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EDITORIAL

Autonomous Vehicles: Ingress and Potential

Rasa Uspalyte Vitkuniene*

Department of Roads, Vilnius Gediminas Technical University, Lithuania

ABSTRACT

New engineering solutions have been developed with the aim to help the driver over the past few decades. 94 ± 2.2% of accidents are caused by a human choice or error, where the critical reason, in the crash causal chain, was assigned to the driver. Autonomous Vehicles (AV) have great potential for improving road safety. This paper provides overview of the autonomic car background, the need for infrastructure for competitive entry of autonomous cars into the urban transport market. The description of the potential of autonomous cars covers the two main most promising areas: the application of AV to public transport and AV in car sharing service.

***Corresponding author**

Rasa Uspalyte Vitkuniene, Department of Roads, Vilnius Gediminas Technical University, Lithuania

Tel: +370-527-45072
E-mail: rasa.uspalyte@vilniustech.lt

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INTRODUCTION

Car security systems have evolved very rapidly over the past few decades. All new engineering solutions have been developed with the aim to help the driver. These technologies help to prevent or reduce the consequences of accidents, but do not guarantee complete safety. Around 1.3 million people are killed in road accidents worldwide each year [1]. The situation has improved significantly during last decade, not only due to new car safety systems, but also changes in road infrastructure, training for drivers and all road users. However, according to the United States Department of Transportation National Highway Traffic Safety Administration 94 ± 2.2% of accidents are caused by a human choice or error. Where the critical reason, in the crash causal chain, was assigned to the driver [2].

We are currently living in a time when the biggest cities have reached a critical point in terms of road safety. Rising transport needs and increasing car traffic do not reduce the number of accidents and their consequences. European regulations pay close attention to the necessary and radical changes in transport, as the old means of development are no longer the same. It is projected that by 2050 congestion losses will increase by about 50%. Communication between central and peripheral areas will be reduced. The social costs of accidents and noise will increase [3]. Therefore, all engineers need to think about the future today, build and prepare for new infrastructure and other transport movements.

A person does not always have a correct understanding of the environment around him, especially when driving a vehicle that is moving at high speed. The research shows, that recognition error, which is the cause of the traffic accident is in 41 ± 2.2% of critical human driving error accidents'. It is necessary to know the duration of a moderate com-plex reaction when examining the behavior of drivers and their understanding [4]. A complex reaction involves choosing the right response from several possible ones. Complex reactions can be combined in a variety of ways, such as depressing the car's brake pedal and turning the steering wheel. It is clear that such a reaction will take much longer, and its length depends on the

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complexity of the situation. Studies have shown that the approximate average time required to evaluate a situation through a rear-view mirror is 1.88 s, and the time required to evaluate a situation at an unregulated intersection is 2.60 s. More complex route arrows require 3-4 s, as the higher the speed of the controlled car, the longer the driver's reaction [5]. Thus, the recognition error is strongly related to the time of the complex reaction, this factor is different and depends on the psychophysiological con-dition of each driver, but always exists and has a significant impact on traffic safety for the outcome of each road situation. The error of choosing the right action accounts for as much as 33 ± 3.7% of all human errors [4] (Table 1).

The development of new road safety technologies has created a new and completely different direction in terms of road safety. Various car manufacturers Tesla, Volvo, BMW, Audi and companies such as Apple, Google, Uber and others are very active in researching, testing and developing autonomous car systems. The massive use of such technologies can reduce the number of accidents by up to 90% [6].

Autonomous Vehicles (AV) have great potential for improving road safety, but also pose some important challenges. While AV can help reduce accidents caused by human error, they can still experience technological and sensory failures as well as decision errors in a mixed traffic environment. Disabling automatic control means switching AV control from autonomous systems to human driving. The results show that factors related to AV systems (e.g., software failures) and other road users, increase the propensity to disconnect without an accident. Moreover, while technology has matured over time, the results show that shutdowns are part of the safe operation of AV, so shutdown alerts may need to be implemented. When the driver is clearly warned about the systems shutdowns the AV technologies could be used smoothly without potency for car accident's [7].

