Safe Road Transport Research Roadmap

Towards Vision Zero:
Following the Safe System Approach

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Road Transport Safety & Security

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2 Executive Summary

Transport crashes are listed by Eurostat as a major cause of death in the EU, particularly for persons aged less than 65 years, and transport safety is mainly an issue of road safety. Actually, road crashes account for about 96% of all transport fatalities in the EU. In its Road Safety Policy Framework 2021-2030, the EU therefore reaffirms its ambitious long-term goal to move close to zero road fatalities and serious injuries by 2050 (Vision Zero). Although the premise that no loss of life is acceptable shall inform all decision making on road safety accordingly, the EU is actually in a phase of stagnation in its efforts to improve road safety. Fatality and in particular injury figures have remained nearly constant from 2013 to 2019, and even if preliminary fatality figures show a massive reduction in 2020, this can most likely be attributed to lower traffic volumes during the COVID-19 crisis.

As a consequence, important European safety targets are getting out of reach. A continuation at the current level of more than 20,000 road fatalities and more than 100,000 serious injuries on European roads per year, however, is fully unacceptable in view of the human suffering which these figures imply, while the associated socio-economic costs of many billion euros are a major burden to the European economy.

Clearly intensified efforts for the improvement of road safety are therefore needed, and research and innovation play key roles here. In this update of its Safe Road Transport Research Roadmap published in 2019, ERTRAC proposes a set of high-priority road safety research needs with their suggested timing for inclusion in Horizon Europe, the EU's key funding programme for research and innovation. These research needs represent a joint stakeholder view and have been developed in an iterative process intensively involving experts from European industry, academia, research providers, road user associations and public authorities amongst others. In this process, ERTRAC has adopted the Safe System Approach which implies that responsibility for road safety is shared by all relevant stakeholders including individual road users as well as system designers and operators from the public and private sector. As a consequence, all layers of safety need to be strengthened: road safety management, road infrastructure, vehicles, road user behaviour and post-crash response. The overall scope of this roadmap is therefore broad, covering all these layers, all road transport modes, all users and all phases from preventive to post-crash safety.

This update of the Safe Road Transport Research Roadmap complements the Strategic Research and Innovation Agendas of the CCAM and the 2Zero Partnership as well as several other ERTRAC roadmaps, in particular those on urban mobility and on Connected, Cooperative and Automated Mobility (CCAM). The joint stakeholder view on the long-term evolution of CCAM presented in the latter is actually an important basis for this Safe Road Transport Research Roadmap: Higher levels of automation show the potential to substantially improve road safety, but they will not avoid all crashes and will take a long time to be fully deployed on rural roads, which account for more than 50% of all road fatalities in the EU.

In order to generate significant impacts, however, also funding support for European road safety research and innovation needs to be strengthened significantly, giving it a fair role in good balance with other thematic areas and reflecting its actual importance in saving the lives and protecting the health of EU citizens. If the EU actually moved close to Vision Zero by 2050, several hundred thousands of lives could be saved and socio-economic costs of more than a trillion euros avoided. These are objectives undoubtedly very worth pursuing.

3 Introduction

3.1 Background

ERTRAC, the European Road Transport Research Advisory Council, represents the diverse range of stakeholders in road transport research and brings them together with representatives from public authorities at the European, national, regional and urban levels. The multi-stakeholder nature of ERTRAC makes it unique in being able to present a holistic and integrated view of road transport research needs. ERTRAC's mission is to seize the opportunity for better coordination of private and public research activities, and to make specific recommendations for their implementation. ERTRAC delivers roadmaps for cross-cutting research that provide a reference for the future planning of European and national transport research programmes. In addition, this reference shall provide an overarching framework for research, innovation and technological development, as well as guidance for individual research planning.

From a safety perspective, this multi-stakeholder approach is of utmost importance to meet the challenges ahead, including such aspects as automated road transport, increasing digitalization of vehicles and society as a whole as well as the development of urban and rural areas.

As an update of the Safe Road Transport Research Roadmap published by ERTRAC in 2019, this roadmap is based on the Vision of ERTRAC, which provides long-term objectives for the improvement of road transport by 2050. This vision anchors future research and innovation (R&I) in road users' needs, while paying attention to the extreme importance of road transport for economy and for society as a whole. The provision of perfect protection to be "safe and secure at any time" is included as an important objective in this ERTRAC Vision for 2050[1]. From this objective, the following attributes of the future road transport system are derived in ERTRAC's Strategic Research Agenda and addressed in this roadmap:

- Nearly zero accidents and injuries due to safety functions and automated driving functions in fully connected vehicles and infrastructure
- Optimised and intuitive human-machine interface following the idea of cognitive safety
- Safe and well maintained physical and digital infrastructure
- Improved levels of in- and post-crash safety in the remaining collisions
- Continuous maintenance of software and system updates constantly improving their performance
- Systematic verification and validation of cyber physical systems
- Resilience: highly automated management systems to minimise the impact of incidents and accelerate recovery

These largely technology-oriented attributes will have to be realised by R&I with a strong focus on human factors. Humans usually show excellent capabilities in moving safely in a system as complex as the road transport system – on average over many thousands kilometres without any crash. However, the extreme amount of kilometres travelled in the European road transport system every year has still brought about the intolerable annual number of about 25,000 road fatalities (EU-28) and many more severe injuries over

[1] Strategic Research Agenda, Input to 9th EU Framework Programme, ERTRAC, 23.03.2018

the last few years from 2013 to 2019[2]. Since human error is an element in the causal chain of most of these crashes (not only when driving a motor vehicle), human factors and in particular the interaction between human and technology in all its different aspects play a more important role in the Safe Road Transport Research Roadmap than in most other ERTRAC research roadmaps.

