AUTOMATED DRIVING SAFETY

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***Abstract**: The purpose of this paper is to provide an overview of automated driving, point out its significance and major safety benefits and offer some recommendations for creating a regulatory environment that gives priority to road safety. Prototypes of automated vehicles capable of self-driving new technologies were and will continue to be tested on public roads throughout Europe and other continents. Automated driving brings many benefits, such as improving traffic safety, reducing the possibility of human error, accelerated use of security technologies, reducing downtime and so on. It is expected that commercial production of automated vehicles started in 2017. The market will be a wide range of models of automated vehicles in place until year 2030. Automated driving technology allows self-driving vehicles, but today is not yet clear how these vehicles will be able to self-drive in all circumstances, especially in trade with conventional vehicles, other participants in traffic and in different climatic conditions. In addition to the benefits brought by automated driving, there are also other potential challenges such as addressing key road risk, but also create new ones. It is necessary to investigate a number of strategic questions that will provide answers and contribute to the efficient use of the partially and fully automated vehicles.*

***Keywords:** automated driving, automated vehicles, the potential benefits and challenges.*

1. INTRODUCTION

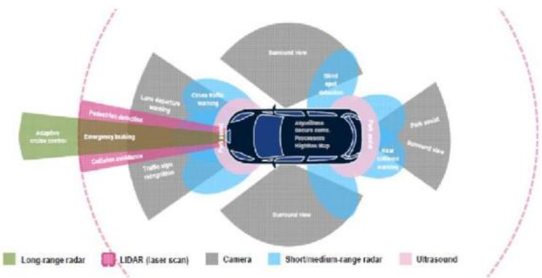
Automated driving technologies built on vehicles already prevent the occurrence of traffic accidents and fatal consequences on roads. Systems such as electronic stability control, automated harsh braking, intelligent speed adjustment, traffic lane departure warning and many others are active on-board safety systems. All these systems use technology to compensate to some extent drivers' mistakes, taking in some circumstances some of the vehicle controls from the driver. Full autonomy of the vehicle can bring significant changes in public transport, employment, in day-to-day performance and urban development in the near future. Theoretically, the potential safety benefits of automated driving are enormous. Autonomous vehicles will not drink and drive, or interfere with telephone conversations. Such vehicles will be programmed to run at custom and regular speeds, and will check the conditions in their environment several times every second. These technologies will clearly mitigate some of the risks, but they can also create new ones. In real driving conditions, automated vehicles will communicate with a large number of unautomatized vehicles and the most vulnerable traffic participants, pedestrians and bikers. Other road users, like pedestrians and bikers, will not become automated. How will it work in traffic that can not contact the eyes with drivers in crossing the road? How this will affect security is one of the important issues. Also, the important issue concerns the adoption of regulations for autonomous systems that have been tested and approved in accordance with common standards, especially in the conditions in which

Self-propelled cars already receive software updates that affect security

performance, such as the recently updated Tesla Autopilot. Also, Google is in the patent application of a sticky substance applied to the body of self-propelled cars, the purpose of which is in the event of an encounter with pedestrians, to remain glued to the vehicle instead of being discarded or overturned. In the last seven years, how long has the development of autonomous driving technology lasted more than 2.4 million test kilometers. Among the first in the world with the project of development and testing of the autonomous driving system is Volvo, which carries out an experiment with more than a hundred vehicles equipped with autonomous driving on Chinese roads. This experiment will gain valuable experience and gain knowledge of the behavior of the most advanced automated driving system on the network of urban roads in the real conditions of traffic. Despite the rapid technological advancement and development of the past few years, there are still no clear answers to many research and regulatory issues related to partially automated and fully autonomous vehicles. Therefore, there is a prior need to consider certain assumptions before the implementation of these vehicles in practice.

and communication with other vehicles and infrastructure. An automated vehicle, like a driver, must collect information, make a decision based on that information, and make that decision. The information comes from vehicle equipment, physical infrastructure, physical-digital and digital infrastructure. Many of these technologies exist today and are capable of driving the vehicle and in some cases with a minimum vehicle drive

or without input from the driver in test situations and in different driving conditions, Figure 1.



2. AUTOMATED DRIVING

Automated driving involves a wide range of technologies and infrastructures, capabilities and contexts, uses, and business cases, and products and services (1). Automated driving should also be seen in a wider context of new developments in the field of automating the imminent connection with new technologies and mobility systems. Automated vehicles can use built-in sensors, cameras, GPS and telecommunications to obtain information on the safety critical crisis assessment.

