Waves are reflected after collision with objects and return to the receiver sensor. The system measures the distance between the sensor and the object based on the consumed time. Among the uses of distance measurement are cruise control, emergency brakes, and spacing between vehicles (Pourseif & Shirkani, 2020).

2.2.3 Ultrasonic

It works similarly to radar, but at close ranges and by using inaudible frequencies (above 20,000 Hz). This system is currently used for parking flasher systems in conventional vehicles (Pourseif & Shirkani, 2020). It also measures the car's blind spot and emergency brake system.

2.2.4. Lidar

It collects 3D information from the environment and is operatable in long and short intervals with high speed and resolution. They are also efficient in different environmental conditions. Its quality is so high that it can categorize small and large objects in addition to detecting them (Pourseif & Shirkani, 2020). The computer links these data in the board to provide a complete illustration of events around the car. There is no hope for safe travel by self-driving vehicles without this data. Multi-sensor automobiles are both safer and more practical (each system can supervise the other), but all systems may be attacked. The camera-based perception system can be deceived by placing labels on traffic signs to change their meaning (Khazaie, 2022).

The RobustNet research group at the University of Michigan, with the help of computer scientist Qi Alfred Chen from UC Irvine and his colleagues from the SPQR laboratory, showed that the Lidar-based perception system could be deceived, too (Wilson, Hoffman, & Morgenstern, 2019). This attack can change the Lidar-based perception system of the vehicle by the strategic deception of signals of the Lidar sensor to see an obstacle that does not exist. If such a thing happens, the vehicle will possibly cause an accident by blocking the traffic or a sudden brake (Wilson, Hoffman, & Morgenstern, 2019). Several hardware and software settings can cause problems in many situations. Changes in the sensors' settings can pinpoint the problem, even if small. For instance, a vehicle's sensitivity or post may make driving difficult. Also, a combination of sensors can provide accurate information for drivers, similar to human senses, so that heavy and fast vehicles can have safe travel. A human driver relies on sight, hearing, and movement senses.

Similarly, a self-driving vehicle needs many sensors in addition to the items noted above (Khazaie, 2022). The main challenge is creating a comprehensive image of the outside world and its effective processing. Training data set collection. An artificially intelligent solution can affect as much as training data. Collecting and processing data sets for self-drive vehicle training is a challenge (Khazaie, 2022).

Challenges and difficulties**:**

Two main challenges should be considered when speaking of creating a data set for self-driving:

Data collection: The best idea is to use vehicles and collect all images and positions.

Data labeling: All collected data should be labeled, which requires heavy manual work by humans (Khazaie, 2022).

The first challenge could be conducted by collecting data through semi-self-driving cars and driving support systems or by collecting data in a virtual reality simulated based on motorcycles of computer games. The most popular environment for this scenario is Carla.

There is no simple response for labeling data, but Captcha is one of the most successful. In this troublesome mechanism, the user should determine the correct elements among two words or images to prove he is not a robot. One of the words is true, while the other is labeled. The same applies to images.

Many internet users label traffic light images, road signs, pedestrians, and other items to be used in training image detection solutions. A company should be very cautious while collecting training data (Khazaie, 2022). Labels should be evaluated occasionally, and the dataset should be 100% accurate. A set with thousands of images will make this process difficult.

2.2.5. The problem outside the training set

There is another crucial challenge in delivering different regions, such as Europe and Africa, while humans do not struggle with generalizing a pin tree or specific objects. Therefore, the self-driving system's problem is its confusion in an unfamiliar environment.

Considering the generalization problem in neural networks, the vehicle trained based on collected data in Europe cannot drive independently in Europe, which is an unsolvable problem for a neural network.

Therefore, when creating a data set aiming at car training with a global use capability, it is crucial to create a data set consisting of images from all over the world (Khazaie, 2022). As a result, the data set expands.

2.2.6. Objects detection

The fundamental task of the computer sight algorithm is detecting an object in the image. Although some computers have better image detection than humans, some cases are challenging in the area of self-driving vehicles (Khazaie, 2022).

2.2.7. Challenges and problems

Object detection should be conducted in an immediate environment. A camera's input may be based on a set of lines obtained frequently from its sensor and used to refresh an image that is constantly changing rather than being used on a set of complete images. Therefore, object detection should be conducted without a complete view of the object. Different elements in an environment may be confusing to a self-driving system, for example, a truck driving in front of a vehicle (Khazaie, 2022). The first challenge is resolved by training a model on delivered data through the sensor as the output. In other words, the model is switched to signal analysis rather than image detection. The second challenge is a common problem that artificial intelligence cannot solve because it has no background. An interesting solution is enriching image detection with detailed evidence. This technique enables neural networks to neglect some extra information (such as the background) to remove possible incorrect results. As a result, if a car is suspended 5 meters above the ground surface, it is likely to be an image of a car on a board, so speed reduction is not required (Khazaie, 2022).

2.2.8. Traffic signs

Detecting traffic signs is an iconic work for the neural network of self-driving cars. The main challenge is to detect traffic signs in an unstable and rapidly changing environment. A traffic sign might be dirty, covered in leaves, or damaged and altered. Also, it is expected to rearrange signs on the road or place temporary signs warning about diversion or road construction, for example. Therefore, one should have adequate accuracy in detecting signs and quick processes (Khazaie, 2022).

2.2.9. Pedestrians

Challenges are even more critical for pedestrians. The self-driving car needs to detect people immediately and estimate its status (Khazaie, 2022). The vehicle should react quickly if a pedestrian appears to be intending to cross the road.

2.2.10. Semantic sample zoning

The semantic sample zoning concerns detecting differences between each object in the scene. Identifying that three cars are on the road is insufficient for self-driving cars; they should be able to distinguish them and track their behavior. Each vehicle, tree, and pedestrian are framed with the semantic zoning and labeled with the semantic sample zoning as car1, car2, tree1, tree2, etc. In this section, presenting extra information about the number of objects on the road and their relative positions without saying their name is a challenge (Khazaie, 2022).

Challenges and problems:

Performance: Object detection is challenging due to the sensor's limitations, as indicated above. This feature limits semantic zoning and semantic sample division, like object detection.

Confusion: Cars fulfill their tasks, but it should be noted that there is always an unpredictable factor in the artificial neural network. Therefore, it is possible for a network to make mistakes under factors such as uncommon light or weather.

Performance: Object detection is challenging due to the sensor's limitations, as indicated above. This feature limits semantic zoning and semantic sample division, like object detection.

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Overcoming these problems depends on accessing and using larger data sets, which provides more examples for the neural network (Khazaie, 2022). Presenting artificial data, which are created manually or by Generative Adversarial Network, to a network, is a solution for this problem.

Deep estimation is critical to ensuring the safety of the vehicle and its passengers. There are several accessible tools, such as Radar, camera, and Lidar, but supporting them is with multiple cameras. Knowing the distance between the lenses of the camera and the accurate position of an object in recorded images is the first step to building a stereo-vision system (Khazaie, 2022).

Challenges and problems:

Configuration of the camera: The distance between lenses and the sensor's sensitivity can be different and target more challenges for the deep estimation system (Khazaie, 2022).

Non-parallel exhibition: The camera used in self-driving cars can provide different images without displaying pixel by pixel. Thus, if a change in the pixel display of an image occurs, the system will have difficulty calculating distances (Khazaie, 2022).

Perspective distortion: The larger distance between camera lenses results in a better deep estimation. It is, however, accompanied by another challenge: perspective, which should be considered in the deep estimation (Khazaie, 2022).

Objects tracking

The objective of object tracking is to present information about the current situation and predict the movement of the objects toward the self-driving car control system. Object detection informs the system if a specific object is a vehicle, truck, or electric train, in addition to information about the objective accelerating, speed descending, or maneuver (Khazaie, 2022).

Challenges and problems:

Risk estimation: The network should predict behavior in addition to the movement. Accordingly, human drivers are more careful when driving beside bike riders than other vehicles (Khazaie, 2022). It is because each incident for a bike rider is more dangerous.

