7th INTERNATIONAL CONFERENCE
''TOWARDS A HUMANE CITY''
Environmentally Friendly Mobility
Novi Sad 6th and 7th December 2019

Ivana Milenković, MSc[1]
E-mail: milenkovic@uns.ac.rs
Milica Miličić, PhD[1]
E-mail: mmilica@uns.ac.rs
Tatjana Savković, MSc[1]
E-mail: savkovic.t@uns.ac.rs
Pavle Pitka, PhD[1]
E-mail: pitka@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
Trg Dositeja Obradovića 6, 21000 Novi Sad

EFFECTS OF AUTONOMOUS VEHICLES TECHNOLOGY USAGE

Key Words

Autonomous vehicles; New vehicle technology; Positive effects; Negative effects

Abstract

Autonomous vehicles technology is a new technological concept of driverless vehicle in the field of automotive industry. This new vehicle technology could improve urban areas mobility and urban life quality. Many companies worldwide are intensively working on developing autonomous systems and testing self-driving vehicles. Driverless vehicle technology is expected to be available on the market and to the customers in the near future. Over the past few years, the potential benefits that can be achieved by switching to new driverless vehicle technology, such as improvements in traffic safety, local and global emissions, traffic flows, reduced travel time, increased mobility of disabled people and many others, were analysed. Accordingly, this paper gives an overview of the potential effects of introducing the driverless vehicle technology.

1. INTRODUCTION

Autonomous vehicles (AVs) also known in literature as self-driving vehicles, robot vehicles and driverless vehicles represent a new technology of vehicles whose usage is expected in the near future of transportation. New autonomous vehicles technology works on the principle of artificial intelligence where the vehicles move independently, without driver's activity, using information from the real environment with the help of sensors (infrared, laser, radar, optical, etc.) automated controls (braking, steering, signals, etc.), navigation – Global Positioning Systems, special high quality maps, etc.

Traffic congestions, as a result of people mobility, currently represent the biggest problem globally. An increase in traffic accidents, wasted time due to traffic congestions, emissions, insufficient parking lots, etc., is also evident. According to expert forecasts, numerous traffic problems the large cities across the world are facing could be resolved by switching to new autonomous vehicles technology. Switching to fully autonomous vehicles would create significant socio-economic advantages including improvements to road safety, energy efficiency, traffic flow, mobility increase, travel time reduction, travel behaviour, congestion reduction and parking benefits [1].

Over the last few years, a large number of companies such as Google, Continental Automotive Systems, Nissan, Volvo, Audi, Toyota, Mercedes-Benz, Volkswagen, Delphi Automotive, Tesla Motors, General Motors and Bosch, have been working intensively on developing the autonomous vehicle systems. Fully automated vehicles are expected to be commercially available between 2025 and 2045, and to penetrate the market rapidly after their introduction, while the respective time-window for conditional automation is shorter, between 2018 and 2028 [2]. Besides developing autonomous vehicle systems, some states in the United States of America have determined and adopted automated vehicle legislation and regulation. Nevada was the first state to adopt automated vehicle legislation in 2011, Florida was the second, followed by California, Michigan, North Dakota, Louisiana, Tennessee and Utah. The most common purposes of state legislative efforts have been to: Introduce Definitions, Regulate On-road Testing, Regulate Deployment, and Address Liability [3].

This paper provides an overview of the potential effects that could be achieved if the fully automated vehicles replaced the vehicles with drivers.

2. AUTONOMOUS VEHICLES – LEVELS OF DRIVING AUTOMATION

There are different Levels of driving automation which are defined by The National Highway Safety Administration (NHTSA), Society of Automation Engineers (SAE) and the Federal Highway Research Institute (BASt), starting from the level where the driver manually controls the vehicle, to a complete automation system which executes control, acceleration and deceleration of the vehicle [4, 5, 6].

Both NHTSA and BASt taxonomies define five levels of automation. NHTSA relies upon a numeric system ranging from Level 0 (No Automation) to Level 4 (Full Self-Driving) while the BASt Expert Group uses labels ranging from Driver Only to Full Automation. SAE, in contrast, identifies six levels of automation ranging from zero (No Automation) to five (Full Automation). A classification system based on six different levels (Figure 1), ranging from no automation to fully automated systems, was published in 2014 by SAE International, an automotive standardization body, as J3016, Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems [5].