DOES THE CAR IS AUTOMOTIVE? LEVEL OF AUTONOMY

The solution for everyone's future is an accurate, tireless and virtually error-free driver or autonomous car. What is an autonomous car? Autonomous car - it is a self-contained vehicle that can orient itself on the road without human intervention at all times or while performing certain functions. There are multiple definitions for various levels of automation and for some time, there has been need for standardization to aid clarity and consistency. In 2014, the International Society of Automotive Engineers (SAE) provided definitions for levels of automation. The SAE definitions divide vehicles into levels based on "who does what, when" (Table 2).

Using the SAE levels, there is a distinction between Levels 0-2 and 3-5 based on whether the human operator or the automated system is primarily responsible for monitoring the driving environment. Throughout this Policy the term "Highly Automated Vehicle" (HAV) represents SAE Levels 3-5 vehicles with automated systems that are responsible for monitoring the driving environment [8].

Autonomous cars will fundamentally change the existing transport system. These cars are projected to reduce accidents by up to 90%, use less fuel and allow unrestricted mobility for those who cannot drive on their own [2]. However, for autonomous cars, the roads need to be properly tidied up and maintained, which requires upfront and additional public investment.

Table 1: Distribution of critical human driving errors [4].

Critical reason	The share accounts for all 94 percent of all human error caused by a traffic accident, %
Recognition error	41 ± 2.2
Decision error	33 ± 3.7
Performance error	11 ± 2.7
Inactivity error	7 ± 1.0
Others	8 ± 1.9

Table 2: Levels of autonomous cars [8].

Level	Title	Functions
0	Driver only	The human driver does everything
1	Driver assistance	An automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task
2	Partial automation	An automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
3	Conditional automation	an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.
4	High automation	An automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions.
5	Full automation	The automated system can perform all driving tasks, under all conditions that a human driver could perform them.

Subject Area(s): MATERIAL SCIENCE

AUTONOMOUSVEHICLEPERFORMANCE COMPONENTS

The reliable operation of an automotive car depends on the amount and quality of information it collects and accurate and fast processing capabilities. This requires a complex system consisting of three main subsystems. First, it is a subsystem of algorithms. It includes the perception of the environment to extract meaningful information from sensor data, localization to accurately orient and control the vehicle, perception to understand the vehicle's environment, and decisions in planning for vehicles for safe reach to the destination. The second is the Customer Subsystem. It consists of an operating system and hard-ware that integrates algorithms to meet real-time, reliability, safety, and energy consump-tion requirements. And the last third subsystem would be the Cloud Platform. This sub-system allows simulation and data storage procedures to be performed without an online connection in order to perform the calculations needed to make decisions, as quickly as possible, and to provide the user with high - resolution maps [9] (Figure 1).

A Global Positioning System integrated with an Inertial Measurement System (GPS / IMU) is used to collect data for location and environmental analysis. It is fully understandable that the GPS system determines the position accurately enough, only the positioning time is long. The GPS system only accurately indicates the current location of the vehicle at a data refresh rate of 10 Hz. The IMU system can quickly update its location, but the accuracy of it is low. The combination of the IMU and the GPS system provides the exact position of the autonomous vehicle at a frequency of at least 200 Hz. In real time, it allows you to have an accurate location of the system and car in area at all times. The GPS / IMU system can determine the exact help of the car when it has uninterrupted data flow, but even when the data is received with some error.

INFRASTRUCTURE NEEDED FOR EXPLOITATION OF AUTONOMOUS CARS

The fast-growing industry of Intelligent Vehicles (ITS) and autonomous cars seeks to adapt the existing transport ecosystem to their basic needs, as they are an integral part of it all. One of the good practices is the C-ROADS platform in Europe to make such technologies smoother, faster and hassle-free. It is a collaboration between the European Member States and several operators to work on the deployment of harmonized and interoperable C-ITS services in Europe. C-ITS is a cooperative intelligent transport systems platform that allows road transport to communicate with each other, with traffic lights or other road infrastructure in the same way as with other road users, using certain standardized technologies [11-13]. These systems are also already known as Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication.