Changing background: The network should resist changes when tracking an object; other vehicles approach, the road color changes, or trees are alongside the road (Khazaie, 2022). It is not an issue for the human driver but can confuse the neural network.

Confusing objects: Objects on the road are usually repetitive; tens of red cars comings and goings on a daily basis. The tracking software might conform a red car with another one and present false information to the controller network (Khazaie, 2022).

3D analysis of the scene

The control system should make a 3D illustration of the surrounding world by combining collected information using described approaches. Essentially, it is comparable to a person's imagination, in which computations are performed, and results are generated (Khazaie, 2022).

Challenges and problems:

Accuracy: The slightest errors in 3d view analysis can result in greater mistakes and lead to diversion; what seems unimportant at the low speed of the vehicle can turn into a challenge by increasing the speed (Khazaie, 2022).

Several unpredictable objects: What is relatively simple on highways becomes complicated in urban traffic. It is because the street and other objects become more complex on the road (Khazaie, 2022).

2.3. People acceptance

It is challenging to measure the uptake of AV-based motorized services since there are so few options now available. Users are unable to fully imagine it and can only make some assumptions. As a result, they can only compare this service to current services. Expectations are measured through expressed preferences. Individual acceptance (willingness to use, actual use), social acceptance, and temporal change (before, during, and after usage) are a few examples of the various dimensions of acceptance (The whole community accepts the transportation system that uses AV). The terms acceptability and acceptance were first used by Meraat et al (Földes & Csiszár, 2018). Acceptability and willingness to use (expectation) are synonymous (Földes & Csiszár, 2018). Numerous surveys have been used to examine user approval of AV-based services. Usefulness, anticipation of effort, convenience of use, and social impact are the key factors that affect acceptability. Individual mode and desire to select an AV-based shared service are strongly correlated. Service features including travel expenses, journey and waiting times may be important factors for the utilization of shared AVs. One of the key problems will be a lack of staff (e.g. security) (Földes & Csiszár, 2018). User trust may be raised by giving users actual hands-on experience with the technology.

Despite all advantages of self-driving cars, the main obstacle in the way of its universality is its acceptance. Recognition of effective factors in the acceptance of these vehicles and their impact is crucial for scheduling and making the right decisions in line with the objectives and perspectives (Taherdoost, 2018). It leads to a better understanding of people's requirements, optimum design, and predicting users' responses to using or not using the self-driving car. Additionally, recognizing effective factors in the self-driving car is a prerequisite for supplying these devices to the market. Distrust is the main obstacle to acceptance (Farzin, Mamdouhi & Nouri, 2021).

Many surveys have been made to evaluate the acceptance value of the self-driving car. Descriptive analysis was mostly used in these polls to describe the acceptance value (Farzin, Mamdouhi, & Nouri, 2021). Some studies used technology acceptance theories to evaluate effective factors in the acceptance of self-driving cars. For instance, Kaspar and Abdu Al Rahman studied the tendency to use self-driving cars for product delivery (Kapser & Abdelrahman, 2020). It was assumed that performance expectancy, endeavor expectancy, social impact, simplifying conditions, joy-related motivations, price sensitivity, and comprehended risk affect the tendency to use self-driving cars (Kapser & Abdelrahman, 2020).

In his first study, known as "the results of novel self-driving technologies," Power, 2012 investigated the owner of the vehicle about his intention to buy a self-driving car (J.D. Power, 2012). He described it as it has capabilities that provide acceleration control and brake by the car without human interaction. According to the results, 37% of respondents were eager to buy such technology. This value was reduced to 20% after respondents were informed about the estimated price (3000 dollars) (J.D. Power, 2012). In addition, the study found that the owners of vehicles with the greatest interest in driving a self-driving car, regardless of the price, are males (25%), individuals aged 18 to 37 (30%), and urban dwellers (30%) (J.D. Power, 2012).

The results of the second and third studies (Power, 2013, Youngs, 2014) with the same title and sample volume, which was above 15000 individuals, were equivalent to and in line with those of the first study (J.D. Power, 2013) & (Youngs, 2016).

Summer, 2013, conducted a study titled "continental movements studies" in Germany, China, Japan, and the US and found that 59% of the respondent believed that self-driving was useful progress (Sommer, 2013). However, respondents were afraid to drive in a self-driving car. 31% of the respondents stated that they did not care about self-driving car development, and 54% did not believe in its reliability. The main concern of these persons is the safety and reliability of this novel technology (Sommer, 2013). Increasing the case history of the person reduces the tendency to use this technology due to the lack of safety feeling and reliability of the car (Farzin, Abbasi, & Mamdouhi, 2019).

2.4. Selected areas of impact

2.4.1. The impact of autonomous cars on road safety

If driverless vehicles live up to their promise to eliminate the great majority of traffic accidents, the technology would rank among the most significant advancements in public health in human history. However, just how many lives will be saved? By the end of this century, there is reason to anticipate that tens of millions of traffic fatalities will be eradicated worldwide. Numerous attempts have been made in the past to alter this value as well as the framework of automotive culture and safety. In the United States, road accidents claimed the lives of around 60,000 individuals in 1970 (Asayesh & Hemmati, 2018). In the decades that followed, there was a significant improvement in road safety, including the need for seat belts and the widespread use of airbags. According to research, autonomous cars might cut road deaths by 90% within 50 years (Asayesh & Hemmati, 2018). Using the 2013 mortality total as a baseline indicates that autonomous cars might prevent 29,447 fatalities per year (Asayesh & Hemmati, 2018). In the US, 1.5 million individuals survive every 50 years, and over ten years, over 300,000 fatalities are avoided (Asayesh & Hemmati, 2018). For instance, over 50 years, anti-smoking campaigns in the United States prevented 8 million deaths (Asayesh & Hemmati, 2018). The World Health Organization estimates that there are 1.2 million road fatalities annually, therefore, autonomous cars will prevent 10 million deaths in the next ten years and 50 million in the next fifty years. Autonomous cars and other advanced driver-aid technologies may eventually drop traffic fatalities from second to ninth in the United States by the middle of this century (Asayesh & Hemmati, 2018). Bertoncello and Dominic Wee calculated that increased road safety may reduce healthcare expenses associated with accidents by up to $190 billion annually in a paper for a consulting business (Bertoncello & Wee, 2015). Naturally, this success hinges on the widespread use of autonomous vehicles.

No one wants to accomplish autonomy in the world unless it is demonstrated to be highly safe, like a factor 100% safer than having a human driver, said Andrew Moore, a specialist at the Computer Institute at Carnegie Mellon (Sivak & Schoettle, 2015). Moore added that there would be circumstances in which an automobile intentionally prepares for its collision because it anticipates doing so. Does he attempt e to help the driver? Or he will make an effort to help someone else. In a previous work, University of Michigan transportation scholars Michael Sivak and Brandon Schwatel wrote: "Safety may be improving throughout the transition time, at least for regular cars, when conventional and autonomous vehicles share the road (Sivak & Schoettle, 2015)." Since 2009, Google's autonomous vehicles have covered more than a million kilometers (Asayesh & Hemmati, 2018). They also participated in 16 incidents in August, none of which were brought on by autonomous vehicles (Asayesh & Hemmati, 2018).

Traffic may be deadly since more than 3,000 people die in accidents every day, most of which are the result of human mistakes (Schwarting, Alonso-Mora, & Rus, 2018). The use of autonomous vehicles has the potential to raise the quality and effectiveness of time spent in automobiles, the safety and effectiveness of the transportation system, and accessibility to transportation at all times. This necessitates improvements in a variety of areas related to vehicle autonomy, including control, perception, planning, coordination, and human-vehicle interaction (Schwarting, Alonso-Mora, & Rus, 2018).