An automated vehicle is one that can, at least in part, perform a driving task independently of the driver, or read out its environment and move without input from the driver. The concept of self-driving, on the other hand, refers to the ability of an automated vehicle to operate independently and without a driver in a dynamic traffic environment, relying on its own systems

Figure 1. Technologies that enable vehicles to feel, plan and operate
in response to the dynamic driving environment, (1).

From a technical point of view, the current technology and systems for highly automated driving in controlled conditions give satisfactory results. These vehicles use sensors (radar, GPS and video camera system) in combination with high accuracy of digital maps that allows control systems to recognize the corresponding motion itineraries, such as barriers and relevant signaling. However, since 2015, there is still no consensus on automated driving. It is to be expected in view of the announcements by some manufacturers of the use of highly automated vehicles before 2020, and even more advanced vehicles by 2030. At the same time, consideration should be given to the risks associated with the implementation of the safety of these vehicles and the possibility of regulatory measures that prevent the development and implementation of new technology.

2.1. Levels of automated driving

The International Automotive Engineers Association has adopted six levels of automated driving, as guidelines describing the emergence of the most common levels of automated driving (SAE, 2014; Adapted from SAE Standard 33016), Table 1 (1).
The levels determine that the "dynamic driving task" is divided between drivers and vehicles. The task is entirely performed by the driver at level 0 (without automation) and with a fully automated system for driving at level 5 (complete automation). Level 0 is quickly becoming less important, as technologies that lead them to Level 1 are already on the market with the emergence of new automated vehicles. Levels 0 and 1 will help develop the program to level 5, and the security systems used for these levels, too to draw developmental guidelines for level 5, potentially with greater security benefits.

Table 1. Automated driving levels, Source: Adapted from SAE Standard (SAE, 2014

Razina		Naziv razine	Upravljanje ubrzavanje usporavanje	Kontrola vožnja okolina	Izvođenje dinamičkih zadataka vožnje	Sposobnost sustava –moduli vožnje
Vozač kontrolira okolinu	0	**Ne automatizacija** pune sposobnosti vozača po svim aspektima dinamičkih zadataka vožnje, čak i kad je pojačano upozorenje ili sustav za intervenciju	☺	☺	☺	
	1	**Pomoć za vozača** izvršenje specifičnih modula vožnje uz pomoć sustava za upravljanje ili ubrzavanje/usporavanje putem podataka za vožnju iz okruženja i s očekivanjem da vozač obavlja sve preostale aspekte dinamičkih zadataka vožnje	☺	☺	☺	neki moduli vožnje
	2	**Djelomična automatizacija** izvršenje specifičnih modusa vožnje s po jednim ili više sustava pomoći vozaču za upravljanje i ubrzavanje / usporavanje koristeći informacije za vožnju iz okoliša i uz očekivanje da vozač obavlja sve preostale aspekte dinamičkih poslova vožnje	☺ 🚘	☺	☺	neki moduli vožnje
Vozilo kontrolira okolinu	3	**Uvjetna automatizacija** izvedba specifičnih modula vožnje s automatiziranim sustavom vožnje za dinamičke poslove vožnje s očekivanjem da vozač primjereno odgovori na zahtjeve intervencije	🚘	🚘	☺	neki moduli vožnje
	4	**Visoka automatizacija** izvedba specifičnih modula vožnje s automatiziranim sustavom vožnje po svim aspektima dinamičkih poslova vožnje, čak i ako vozač ne primjereno odgovoriti na zahtjeve intervencije	🚘	🚘	🚘	neki moduli vožnje
	5	**Potpuna automatizacija** potpuno automatizirana vožnja sustava sa svih aspekata dinamičkih zadataka vožnje na svim cestama i ekoloških uvjeta koji mogu biti upravljani od strane vozača	🚘	🚘	🚘	svi moduli vožnje

The expert commission responsible for this textual description (SAE, 2014) emphasizes that these are not normative, technical or legal, but descriptive levels of automated driving. They do not mean any particular order of introduction to the market. Elements indicate a minimum, not the maximum system capability for each level. A special vehicle can have more automated driving possibilities, so it can work at different levels, depending on its characteristics.

