European Transport Safety Council

Briefing

Prioritising the Safety Potential of Automated Driving in Europe

April 2016

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Introduction

Automated driving technologies are already preventing collisions and deaths on our roads. Electronic Stability Control (ESC) is now mandatory on all new cars sold in Europe. Automated Emergency Braking (AEB), Intelligent Speed Assistance (ISA) and lane-keeping systems are increasingly commonplace. All these systems use technology to compensate, to some extent, for human error, taking some control away from the driver under certain circumstances.

But we now stand on the verge of something much bigger. Fully autonomous vehicles may, in the near future, transform our world. Cars that drive themselves could bring dramatic shifts in car ownership, public transport, employment patterns, business and urban development.

The theoretical safety benefits are huge. Autonomous vehicles won't drink and drive or get distracted by telephone calls, facebook posts, or children in the back. They will be programmed to drive at appropriate and legal speeds, and will pay attention to their environment in 360 degrees at millions of times every second.

These technologies will clearly mitigate some risks; but they may also create new ones. And despite the rapid technological advances in recent years, Europe is very far from answering the many research and regulatory questions that partly-automated and fully autonomous vehicles present.

We face a medium to long-term scenario where autonomous vehicles will interact with large numbers of non-automated vehicles. What will the impact be on safety?

Other road users such as cyclists and pedestrians will not become automated – how will they manage in a world where they can no longer establish eye contact with drivers before crossing the road?

How will regulators ensure autonomous systems are tested and approved to common standards, especially in a world where cars are already receiving over-the-air software updates that affect safety performance, such as Tesla's recent autopilot update?

In short, there is an urgent need to put in place certain prerequisites *prior* to the wider deployment of automated vehicles in Europe.

The aim of this paper is not to answer all these questions. Its purpose is to give an overview of automated driving, identify the main safety benefits and offer some key recommendations for the near future for the EU and its Member States to create a regulatory environment that prioritises safety.

1 What is automated driving?

Automated driving encompasses a wide range of technologies and infrastructures, capabilities and contexts, use cases and business cases, and products and services[1]. Automated driving should also be seen within the broader context of new developments in automation and connectivity enabled by new technology and systems in mobility and elsewhere.

Automated vehicles are those is which at least some aspects of a safety-critical function (e.g. steering, throttle or braking) occur without direct driver input[2]. Automated vehicles may use on-board sensors, cameras, GPS, and telecommunications to obtain information in order to make their own judgements regarding safety-critical situations[3]. An automated vehicle is one that can, at least partly, perform a driving task independently of a human driver.

The word autonomous, 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 the vehicle's own systems and without communicating with other vehicles or the infrastructure[4].

The International Society of Automotive Engineers has adopted ‘Levels of Driving Automation’ guidance which captures the emerging descriptive consensus that is most used. The levels identify how the “dynamic driving task” is divided between human and machine. It is performed entirely by a human driver at Level 0 (no automation) and entirely by an automated driving system at Level 5 (full automation)[5]. Level 0 is quickly becoming less relevant with most new vehicles already on the market offering technologies which bring them up to Level 1. Levels 0 and 1 will help the developers reach Level 5 in that safety systems which are used for Level 0 and 1 will also pave the way for Level 5, and potentially with greater safety benefits.

For example low speed autonomous parking systems may be seen as a precursor to higher speed automated steering[6]. Collectively the systems provide a platform with the potential to support the introduction of vehicles with high levels of automation where the driver is not required to continuously monitor the vehicle and traffic environment[7].

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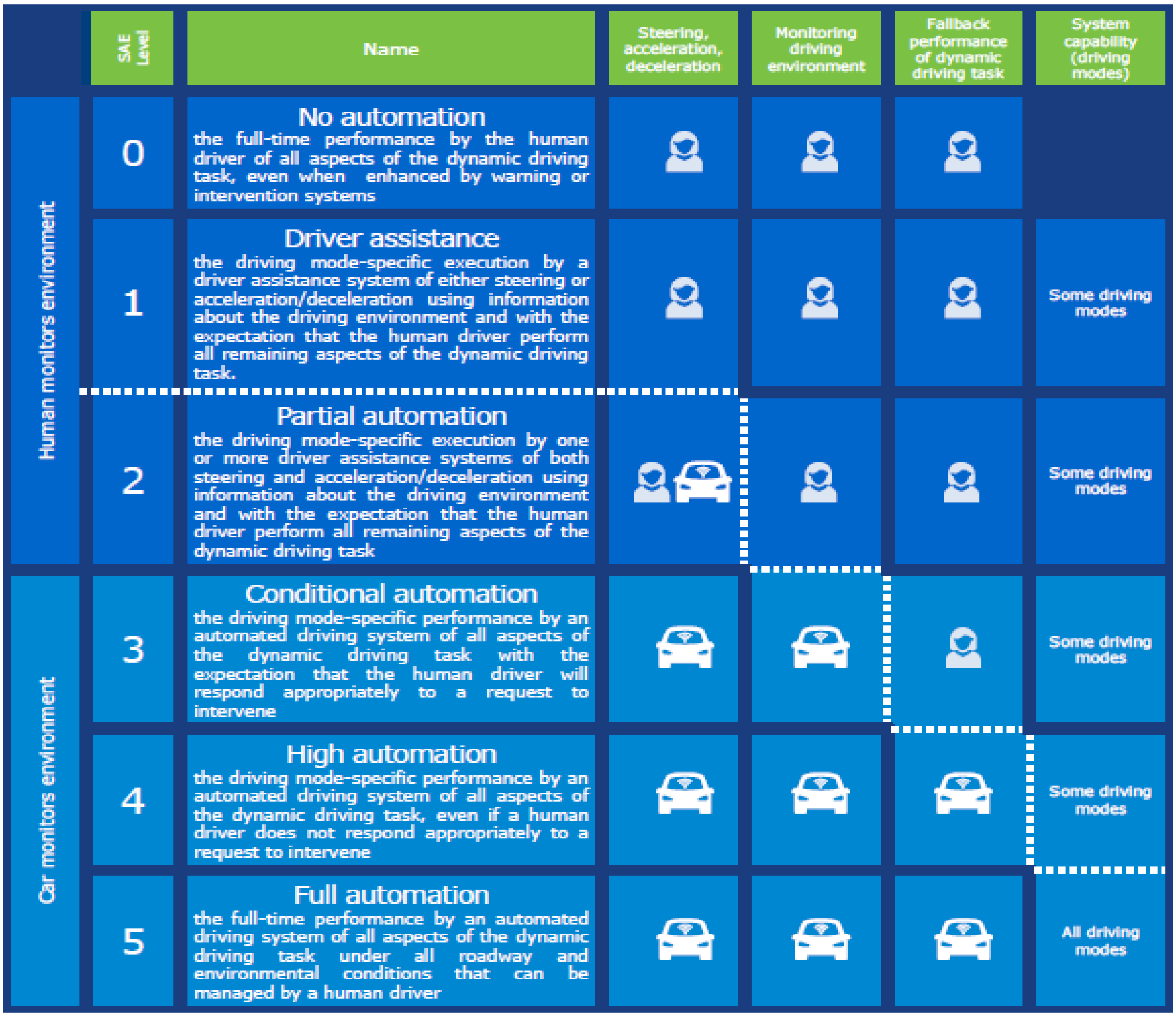
[1] OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.
[2] NHTSA (2013) Preliminary Statement of Policy Concerning Automated Vehicles.
[3] Ibid
[4] Ministry of Transport and Communications, (2015) Finland, Robots on land, in water and in the air.
[5] OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.
[6] PACTS Conference Report (2014) Driverless Vehicles: From technology to Policy.
[7] ibid