Conducting the research proposed in this roadmap and applying the results in innovation on European roads shall contribute to a road transport system which offers at least a comparable level of safety as other transport systems and other socio-technological systems in which European citizens are involved in their daily lives, e.g. at their workplaces. This, of course, will have to be achieved while safeguarding the primary function of the road transport system – the efficient and resilient transport of people and goods in an open public environment.

ERTRAC therefore supports the Safe System Approach, which accepts that humans inevitably make mistakes and aims to ensure that this does not lead to fatalities or serious injuries in spite of humans' limited capabilities to tolerate crash loads. Individual road users as well as system designers and operators from the public and private sector share responsibility in this approach. As a consequence, all five pillars of road safety, as identified by the WHO[3], need to be improved – road safety management, road infrastructure, vehicles, road user behaviour and post-crash response. If one pillar or safety layer then fails, another one will compensate and provide protection. Finally, proactive instead of reactive management is another key principle of this approach, proactively identifying and tackling risks, rather than just reacting to incidents. In the Safe System Approach, the user is therefore at the centre of a system that is taking into account essential human factors to ensure that people are not easily tempted, make preventable mistakes and, when this does occur, are protected from harm.

3.2 State of the art

Horizon 2020, the EU Framework Programme for Research and Innovation, covered a period of 7 years: 2014 to 2020. Input on the topics of safety and security research in Horizon 2020 were proposed in the ERTRAC Safe Road Transport Research Roadmap dating from 2011 and by the PROS Coordination and Support Action that delivered its road safety research roadmap by the end of 2014[4]. Based on former reports regarding societal scenarios and trends, key factors having an impact on road safety were identified when preparing these roadmaps:

- Road users getting increasingly older
- Growing cities
- A more diverse traffic mix
- Effects resulting from efforts to meet the carbon-dioxide emission reduction targets
- Increased connectivity of persons and things
- Time for penetration of new technologies into the transportation system

[2] Road safety evolution in the EU, based on CARE (EU road crash database) and national publications, https://ec.europa.eu/transport/road_safety/specialist_en, www.gov.uk/government/statistical-data-sets/reported-road-accidents-vehicles-and-casualties-tables-for-great-britain#casualties-in-reported-road-accidents-ras30
[3] Global Plan for the Decade of Action for Road Safety 2011 – 2020, the United Nations Road Safety Collaboration, https://www.who.int/roadsafety/decade_of_action/plan/en/
[4] Urban, P., Op den Camp, O., Skogsmo, I. "Priorities for Road Safety Research in Europe (PROS) – final report", grant agreement No. 314427, January 2015

- No focus on Europe only - most of the expected growth of transport volume will take place in other parts of the world, and most road fatalities occur there already today

Within Horizon 2020, six call topics were specifically dedicated to the improvement of road safety:

- MG-3.4-2014 Traffic safety analysis and integrated approach towards the safety of Vulnerable Road Users
- MG-3.5-2016 Behavioural aspects for safer transport
- MG-3.6-2016 Euro-African initiative on road safety and traffic management
- MG-3.2-2017 Protection of all road users in crashes
- MG-2.7-2019 Safety in an evolving road mobility environment
- MG-2.12-2020 Improving road safety by effectively monitoring working patterns and overall fitness of drivers

At the same time, many calls in the Horizon 2020 programme included road safety as an important constraint to consider in the development of infrastructure and vehicle technologies, and some topics addressed road safety in the wider context of transport safety, such as:

- MG-2.1-2018 Human Factors in Transport Safety
- MG-2.8-2019 Innovative applications of drones for ensuring safety in transport

In total, the European Commission invested a sum of 121 M€ in road safety research in Horizon 2020, not including road safety related aspects in research on automated road transport, urban mobility and socio-economic issues[5].

The following graph gives an overview of road safety-related projects, which have been funded partially or fully by the EU. The corresponding analysis has been done for the period from 2013 to 2023, covering projects that have been running during the Horizon 2020 programme period from 2014 – 2020 and beyond, if still funded from Horizon 2020. Projects are sorted in five categories: the three Haddon categories (Road User Behaviour, Vehicle Technology and Infrastructure) extended with Vulnerable Road Users, whose modal share is increasing especially in urban areas, and a category for Roadmap & Assessment activities. Red arrows refer to FP7 projects completed in 2014 or later. Completed Horizon 2020 projects are shown with blue arrows, while green arrows indicate projects which are still running. More information on the latter is given in the annex of this document.

In the Horizon 2020 Framework Programme, projects have clearly evolved from technological research and development towards innovation with a focus on the interaction between all road users, considering the impacts of new developments on human behaviour and user acceptance as well as the added value of the proposed concepts for the transport system as whole. Moreover, the technological developments towards the realisation of connected, cooperative and automated mobility have been more and more considered in view of their impact on road safety. Still, the overview below is not intended to cover all projects with a focus on automated driving technologies and their demonstration.