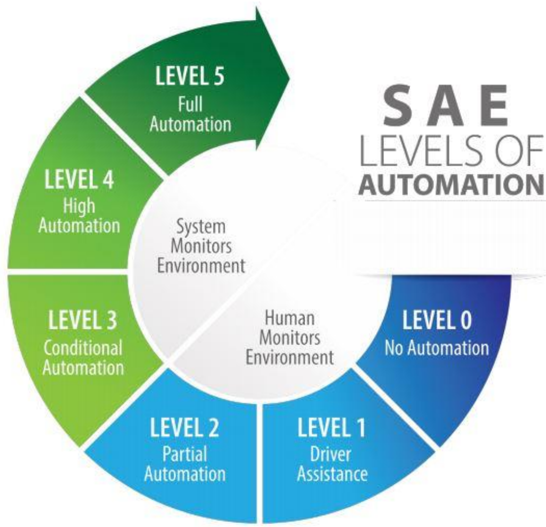

Figure 1. Levels of driving automation according to SAE International [7]

Level 0 – no automation refers to vehicles without any level of automation. Such vehicles require full attention of the driver who manually controls the vehicle, from steering, deceleration, acceleration to monitoring the environment and traffic conditions.

Level 1 – driver assistance refers to an automated driving system that assists driver when steering, braking and accelerating. This level features the facilitation of driving while expecting the driver to monitor the traffic conditions and perform other dynamic aspects of driving.

Level 2 – partial automation refers to one or more driving assistance systems, with vehicle controlling the steering, acceleration and deceleration while expecting the driver to take full control of the driving.

Level 3 – conditional automation means that, in a series of situations, the driver can let go of the controls in certain circumstances under specific conditions, and even direct attention at something else for a long period of time, but has to be alert and ready to take control at any time, if required. Compared to Level 2, the driver does not need to focus on operating the vehicle while the autonomous driving is active.

Level 4 – high automation refers to driving regime without the intervention of the driver. However, these vehicles are used in limited driving conditions, for example, a transport on limited road sections with lanes reserved for autonomous vehicles. The vehicle has the ability to stop if the driver does not take control of the vehicle.

Level 5 – full automation is the final goal of the driverless vehicle technology. At this level, the vehicles will perform all driving tasks without the driver, which is expected in the coming decades.

3. EFFECTS OF USING THE AUTONOMOUS VEHICLES

The potential traffic safety benefits - Because of the increased reliability of autonomous systems and reduced reaction time with respect to drivers, the automation has the potential to impact traffic safety significantly. Driver errors are believed to be the main reason of traffic accidents (errors of the perception process and reception of information). By switching to fully automated vehicles, it is expected for autonomous vehicles to lead to further reduction of road accidents [8]. With full automation there would be no more human error, and practically, the complete elimination of accidents would be possible if fully autonomous vehicles successfully reached the market. The technical failure category could become proportionally larger in the future, with the new technical risks of fully automated driving. However, the current prediction about the degree of efficiency of fully automated vehicles can not be precisely determined as numerous technical factors are still unknown.

Parking benefits – In addition to the positive impact of fully automated vehicles on traffic safety, the vehicle parking can also benefit from this technology. Autonomous vehicles have a positive effect on reduction of parking space demand close to destination because they have the ability to take the passengers to their destination, find a parking space without a human interaction, park further away, and then return later to pick up the passengers when needed. This allows passengers to enter/exit directly at the origin/destination of their trips. The driver saves the time in finding a parking spot as well as walking to/from a remote parking spot. In addition, access to the vehicle is eased spatially and temporally. After the passengers exit the vehicle, the autonomous vehicles can search for a cheaper/free parking space on their own, or eventually drive back home or even remain in the traffic for a short period. This yields a significant reduction in the generalized costs of parking in terms of both parking fees and search time [9]. Research results show that, by introducing shared autonomous vehicles technology, many trips will convert quickly to mobility-on-demand which will lead to a reduction of trips of personal vehicles requiring a parking spot. According to research results in Boston, shared AVs will lead to a reduction of number of parking spaces needed by 48%, including those on the streets and in the parking structures (Figure 2). Research results also show that the number of personal vehicles on the road will decrease by 15% because, more convenient, shared vehicle services will allow households to reduce vehicle ownership and use, whereas the total number of miles travelled will increase by 16% because the increased convenience and productivity contribute to increase in travel. However, travel time will improve by just 4% on average [10].