	SAE Level	Name	Steering, acceleration, deceleration	Monitoring driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human monitors environment	0	**No automation** the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems				
	1	**Driver assistance** the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.				Some driving modes
	2	**Partial automation** the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task				Some driving modes
Car monitors environment	3	**Conditional automation** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene				Some driving modes
	4	**High automation** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene				Some driving modes
	5	**Full automation** the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver				All driving modes

Source: Adapted from SAE Standard J3016 (SAE, 2014).

1.1 Routes to automation

The OECD paper "Automated and Autonomous Driving: Regulation under Uncertainty" identifies two major routes to automation. The first route is described as "something everywhere" which are vehicles which have some driver assistance (Level 1); these are already present today. The second, "everything somewhere", is at the other end of the scale and refers to vehicles without a human driver and entails expanding the use of such a vehicles to more contexts[8]. These scenarios link to different business cases and use cases. High speed motorways may be promising for the early application of increasingly automated conventional cars and trucks (including platooning[9]), urban areas are well suited for specialised passenger and delivery shuttles. Within the context of these different scenarios there will be implications for other road users including cyclists,

[8] OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.

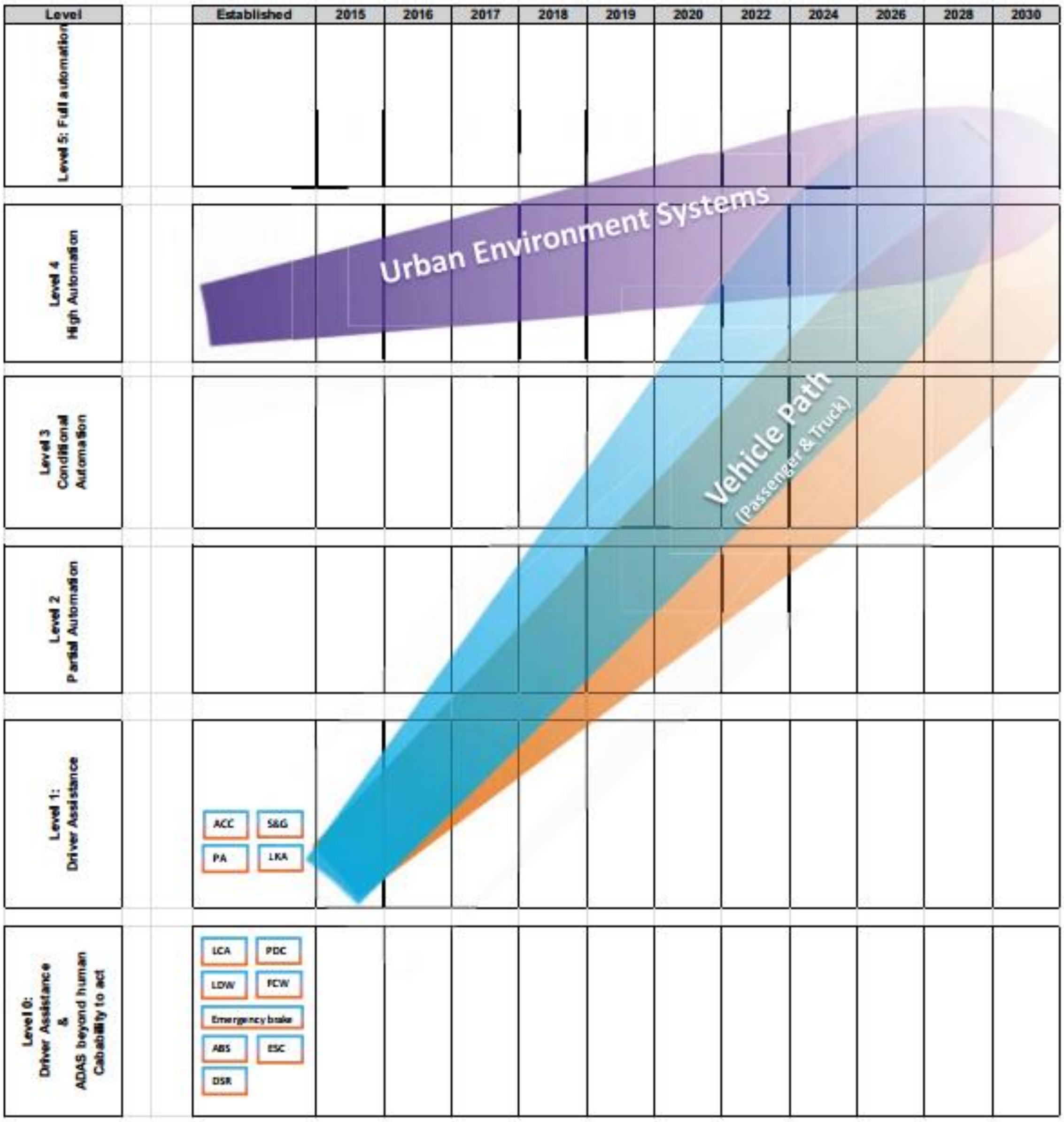
[9] Platoons decrease the distances between vehicles using electronic, and possibly mechanical, coupling. This capability would allow a group of vehicles to accelerate or brake simultaneously. This system also allows for a closer headway between vehicles by eliminating reacting distance needed for human reaction.