2.2. Automated driving in Europe

Europe has a long history of investing in research projects that contribute to automated driving (2). A number of European Union (EU) member states are already open for automated driving, both in terms of the ability to test new vehicles and in terms of project implementation. The example includes urban mobility showing the use of a robotic vehicle for transport services in a protected urban area (3). Sweden plans to introduce 100 self-suffers vehicles, which will be used on public roads in Gothenburg in 2017. Finland will also enable the testing of robotic vehicles on public roads in limited periods in predefined areas (4). The United Kingdom has also announced rehearsals, including taking practical steps (5). Belgium develops a similar program based on the UK document and prepares, together with the Netherlands presentation of freight vehicles. In Spain, the General Transport Directorate approved the framework for testing autonomous vehicles on open roads at the end of 2015 (6). One vehicle is already on the market, the Tesla Model S, which has an autopilot function that, by combining cameras, radars, ultrasonic sensors and data, automatically directs the vehicle by motorway, still under the control of the driver, and also allows changing the route, and adjusting the speed to the traffic conditions 7). Vehicle manufacturers are also interested in the benefits of this new area. Various studies have uncovered a potential (8) economic impact on automated driving in the years to come in the range of up to 71 billion euros in 2030. The estimated global market for automated vehicles is 44 million vehicles by 2030 (9).

3. POTENTIAL SAFETY ADVANTAGES OF AUTOMATED DRIVING

The potential safety benefits of automated driving are manifested through the achievement of a European vision of zero-dead by 2050, by reducing human error, speeding up the use of security technology, and by supporting high-risk drivers of driving.

3.1. Achieving the safety benefits of automated driving

According to the European project (2), the safety and potential for reducing traffic accidents caused by human errors is one of the main drivers for higher levels of automated driving. Thus, automated driving can be considered as a key aspect of supporting the achievement of EU transport policy goals, including road safety (10). However, based on previous research results, it is estimated that the potential benefits of automated driving are only beginning to be achieved, with improvements in all areas of road safety, including road infrastructure and driver behavior. A study by a group of authors from Finland (10) shows that traffic safety is on the rise, given the gradual development of automation. The positive impact of traffic automation on traffic flows will be seen at Level 3, that is, at the level of conditional automation, with road traffic flow and traffic efficiency improving and speeding down.

Impacts in the context of the transport system will already be visible at Level 2, where congestion and congestion will be reduced, and traffic safety will be improved.

However, the authors (11) in their research claim that self-driving or automated driving will be difficult to perform perfectly, for example driving in different weather conditions or due to collisions caused by other road users, such as the sudden crossing of pedestrians across the road or a pedestrian crossing. The benefits of road traffic safety by reducing the driver error by introducing automated driving can be significant, as most collisions include certain elements of its error, and autonomous driving reduces or eliminates these errors (1). The European Commission accepts such an approach to the "safety system", which means that "the driver / driver has made a mistake and his mistakes must be foreseen and the risk of serious consequences should be reduced to a minimum." Also, for further consideration of automated driving, it is of great importance and "that responsibility for reducing deaths and serious injuries is not only placed on traffic participants but also shared with vehicle manufacturers and management of road infrastructure". There are currently many

different circumstances that can lead the driver to a wrong assessment of the situation, negligence or

interference. Estimates are those contributing to road deaths from 10 to 30% (12). Increased vehicle automation levels can contribute to the elimination or mitigation of conflict situations. It is expected that this could contribute to the reduction of visual errors, in the collision of one vehicle and on collisions at intersections. Automation can be expected to reduce some collisions due to excessive speed on the highway due to the rapid reaction time (13,14). It could also solve crashes related to driver fatigue, although driver drowsiness due to monotony and separation from vehicle control can be enhanced. However, the OECD report claims that the true safety test for autonomous vehicles will be to restore a good ride without collisions and drivers.

New challenges and new types of road accidents that may occur when autonomous vehicle technology becomes commonplace, such as mixing autonomous and conventional vehicles or other road users, will arise. Therefore, in the first years of introduction, full automation can be allowed only in certain places where the traffic environment will be more homogeneous and more customized to automated vehicles. This can minimize the mixing of autonomous and conventional vehicles and thus reduce conflicts between different types of vehicles.

Accelerated introduction of security technology today in the market has several consequences
systems that emerge outside the framework of human abilities (1). According to the SAE classification, vehicles have currently reached level 2 in automated traffic (partial automation), and level 3 (conditional automation) of vehicles can come on European roads in two or three years, and by 2020 at the latest. Some of the systems are already legally prescribed in respect of EU vehicle safety regulations. The goal of most of these active technologies is to intervene
this way to prevent the collision. One of the other implications for automated driving is a limited number of disabled drivers with difficulty in starting or continuing driving using automated systems or within a fully autonomous mode. It is recommended that when designing automated systems, a diverse population of driving in different traffic situations should be taken into account. One group that might benefit is older drivers, very relevant in the context of society's aging in Europe. Thus, automation could bring benefits to high-risk drivers, increase or expand mobility with the potential reduction of security risks that might pose for other road users.