[5] Road Safety R&I Projects under Horizon 2020, presentation by Patrick Mercier-Handisyde (EC Directorate-General for Research & Innovation) based on figures by the Innovation and Networks Executive Agency INEA, 24.03.2021

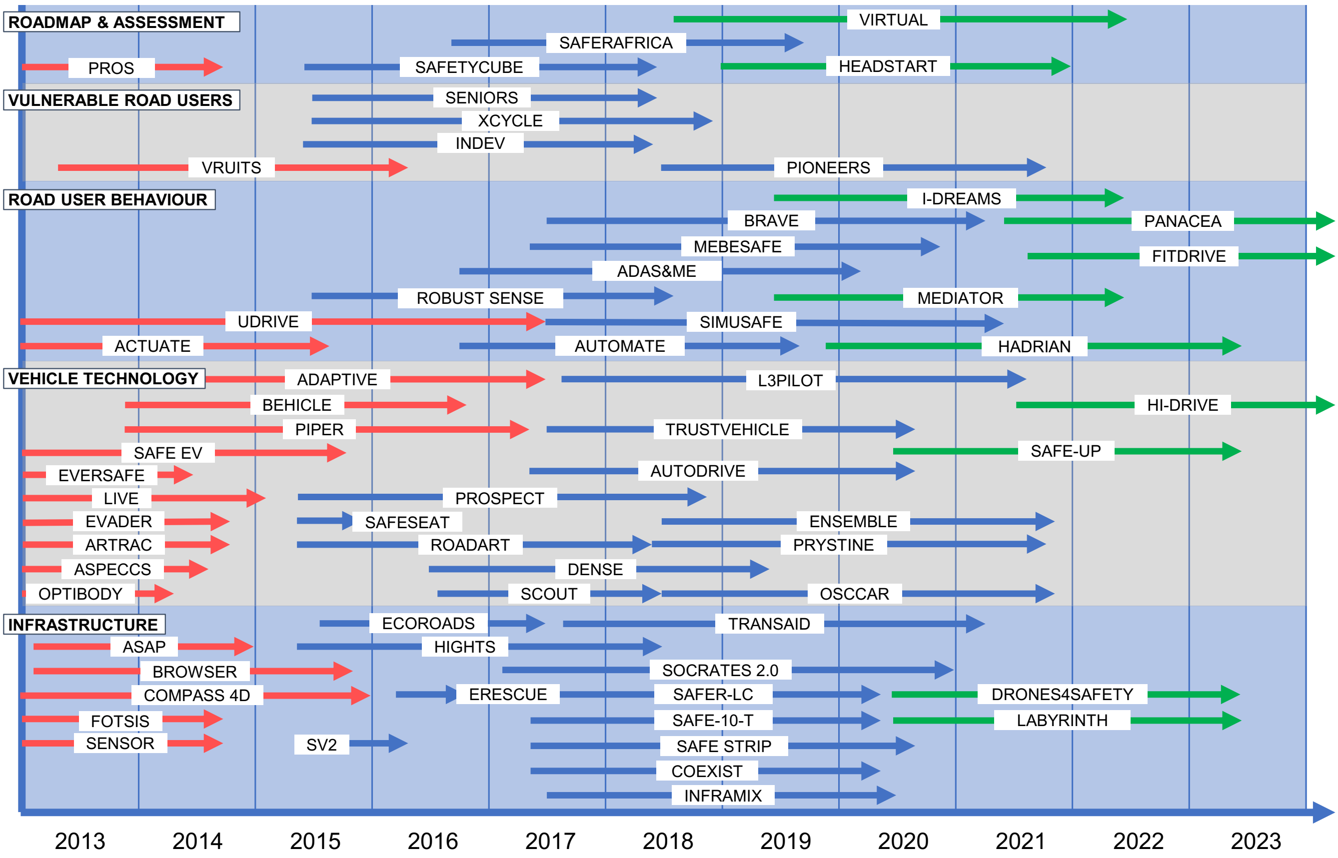

Figure 1: Overview of EC funded projects related to road safety

In Horizon Europe, the EU's key funding programme for research and innovation for the period from 2021 to 2027, a dedicated partnership has been established to develop and implement a research and innovation programme on Connected, Cooperative and Automated Mobility (CCAM). While the drastic improvement of road safety is a key expected impact of the CCAM Partnership, there is a common understanding that additional measures will be necessary to further reduce the number of fatalities and injuries caused by road crashes according to the Safe System Approach. Three call topics have therefore been dedicated to road safety in the first two years of Horizon Europe beyond the CCAM Partnership. They are part of Destination 6 "Safe, resilient transport and smart mobility services for passengers and goods" in the Work Programme of Cluster 5 "Climate, energy and mobility":

- HORIZON-CL5-2021-D6-01-10: Testing safe lightweight vehicles and improved safe human-technology interaction in the future traffic system
- HORIZON-CL5-2021-D6-01-11: Radical improvement of road safety in low and medium income countries in Africa
- HORIZON-CL5-2022-D6-01-06: Predictive safety assessment framework and safer urban environment for vulnerable road users

The funding budget of 33 M€ which is indicated for these topics basically represents a continuation of the average annual budget for road safety research in Horizon 2020 at a slightly reduced level (- 5%). At the same time, the contents of these call topics show a good reflection of research needs proposed in the latest ERTRAC Safe Road Transport Research Roadmap published in 2019. As a consequence, the roadmap published in 2019 needs an update, which is provided with this document.

3.3 Policy context, challenges and objectives

With approximately 1.3 million fatalities each year[6], road crashes are one of the leading causes of death worldwide. According to WHO figures, more people die from the consequences of road crashes than from HIV/AIDS or tuberculosis[7], and even if WHO estimates suggest a much higher actual number, at least the officially reported number of COVID-19 deaths was in a similar order of magnitude in 2020 with about 1.8 million[8]. With good cause, road safety is therefore well reflected in the UN Sustainable Development Goals (SDGs) and their related targets already set in 2015. This applies in particular to SDG 3.6 ("By 2020, halve the number of global deaths and injuries from road traffic accidents") and SDG 11.2 ("By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons").