pedestrians and powered two wheelers (PTWs) which will be looked at later in this report.
In general, it is expected that the first vehicles with full or advanced automation, which will only operate within limited areas, will become commercially available in the early 2020s. According to some estimates, optional equipment packages for "autonomous driving" as factory installations in new cars may be available as early as in 2019[10]. The same estimate suggests that by 2025 there may be a sufficient range of standard equipment and options available to support automated operation and vehicles of levels 3 and 4. Fully automated vehicles that operate on public roads among other traffic are unlikely to be on the market before the 2030s[11].

1.2 The main automation deployment paths

The main automation deployment paths are set out in ERTRAC's Roadmap to Automation. These cover the urban environment path (high automation in areas with low speed and/or dedicated infrastructure[12]) and the automated vehicle path (building on Level 0 use of ADAS to full automation of Level 5 for trucks and cars). It must be noted that it will take a number of years beyond the framework shown below for full Level 5 vehicles to penetrate to the entire EU driving fleet. Whereas elements of assisted driving (Levels 1 and 2) may come earlier.

[10] KPMG (2013). Self-driving Cars: Are We Ready?
[11] ibid
[12] City Mobil2 in ERTRAC (2015) Automated Driving Roadmap.



1.3 Automated Driving in Europe

The EU has a long history of investing in research projects contributing to automated driving[13]. A number of EU Member States have already opened up to automated driving both in terms of enabling testing of new vehicles and running pilots[14]. Examples include CityMobil 1 and 2 which have demonstrated the use of robotic vehicles for shuttle services in the protected urban environment[15]. Sweden plans to permit 100 autonomous cars to be used on public roads in Gothenburg in 2017. Finland will also allow testing of robotic cars on public roads for limited periods and in predetermined areas[16]. Another

[13] ibid

[14] Overview of EU MSs Initiatives: ERTRAC (2015) Automated Driving Roadmap and OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.

[15] http://www.citymobil2.eu/en/

[16] Aurora Project : http://liikennelabra.fi/test-environments/aurora/

use example which is already being tested is vehicle platooning of cars or trucks on the motorway whereby a platoon consists of two to six vehicles closely spaced and tightly coordinated through both vehicle-to-vehicle communication and some degree of automation[17]. The UK has also announced trials including the launch of a code of practice[18],[19]. Belgium is developing a similar code of practice based on the UK document and is preparing together with Netherlands a Truck Platooning demonstration. In Spain, the Directorate General for Traffic approved in late 2015 a framework for the testing of autonomous vehicles on open roads[20]. In Switzerland the Post service which also transports people will trial two autonomous shuttles in an urban environment[21]. One vehicle already on the market, the Tesla Model S, has an autopilot function which, through a combination of cameras, radar, ultrasonic sensors and data, automatically steers the vehicle down the highway, still under driver supervision, and also enables it to change lanes, and adjust speed in response to traffic[22].

Vehicle manufacturers are also keen to reap the benefits of this new field. Various studies revealed the potential[23] economic impact projected for automated driving for the years to come ranging up to €71bn in 2030[24]. The estimated global market for automated vehicles is 44 million vehicles by 2030[25].

Driverless vehicles can be seen as a 'new mode of transport' capable of changing travel patterns and changing mobility culture[26]. Research from the US on the implications of fully automated vehicles for vehicle ownership and use found that they may lead to a reduction in vehicle ownership of up to 43% due to increased vehicle sharing. Moreover, the same research found that this could also lead to a large increase of 75% in individual vehicle usage[27].

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[17] OECD/ITF (2015) Automated and Autonomous Driving : Regulation under Uncertainty.

[18] https://www.gov.uk/government/publications/automated-vehicle-technologies-testing-code-of-practice

[19] Ibid.

[20] http://www.dgt.es/Galerias/seguridad-vial/normativa-legislacion/otras-normas/modificaciones/15.V-113-Vehiculos-Conduccion-automatizada.pdf

[21] https://www.postauto.ch/de/news/schweizer-premiere-mit-autonomen-shuttles

[22] https://www.teslamotors.com/presskit/autopilot

[23] These studies must be viewed with care due to the variables that are used for their calculation.

[24] KPMG, Connected and Autonomous Vehicles – The UK Economic Opportunity, Boston Consulting Group (2015). Revolution in the Driver's Seat: The Road to Autonomous Vehicles in ERTRAC (2015) Automated Driving Roadmap.

[25] Autonomous Vehicles, Navigant Research Aug/13 in ERTRAC (2015) Automated Driving Roadmap.

[26] Carsten, O & Kulmala, R. Road Transport Automation as a Societal Change Agent EU-US Symposium on Automated Vehicles White Paper II 2015

[27] Schoettle, B & Sivak, M. (2015) Potential Impact of Self-Driving Vehicles on Household Vehicle Demand and Usage.
N.b. Research stresses that due given the number of current unknowns regarding sufficient gaps between trips, future self-driving-vehicle implementation, self-driving-vehicle acceptance, and possible vehicle-sharing strategies within households, these results serve only as an upper-bound approximation of the potential for household sharing of completely self-driving vehicles.

1.4 Regulatory framework

At present there is not yet a harmonised regulatory framework for automated driving at EU level. Setting this up would be an essential precursor to automation. A new initiative called Gear 2030 has been launched by the European Commission and will aim to develop a roadmap for automated driving in the EU[28].

The 1968 Vienna Convention on Road Traffic is an accord among participating members of the United Nations administered by the UN Economic Commission for Europe. The convention covers road traffic safety regulations and as such establishes principles to govern traffic laws. One of the fundamental principles of the Convention has been the concept that a driver is always fully in control and responsible for the behavior of a vehicle in traffic[29].