AV required V2I data for minimum performance [12]:

- Information on road hazards;
- Information on road works;
- Weather conditions;
- Road signs;
- Speed limits;
- Data sent from car sensors;
- Car suspension data

Horizontal marking is currently a very important criterion for the smooth movement of an AV, which must be taken into account. Horizontal markings must be clear, indelible, undamaged, properly fitted and clearly visible. It cannot suddenly end and start suddenly, should to have a smooth connection and mark the required boundaries.

Vertical marking is important for both the driver and the AV systems and must be understood in the same way. Vertical

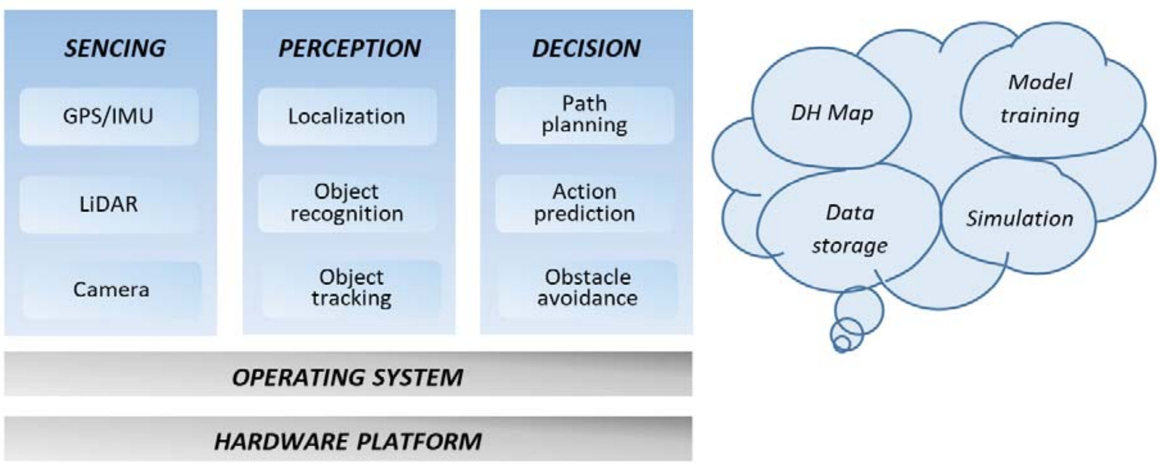

Figure 1 Scheme of performance components of Autonomous vehicle [9].

signs must be undamaged, uncontaminated or other-wise restricted in their visibility.

The reliability and security of the GPS signal is also a very important factor for the movement of an AV. The average number of satellites to be connected and the average discrepancy are checked on the road section, should be the highest possible.

Internet connection packet latency. The maximum possible time for data to be sent from the car system to the server and receive a response is 8 ms. The fluently working system should to have less than 1 ms response latency. The latency issue requires careful attention so as to satisfy the needs of consumers, the manufacturing industry, and government regulations. In this direction, 5G-based testbeds across the globe are used by researchers with an aim to reduce the latency in autonomous vehicles [14,15].

POTENTIAL OF AV USAGE

Public transport

Public transport is one of the social services, where all mobility needs must be met for all citizens as much as possible. Public transport is becoming an important eco-friendly alternative for the country's citizens those who can't buy / drive a car, whereas the majority of the population consists of children, adolescents, seniors, the disabled, women on pa-rental leave, etc. Public transport must be accessible to all interested transport participants, regardless of gender, age, nationality, etc. [16-18]. Public transport is the service of the population on a certain fixed route line, which greatly facilitates the introduction of AV. Such a system facilitates the need for the necessary infrastructure for the smooth operation of the AV. Automation of public transport may be the first step in the mass entry of AV into the transport system.