In the EU, road safety has greatly improved in recent decades thanks to actions at European, national and local levels. Figures from the European CARE database, for example, show a 45% reduction of road fatalities between 2000 and 2010 (Figure 2). Actually, European roads are considered the safest in the world today. However, the EU has entered into a phase of stagnation in its efforts to further improve road safety. Fatality and injury figures have remained nearly constant from 2013 to 2019 resulting in an increasing gap versus the EC long-term targets, as indicated by the dashed lines in Figure 2. Even if preliminary fatality figures for 2020 show a fall by 17% compared to the previous year, this can most likely be attributed to lower traffic volumes during the COVID-19 crisis[9]. Analyses for the strict lockdown period in April 2020 even reveal that the number of road fatalities did not decrease to the same degree as traffic volumes in many EU countries[10][11]. Reports from some national authorities also confirm that the reduction of road fatalities and injuries has slowed down or even reversed over the last few years. As a consequence, important European safety targets are getting out of reach. In spite of the unprecedented fall in 2020, road fatalities have not been cut by 50% in last decade, as called for in the EC Policy Orientations on Road Safety 2011-2020. Extrapolating the current longer-term trend, the EU is not likely to move close to zero fatalities by 2050, either, which was set as a target in the EC Transport White Paper 2011 and confirmed by the 3rd Mobility Package in May 2018. The latter even expands the target of moving close to zero also to serious injuries and adds the interim target of minus 50% for fatalities and serious injuries between 2020 and 2030[12], which seems very ambitious in view of the current trend, as well. In the EU Road Safety Policy Framework 2021-2030 "Next steps towards 'Vision Zero'", the EC emphasizes the importance of this vision not only as a numerical target, but as a new mind-set, and adopts the Safe System Approach as the basis of its future road safety policies. The Sustainable and Smart Mobility Strategy published in 2020 reflects

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[6] Road traffic injuries, factsheet by the World Health Organisation, 21.06.2021, https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

[7] Global status report on road safety 2018, the World Health Organisation, ISBN 978-92-4-156568-4

[8] The true death toll of COVID-19, data story by the World Health Organisation, www.who.int/data/stories/the-true-death-toll-of-covid-19-estimating-global-excess-mortality

[9] Road safety: 4000 fewer people lost their lives on EU roads in 2020 as death rate falls to all time low, press release, EC Directorate-General for Mobility and Transport, 20.04.2021, https://ec.europa.eu/transport/modes/road/news/2021-04-20-road-safety_en

[10] The impact of COVID-19 lockdowns on road deaths in April 2020, report by the European Transport Safety Council, July 2020, https://etsc.eu/wp-content/uploads/PIN-Corona-Briefing_final.pdf

[11] Road safety annual report 2020, the International Transport Forum, https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2020_0.pdf

[12] Europe on the Move – Sustainable Mobility for Europe: safe, connected, and clean, Communication from the European Commission, COM(2018) 293 final, 17.05.2018

the need to urgently improve road safety in several flagship areas, in particular in Flagship 10 “Enhancing transport safety and security”, and re-confirms the EC’s commitment to the afore-mentioned targets.

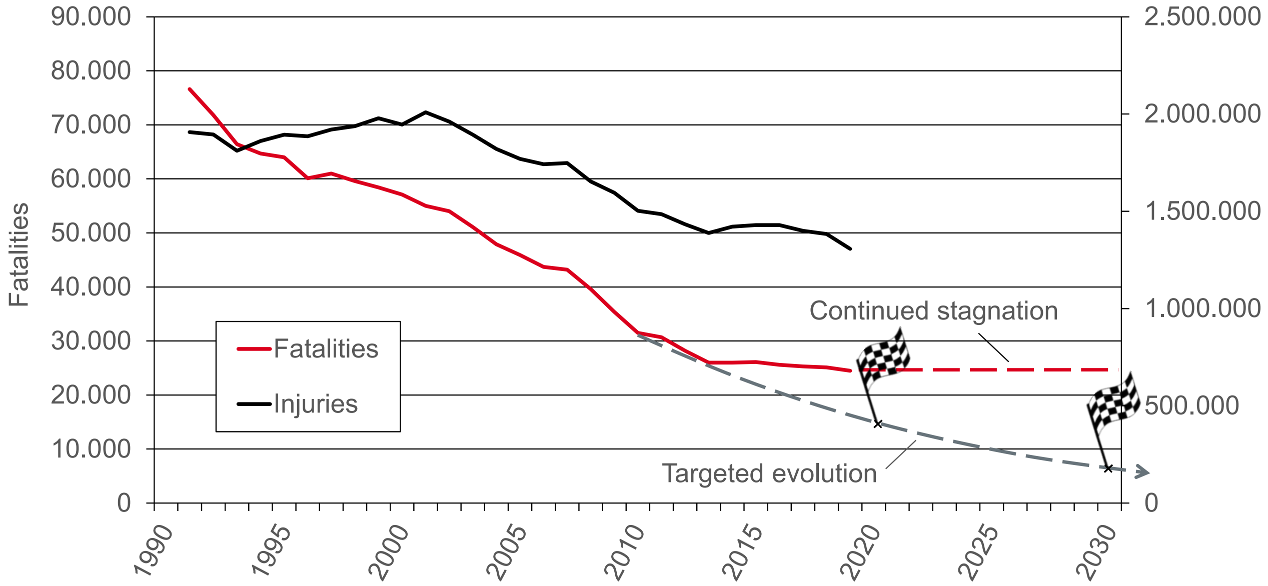

Figure 2: Road safety evolution in the EU-28[13]

In view of the limited progress in European road safety over the last few years, the human suffering and the cost burden of severe road crashes are at risk of continuing on an unacceptable level. In fact, the unnecessary loss of 24,500 lives of EU-28 citizens in 2019 during a daily life activity like travelling in the road transport system is fully unacceptable, while the estimated socio-economic costs from road crashes of about EUR 280 billion are a major burden to the European economy[14]. Clearly intensified efforts therefore have to be made by all relevant stakeholders not to completely miss the long-term objective of “Vision Zero”: a transport system in which human life is the paramount concern and no-one is killed or severely injured anymore.