At international level, work is ongoing but not all EU Member States are party to both the UN Vienna Convention on road traffic and all of the relevant UNECE agreements on technical vehicle requirements. Until now the UN Vienna Convention has been the reference point, new amendments have been adopted and will come into force in March 2016. The key amendment would allow a car to drive itself, as long as the system "can be overridden or switched off by the driver". A driver must be present and able to take the wheel at any time. The technical regulations for type approval at the UN ECE (WP 29) have to be amended to enable conditional automated driving functionalities: Steering (UN R79) and Lighting (UN 48)[30]. The interpretation in member states' traffic codes has to still be adapted to enable level 3 – conditional automated driving[31].

At European level there are a number of areas of legislation which should be reviewed in light of increased automation. The EU's vehicle type approval Directive 2007/46/EC must be revised to ensure that these vehicles can respect all specific obligations for safety set out in different traffic laws across the EU. Vehicles must be tested in all different situations where a vehicle will replace a human driver to the extent that an automated vehicle will pass a comprehensive equivalent to a 'driving test'. This should take into account high risk scenarios for occupants and road users outside the vehicle. The EU's Roadworthiness legislation (Directive 2014/45) should also be updated.

Another aspect of relevant EU legislation is the Driving Licence Directive 2006/126/EC which should be amended to include specific training and licencing on semi and full automation and how to use the technology including disengaging and re-engaging. Another is the Motor Insurance Directive 2009/103/EC which should be revised in light of the need to clarify liability for both a fully or semi-automated vehicle. Product liability for defective products under Directive 85/374/EEC would also be relevant. Yet, there is currently no framework in place for harmonising the rules on liability for damages caused by collisions in which motor vehicles are involved. Liability issues are also under review within the context of the European Commission's Digital Market Strategy.

[28] Gear 2030 http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8507
[29] https://globalautoregs.com/rules/157
[30] Ibid
[31] Ibid

Other ongoing areas of EU collaboration of relevance include the ITS Directive 2010/40, DG MOVE's Co-operative-ITS platform[32] which is developing a road map for C-ITS deployment which has working groups developing recommendations on, for example, the Human Machine Interface (HMI) and DG Connect's structured dialogue between the Telecoms and Car Industry.

The existing Directive 2008/96/EC on Infrastructure Safety Management should be revised to include requirements of automated and semi- automated vehicles such as clear road markings and adapted intersections.

Finally, data protection is also affected and any processing of personal data by an automated vehicle will have to comply with EU data protection rules of Directive 95/46/EC and 2002/58/EC. This could be relevant to road safety in terms of collision investigation and use by insurers and others such as fleet managers using feedback from systems to manage drivers in a professional setting.

[32] C-ITS Platform
http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=318

2 What are the potential safety benefits?

2.1 Reaching the EU's Vision Zero of 2050

According to ERTRAC, "safety and the potential to reduce accidents caused by human error" is one of the main drivers for higher levels of automated driving[33]. Automated driving can therefore be considered as a key aspect to support several EU transport policy objectives including road safety[34].

However, research to assess the potential of automated driving's safety benefits is only just beginning.

It is imperative that work continues to improve in all areas of road safety including infrastructure and driver behaviour. Passive safety will still remain relevant.

Research from Finland shows safety increasing as automation goes up[35]. Positive impacts of transport automation on traffic flows will be seen at level 3, or conditional automation: the throughput of the network will improve, shockwaves will dissipate faster, speeding will be reduced and traffic efficiency will be improved. In the context of the transport system, clear impacts will already be visible at level 2, where improved safety will reduce traffic disruptions and congestion[36]. Increased vehicle safety gains from automation and reducing driver error will deliver safety gains.

Research has also been undertaken which may dampen the high expectations of automated driving as a tool to reach the road safety goal of zero deaths. Sivak et al. cite other influencing factors that an automated vehicle would find it difficult to deal with[37]. They argue that self-driving vehicles will find it hard to perform perfectly, for example, under all weather conditions or in cases of crashes being caused by other traffic participants, for example a pedestrian stepping out unexpectedly within a short distance[38].

2.2 Less chance for human error

Most crashes involve some element of human error. If greater autonomous operation reduces or eliminates these errors, then benefits for road safety may be substantial[39]. ETSC endorses the 'safe system' approach meaning that *"human beings are fallible, and their errors must be anticipated and the risk of serious consequences from these errors minimised."* Also, of relevance to the discussion about automated driving that *"The responsibility for reducing fatalities and serious injuries is therefore not solely placed on*

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[33] ERTRAC (2015) Automated Driving Roadmap.
[34] Innamaa, S., Kanner, H., Rämä, P. & Virtanen, A. (2015). Automaation lisääntymisen vaikutukset tieliikenteessä. Trafi reports 1/2015, available at http://www.trafi.fi/index.php?id=11408
[35] ibid
[36] Ibid
[37] Sivak, M. & Schoettle, B. (2015) Road Safety with Self-Driving Vehicles : General Limitations and Road Sharing with Conventional Vehicles.
[38] Ibid.
[39] OECD/ITF (2015) Automated and Autonomous Driving : Regulation under Uncertainty.

the road users but shared with e.g. vehicle producers and infrastructure managers.[40]*"* Thus, automated driving can be welcomed as a way of further sharing the responsibility to vehicle manufacturers and infrastructure managers in the future.

At present there are many different circumstances that can lead to a driver's inappropriate situation assessment, inattention or distraction. These have been calculated as contributing to as much as 10-30% of road deaths[41].

Increased levels of vehicle automation could contribute to eliminating or easing conflict situations[42] . It is expected that it could make a contribution by reducing visual error, single-vehicle crashes and crashes at intersections[43]. Automation could be expected to reduce some high speed collisions on the motorways due to the fast reaction times[44]. It could also address fatigue related crashes although driver operator sleepiness may be enhanced due to boredom and to disengagement from vehicle control[45]. However, the OECD report argues that the real safety test for autonomous cars will be how well they can replicate the crash-free performance of human drivers.

A "fail-safe" operation for automated vehicles needs to be mandated. Moreover, there will be new challenges (see Section 3 of this briefing) and new types of crash which may emerge as autonomous technologies become more common – for instance crashes resulting from the car handing control back to the driver or from mixing autonomous and conventional vehicles or other road users such as pedestrians, cyclists or PTWs. This is also shown in the figure below, though the relative size of the numbers of collisions that may come is difficult to quantify[46].