2.4.2. The impact of autonomous cars on the economy

There were around 30,800 fatal accidents in 2012 (Ozimek, 2014). About 22,912 drivers and passengers, 4,950 motorcycle riders, 4,743 pedestrians, and 726 cyclists have died as a consequence of these incidents (Ozimek, 2014). The Department of Transportation estimates the official statistical value of a life to be $9.2 million (Ozimek, 2014). Therefore, the profit would be approximately $276 billion if driverless automobiles could save 30,000 lives annually (Ozimek, 2014). The Disease Prevention and Control Organization calculated the cost of medical care in 2005 to be almost 41 billion dollars in addition to the fatalities from accidents (Ozimek, 2014). Fatal accident-related costs have been reduced by $317 billion so far (Ozimek, 2014). Accidents can result in fatalities, deep and superficial injuries, limb deformities, and other outcomes (Asayesh & Hemmati, 2018). The Highway Traffic Safety Administration calculates that 362,000 people were hurt (and survived) in collisions in 2012 (Ozimek, 2014). According to the transportation organization's data, the average injury costs $432,400, a serious injury costs roughly $5.4 million, and a typical injury costs about $27,000 (Ozimek, 2014). The entire cost of accident injuries will be around $189 billion if we conservatively estimate the average cost of an accident injury at $80,000 (Ozimek, 2014). Accidents can also occur in which no one is wounded (Asayesh & Hemmati, 2018). 2009, the US Census Bureau estimated that there were 10.8 million car crashes (Ozimek, 2014). To prevent double counting, we estimate that the above-mentioned incidents only resulted in 2.3 million injuries and 30,000 fatalities, or 50% of this total (Ozimek, 2014). Last but not least, there are 5 million incidents that do not result in any fatalities or serious injuries (Ozimek, 2014). If we estimate the cost of each accident at $7,400, this totals around $37 billion (Ozimek, 2014). There is a different kind of economics that is time-related. Considering how much time individuals spend traveling in automobiles, this is a major problem (Asayesh & Hemmati, 2018). If there are 2.9 trillion miles a driven year, then each individual drives around 10,000 miles (Ozimek, 2014). About 49.6 billion hours are spent driving, assuming a speed of 60 miles per hour and treating each vehicle as a single person i.e. 157 hours per person per year (Ozimek, 2014). The Transportation Organization values each journey hour for cost-benefit analysis at $12.98 (Ozimek, 2014) . However, given that the lost time is not included, the actual cost is certainly higher. If we use the conservative assumption that every hour spent doing something other than driving is worth roughly $2, the total profit from this time is about $99 billion annually (Ozimek, 2014). Thus, $317 billion will be saved from fatal accidents, $226 billion from non-fatal accidents, $99 billion in time savings, and a total of $642 billion in profits will be generated by autonomous automobiles (Ozimek, 2014). This sum is quite cautious because it ignores a variety of additional circumstances, e.g. some residents are no longer able to drive. 642 billion dollars is a pretty large number (Ozimek, 2014).

The insurance sector is one of the most significant businesses that will be highly impacted by this new technology and may potentially go extinct. These vehicles will eliminate the requirement for driver's liability insurance. Although this problem won't arise anytime soon, Volvo has previously stated that it would accept complete responsibility if one of the firm's autonomous vehicles causes a collision (Asayesh & Hemmati, 2018). Instead of driver's liability insurance, insurers will provide product liability insurance since when something goes wrong with these automobiles, the automaker is responsible. Therefore, these automobile producers ought to be covered by insurance. The National Highway Traffic Safety Administration (NHTSA) estimates that airbags save about 2,500 lives annually in the United States, directly impacting life insurance statistics (Ozimek, 2014). Before completely autonomous vehicles join the mainstream automotive market, autonomous technology will similarly influence insurance risk models, and safety is projected to improve quickly. A Google autonomous car experienced its first accident after 1.45 million kilometers of operation or around 0.7 accidents per million trips (Asayesh & Hemmati, 2018). This is much less than the US average right now (two accidents per million miles traveled). Everything is still in favor of autonomous car technology. In 2020, it is anticipated that the number of these automobiles would increase by 49% annually (Ozimek, 2014). As a result, the business structures of automakers and insurance providers must change as soon as possible to address this problem (Asayesh & Hemmati, 2018). The insurer that responds fast to the drop in traditional auto insurance prices and seizes new possibilities will win (such as cyber security coverage in cars).

2.4.3. The impact on energy consumption and carbon emissions

On a large scale, autonomous cars can help cut energy use dramatically. For instance, autonomous cars can interact with one another and travel in groups on roads. As cars experience the least air resistance when they move close to one another, this can lower the overall energy consumption of road transportation. Additionally, linking vehicles to other vehicles and to road infrastructure, such as traffic control systems, increases traffic flow and eases congestion. Moreover, "eco-driving" (a method of driving that regulates speed and acceleration for more excellent fuel economy) can save energy use by up to 20% (Asayesh & Hemmati, 2018). Autonomous vehicles are projected to improve vehicle safety significantly, thus, some cumbersome safety equipment has been eliminated from the system, making the vehicle lighter and lowering energy usage. The travel demand also influences overall carbon emissions. The number of automobiles in the US will rise by 60% as a result of autonomous vehicles (Ozimek, 2014). Autonomous cars may potentially inspire a whole new demographic to utilize cars, including the young, the old, and even the crippled. This promotes social welfare and fosters more mobility. Demand for travel, energy use, and carbon emissions all rise. Consequently, the properties of autonomous cars have an impact on energy usage both positively and negatively (Asayesh & Hemmati, 2018).

Additionally, the advent of AVs may reduce traffic congestion. On the one hand, some people believe that since AVs can communicate with one another, they will move close to one another and interact with each other. Others, however, contend that as more people choose AVs for their travel, traffic will get worse since they provide a level of convenience and usability that public transit may not be able to match (Faid, Krahn, & Krogman, 2021). Other unforeseen factors might also contribute to increased congestion.

The features of the automatic movement of electric self-driving cars can neutralize their environmental advantages. A statistical model developed by MIT researchers shows that soon the energy required for a fleet of electric self-driving cars could produce greenhouse gases equal to those produced by all the data centers in existence today (Sudhakar, Sze, & Karaman, 2023). There are physical places incorporating large computer arrays, and these computers support countless programs worldwide.

It is estimated that these facilities emit 0.3% of the total carbon emissions, which is approximately equal to the annual carbon emission of Argentina (Sudhakar, Sze, & Karaman, 2023). Researchers estimate that this level of energy is required by self-driving technology for 1 billion vehicles that drive only an hour a day (Sudhakar, Sze, & Karaman, 2023). Comparatively, global road traffic consists of approximately 1.5 billion vehicles (Sudhakar, Sze, & Karaman, 2023). Electric vehicle computers should consume below 1.2 KW of computational power in 90% of created models to remain within the current data center propagation range; this is something we cannot simply achieve, considering the capabilities of existing hardware (Sudhakar, Sze, & Karaman, 2023). For instance, another statistical model analyzing this scenario states that by 2050 95% of all vehicles will be self-driving (Sudhakar, Sze, & Karaman, 2023). Aside from the triennial double in computational workload, this statistic necessitates the hardware efficiency of vehicles to double per year to maintain the same pollution levels. Comparatively, Moore's Law, which governs the acceptable industrial rate in decades, shows that computational power will double roughly every year or a few years; this period is expected to become slow over time, not accelerate (Najjaran, Rahmani, & Hassanzadeh, 2017). It is probable that the parameters of such scenarios, including the number of vehicles on the road, traveling time, computational power, and required energy, appear vague. However, there are frequent unpredicted consequences that need to be considered. A self-driving vehicle, for example, can spend more time on the roads while people are doing several things simultaneously, which leads to more traffic. Hardware and software modeling is also unmet needs. Semi-self-driving vehicles currently rely on popular algorithms, such as multi-tasking deep neural networks for travel leading by using several high-definition cameras, which record immediate and constant records on their system (Najjaran, Rahmani, & Hassanzadeh, 2017). The researchers estimate that if a self-driving car analyses 10 cameras during driving for an hour, it will generate 21.6 million results per day (Sudhakar, Sze, & Karaman, 2023). Generalize it for 1 billion vehicles, and you will have 21.6 quadrillion data analysis (Sudhakar, Sze, & Karaman, 2023). MIT explains: For a better comprehension of this number, all data centers of Facebook have several trillion data analysis daily (1 quadrillion is 1000 trillion) (Sudhakar, Sze, & Karaman, 2023). To put it another way, if the vehicle industry wishes to develop self-driving technology, these are serious obstacles that need to be removed (Najjaran, Rahmani, & Hassanzadeh, 2017). While electric cars are crucial for our sustainable future, self-driving cars can exacerbate the energy crisis.