3.4 Importance of road safety research and innovation

Research and innovation are key factors in future efforts to switch from the current stagnation in EU injury and fatality figures towards drastic improvements in road safety, as step changes are obviously needed. CCAM in particular shows the potential to become a key enabler for substantial reductions in collisions on European roads as well as in the number of injured road users and fatalities. This assumption is based on the finding that human error is an element in the causal chain of most road crashes. Increasing the automation levels of vehicles and reducing the reliance on permanent human control only should therefore reduce the risk of collisions, e.g. in monotonous situations with reduced cognitive activity, in which human drivers may easily get distracted or inattentive. This is backed up by the notion that highly automated vehicles will hardly find acceptance if they do not offer substantially higher levels of safety than motorised private transport today. The first applications of higher automation levels, however, are likely to address

[13] Road safety evolution in the EU, based on CARE (EU road crash database) and national publications https://ec.europa.eu/transport/road_safety/specialist_en, www.gov.uk/government/statistical-data-sets/reported-road-accidents-vehicles-and-casualties-tables-for-great-britain#casualties-in-reported-road-accidents-ras30

[14] Handbook on the External Costs of Transport, EC Directorate-General for Mobility and Transport, version 2019 - 1.1, ISBN 978-92-76-18184-2, https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1

relatively safe traffic scenarios (very low-speed traffic in urban areas, traffic in confined areas and on highways)[15]. While this can only have limited influence on the total number of road fatalities and seriously injured, experts question, if even in 2050, highly automated driving will be widely deployed on rural roads, which account for more than 50% of all road fatalities in the EU[16]. Sustainable impact on road safety is likely to be achieved when the proportion of these vehicles is high, systems are accepted by drivers and other road users, and automation encompasses mixed traffic, suburban and rural roads with on-coming traffic on not separated lanes. However, some road safety risks will still remain, for example non-automated vehicles crashing into other road users, single vehicle crashes of two-wheelers, which are unlikely to be highly automated in the foreseeable future, or collisions with citizens who simply do not wish to always be connected. Moreover, even connected and automated vehicles may not be able to compensate for all erratic behaviour of other road users, and for a very long time, their Operational Design Domains (ODD)[17] will have limits, beyond which manual control may be necessary. Finally, a limited number of collisions may even be caused by failures of CCAM systems or by imperfect hand-over of control between vehicle and driver.

In the end, it is not one single route of technological development, but the combination of innovations targeting all road users and all elements of the road transport system, including the control and management of vehicles and infrastructure, which may bring Europe closest to Vision Zero. This is actually one of the principles of the Safe System Approach explained above: All layers of road safety need to be strengthened – road safety management, road infrastructure, vehicles, road user behaviour and post-crash response – so that if one fails, another one will compensate.

In addition to the implementation of known measures, clearly intensified efforts in road safety R&I are therefore needed. As outlined in the EU Road Safety Policy Framework 2021-2030, funding support for the development and implementation of Safe System strategies needs to be strengthened, especially in Horizon Europe. EU citizens actually need safe as much as they need green transport systems. This should be reflected by a significant increase in the resources provided for transport safety R&I, and transport safety is mainly an issue of road safety. In fact, road crashes account for about 96% of all transport fatalities in the EU[18]. (The vast majority of the remaining for 4% are a consequence of collisions in the railway system.) This should also be reflected in the funding resources made available. A dedicated action / instrument, e.g. a Mission, going far beyond research and driving innovation to finally deliver effective solutions, may complement road safety-related actions in Horizon Europe.

Funding support for European road safety R&I needs to be strengthened significantly,

- **giving road safety R&I a fair role** in good balance with R&I in other thematic areas,
- reflecting its actual importance in **saving EU citizens' lives and protecting their health**,
- **complying with the mind-set of Vision Zero** that no loss of life is acceptable.

[15] ERTRAC Connected, Cooperative and Automated Mobility Roadmap 2021
[16] Road Safety – Key Figures 2020, EC Directorate-General for Mobility and Transport, ISBN: 978-92-76-25168-2, https://ec.europa.eu/transport/road_safety/sites/default/files/pdf/scoreboard_2020.pdf
[17] "the specific conditions under which a given driving automation system or feature thereof is designed to function" [SAE J 3016-2018]
[18] Analysis based on Eurostat data for 2015 – 2019 (with fatalities from air crashes limited to commercial air transport) : https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Category:Transport_safety

Expected impacts are multiple:

- reducing human suffering by saving thousands of lives and serious injuries,
- reducing the burden on the health care system and total socio-economic costs by many billion euros,
- facilitating efficient investments in road safety by public and private stakeholders,
- making the road transport system more inclusive for all.

If Europe managed, by the combination of all possible measures, to stop the current trend and enter into a steady decrease of fatality and injury figures according to the EC targets from mid-decade onwards, a cumulative total of about 300,000 lives could be saved and several times as many serious injuries avoided until 2050. While this is already an objective more than worth pursuing, the estimated socio-economic cost saving would add up to a total of about EUR 2 trillion.