[40] Full definition of the 'Safe System' approach: *"The Safe System philosophy takes a wider perspective of road accidents, recognising that human beings are fallible, that their errors must be anticipated and the risk of serious consequences from these errors minimised. The responsibility for reducing fatalities and serious injuries is therefore not solely placed on the road users but shared with e.g. vehicle producers and infrastructure managers. The basic ethical assumption is that it is not acceptable to pay a price in deaths for the mobility the society needs."* Endorsed by the European Commission in European Commission (2013) Commission Staff Working Document: On the Implementation of Objective 6 of the European Commission's Policy Orientations on Road Safety 2011-2020 – First Milestone Towards an Injury Strategy.

[41] TRL (2015) Study on good practices for reducing road safety risks caused by road user distractions.

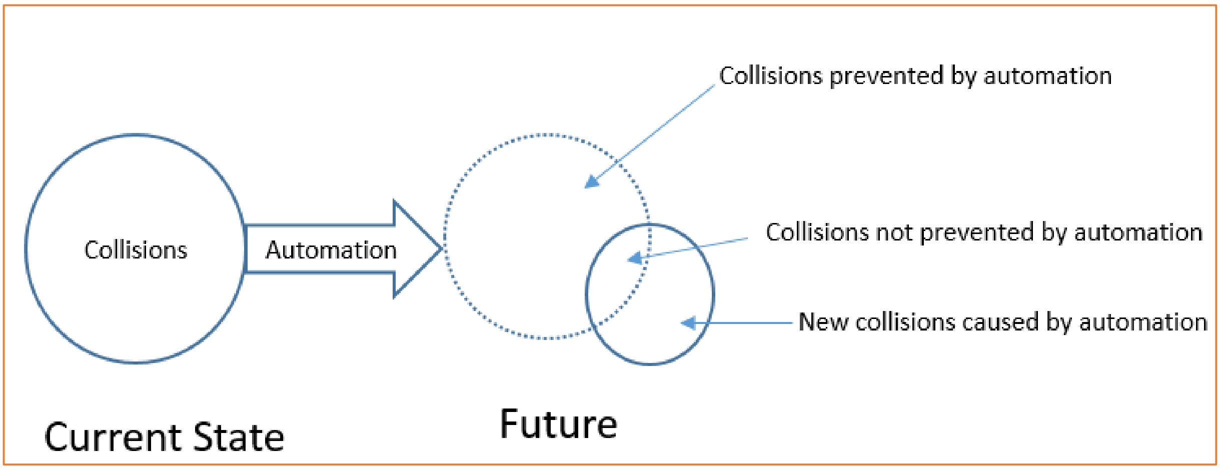
[42] Ibid

[43] Carsten, O. Presentation on Automated Driving Australian International Driverless Vehicle Conference in Adelaide November 2015

[44] Carsten, O & Kulmala, R. Road Transport Automation as a Societal Change Agent EU-US Symposium on Automated Vehicles White Paper II 2015

[45] Carsten, O & Kulmala, R. Road Transport Automation as a Societal Change Agent EU-US Symposium on Automated Vehicles White Paper II 2015

[46] Adapted from diagram in Finnish Transport Safety Agency, 2015.



In the early years of introduction, full automation may only be allowed in certain locations where the traffic environment will be more homogeneous and more adapted to automated vehicles. This may minimise the mixing of autonomous and conventional vehicles and thus reduce confrontations between different vehicle types.

2.3 Accelerated uptake of safety technologies

There are several systems already on the market today that intervene beyond the human capability to act[47].

According to the SAE classification, vehicles have currently reached level 2 in automated transport (partial automation), but level 3 vehicles (conditional automation) may reach the European roads in two or three years and no later than 2020. Some of these systems are also legally required by EU vehicle safety regulations. The aim of most of these active technologies is to intervene and thus prevent a collision from occurring. These systems, like ABS (Anti-Lock Braking System), ESC (Electronic Stability Control) and Automated Emergency Braking (AEB) are active safety systems that allow higher levels of automation and will facilitate deployment. Future versions of these systems will include emergency evasion and emergency stopping[48].

It is important to note that there was the expectation that there would be significant numbers of collisions prevented with the introduction of ABS, but this was not observed in real-world studies and the impact on safety was low[49].

Yet with ABS came sensors, actuators and a control mechanism that provided a platform for ESC and this technology has been observed to prevent crashes by typically 20%[50].

ESC has, in turn, become a platform for Advanced Emergency Braking (AEB). All new EU heavy commercial vehicles have been fitted with advanced emergency braking technology since November 2013, thanks to a requirement set out in the 2009 review of the General Safety Regulation.

[47]OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.
[48] Ibid
[49] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy.
[50] Ibid.

AEB has an estimated death reduction of 7% on the EU25 scale with full penetration, and one of the highest benefit-cost ratios there is for driver support systems[51],[52]. These aforementioned examples are technologies for which there is some evidence. The eImpact project, which looked at 12 different driver support systems[53] estimated that combining all of 12 driver support systems together could produce a death reduction of about 50%[54]. Although a number of these driver support systems have had their life saving potential evaluated[55], evidence of crash avoidance effectiveness under real-world conditions is scarce for many new systems[56]. Having this information is crucial when it comes to market deployment and regulation.

As mentioned previously the interest in reaching higher levels of automation may give a market, regulatory and testing push to in-vehicle safety technologies with a high life saving potential. Some of the semi-automated in-vehicle systems up for future regulation such as pedestrian AEB are already being included in Euro NCAP's current testing. Euro NCAP recognises in its 2020 Roadmap the need to engage in the roll out of vehicle automation as a way to dramatically improve vehicle safety and safe driving[57]. Although the priorities chosen by the pull for automation may not be the same as the pull for safety. Some developers may favour technologies and technology platforms that may help target the main road safety risks such as speed with the use of Intelligent Speed Assistance (ISA) for example. But others may not. Thus other technologies (such as for example support with automated parking) may benefit from accelerated development and fitment because of the automation drive, but their safety benefit may only be marginal.