2.4.4. The impact of autonomous cars on urban structure

One of the largest and most potent threats to the design of cities is the development of autonomous vehicles. The public is aware of the excitement and allure of autonomous cars, but many cities are still unprepared for the effects that these vehicles will have on their future urban planning. Many urban development agencies have also overlooked the effects that these vehicles will have on infrastructure, taxation, traffic safety measures, and even real estate. The future will reveal how technology will affect travel time, speed, and urbanization. As a result, they will evolve and a large number of them will be unexpected (Asayesh & Hemmati, 2018). These are a few examples:

- Reduced need for parking

Reducing the requirement for parking is one of the autonomous car's most significant implications on the urban structure. Charges and other parking-related fines are a significant source of revenue for many communities (Asayesh & Hemmati, 2018). For instance, parking lots alone in San Francisco produce approximately $130 million yearly (Chris, 2016). In metropolitan regions in America, automobiles are in park mode 95% of the time (Chris, 2016). Parking is less of an issue if you have a vehicle that can get you where you are going and back home again. Moreover, the requirement for parking permits and other related expenses are reduced with autonomous cars (Asayesh & Hemmati, 2018). Manufacturers anticipate that autonomous car technology will help millions of Americans and people worldwide enhance their standard of living. Instead of wasting their time, which is primarily spent commuting, they will have more time for other pursuits like work and leisure (Chris, 2016).

- Public transportation

Urban planners have long envisioned a low-density, point-to-point transportation system without the expenses that conventional transit networks now entail. The idea of an automobile using city streets without a driver thrills urban planners. They must thus be prepared to come up with a clear plan for the entrance of these cars (Asayesh & Hemmati, 2018). As a result, the fleet of public transit might be significantly impacted by autonomous automobiles (Asayesh & Hemmati, 2018).

- Changing urban transportation policies

We have observed that the performance of cities and the creation of revenue may be significantly and differently impacted by autonomous cars (Asayesh & Hemmati, 2018). The fundamental question that now has to be addressed is what impact these automobiles may have on urban planning. With the advent of autonomous automobiles, another subject that has been on people's minds is who should be in charge of urban planning. Public or private organizations? Many communities are unable to establish services like public transportation systems due to rising budgets and property values. While some may view the industrialization of public transportation as a failure of public welfare, others see it as a chance to raise standards and increase funding (Asayesh & Hemmati, 2018). Such change will be noticeable, particularly in small cities and suburbs with insufficient public transit. However, autonomous car transportation systems are not effective and affordable enough to operate as bus lines constantly. Experts also agree that it is essential to ensure system security before further privatising public services (Asayesh & Hemmati, 2018).

3. Discussion and conclusions

3.1. Urban planning in the modern era

Private industries have acknowledged the weaknesses of the underfunded public transportation providers during the past few years. Uber, Lyft, and Communauto are just a few of the businesses that have evolved to fill the void between the ownership of private vehicles and the provision of public transit (Faid, Krahn, & Krogman, 2021). The traffic, price, and accessibility issues related to urban transportation are frequently not resolved by the goods offered by these corporations, and in some cases, they make these issues worse by worsening congestion. To expand transit access, enhance transit efficiency, and adhere to increasingly tighter municipal budgets, some of the biggest firms in the world continue to invest billions of dollars in disruptive transportation technology. In the last 10 years, many new technologies have been introduced, ranging from small-scale application-based services to physical add-ons and portable transportation like e-scooters (Faid, Krahn, & Krogman, 2021).

The notion of the autonomous car was first shown to the public at the New York World's Fair in 1939, though it could look like a new invention (Faid, Krahn, & Krogman, 2021). The audience witnessed autonomous electric automobiles powered by embedded road circuits and controlled by radio waves at Futurama, created by Norman Bell Geddes and supported by General Motors (GM) (Faid, Krahn, & Krogman, 2021). General Motors thought that this vision would become a reality within twenty years. Even 80 years later, much is still being discussed regarding how autonomous vehicles (AVs) will revolutionize transportation (Faid, Krahn, & Krogman, 2021).

In recent years, articles praising driverless technology as the salvation of our cities have appeared almost daily in newspapers, journals, and tech blogs (Faid, Krahn, & Krogman, 2021). We are informed that AVs reduce traffic, save lives, and provide pedestrians with more space. We are led to assume that we can replace our automobiles with a fleet by reading headlines like "autonomous cars are just around the corner" and "autonomous driving is here, and it is going to alter everything." The AV industry has already attracted enormous investment, predicted to reach over $724 billion by 2027 (Faid, Krahn, & Krogman, 2021). Several large corporations are positioning themselves as the pioneers of the driverless revolution. Despite these upbeat forecasts, the large market for AVs has yet to materialize.

3.2. Autonomous road vehicles and urban development

Connectivity, artificial intelligence, flexible automation, and fully autonomous vehicles (AV) are the three technological megatrends of the Fourth Industrial Revolution (Industry 4.0) identified by the World Economic Forum (Gavanas, 2019). Technology is in line with these megatrends, particularly in the case of connected and autonomous vehicles (CAV), which enable communication between vehicles, infrastructure, and other road users (V2X connectivity) (Gavanas, 2019). According to scientists, the widespread usage of AVs will lead to radical changes in employment, mobility and accessibility, safety and security, travel habits, energy efficiency, greenhouse gas emissions, and business models. However, the paucity of information needed to accurately analyze these changes sometimes forces scientists to draw ambiguous or even debatable conclusions. The estimated effects of AVs on greenhouse gases (GHGs), for instance, range from an 80% reduction to a threefold rise (Gavanas, 2019).

Governments at all levels should review their transportation plans in light of the development of AV. Planning also has to change to account for this hazy future (Gavanas, 2019). Given that the goal of the transportation system is to provide people and goods access to the locations where the activity is carried out, implementing programs presents unique challenges for spatial planning and use organization.

The planning difficulties brought on by the use of AVs are still not sufficiently addressed in the international literature. However, these issues must be resolved quickly since, according to experts, fully autonomous road cars will be commercially accessible within the next ten years and make up most of the fleet by 2050 (Gavanas, 2019). Urban planners are now arguing how AVs may aid in their planning objectives, but it is probable that in the future, cities will need to discover methods to adapt to the rise of autonomous mobility, such as mobility based on autonomous cars (Gavanas, 2019). Identifying and tackling urban planning issues fully is especially important in Europe, where urban areas are responsible for 80% of energy consumption, 70% of the population, and 85% of the country's gross domestic product (GDP) (expected to rise to 80% by 2050) (Gavanas, 2019).

The results of the widespread use of AVs in European cities will vary depending on the attributes of each city and its transportation infrastructure. They also rely on urban development strategy in terms of regional priorities and global objectives shared by the European Union and its members. Also, they are dependent on the particular AV technology to be used (AV for private, shared, and/or public transportation, with or without V2X communication). Urban planners must pool data from many sources, share knowledge, and forge strategic alliances in this challenging circumstance to accomplish the following goals: (Gavanas, 2019)

- Evaluating the impact that autonomous vehicles may have on metropolitan areas;
- Urban planning should incorporate autonomous mobility options to serve the unique requirements of the city under consideration and realize shared objectives for socioeconomic and environmental sustainability (Gavanas, 2019).