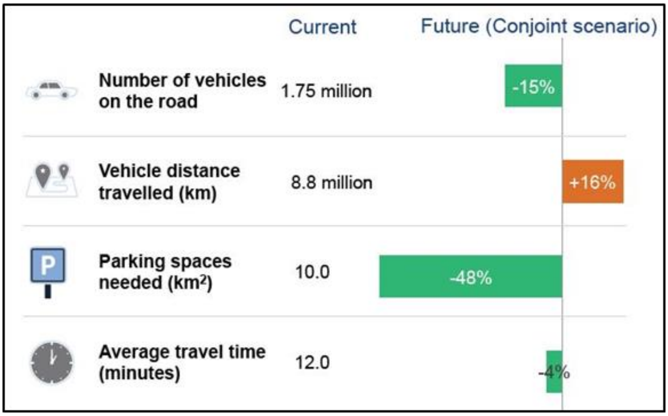

Figure 2. The impact of autonomous vehicles on the number of personal vehicles, distance travelled, parking spaces needed and overall travel time [10]

Increased mobility of user groups – Automation presents enormous potential for improvement of mobility and travel demand of the user groups whose mobility is limited and difficult such as elderly persons, disabled people, children, adolescents, people under the influence of alcohol and people who are otherwise deprived or do not want to drive. These user groups can use different transport models for mobility-on-demand, such as autonomous taxi, autonomous shared taxi or autonomous minibus. That directly benefits these user groups, improves their access to education and employment opportunities, increases their economic productivity, reduces responsibilities and burdens on their friends and family members [11, 12]. Participation of these user groups in economic and social life might yield benefits associated with increase in vehicle kilometres travelled. Total vehicle kilometres travelled is expected to increase between 0% and 3% in 2030 and between 0% and 27% in 2050 [2]. Another travel demand research has shown that the total vehicle kilometres travelled could increase between 4% and 26% after introduction of automated vehicles [13].

Reduced congestions and fuel consumption and increased road capacity – Autonomous vehicles can also have a positive impact on both, the increase of road capacity and the decrease in traffic congestions, on fuel consumption and consequently emissions because of the so called safety gaps between the vehicles and better management of traffic flow [14]. Such technology allows fine speed adjustments of following vehicles and shorter travel times, leading to slower brake wear and fuel savings. These improvements are related to the implementation of adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC) which is already being integrated into automobiles. Some of the benefits will be realized before autonomous vehicles are fully operational [15, 16]. Some predicted benefits of the reduced congestion and pollution emissions etc. require that autonomous vehicles have dedicated lanes to allow numerous vehicles driving close together at relatively high speeds (platooning). Capacity benefits are expected to be higher on motorways than on urban streets. According to the research results, the capacity on motorways is expected to increase between 0% and 5% in 2030 and vary between -3% and 25% in 2050 [2].

In addition to these positive effects that are expected in the future, there are also predicted negative effects and additional risks of using fully automated vehicles [11]:

- Hardware and software failures - Compound electronic systems frequently fail, and even small vehicle operating system malfunctions such as false sensor, distorted signal, or software error can have disastrous consequences,

- AVs will certainly lead to additional crashes caused by system failures, platooning, higher traffic speeds, further risk-taking, and enhanced total vehicle travel,

- Assigned highway lanes for autonomous vehicle platooning may reduce capacity for human-operated traffic, which can present new risks, such as human drivers joining platoons and increased crashes austerity,

- Many potential advantages, such as decreased congestion and emission rates, reduced traffic signals and lane widths, require that most or all vehicles on a road function autonomously,

- In the long-term, the autonomous vehicles will probably be unable to operate in heavy rain and snow, on unpaved roads, or where GPS service or special maps are unavailable, and they may be rather slow and inaccurate in mixed urban traffic,

- Private autonomous vehicles are going to be more expensive than human-operated vehicles, because of additional vehicle equipment,

- Autonomous vehicles entail further investments for transport networks (physical and digital infrastructures), increased infrastructure costs can require higher roadway design and maintenance standards,

- Increased traffic problems. Enhanced vehicle travel may increase congestion, pollution and sprawl-related costs,

- Increased risk-taking. When travellers feel safer they commonly take further risks. If autonomous vehicles are regarded as very safe, passengers may cut down on a seatbelt use, and other road users may be less careful,

- May increase risks to other road users. Autonomous vehicles may have difficulty spotting, conveying and conforming to pedestrians, bicyclists and motorcycles, and also can decrease affordable mobility options such as walking, bicycling and transit services,

- Optimistic forecasts of autonomous vehicle advantages may reduce mobility options for non-drivers, because some communities may cause to reduce support for public transit services (transport improvements and management strategies),

- Autonomous vehicles are estimated to cost less than human-driven taxis and ride-hailing services, but more than human-driven private vehicles and public transit services,

- Self-driving taxi (shared autonomous vehicles) services will be more economical than human-operated taxis, but offer limited service quality. There will be no drivers to help passengers with the luggage and the vehicles may be unclean,

- Self-driving vans (micro-transit) take passengers to/or near destinations, but offer least convenience, comfort and speed, particularly in sprawled areas.