In contrast, young drivers who have access to automated driving can gain less driving experience. It's an area that needs more research. It also presents driver training questions: how through training you can train people to drive safely and use an automated driving technique, and how drivers will be trained to be safe
transition between fully independent and automated driving.

3.2. Potential safety challenges of introducing automated driving

Potential safety challenges related to automated driving are possible through solving key road risks, reducing collision, transition phase of automated and non-automated vehicles, automated vehicles and vulnerable traffic participants, smart roads, or roads and digitization, customization of driver behavior, social acceptance and accountability data protection. One important issue in assessing the possible impact of an automated safety drive is whether the automation of key road risks such as speeding or driving under the influence of alcohol is resolved. Some recent preliminary analysis of the reality of the collision on the involvement of self-propelled vehicles taken over in the United States comes with various findings. The first set of research reveals that self-propelled vehicles for millions of miles of travel are more involved in traffic accidents than
conventional vehicles (11). This research indicates important warnings. Firstly, the distance traveled by self-propelled vehicles is still relatively low (about 1.2 million miles, compared to about 3 trillion per year in the US by conventional vehicles). Until now, autopilot vehicles have been driven only in limited (and generally less demanding) conditions, such as avoiding snow runs. Therefore, their exposure is not yet representative as the exposure of conventional vehicles. The study also showed that self-propelled vehicles were

not wrong for the collisions they were involved with and that overall crash injuries involving self-propelled vehicles were lower than conventional vehicles. Other recent surveys also from the United States, "A comparison of data on collision of automated vehicles" conducted by the Virginia Tech Transportation Institute (VTTI), was commissioned by Google. It has been shown that self-propelled cars are less involved in car accidents than normal cars, especially for more serious traffic accidents. In addition, in the same research, when the events of automated vehicles were analyzed, not a single vehicle operating in an automated mode was considered to be guilty of an event. One of the key challenges on the road to full automation is the ability and way of managing automated and semi-automated vehicles in a transitional phase that could last fifteen or more years, depending on market conquest and vehicle renewal. Security assessments and forecasts are based on assumptions that include fully equipped fleets of vehicles and vehicle comparisons, with very few studies performed on safety effects during the transition phase (15). Another problem, especially at the time of the introduction and the transition period, is the way in which these vehicles will communicate with the most vulnerable traffic participants. Of course, some of the safe technologies have already been incorporated into vehicles, especially to prevent vehicle collisions on the most vulnerable participants. Although research with new ideas is in progress, current pedestrians and bicyclists with their ITS safety equipment in interaction with automated vehicles are generally incapable. The interaction between current vehicle drivers and the most vulnerable traffic participants (pedestrians and cyclists) sometimes takes the form of communication through eye contact. Vehicles and their sensors and cameras will have to go above and beyond simple detection and be able to communicate with different forms of communication. This communication should be able to function even in bad weather conditions. The operation of automated vehicles in a safe condition should be ensured even under unfavorable conditions. This also applies to digitization and road infrastructure, and both will require investments for upgrading and maintenance. Numerous semi-automated or fully automated technologies will rely on road infrastructure to read their applications. Infrastructure performance (visibility, repair status) related to traffic signs, signals and road markings to support a higher level of safety and reliability of automated driving must be recognized. This will include common standards and harmonization. One option, which could be very likely in the context of facilitating common urban traffic, is to limit the area in which automated vehicles operate or provide them with a dedicated infrastructure, such as the use of traffic lanes for public passenger transport vehicles (1).

4. CONCLUSION

Based on the prior knowledge about the safety benefits and challenges of automated driving at the EU level, recommendations have been made aimed at introducing measures that can have a priority impact on improving road safety. In doing so, it is most important to develop a single and comprehensive EU regulatory framework for the implementation of automated vehicles and automated driving standards. It is necessary to establish a broad and effective monitoring and evaluation framework covering all aspects of automated driving, including investigating traffic accidents during the testing and implementation of automated vehicles and conventional vehicle relationships.

In order to obtain relevant responses to numerous challenges, it is necessary to continue research on the implementation of automated driving with emphasis on the interaction of automated vehicles and the most vulnerable traffic participants, the ability to solve the mobility of high-risk traffic participant groups and driver engagement during automated driving. By introducing automated driving, driver training needs to be adapted, including the development of a curriculum so that drivers can get operational knowledge of when and how to use the benefits of automation and understand the basics, advantages and limitations of innovative Technology.

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