3.2.1. Main urban planning-related parameters and challenges

The following subsections outline the key elements that explain the potential impacts of AV deployment for urban passenger transport on urban development. These parameters are connected to particular difficulties in European urban planning (Gavanas, 2019).

Possible impacts of autonomous road vehicles on urban development

3.2.2. Value of time, access and location selection

The perceived value of time and cost to the passenger is anticipated to change due to new and sophisticated transportation services. Regular commuters significantly impact the value of time for commuter drivers and professionals who must drive as part of their businesses (such as couriers and delivery services) since drivers may be required to take their place. Moreover, those who are unable to operate standard automobiles, such as the old, the disabled, and young children, may have access to autonomous cars. People who cannot afford to purchase a car have more mobility options because of shared usage and public transit (Gavanas, 2019).

Autonomous cars will make the roads safer, provide grandparents and parents greater independence as they age, and let us go anywhere, anytime. Approximately 3 trillion miles are driven by Americans each year, which equates to countless hours spent stuck in traffic (Schwarting, Alonso-Mora & Rus, 2018). At the global level, this amount rises dramatically.

The aforementioned changes in the value of time, cost, and accessibility impact the location decisions made by households and businesses. Urban sprawl is a typical result of lowering the value of time and raising accessibility, as demonstrated by the rise in private vehicle use in the United States during the first half of the 20th century (Gavanas, 2019). Although most European cities are smaller than their American counterparts, Europe has had a noticeable urban sprawl tendency since the 1950s (Gavanas, 2019).

However, other academics contend that employing AVs to provide adaptable and demand-driven public transportation services may accelerate urbanization. This is especially true for European cities, where public transportation and urban growth go hand in hand. Therefore, to select the most appropriate methods, urban planners should consider the various AV implementation strategies and any potential effects on the site preferences of families and businesses (Gavanas, 2019).

3.2.3. Traffic, parking conditions and land use

Autonomous cars will probably result in more predictable traffic patterns, consistent speed profiles, fewer accidents, and more comfortable travel behavior. Likewise, it improves accessibility, which is anticipated to increase travel demand with potential implications for congestion. The cohabitation of AVs with traditional and semi-autonomous cars, pedestrians, cyclists, e-scooters, and other forms of "light mobility" in congested urban areas is anticipated to have the most influence on congestion. This results from the many features, modes, and decisions made by unique users over their excursions (Gavanas, 2019). It should be mentioned that the historic districts of European cities frequently exhibit the coexistence of many forms of mobility in congested urban settings (Gavanas, 2019). Due to their high level of driving precision, autonomous cars require less space and lane width than conventional vehicles from a technical perspective. AVs can expand the capacity of the road infrastructure in this way. The impact on capacity may be larger in the case of shared-use cars, which are anticipated to run at occupancy rates generally higher than private vehicles. By increasing capacity, public space is made available to construct infrastructure for other modes of transportation, such as active transportation, or for other land uses. Planning for land use is made possible by the reduced need for road capacity, especially in the congested center regions of European towns (Gavanas, 2019). Besides, the capacity of autonomous cars to go through terrain with bad geometric characteristics may open up new possibilities for providing better service to metropolitan regions that are more difficult to access.

On the contrary, a high traffic density brought on by a narrower road and shorter distance between vehicles may compromise the comfort and safety of pedestrians and cyclists, particularly when there is mixed traffic. Today, creating mixed-traffic zones is a typical approach to traffic calming in many European city areas (Gavanas, 2019).

Private vehicles are parked in around 95% of European cases (Gavanas, 2019). Drivers looking for free parking places account for about 30% of the traffic in urban areas (Gavanas, 2019). In Europe, planners and decision-makers strive for sustainable urban development strategies that include parking's impact on the deterioration of the urban environment (Gavanas, 2019). In this situation, the capacity of AVs to discharge passengers and then park themselves a distance from the travel destination may inspire creative ways to arrange and manage parking spots. Furthermore, since entrance and parking actions will be automated and extremely accurate, AV cars will take up less space in the parking lot. As a result, parking facilities can accommodate the same number of AVs at a lower level than they could in the past (Gavanas, 2019). In turn, it is anticipated that demand for on-street parking close to the ultimate destination would decline, freeing up space for other purposes, however, it is also possible that on-street parking will be replaced with off-street parking. This is especially crucial in congested regions with limited on-street parking and high demand during peak hours, including Commercial Business Districts (CBDs) (Gavanas, 2019).

Whether AVs are utilized for personal or shared transportation affects how close parking lots are to the ultimate destination of journeys. The passenger may utilize the closest accessible vehicle in the event of AVs with shared usage, allowing for greater flexibility in the distribution of parking places. However, while arranging the distribution of parking spaces, consideration should also be given to the "empty" kilometers driven by AVs, or the distance driven by AVs without any passengers. Planners must thus balance the advantages of restructuring the city's parking system and the chances to create space around extremely desirable locations against the externalities of "empty" kilometers driven by Avs (Gavanas, 2019).

3.2.4. Infrastructure, network and design

To enable their navigation and protect the safety of other road users, the widespread use of AVs is anticipated to lead to new specifications and guidelines for infrastructure design. These new design ideas may be related to the general shift toward a more integrated, networked, and "smart" city. "smart cities" are defined in various ways. For this article, a "smart city" is one where "investment in human and social capital and traditional (transportation) and modern communication infrastructure (ICT) results in sustainable economic growth, a high standard of living, and prudent management of natural resources through participatory governance." (Gavanas, 2019) As the EU actively promotes the development of smart city infrastructure through legislative measures under the Innovation Union agenda and other initiatives, the possibility of integrating innovative AV-related design concepts is of major relevance for Europe (Gavanas, 2019). Transportation spaces for AVs are a further necessity for urban infrastructure planning. These places should be planned to provide passenger comfort and safety as well as access to surrounding usage. The possibility of access to AVs for vulnerable and disabled users of the transportation system should be considered in the efficient design of these places. Some European cities should increase their efforts to make their urban infrastructure accessible to everyone in this context (Gavanas, 2019).

Integrating the concept of autonomous road vehicles with the priorities of sustainable urban development

3.2.5. European-level policy priorities

Since 2001, the European Union has advocated for sustainable development, which it defines as development that strikes a balance between current demands and the ability of future generations to satisfy their own (Gavanas, 2019). Three social, economic, and environmental pillars support sustainable development. With the Energy Union and its continued support of the Paris Agreement's and the Sustainable Development Targets' objectives, the EU has recently increased its efforts to meet particular sustainable development goals (SDGs) on the local and international levels (Gavanas, 2019).

The priorities of EU sector policies, such as the transportation policy, clearly reflect the ideals of sustainable development. One of these tenets is related to technology advancement has role in advancing sustainability. The major influence of urban transportation on traffic congestion and greenhouse gas emissions is acknowledged as part of the Europe 2020 plan, which was formed in 2010 to promote smart, sustainable, and equitable growth (Gavanas, 2019). The significance of Intelligent Transport Systems (ITS) and innovative technologies for achieving sustainable mobility in European cities is highlighted in the 2001 and 2011 Transport White Papers as well as the Green Paper on Urban Mobility (Gavanas, 2019). To fulfil the goals of Europe 2020, the European Union established some rules for transnational urban mobility planning in 2013, known as Sustainable Urban Mobility Plans (Gavanas, 2019).