3.5 Scope

The main objective of this ERTRAC roadmap is to provide a joint stakeholder view on the road safety research needs in Europe. The roadmap is based on the current state of the art and on the Safe System Approach to reach the ambitious goals set for the European Union and for its individual member states. With the current longer-term development in many parts of Europe, where the numbers of fatalities and serious injuries no longer decrease significantly, but, in certain countries, even increase, it is even more important that the correct measures are taken and that resources are used wisely.

The research needs identified should lead to targeted efforts in research and innovation. ERTRAC calls for pre-competitive collaboration among European industry, road operators, service providers, academia and research organisations. The key role of public authorities is also highlighted, amongst others for policy and regulatory needs, with the objective of European harmonisation. In addition, the R&I proposed in this roadmap gives ample room for European citizens and road users themselves to engage in the suggested activities. While individual R&I activities should be clearly targeted, the overall scope of the R&I considered in this roadmap is broad, covering all pillars of road safety (road safety management, road infrastructure, vehicles, road user behaviour and post-crash response), all road transport modes, all phases of safety from preventive to post-crash safety and all potential road users. This explicitly includes people who are not able or willing to make use of the European road transport system today, but may do so more intensively when road transport will become safer and more inclusive. At the same time, this roadmap does not address safety research needs which are directly linked to highly automated driving or to zero tailpipe emission technologies and already covered by the Strategic Research and Innovation Agendas (SRIAs) of the CCAM Partnership and the 2Zero Partnership respectively. A number of research needs that fall under the thematic scope of the CCAM Partnership, but are not explicitly addressed in its SRIA, are still mentioned in this roadmap for consideration by the partnership in the further development of its SRIA and in the discussion of the contents of future Work Programmes in the Partnership Board.

Chapter 4, which is the main part of this roadmap, outlines in detail the most important needs for road safety R&I identified by ERTRAC, structured in expected outcomes and scope of each R&I need. This gives the reader a clear view of the identified areas, including a clarification of the proposed timing of the corresponding R&I activities.

3.6 Complementarity between ERTRAC roadmaps

The Safe Road Transport Research Roadmap by ERTRAC is based on the individual roadmaps of several European stakeholder associations, who provided their current road safety R&I priorities as a starting point for the updating process of this ERTRAC roadmap in 2021. At the same time, it is strongly connected and complementary to several other ERTRAC roadmaps, especially the CCAM Roadmap, the Integrated Urban Mobility Roadmap and the roadmaps on New Mobility Services and Urban Mobility Resilience.

CCAM will be an important enabler of significant improvements in road safety in future. Therefore, the joint stakeholder view on the long-term evolution of Connected, Cooperative and Automated Mobility over time, as presented in the ERTRAC CCAM Roadmap, is an important basis for the Safe Road Transport Research Roadmap. Also with regard to the further development of infrastructure, artificial intelligence (AI), human-technology interaction, safety assessment and risk predictions, the roadmaps complement each other. More specifically, the concepts of ODDs and Infrastructure Support Levels for Automated Driving (ISAD)[19] are relevant for the Safety Roadmap, as well, enabling the information exchange between vehicle and infrastructure in different ways and on different levels depending on the current ODD and ISAD in which the vehicle is moving. Both the CCAM and the Safety Roadmaps by ERTRAC are also complementary to the SRIA of the CCAM Partnership. The latter presents a more detailed portfolio of R&I actions with their timelines and expected outcomes than the CCAM Roadmap by ERTRAC, but covers road safety research only to the extent that is directly linked to higher levels of automation.

With respect to the Integrated Urban Mobility Roadmap, there are common challenges, as well, for instance the introduction of automated services in a multimodal scenario and its impact on road user behaviour in urban environments. Another common challenge is the multitude of changes brought about by digital lifestyles, amongst others providing measures for better detectability of pedestrians and two-wheelers and increased awareness of dangerous situations. The aspect of mixed traffic with vehicles with radically different levels of automation capabilities (and of different sizes) as well as road users with a varying degrees of connectivity is one of the top challenges requiring cross-thematic approaches.

Moreover, regarding the New Mobility Services Roadmap, the potential use of shared data is a common and highly relevant research area for the design of safe infrastructure and to monitor and improve road safety. Data sharing by mobility services, for instance, with vehicles such as shared e-bikes or e-scooters could contribute to increased road safety through better understanding of behavioural patterns and their changes. Another link to the ERTRAC New Mobility Services Roadmap is related to the design and delivery of trainings for different groups of road users, targeting e.g. children and professional drivers after integration in educational programmes and also addressing the issue of safety culture.

With respect to the Urban Mobility Resilience Roadmap, complementary is mainly related to the safety aspects of designing and maintaining a resilient transport system offering mobility during both normal and crisis times, which has an impact e.g. on research needs related to safe infrastructures and urban vehicles.

The above-mentioned roadmaps interplay and create a solid foundation for the research needed to reach the EU targets in road safety, with the Road Safety Roadmap focussing on R&I needs that are not directly linked to highly automated driving nor to the higher system level of sustainable and resilient urban mobility.

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[19] scheme "to classify and harmonize the capabilities of a road infrastructure to support and guide automated vehicles" [website of the INFRAMIX project (www.inframix.eu), grant agreement No. 723016]

4 Research Needs

This chapter gives an overview and explains in detail the road safety research needs which ERTRAC developed in two dedicated online workshops in 2021 starting from the contents of the 2019 Safe Road Transport Research Roadmap and from the individual roadmaps of several European stakeholder associations. Contents of the existing ERTRAC roadmap that were suggested for the time period 2023 – 2027 and that were not fully reflected in the first Work Programmes of Horizon Europe yet were updated and complemented by new ideas and inputs from the roadmaps of stakeholder associations. Research needs were elaborated by a group of experts in the specific areas, and further refined based on three electronic feedback loops giving all members of the ERTRAC Working Group Road Transport Safety & Security the possibility to contribute.