Full vehicle automation will solve the problem of the non-effective public transport system in rural areas [19]. The whole sector engaged in driver management and other activities will be significantly reduced. It is a threat public authorities will need to deal with. For business, it will be beneficial in cost reduction. For end-users, it is also a positive aspect in the long-term, as the price of the service potentially will decrease. In a short time and transfer period, the price may be higher due to equipment costs.

AV prototypes run slowly with maximal velocity up to 50 km/h but in reality even less (10-30 km/h). The number of passengers carried varies from 4 to 15, and such an interval is very suitable for most of the tasks in rural areas. The distance traveled on a single battery charge is about 100-150 km, and should be increased to at least up to 300 km.

Automated vehicles may appear and service will change from conventional public transport system to the bus by demand. Automated driving is a kind of technology that can change the whole paradigm of transportation.

Car sharing

It should be mentioned that a part of people is older or very young people who do not have a driver's license or are not able to drive a motor vehicle. Public busses with only one or two passengers are more ecologically harmful and more expensive to run than individual trips in car sharing vehicles. This can be important for municipal financial support of various transportation modes, thus further increasing the attractiveness of car sharing [20,21].One of the solutions to emerging challenges of transport accessibility in rural areas could be more flexible transport system as car sharing. Recently rapidly expanded car sharing services have grown worldwide mostly in large cities. Although car sharing has proven to be a successful alternative for the private car in big cities up to now, faster deployment of this service is required in smaller towns and rural areas. Therefore car sharing may face greater challenges in lower density areas than in huge cities mainly because lower demand prevents from profitable car sharing supply [22].

One of the main challenges' for car sharing system is to provide the vehicle where is it needed. This problem could be completely solved by AV. An Automated Vehicle (AV), which will perform as transport on demand and will be the best alternative. It will lead to a significant decrease in emissions and noise as well as visual pollution by parked cars.

CONCLUSION AND PROSPECTS

Technological solutions for increasing automated driving reliability, as well as a decrease in the cost of the sensing and processing system, are necessary. The certification procedure is also a complicated task because Artificial Intelligence (AI) technology will affect the functional safety of the vehicle. Law and regulation are the main problems public authorities need to focus on. Numerous technological solutions for AVs are at the stage of development. The challenge is to create a regulation system for AVs, the complexity of which is the employment of the vehicle in the independent law systems in different countries, and therefore, a universal system needs to be proposed. The legal mechanism should be provided to ensure the responsibility and security of personal data and cybersecurity of both the AV manufacturer and road user.

Human-robot interaction is the next issue to be addressed in the path of new technology. This is very important for transitional automation levels. It is a challenging task solving which the results are subject to technological solutions and the law system. If user acceptance does not increase, the last two aspects need to be reviewed.

Technology will work globally, and plenty of new opportunities will appear. Huge demand for new technologies is faced, which means that highly qualified professionals will be required. This will provide prospects for the emergence of new companies. The car sharing model has already become popular all over the world, but the AV can flip the ratio between privately owned and shared vehicles in the fleet, which is a contribution to the implementation of sharing economy.

The main strength of AV technology is the possibility of solving the problems of the transport sector, which are difficult or even impossible to be solved, taking into consideration conventional vehicles. Due to the elimination of the human factor, an increase in safety is of utmost importance. The other strength is an increase in mobility and a decrease in parking demand, which can be achieved through the employment of optimized control strategies. Furthermore, it may lead to a decrease in fuel consumption, emission levels, and noise (in electric vehicle case). The main effect will be reached when internal combustion engines are replaced with electric ones. In this case, the AV will not have significant influence but may create a slight impact due to new control strategies. The transition from the vehicles powered by internal combustion engines to electric motors is not as fast as expected previously, and thus the employment of new kind of transport will be even more complicated because of many challenges and difficulties faced nowadays. Moreover, some of the ongoing issues could be hardly predicted from the present point of view.

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Conflicts of interest

The authors declare no conflict of interest.

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