Also, the agreement signed by the EU ministers in charge of urban affairs in 2016 makes technical advancement in "smart" cities a top goal (Gavanas, 2019). The agreement focuses on improving connection and accessibility for all in the context of urban transportation. The European Commission released a statement in 2018 outlining a plan for bringing autonomous mobility to market (Gavanas, 2019). Due to their capacity to improve shared mobility and free up public space, AVs have the potential to play a role in urban planning. The EU encourages autonomous cars to enhance sustainable urban transportation based on the aforementioned policy framework by applying particular instruments and actions. Some illustrative examples are as follows:

- Research and Innovation (R&I) Framework Program-funded initiatives that seek to test and gauge the consequences of automated and connected driving (CAD);
- WISE-ACT (Wider Impacts and Scenario Evaluation of Autonomous and Connected Transportation);
- Organization for European Cooperation in Science and Technology action (COST);
- The European Innovation Partnership on Smart Cities' New Innovation Services (NMS) program;
- Cities and Communities (EIP-SCC);
- European-connected cooperative ITS (C-ITS) and C-Roads platform deployment (Gavanas, 2019).

3.3. Definitive statements

The literature predicts that autonomous vehicles (AVs) will be ready to enter the market in the next ten years and fundamentally change the accessibility and mobility of metropolitan areas. The features of urban development will alter as a result of these developments. The widespread usage of AVs has an impact on a variety of factors, including the location decisions made by homes and businesses, the accessibility of locations with poor road qualities, and the availability of public space. This gives rise to the possibility of reorganizing uses. New opportunities are also anticipated for the creative design of urban infrastructure, the integration of the AV network into the energy network, in the case of electric AVs, and the integration of the AV network into the telecommunications network in the case of connected and autonomous driving (CAD) (Gavanas, 2019). CAD is related to the possibility of urban planners adopting AVs as large data sources. The social, economic, and environmental pillars of sustainable urban development will be impacted by the aforementioned repercussions and possibilities (Gavanas, 2019).

Urban planners should concentrate on comprehending the relationship between autonomous mobility and sustainable development and evaluating the unique effects of AVs on their cities to better prepare for these developments (Gavanas, 2019). They will be better equipped to establish synergies between cities, AV developers and operators, data managers, and the research community as well as capitalize on the potential advantages of autonomous transportation.

Traditional planning methods for autonomous cars segment the highway into several lanes. Such a movement is referred to as an organized movement. However, several nations have chaotic traffic patterns where cars can drive in and out of lanes (Kala & Warwick, 2015). When the vehicles are significantly dissimilar in size and speed, traffic flow can be greatly improved in such circumstances. Because of the size disparity, more cars may share a lane, increasing traffic bandwidth. Due to the difference in speeds, it is urgently necessary for a very fast car to pass a very slow car on the road (Kala & Warwick, 2015). This can be facilitated if the slow car can change across lanes to allow for an earlier overtake. As an illustration, consider the startling speed and size variations in Indian traffic. Consequently, structured patterns and consistent overtaking are frequently apparent. The vehicle path planning problem may be generally understood as a motion planning problem for a mobile robot with such a broad definition of laneless traffic. It is often a multi-robot path planning problem due to the presence of other vehicles.

3.3.1. Autonomous cars and the future of urban tourism

The way people live, work, and move in cities might be drastically changed by connected and autonomous vehicles (CAVs). At its most developed, CAV navigation will be automated, making the need for drivers to perform driving responsibilities unnecessary or perhaps unlawful. By 2022, Nissan, Volvo, and other current automakers expect to have many car models with commercially viable autonomous capabilities (Cohen & Hopkins, 2019). On a similar timetable, newcomers to the automotive sector Google, Apple, and Uber also intend to create a completely autonomous car (Cohen & Hopkins, 2019). Such deadlines have fueled a race for vehicle automation spearheaded by national governments as well as market leaders and upstarts, and as a result, automation has taken center stage in theories about the future of transportation. CAVs could enter the mass market as early as 2025, depending on how long it takes for CAVs to become cost competitive with non-CAVs, for legislation to catch up to technology advancements, for some degree of mass market penetration, and for public acceptability to increase (Cohen & Hopkins, 2019). For the first time in several regions of Asia, Europe, and the United States, some optimistically forecast that by the 2040s they would replace all other forms of automotive transportation (Cohen & Hopkins, 2019). These presumptions imply that all transportation-related businesses, including the tourist industry, will experience incremental disruption.

Remarkably, no research has examined in detail the possible broad consequences of CAVs for the tourist sector given the very short time until CAVs reach the mainstream market. To the best of our knowledge, Tussyadiah, Zach, and Wang's (2017) survey of public perceptions on the idea of "autonomous taxis" is the only study conducted on CAVs in tourism (Cohen & Hopkins, 2019). CAVs, however, go well beyond "autonomous taxis" and "public perceptions." They pose concerns regarding evolving urban forms and visitor encounters (Cohen & Hopkins, 2019). Additionally, because CAVs are still in the conceptual development stage, the majority of study on them focuses on technical and technological issues, with social science literature making up just 6% of the overall scientific literature on CAVs (Cohen & Hopkins, 2019). Cavoli et al. (2017) noted that few authors have investigated CAVs in the context of urban planning and urgently called for further studies on their socio-behavioral ramifications as a result of the relative scarcity of social science viewpoints and the quick development of CAV technology (Cavoli et al., 2017).

CAVs, often referred to as "driverless," "autonomous," or "autonomous" cars, are frequently portrayed as inevitable, revolutionary, and generally indisputable in the business, media, and public discourse. These analyses of technical algebra are frequently criticized for overstating efficiency and making generalized, generally unfounded claims about advantages. The "spatial morphology of cities," the regulation and control of vehicle occupants, the production of public revenue through vehicle taxation, the livelihoods of current working drivers, the power of access, and the usability of other modes of transportation are all potential areas where CAVs have the potential to disrupt current modes of mobility (Cohen & Hopkins, 2019).

The frequently idealistic image of autonomous city automobiles is supported by many unexpected characteristics. These characteristics include the development of creative urban governance narratives, economic progress, and a focus on technical solutions to urban challenges (such as air pollution and traffic congestion) (Cohen & Hopkins, 2019). First, promoting the future of autonomous transportation centers on safety discourses. According to some claims, CAVs eliminate up to 90% of collisions by lowering driver error (Cohen & Hopkins, 2019). This is crucial in the context of travel, because foreign surroundings, exhaustion from travel, new driving regulations, and driving directions (such as left or right) can all result in tourist-related accidents. Second, it has been argued that fewer accidents may lead to less congestion, but also that fewer CAVs are required to provide mobility demands than human-driven cars. This argument is very reliant on the prevalent ownership arrangements, and we will examine it in more detail later. Automated vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications may optimize traffic flows, while Fagnant and Kockelman (2015) contend that the problems of city driving may reduce the advantages of congestion (Cohen & Hopkins, 2019). It is more challenging to navigate than freeways and other fast routes.

Third, CAV innovation has been suggested to provide advantages for social justice in urban mobility by increasing accessibility for non-drivers, such as the elderly, the disabled, or children. However, this wider societal availability of automobiles can put metropolitan areas at risk. Fourth, through improved driving behavior, CAVs may have a positive impact on the environment, especially in terms of fuel savings and decreased greenhouse gas emissions (Cohen & Hopkins, 2019).

3.3.2. Predicting the implementation of autonomous cars

The table shows some advantages and disadvantages of autonomous cars.

Table 1: Advantages and disadvantages of AVs

Advantages	Disadvantages
driver productivity improvedayment by lowering stress and weariness	High cost of establishing related infrastructures
Reduction of traffic accidents and their casualty and, as a result increasing road safety	Abolition of job
Reduction of transportation cost	Possibilities concerning pedestrians
Reduction of fuel consumption	Risk of the incorrect function of technology
Reduction of parking lot requirement	Risk of losing privacy and the possibility of key takeaways
Energy and environmental impacts	Lack of public trust
Possible reduction of casualties	Legal matters
Reduction of waste of time	Relative risks in different environmental and climatic conditions
Easier movement for disabled people	

Source: by author

Reducing driver stress, improving productivity and mobility

Autonomous cars can improve driver productivity by lowering stress and weariness. They can serve as portable workplaces and sleeping quarters for people on the road. As a result, the cost per unit of travel time is decreased (cost per hour). Car interiors are prone to get unkempt and unclean, just like any restricted area, therefore it is important for everyone's safety that passengers wear seat belts and keep the usage of in-car beds to a minimum (Litman, 2017).