2.4 Supporting high risk groups with the driving task

One of the other implications for automated driving is that it could enable some drivers who are limited by health impairments to continue or start to drive either with support from automated systems or within a fully autonomous mode[58]. It is recommended that, when designing automated systems, engineers should take the entire diverse driving population into account and look at different traffic situations. One group that could benefit are older drivers, highly relevant within the context of Europe's ageing society. Thus automation could bring benefits for high risk drivers, increasing or extending mobility whilst potentially reducing safety risks that they may pose to other road users.

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[51] eIMPACT Project Results. http://www.eimpact.eu/download/eIMPACT_D6_V2.0.pdf

[52]ETSC recommends its introduction to all vehicle types. ETSC (2015) Position on the Revision of the General Safety Regulation.

[53] Electronic Stability Control ESC, Full speed range ACC, Emergency braking, Pre-crash protection of vulnerable road users, Lane change assistant (warning), Lane keeping support, Night Vision Warn, Driver drowsiness monitoring and warning, eCall, Intersection safety, Wireless local danger warning, and SpeedAlert, i.e. advisory ISA
eIMPACT Project Results. http://www.eimpact.eu/download/eIMPACT_D6_V2.0.pdf

[54] eIMPACT Project Results. http://www.eimpact.eu/download/eIMPACT_D6_V2.0.pdf

[55] Vaa et al. 2014. Driver Support Systems. Estimating road safety effects at varying levels of implementation.

[56] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy.

[57] EuroNCAP (2015) 2020 Roadmap.

[58] ERTRAC (2015) Automated Driving Roadmap.

In contrast, young drivers who have access to automated driving may build up less driving experience. This is an area that needs more research.

This also poses questions for driver training: how will training teach people to drive safely and make the most of automated driving techniques, and how will drivers be taught to safely make the switch between fully autonomous and automated driving.

3 What are the potential safety challenges?

3.1 Does automation address the key road risks?

One important question when assessing the potential impact on safety is how automation actually addresses the key road risks such as speeding or drink driving. Speeding is a primary factor in about one third of collisions ending in death and an aggravating factor in all collisions where it occurs[59]. Under automation vehicles will be able to comply with static and dynamic speed limits and both car following and lane-keeping will be enhanced due to control that is superior to human performance[60]. As said in the previous section, the technologies which are needed for higher automation may not be the same as those needed for the greatest casualty reduction[61]. Thus the challenge in terms of maximising the safety benefit will be to target those key risk factors.

3.2 Evidence of lower crash rates?

Currently there is a real need for more research covering exposure and levels of safety of automated vehicles, especially on how they react in real-world driving conditions. This underlines the need for trials such as the one being launched in Sweden (See Section 1.3). ETSC insists on full openness and transparency in disclosing collision data involving automated vehicles including also on which roads they occur (urban, rural, highway). It must also be possible to interrogate vehicle safety systems after a crash so as to analyse causes.
Some recent preliminary analysis of real-world crashes involving self-driving vehicles, undertaken in the U.S. comes up with different findings. The first set of research found that self-driving vehicles were involved in more crashes per million miles travelled than conventional vehicles[62]. This research must be seen with these important caveats. Firstly, that the distance accumulated by self-driving vehicles is still relatively low (about 1.2 million miles, compared with about 3 trillion annual miles in the U.S. by conventional vehicles). Self-driving vehicles were thus far driven only in limited (and generally less demanding) conditions (e.g., avoiding snowy areas). Therefore, their exposure has not yet been representative of the exposure for conventional vehicles[63]. The investigation

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[59] OECD/ECMT (2006), Speed Management.

[60] Carsten, O. Presentation on Automated Driving Australian International Driverless Vehicle Conference in Adelaide November 2015

[61] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy;

[62] Sivak, M and Schoettle, B. (2015) A Preliminary Analysis of Real-World Crashes Involving Self-Driving Vehicles.

[63] The distance accumulated by self-driving vehicles is still relatively low (about 1.2 million miles, compared with about 3 trillion annual miles in the U.S. by conventional vehicles). Self-driving vehicles were thus far driven only in limited (and generally less demanding) conditions (e.g.,

also showed that they were not at fault for the crashes they were involved in and the overall severity of crash-related injuries involving self-driving vehicles has been lower than for conventional vehicles[64].

Other recent research also from the U.S. was an "Automated Vehicle Crash Rate Comparison Using Naturalistic Data," and was performed by the Virginia Tech Transportation Institute (VTTI), commissioned by Google. It showed that self-driving cars were involved in fewer crashes than normal cars especially for more severe crashes. It examined both national crash data and data from naturalistic driving studies then compared the results to data from Google's Self-Driving Car program[65]. Additionally, in the same study, when the automated vehicle events were analysed, none of the vehicles operating in autonomous mode were deemed at fault.

3.3 The transitional stage I: automated and non-automated Vehicles

One of the key challenges along the roadmap to full automation will be how automated and semi-automated vehicles will manage to co-exist in the interim phase which could last fifteen or more years depending on market penetration and vehicle renewal. This is more relevant for the 'something everywhere' deployment scenario. Safety evaluations and predictions are based on assumptions of a fully equipped fleet and comparable vehicles and very little research has been conducted on the safety impacts during the transitional phase[66]. One interesting question is how will vehicles with speed management systems operate in a fleet with unequipped vehicles: will the unequipped vehicles travel faster and continually overtake so that the speed management system is finally switched off by a dissatisfied driver?[67]. Another likely aspect is that there will be a much greater need to update the « old » automated vehicles: technology will most-likely develop very fast. Vehicle manufacturers are most likely to keep closer contact with their consumers – similar to upgrading a smart phone with an update.

3.4 The transitional stage II: automated vehicles and vulnerable road users

Another concern, especially during the introduction and transitional stage, is looking at how these vehicles will interact with vulnerable road users. Of course some of the in-vehicle safety technologies now already being deployed are specifically able to help prevent collisions with VRUs. Although research is ongoing with new ideas in this field[68], at present pedestrians and cyclists are largely unequipped with ITS safety equipment which might allow them to interact with automated vehicles.