4. CONCLUSION

A review of the available literature and the research results about the potential effects that could be achieved by switching to driverless vehicle technology shows that there are a number of potential positive and negative effects associated with the introduction of this new technology.

Many vehicles currently have Level 1 and 2 technologies. Automation levels 0 to 3 require a licensed driver and driver alertness at all times because of their limited functionality, but levels 4 and 5 allow driverless operation. For many predicted benefits associated with autonomous vehicles, such as independent mobility, reduced traffic congestion, crash risk, parking benefits, etc. levels 4 and 5 are essential, whereas automation levels 2-3 can reduce driver stress.

With their arrival on the market, the autonomous vehicles could mitigate the effects of traffic and make the mobility of people safer and easier. However, the possibilities offered by this technology also carry some risks that may adversely affect the benefits of autonomous vehicles. Therefore, before autonomous vehicles fully reach the market, a high testing, defining the regulatory standards and approvals, will be required in order to avoid potential drawbacks and justify the use of this vehicle technology.

REFERENCES

[1] D. J. Fagnant, K. Kockelman, “Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations,” *Transportation Research Part A: Policy and Practice*, 77, pp. 167–181, 2015.

[2] D. Milakis, M. Snelder, B. van Arem, B. van Wee, and G. Correia, “Development and transport implications of automated vehicles in the Netherlands: scenarios for 2030 and 2050,” *European Journal of Transport and Infrastructure Research*, 17(1), 63–85, 2017.

[3] E. Paul Dennis, A. Spulber, "International Scan of Connected and Automated Vehicle Technology Deployment Efforts," Center for Automotive Research (CAR), 2016.

[4] National Highway Traffic Safety Administration – NHTSA “Preliminary statement of policy concerning automated vehicles,” Washington, DC, 2013.

[5] SAE International, “Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems J3016”, 2014.

[6] http://onlinepubs.trb.org/onlinepubs/conferences/2012/Automation/presentations/Gasser.pdf

[7] https://www.oregon.gov/ODOT/Get-Involved/Documents/AVTF-vehiclecode-presentation-20190408.pdf

[8] T. Winkle*, "Safety Benefits of Automated Vehicles: Extended Findings from Accident Research for Development, Validation and Testing,"* In M. Maurer, J. Gerdes, B. Lenz, H. Winner (eds) Autonomous Driving. Springer, Berlin, Heidelberg, 2016.

[9] G. H. d. A Correia, B. van Arem, "Solving the User Optimum Privately Owned Automated Vehicles Assignment Problem (UO POAVAP): A model to explore the impacts of self-driving vehicles on urban mobility," *Transportation Research Part B: Methodological*, vol. 87, pp. 64–88, May 2016.

[10] "Reshaping Urban Mobility with Autonomous Vehicles-Lessons from the City of Boston," World Economic Forum in collaboration with The Boston Consulting Group, 2018.

[11] T. Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," Victoria Transport Policy Institute, 2019.

[12] "Preparing for the Future of Transportation: Automated Vehicle 3.0," U.S. Department of Transportation, Washington, DC, 2018.

[13] D. Milakis, B. van Arem and B. van Wee, "Policy and society related implications of automated driving: A review of evidence and directions for future research," *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, vol 21, pp. 324-348, 2017.

[14] R. Hoogendoorn, B. van Arem and S. Hoogendoorn, "Automated Driving, Traffic Flow Efficiency And Human Factors: A Literature Review," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2422, pp. 113–120, 2014.

[15] A. Kesting, M. Treiber, M. Schönhof, F. Kranke and D. Helbing, "Jam-avoiding adaptive cruise control (ACC) and its impact on traffic dynamics," *In: A. Schadschneider et al. (eds.), Traffic and Granular Flow'05. Berlin, Heidelberg: Springer,* pp. 633–643, 2007.

[16] W. J. Schakel, B. van Arem, B. D. Netten, "Effects of cooperative adaptive cruise control on traffic flow stability" *In 13th International IEEE Conference on Intelligent Transportation Systems,* pp. 759–764, 2010.