Autonomous cars may bring additional worries and discomfort. Travelers may have "access anxiety" if unusual weather conditions prevent cars from reaching their destination, such as severe rain or snow, or if the location lacks the precise maps necessary for autonomous operation. Despite being less expensive than human taxis, autonomous taxis and mini-transportation services will provide lower-quality service since there will not be any drivers to handle clients' items or assure their safety (Litman, 2017). Although security cameras keep an eye on passengers and the majority of surfaces are constructed of stainless steel and plastic to save cleaning and vandalism expenses, travelers may still come into contact with trash, stains, and scents from past inhabitants. Autonomous shared rides (microtransit) force riders to share space with strangers, and each time they board or exit the vehicle, delays might occur that reduce speed and reliability (Litman, 2017).

For those who, for whatever reason, cannot or should not drive, autonomous cars can offer independent mobility. These passengers gain directly from this, and expanding their access to educational and career prospects, it can enhance their productivity and relieve the strain on the driver's friends and family. Conversely, too pessimistic assessments of the advantages of autonomous vehicles would lead some communities to cut back on their support for public transportation, which would restrict the alternatives available to people who do not drive. The capacity for human traffic may be reduced and the occupants of human-driven vehicles may suffer if highway lanes are set aside for autonomous vehicles (Litman, 2017).

Autonomous cars are supposed to lower accident rates and expenses by up to 90% because around 90% of accidents are caused by human error, however, this ignores the new hazards these technologies may bring about (Litman, 2017).

- Hardware and software failures: Inaccurate sensors, confusing signals, and software flaws frequently cause complex electrical systems to malfunction. Accident-causing malfunctions in autonomous cars are unavoidable, however, it is hard to forecast their frequency (Litman, 2017);
- Autonomous technology hacking can be done maliciously for nefarious or recreational purposes (Litman, 2017);
- Higher risk-taking: Risk-compensation behavior is the tendency of travelers to take more risks when they feel more comfortable. The usage of seat belts by passengers in autonomous vehicles, for instance, may decline, and other road users may become less careful as a result of what has been referred to as "over-trusting" the technology (Litman, 2017);

- Many potential advantages, including lowering traffic and pollution emissions (cars moving quickly in close quarters) might also bring up new dangers, like human drivers joining carpools and worsening collisions (Litman, 2017);
- Increasing the total travel of the vehicle: Autonomous cars might enhance overall vehicle travel and, consequently, collision risk by enhancing comfort and convenience (Litman, 2017);
- Additional risks for non-vehicle passengers: Autonomous cars could have trouble spotting and accommodating motorbikes, bicycles, and pedestrians (Litman, 2017);
- Reduced investment in conventional safety strategies: Future attempts to increase driver safety may be undermined by the possibility of autonomous cars (Litman, 2017);
- Higher vehicle repair costs due to additional equipment: Costs for collision repair will probably rise dramatically as a result of more sensors, control systems, and quality control measures (Litman, 2017).

Autonomous cars are unlikely to reduce accidents by 90% as predicted because of these additional dangers. Müller, Cicchino, and Zubi (2020) found that autonomous cars can avert approximately 34% of accidents after examining the risk variables for car accidents (Litman, 2017). Sivak and Schüttel reported that the accident rate for autonomous cars will be the same as that of a typical driver and that the overall number of accidents may rise with the use of both autonomous and human-driven cars (Litman, 2017). Accidents and fatalities have been brought on by Tesla's "Full Autonomous" software and Autopilot. Groves and Kalera (2017) contend that the deployment of autonomous vehicles is acceptable even if it merely lowers the collision rate by 10%, but their research disregards the rise in overall vehicle travel (Litman, 2017). For instance, if they lower the accident rate per mile by 10% while increasing vehicle traffic by 20%, the number of accidents would rise overall and the risk to other road users will increase (Litman, 2017). Autonomous vehicles are susceptible to hacking. In one experiment, researchers demonstrated that placing markings that resembled graffiti on a stop sign by the side of the road led the program to display an incorrect "45-speed limit" (Litman, 2017).

3.5.1. Ownership and operational costs

Different tools and services are required for autonomous cars. Autonomous cars need reliable, redundant parts that are professionally installed and maintained since malfunctions might be fatal, raising maintenance costs. At the moment, optional automotive additions like remote starting, active lane assist, and safety cameras sometimes cost several thousand dollars, while yearly subscriptions to navigation and security services like OnStar and TomTom cost several hundred dollars (Litman, 2017). Owners sued Tesla in 2022 for falsely promoting the availability and advantages of the $15,000 upgrade to Tesla Service (FSD), which allows for limited autonomous operation (Litman, 2017). Owners of vehicles would likely need to pay for ongoing upgrades to their navigational software and services. The cost of minor accident damage, which generally adds $3,000 to the repair bill, nearly doubles with the use of advanced driver-assist system sensors (cameras, radar, and ultrasound), implying that the cost of car repairs will rise with the use of autonomous cars (Litman, 2017).

3.6. Effects of social equality

Autonomous cars are anticipated to have a variety of social justice effects, as outlined below:

3.6.1. Horizontal justice concerning subsidies

A fundamental tenet of economics is that markets—and a transportation system may be thought of as a market for mobility—are the most effective and equitable when pricing, or what customers pay to use a thing, reflect the costs of production. Electric vehicles currently receive significant purchase subsidies, and they are exempt from road usage fees that users of fossil fuel vehicles must pay through fuel taxes. Autonomous vehicles require dedicated travel lanes to reduce congestion, crash risk, energy consumption, and pollution emissions. As a result, EVs could be unjustly subsidized in the absence of new cost-recovery pricing schemes (Litman, 2017).

3.6.2. Foreign traffic costs

External costs of traffic—congestion, delays for pedestrians, expenses for roads and parking, the danger of accidents, and pollution emissions—that affect other people as a result of automobile travel are unjust. The real consequences of electric autonomous cars are yet unknown and will depend on whether they increase total vehicle travel and public policy, contrary to optimistic experts' predictions that they will do so. If given dedicated lanes, autonomous cars can enhance traffic flow, but in most cases, their congestion-reducing impacts would differ. They will probably lessen accidents brought on by human mistakes, but they will also bring about new dangers, like hardware and software malfunctions, malicious hacking, an increase in risk-taking if other road users feel insecure, and more exposure from travel caused by vehicles. Compared to fossil fuel-powered vehicles, emissions from electric autonomous cars should be reduced but not entirely eliminated. These advantages could be somewhat negated if automated driving results in an increase in overall vehicle travels (Litman, 2017).

3.6.3. Horizontal equality concerning the road space

Road space is a rare and valuable resource. To prevent congestion caused by users of modes with limited space, such as single-occupant automobiles, horizontal equality involves providing priority to space-efficient vehicles, such as trucks and buses.

Low occupancy rates are predicted for private autonomous vehicles. Without effective road pricing, as previously mentioned, it will frequently be less expensive for drivers to design their autonomous cars to go around the corner or back home to avoid paying for off-street parking, which exacerbates traffic congestion (Litman, 2017). Public roads should be operated and charged in a way that favors space-efficient modes, such as shared autonomous taxis and micro-transit, and that keeps traffic volumes within the limits of the available capacity of the roadways. This will become more crucial as autonomous cars become more prevalent and prospective travel needs arise (Litman, 2017).

3.6.4. Vertical equality according to abilities and needs

It is presumptive that those with special requirements, such as those with disabilities or other conditions, families with young children, those traveling with baggage, or non-drivers living in car-dependent regions, should benefit from the mobility policy (Litman, 2017). Those with certain disabilities, such as vision impairments, may be able to move around more independently with the help of autonomous cars. Additionally, because autonomous taxis are less expensive than traditional taxis, they may be a choice for some travels for people who do not drive.