Deaths among pedestrians and cyclists, who are the most vulnerable road users and whose use of the roads is being encouraged for reasons of health and sustainability, account for 29% of all road deaths across the EU. Pedestrians killed represent 21% and

avoiding snowy areas). Therefore, their exposure has not yet been representative of the exposure for conventional vehicles. Referenced in Sivak and Schoettle (2015).

[64] Ibid

[65] Blanco, M. et al (2016) Automated Vehicle Crash Rate Comparison Using Naturalistic Data, Virginia Tech Transportation Institute

[66] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy.

[67] Ibid

[68] http://www.prospect-project.eu and http://www.vruits.eu/

cyclists 8% of all road deaths[69]. In the EU27 PTWs represent 18% of the total number of road user deaths.[70] Powered two wheeler interaction with automated vehicles pose a particular concern in motorway traffic[71].

Interaction between current vehicle drivers and VRUs 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 pick up on different forms of communication. This communication should also be able to function even in bad weather conditions. The appearance of automated vehicles in traffic may also change the mobility patterns to the extent of changing the behaviour of VRUs themselves –the simple act of crossing the road may also be transformed. High risk scenarios should be identified and ways found to manage all these different possibilities. This is another area that should also be a priority for research and testing.

One example of an ethical dilemma that is often raised within the fully automated level is how a vehicle should react when 'deciding' to swerve to avoid a car but then colliding with a pedestrian instead. Clearly, ethical issues should also be considered within the context of development of fully automated vehicles.

3.5 Infrastructure: roads and digital

A fail-safe/fault tolerant architecture is required to guarantee that automated vehicles operate in a safe state in any event or under adverse conditions[72]. This is true for both digital and road infrastructure and both will require investments for upgrades and maintenance.

3.5.1 Digital infrastructure

There are two trains of thought regarding the extent to which fully automated vehicles will rely on data input and external information systems. Some argue that a fully automated car should be able to rely on its own sensors and capabilities of perception[73]. Others say that automated driving may rely on improved digital infrastructure[74] to enable Co-operative ITS technology. Authorities also have certain obligations under the EU's ITS Directive[75]. If this is the case, then more investment is needed in improving the digital infrastructure needed to enable vehicle-to-vehicle and vehicle-to-infrastructure communication. Benefits could be gained in opening up information from the traffic management system, for example, in passing information about upcoming congestion

[69] ETSC (2015) Making Walking and Cycling Safety on Europe's Roads
[70] ibid
[71] Carsten, O & Kulmala, R. Road Transport Automation as a Societal Change Agent EU-US Symposium on Automated Vehicles White Paper II 2015
[72] ERTRAC (2015) Automated Driving Roadmap.
[73] Ministry of Transport and Communications, (2015) Finland Robots on land, in water and in the air;
[74] Digital infrastructure (for road automation) includes static and dynamic digital representations of the physical world with which the automated vehicle will interact to operate. Issues to address include: sourcing, processing, quality control and information transmission.
Definition in: OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.
[75] ITS Directive 2010/40.

or suggested route mapping. Thus a fully automated vehicle will require a more demanding and more accurate set of data on the traffic environment. However, there are security issues as insecure communication may open the system to cyber hacking[76]. This also raises concerns for data security and data protection (see section 3.8 below).

3.5.2 Road infrastructure

Many semi-automated or fully-automated technologies will rely on road infrastructure being readable for their applications. The infrastructure performance (visibility, state of repair) regarding traffic signs, signals and road markings to support higher levels of safe and reliable automated driving have to be recognised. This will involve common standards and harmonisation[77]. In a joint 2013 report "Roads that cars can read" EuroRAP and Euro NCAP deplored the fact that inadequate maintenance and differences in road markings and traffic signs are a major obstacle to the effective use of technology in vehicles such as lane departure warning and traffic sign recognition [78]. ETSC encouraged EU member states to prioritise investing in road markings and road signs in their road maintenance budgets. There is a need for close collaboration between the road operators and the developers of semi and fully automated vehicles to communicate about the needs from both sides.

One option, which could be quite likely within the urban context to facilitate shared traffic, is to limit the area where automated vehicles operate or provide them with some dedicated infrastructure (e.g. using public transport lanes only for automated vehicles)[79]. Other adaptations could be to provide a more simplified and logical environment that can support the vehicle to avoid situations of many stops (cross sections, possible interactions with pedestrians or cyclists)[80]. Motorway infrastructure may also have to be adapted as well to allow for the requirements of automated traffic. For example, there may be the need for lay-bys for drivers to re-engage in the driving task before leaving the motorway. This will also have implications for current infrastructure arrangements such as bus lanes which allow PTWs.

3.6 Driver behavioural adaption

A priority for maximising the safety potential of automated driving should be looking at driver engagement and driver re-engagement for various levels of automation in a safe and conclusive manner[81]. Driver interaction with the vehicle should be standardised. Further research is needed when looking at the impact on the driver and time needed for transition. If the driver is not able to regain control then the system must still ensure a safe level of performance and respect the traffic rules. Issues that should be covered should be the possibility that the driver is so distracted by the opportunities offered by being able to switch off during automated driving that they miss the message to take

[76] ERTRAC (2015) Automated Driving Roadmap.
[77]Ibid.
[78]See EuroNCAP and EuroRAP (2011) Consultation Paper Roads That Cars Can Read. http://www.erf.be/images/Roads_That_Cars_Can_Read_2_Final_web.pdf
[79] OECD/ITF (2015) Automated and Autonomous Driving : Regulation under Uncertainty.
[80] ERTRAC (2015) Automated Driving Roadmap.
[81] Ibid

back the driving task[82], and making sure that the Human Machine Interface is refined to be as clear as possible[83]. The Information, Warning and Intervention (IWI) sub-set of HMI is most relevant to safety and needs to be more standardised in the future so that each automated car communicates in an identical and recognisable way, particularly when it comes to safety critical elements. Research rather shows that behavioural adaptation is more likely when drivers are aware of a change rather than not being aware of a change[84].