As a result, Figure 3 shows an overview of future road safety research needs with their allocation to different time periods taking into account criteria such as the complementarity with research to be funded under the first Work Programmes of Horizon Europe, the technological feasibility of different research activities and the consistency with the 2019 Safe Road Transport Research Roadmap.

	2023-2024	2025-2027
Road Safety Management	◆ **Effects of disruptive changes on transport safety issues**	◆ **Road safety analysis supporting road safety management** ◆ **Leveraging a predictive safety assessment framework**
Safer Road Infrastructure	◈ **Infrastructure Safety**	◈ **Predicting and avoiding crashes based on AI and big data**
Safer Vehicles	■ **Safe human-technology interaction: Ensuring the right level of driver vigilance** ■ **New ways of reducing the long-term consequences of road crashes**	■ **Safe human-technology interaction: Communicating and understanding other road users' intentions** ■ **Safety of bicyclists and other users of micro-mobility devices**
Safer Road User Behaviour	▣ **Establishing a framework to improve traffic safety culture in the EU**	▣ **Safer behaviour in road traffic**
Post-crash Response	● **Smart rescue operations**	

Figure 3: Allocation of research needs to time periods in which research should start

The overview in Figure 3 nicely reflects the adoption of the Safe System Approach: As humans inevitably make mistakes, which must not lead to death or serious injury in spite of human fragility, the long-term consequences of road crashes must be reduced and care and rescue measures be improved. As responsibility is shared, all the pillars of road safety with their respective stakeholders are addressed, and the transition from re-active towards pro-active management is reflected amongst others in the research needs on leveraging a predictive safety assessment framework and on predicting and avoiding crashes based on AI and big data.

Not included in Figure 3 are four road safety research needs which have been identified during the development of this research roadmap, but fall under the thematic scope of the CCAM Partnership. These are recommended for inclusion in future updates of the CCAM SRIA and in the discussion of the contents of future Work Programmes in the CCAM Partnership Board. Their allocation to different time periods will be managed best by the respective thematic Clusters in the CCAM Partnership:

- Operational safety; new methods for AI-based systems
- Assessment of road user capabilities in future scenarios of road transport
- Reliability of safety-critical systems and components in future vehicles
- Preparing the regulatory framework for safe, secure and inclusive operation of CCAM

Detailed descriptions of the expected outcomes and scopes of all the individual research needs are given in the following paragraphs. Ideally, research on every research need will result in safety benefits to all groups of (potential) road users. If, still, a focus on particular groups, such as children, is clearly recommended, this will be indicated in the descriptions

Moreover, road safety is a global challenge as shown clearly by the WHO figures quoted in chapter 3.3 and by its inclusion in the UN Sustainable Development Goals. Consequently, excellent road safety research is done not only in Europe. International cooperation can therefore increase the leverage effect and impact of European road safety research significantly, as concerns e.g. data availability (both field data and data from costly experimental tests), international interoperability of safety systems and the preparation of standards and regulatory requirements, e.g. in the framework of UNECE. If additional importance is seen in international cooperation, this will be indicated in the descriptions of the respective research needs below, sometimes also mentioning particular countries which are recommended for such road safety research cooperation.

4.1 Effects of disruptive changes on transport safety issues

Expected outcomes: Research is expected to contribute to the following outcomes:

- Transport systems prepared for disruptive changes, supporting continuously improved traffic safety
- Resilience as an integrated principle in the design and development of future transport systems
- Increased understanding of the underlying psychological effects and reactions to sudden changes in availability of transport means, as well as authority interventions, inflicting the safety of users

Scope:

The importance of a robust transport systems becomes highly evident in times of rapid, unplanned changes. The COVID-19 pandemic has pointed at several issues that need to be addressed to secure future resilience in the transport systems and to ensure that the level of transport safety is not only maintained, but also meeting more demanding targets. For instance, the decreased use of public transport during the pandemic has to some extent led to increases in both biking and walking, but also an increased use of cars in some parts of the world. At the same time, decreased traveling has meant fewer vehicles on the roads in certain areas, whereas others have seen an increase of delivery vehicles, as home deliveries have surged.

In order to provide safe and resilient transport for all, many aspects must be considered in a clearly multidisciplinary approach, such as:

- Safety implications of rapid changes / new incentives (sometimes contradictory to previous ones)
- Socio-economic differences: How do they affect the safety of individuals?
- Resilience at the system level: How can that be applied and used for improved transport safety?
- How can safety and resilience be improved by future housing developments/suburban planning?

A definition of a resilient road transport system shall be provided and transport safety factors be determined that are essential to take into account. Moreover, scenarios for disruptive changes shall be identified that can make a transport system instable, the consequences on transport safety be analysed, and solutions to tackle them be developed. Hence, a structured method to secure safety as an integrated part in resilient transport systems shall be provided.

A solid foundation for this research is the Safe System Approach. It requires the inclusion of relevant expertise in social sciences and humanities (SSH) and will benefit from international cooperation.

4.2 Infrastructure safety

Expected outcomes: Research is expected to contribute to the following outcomes:

- Enhanced criteria catalogue for road safety assessment with particular applicability for non-trunk roads and the safety impact on all – including new – types of users
- Technology for the real-time generation and communication of infrastructure Key Performance Indicators (KPIs) related to safety, including those created/derived from vehicle sensor data
- Concepts for interaction of infrastructure elements in a digitalised ecosystem for road safety

Scope:

Road infrastructure can be improved to decrease the risk of crashes and other incidents as well as crash severity. The benefits of this will be amplified in a connected transport system where automated or partially automated vehicles are supported by infrastructure features to perform as expected. In addition, road infrastructure can provide clear guidance towards desirable road user behaviour, which may lead to more predictable behaviour, and consequently to less crashes.