Governmental policy should prioritize the less fortunate over the wealthy and enhance the availability of cheap transportation choices, particularly for those who need to obtain basic goods and services (health care, primary care, education, jobs, etc.) (Litman, 2017).

In the near future, various degrees of autonomous vehicles will join the market and eventually displace conventional vehicles. To establish the required infrastructure to adapt to this system, it is thus preferable to recognize the need for change and adaptation in all businesses and occupations during this time. However e, there are multiple problems to be solved before autonomous cars can be produced in large quantities. One of these issues is the high cost of the technology used in the car, such as the lidar, radar, and different sensors, which has an impact on the price of the car and makes it unaffordable for all social groups to purchase these vehicles. The capabilities of autonomous vehicles require a full revision and updating of traffic legislation. The van system, which serves as the interface between autonomous vehicles, is primarily responsible for message transmission. Any breakdown in communication between these vehicles, which directly affects human life, might result in catastrophic accidents. Systems for autonomous cars must thus be very secure against cyber-attacks. There is a lot of ambiguity around the global emergence and proliferation of CAV.

Many presumptions must be made to determine whether, how, where, when, and how quickly CAVs will arise, as well as any potential ramifications for larger industries, sectors, practices, and infrastructures. In this article, the sounds and sensations of a small number of urban tourist futures with various configurations of CAV innovations (for example, private vs. shared) have been imagined. Our conversation, which was mostly about what to expect from CAV, was associated with important areas of research in urban studies relating to driving rights regimes, gentrification, sustainability, (re)conceptualizing "cores" and "peripheries," as well as urban innovation and experimentation. How much autonomous vehicles will contribute to the solution of transportation issues is a popular question. According to optimists, autonomous cars will be trustworthy, economical, and widespread enough to replace more people from driving by 2030, resulting in huge savings and advantages. Nevertheless, there are valid grounds for scepticism. People with financial interests in the sector tend to make the most optimistic predictions based on their knowledge of disruptive technology like digital cameras, cellphones, and personal computers. They frequently overstate the potential advantages of autonomous cars while downplaying the major challenges that remain. There is a great deal of ambiguity around the demands for, advantages of, costs of, and travel-related effects of autonomous vehicles. Because automobiles, pedestrians, and animals frequently cross paths on public highways, driving is frequently unexpected. Before autonomous cars can navigate crowded cities, inclement weather, poorly paved or marked roads, and intermittent wireless connectivity, significant advancements must be made. Before they are marketed in the majority of nations, they must undergo extensive testing and receive regulatory clearance. The initial autonomous vehicles that are offered for sale are probably going to be pricy, have a restricted range of capabilities, and pose new dangers. These limitations reduce sales. Many drivers are hesitant to shell out thousands of dollars more for vehicles that occasionally cannot get them where they are going because of poor weather or unmapped routes. New automotive technologies take a while to catch on in the market because vehicles are more expensive, last longer, incur more external expenditures, and are subject to more regulations. Before most cars are autonomous, it will probably be decades, and some motorists might not like them.

To reach reliability at the human level and respond safely to even the most complicated metropolitan scenarios, autonomous cars working in complex dynamic settings need methodologies that can be adapted to unknown situations and reason efficiently. Careful comprehension is necessary for conscious decisions. Advanced computer vision technologies, however, are still unable to produce acceptable error rates for autonomous navigation. Combining decision-making, control, and perceptual techniques has recently produced promising outcomes (Schwarting, Alonso-Mora, & Rus, 2018). The verification and the assured performance of the autonomous driving pipeline have become some challenges that still need to be solved due to the rising popularity of machine learning techniques and sophisticated planning and decision-making processes.

By 2025, Level 5 autonomous cars should be trustworthy and safe. The testing and regulatory licensing process may take a few more years, so autonomous cars may be commercially accessible and legal to drive in many places by 2030. If they proceed in the same manner as earlier automotive technologies, they will be costly and have a finite performance window in the 2030s and maybe 2040s, occasionally failing to arrive at their destination or requiring human intervention when faced with unforeseen circumstances. Customers include wealthy motorists with high yearly mileage and organizations that employ vehicles to move supplies and equipment. Most middle- and low-income households will continue to utilize human cars for the foreseeable future. Before autonomous personal vehicles are accessible to the majority of middle- and low-income drivers, it will likely be the 2050s.

Although several governments are testing shared autonomous cars (autonomous taxis) and rideshares (minibus services), it is most probable that these services will not be publicly accessible until the 2030s. The running expenses and comfort levels of shared automobiles are reasonable. Since there will not be any drivers to assist passengers, provide security, or maintain cars, they should be less expensive than present taxis and shuttle services. Particularly in low-density regions, the delivery of vehicles can occasionally be delayed and erratic. Shared rides are the most affordable but the least pleasant since they cannot provide home-to-door service, picking up passengers creates delays, and customers must share small quarters with strangers. Due to these drawbacks, ride-hailing and shared vehicles are most useful for urban travel and are unlikely to take over for suburban and rural travel.

Conclusion

From the practical point of view

The advent of autonomous vehicles (AVs) heralds a transformative era in urban mobility, promising to redefine the landscape of city transport systems. From a practical standpoint, integrating

AVs into urban environments presents a unique opportunity to address some of the most pressing challenges of contemporary urban living, including traffic congestion, road safety, and environmental sustainability.

Firstly, the deployment of AVs is poised to reduce traffic congestion in cities significantly. By optimising routes and facilitating smoother traffic flow through advanced navigation systems, AVs can alleviate the perennial problem of urban congestion, thereby enhancing the efficiency of city transport systems. This improvement in traffic management is expected to save commuters time and contribute to cities' economic productivity by reducing the costs associated with traffic delays.

Secondly, the safety benefits of AVs cannot be overstated. With human error being a leading cause of road accidents, the precision and reliability of AVs offer a promising solution to enhance road safety. The implementation of AVs is anticipated to drastically reduce the incidence of traffic accidents, thereby saving lives and reducing the burden on healthcare systems. This shift towards safer transportation is a critical step towards creating more livable urban environments.

Furthermore, AVs present an opportunity to advance environmental sustainability in urban transport. By facilitating the transition to electric vehicles and optimising fuel efficiency through intelligent driving algorithms, AVs have the potential to reduce greenhouse gas emissions and urban air pollution significantly. This environmental benefit aligns with the broader goals of sustainable urban development, emphasising the role of innovative transportation solutions in combating climate change.

From the scientific point of view

The scientific exploration of AVs has yielded a wealth of insights that underscore the multifaceted implications of this technology for urban transport systems. The literature review reveals a consensus among researchers on the transformative potential of AVs, highlighting the complexities and challenges accompanying their integration into urban environments.

One of the key scientific contributions to the field is the development of sophisticated algorithms and models that underpin the operation of AVs. These technological advancements are crucial for enabling AVs to navigate complex urban landscapes safely and efficiently. Moreover, the ongoing research into human-vehicle interaction provides valuable knowledge on how to design AV systems that are intuitive and user-friendly, thereby facilitating their acceptance and adoption by the public.

Additionally, the scientific literature emphasises the importance of a holistic approach to integrating AVs into urban transport systems. This includes considerations of infrastructure adaptations, regulatory frameworks, and the socio-economic impacts of AV deployment. The interdisciplinary nature of AV research highlights the need for collaboration across various fields, including engineering, urban planning, environmental science, and social sciences, to address the challenges and maximise the benefits of AVs.

In conclusion, the practical and scientific perspectives on AVs converge on recognising their potential to revolutionise urban transport. However, realising this potential requires careful planning, robust technological development, and an inclusive approach considering urban populations' diverse needs and concerns. As cities stand on the brink of this transportation revolution, the insights from both practical experiences and scientific research will be instrumental in guiding the successful integration of AVs into the fabric of urban life.

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