3.7 Societal acceptance?

Safety of automated vehicles will also impact on the level of social acceptance and uptake. Acceptance will depend on the likely deployment scenarios and feelings towards it may be very different for example towards truck platoons on the motorway or low speed delivery vehicles on separate infrastructure in urban areas. The role of consumer information programmes will also be important to explain and build confidence and drive best practice in safety. At this stage, user acceptance poses a challenge with over half (56%) of AA UK members indicating that they "would not trust manufacturers and government assurance that driverless cars were safe"[85]. The technology should also be accessible to all categories of the population. It is not acceptable that only a certain group can acquire such vehicles even if the technology is regulated. New financing models (with the support of the insurance sector) could also be developed.

3.8 Liability and data protection

Clarifying the liability circumstances in both a partly or fully automated context is crucial. At present the driver is expected to remain in control of the vehicle at all times and it is clear that the driver is liable should a crash occur. As long as the driver has the opportunity to take control over a partially automated car and avoid a crash, the liability will remain with the driver. In case of a malfunction of an automated vehicle it is important to know who is liable in case of a collision; the manufacturer or the driver. There is a strong interest from the side of insurers as to know who was in control in case of a collision. At the highest levels of automation, however, the driver will not be able to override the system and will be reliant on the operation of the vehicle systems. This is when the vehicle manufacturer will become liable[86]. There are a number of different actors whose liability must be developed, namely the developers, the operators (infrastructure and service providers) and the owners[87] [88]. There is already a work on these areas ongoing under, for example, the C-ITS Platform of the EU and the ITS Action Plan of the EU[89]. One suggestion is also that the vehicle should store data, in case of a collision, which helps to identify who is liable, whilst fully respecting data privacy law. New actors have also entered the market. Both Google and Volvo have announced that vehicles to

[82] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy.
[83] See EC C-ITS Working Group Recommendations on HMI (2015)
[84]Jameson, S. (2014) Presentation Vehicle Safety Technologies: The Human Behind the Wheel.
[85] AA Populus poll based on 21,202 members answers (2012) from the UK cited in FIA Region 1 Policy Briefing on Autonomous Driving.
[86] PACTS Conference Report (2014) Driverless Vehicles: From Technology to Policy.
[87] OECD/ITF (2015) Automated and Autonomous Driving: Regulation under Uncertainty.
[88] ERTRAC (2015) Automated Driving Roadmap.
[89] http://ec.europa.eu/transport/themes/its/road/action_plan/liability_en.htm

be tested will be insured through their own insurance companies; insurance providers owned by the manufacturers could change the insurance sector[90].

Another area, beyond the scope of this report, is envisaging how police enforcement work will change with the rise of fully-automated vehicles, for example determining who was to blame in case of a collision.

[90] Ministry of Transport and Communications, (2015) Finland Robots on land, in water and in the air.

4 ETSC recommendations

EU level

- In the short term, prioritise the introduction of safety technologies for Levels 1 and 2 which have the highest life-saving effect through public information and legislation.
- Develop a coherent and comprehensive EU regulatory framework for the deployment of automated vehicles.
- Revise the EU type approval regime to ensure that automated vehicles comply with all specific obligations and safety considerations of the traffic law in different Member States.
- Revise type approval standards to cover all the new safety functions of automated vehicles, to the extent that an automated vehicle will pass a comprehensive equivalent to a 'driving test'. This should take into account high risk scenarios for occupants and road users outside the vehicle.
- Ensure that automated vehicles are regularly tested to evaluate safety performance, within the framework of regular roadworthiness tests, linked to reporting, some of which could be based on self-diagnosis.
- Define the information and its documentation (and clarify the access rights) for the highly automated driving mode, e.g. in case of collisions.
- Develop clear internal and external Human Machine Interfaces, in particular Information, Warning and Intervention strategies, to maximise clear communication and safety and minimise possible distraction especially at the lower levels.
- Interaction schemes should be standardised. In case the driver does not regain control despite warning given by the vehicle system, then the system has to ensure a minimum safe level of performance.
- In line with an updated type-approval regime, develop roadworthiness requirements for automated vehicles including accounting for over-the-air updates.
- Facilitate the exchange of information and co-operation between member states who are testing autonomous vehicles.
- Support the development of clear consumer information about the capabilities of self-driving cars and thus drive best practice solutions at lowest cost for consumers.
- Set up an effective EU wide monitoring and evaluation framework covering all aspects of driving including accident investigation during the testing and deployment stage comparing automated vehicles and conventional vehicles.
- Encourage the wider use of in-vehicle "Event Data Recorders" (black box) devices, which record vehicle situational information before and during any collision and allow for additional useful information to be collected. This additional information could include speeding as well as vehicle manoeuvres, which cannot be reliably identified by the usual police investigations.
- Exceptions must be introduced into national privacy rules to allow accident investigators to understand what the contributions were of driver and vehicle technology. Researchers must be protected against litigation claims.
- Work further to clarify the liability regime in relation to both insurance and data protection and security for automated vehicles.

- Revise the existing Directive 2008/96/EC on Infrastructure Safety Management to include requirements for automated and semi- automated vehicles such as clear road markings and adapted intersections.
- Conduct research looking at the transitional phase of mixed automated and semi-automated vehicles and interaction with vulnerable road users.
- Conduct research to examine the potential of automated driving for addressing social exclusion and the potential it brings for mobility of certain high risk groups.
- Conduct research into the safety implications of driver dis-engagement and re-engagement during automated driving.
- Consider revising the Driving Licence Directive to include driver assistance systems with regular updates as the technology develops.
- Adapt driver training, including the development of a curriculum, so that drivers can gain a working knowledge of when and how to use automation features and understand the basics, advantages and limits of the technology.

Member state level

- Support the development of a coherent and comprehensive framework for the deployment of automated vehicles with the EU.
- Ensure that highly automated vehicles comply with the respective national traffic rules and that enforcement is in place.
- Include road markings, road signs and digital data needs in infrastructure maintenance budgets to achieve optimal performance of Advanced Driver Assistance Systems.
- Work further to clarify the liability regime in relation to both insurance and data protection and security for automated vehicles.
- Develop the necessary technical and legal framework to allow testing of vehicles on their networks.
- Develop driver training so that drivers are able to use semi-automated vehicles and to switch from automated to non-automated mode.
- Consider adapting driver licence systems that take into account the level of automation of the vehicles driven.

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The European Transport Safety Council (ETSC) is a Brussels-based independent non-profit making organisation dedicated to reducing the numbers of deaths and injuries in transport in Europe.

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