It is essential to understand how to upgrade the infrastructure network to make it compatible with all road users (e.g. powered two-wheelers are not considered as users for which urban infrastructures are usually designed) and in particular with automated vehicles at different levels of automation. The research should focus on urban and secondary rural networks as most of the resources for upgrading the road network is often devoted to primary networks (with specific attention to the Trans-European Road Network). For urban and secondary roads, resources are generally limited, and potential negative impact of roadworks on the surrounding territory is extremely relevant. Low-cost interventions with low negative impact need to be studied for these roads.

Advanced monitoring, warning and maintenance techniques need to be developed to guarantee a timely assessment of the operating conditions of road structures and furniture. Recent events have highlighted the importance of roadside safety devices monitoring, but also proper signs and marking, pavement and overall road structures (bridges, tunnels etc.).

The results of the research will enhance the safety level of the infrastructure by enabling a prompt reaction to potentially unsafe conditions and will enable to identify the infrastructures where connected, automated vehicles can travel under safe conditions.

Aspects to be addressed shall include:

- Identification of criteria to perform safety assessments of urban and secondary rural roads accounting also for new users (including but not limited to powered two-wheelers, e-bikes etc.) and to identify cost effective upgrade solutions
- Further development of infrastructure measures to elicit desired road user behaviour
- Development of new technology for monitoring and communicating in real time infrastructure distress conditions and deterioration. This should include malfunctioning and post impact warning for road equipment.
- Integration of safety and V2I issues in asset management to ensure that the infrastructure is always capable to provide the minimum required level of performance to provide safe travel conditions for automated vehicles (ISAD concept)
- Development of new maintenance techniques for road equipment with low negative impact on the surroundings (including but not limited to roadside safety features, signs and marking, lighting)
- Connection of infrastructure elements to the digitalised ecosystem, including but not limited to research on digital twins
- Development of onsite data storage and communication systems (e.g. RFID) capable to provide in real time details on the properties of the road equipment relevant to road safety
- Use of data from connected probe vehicles to detect safety relevant conditions and collect maintenance indicators

4.3 Safe human-technology interaction in the coming decade

Expected outcomes: Research is expected to contribute to the following outcomes:

Until full automation in transport is reached, the driver will play an important role in vehicle safety. In this context, the proposed research will lead to human-technology interaction (HTI[20]) systems for L0-L3 vehicles (with overlap to L4 vehicles) and development guidelines contributing to the following outcomes:

- Increased road safety by ensuring that the driver has the right level of vigilance and situation awareness with respect to the context and the automation level and by facilitating the handling of high-cognitive load situations
- Reduced number and severity of crashes related to low vigilance and/or misinterpretation during the hand-over and take-over phase
- Improved protection of all road users, in particular pedestrians and riders of two-wheelers, by facilitating the exchange of information on the imminent behaviour of the vehicle

Scope:

Part A: Ensuring the right level of driver vigilance with respect to the context and the automation level

The increasing automation of road transport is bringing up new challenges especially in lower automation levels (L0-L3) when driving control is transitioning from the driver to the vehicle or vice versa. For these levels, ensuring the right level of driver vigilance with respect to the context and the automation level is important to avoid dangerous situations.

In addition, systems based on HTI are generally built on a non-stationary and non-deterministic foundation – human behaviour. Therefore, the concept of individually adaptive systems has to be followed and elaborated in all its particular aspects, as the consideration of “average” human behaviour is not sufficient.

This has large implications on the design of HTI systems.

Such systems should provide a reliable and seamless interface between the driver and the vehicle in normal driving conditions as well as in specific situations with a risk of generating high cognitive load, diverted attention, inattention, impaired driving or in the case of instantaneous limitations in driving capabilities.

As drivers and their experience, as well as driving conditions, may vary a lot, HTI systems will need to address a wide variety of use cases. Therefore, in-cabin monitoring systems with adequate accuracy are key to have a clear understanding of the driver state, while considering all contextual in/out cabin data, so

[20] “Human-technology interaction” reflects the increasing and broader seamless, indirect or direct interactions that the human is having with different technologies (e.g. mobile phone, V2X communication, personal devices, general public monitoring systems…), which are then also used as data sources for various interconnected services (e.g.; Google Traffic, general traffic management etc.). On the technology side, this aspect will be relevant for AI-managed systems, which observe human behaviour and then adapt themselves to such behaviour.

that the vehicle can propose a pertinent and tailored strategy to prompt the required driver action or behaviour.

Special attention should be dedicated to the “hand-over” and “take-over” phases. Hand-over/take-over requests should be done considering the context and the state of the driver in a way to minimize cognitive stress related to hand-over and take-over. In this context, it is important to investigate standardized requirements for the human-machine interface (incl. in case of system failure).

Advances in cabin monitoring and sensing technologies as well as robust detection/prediction of driver cognitive status will be necessary to achieve these objectives.

In this respect, research should address the development of relevant strategies to avoid driver disengagement and reduce cognitive load in critical situations, as well as behavioural models and methodologies to identify activities/behaviours that should be avoided or blocked by the vehicle HTI. These strategies should be scalable to the available vehicle sensing sophistication.

Part B: Communicating and understanding other road users’ intentions in traffic

HTI also plays a key role in facilitating the communication between road users in traffic. The need for communicating and understanding other road users’ intentions in traffic with L0-L3 vehicles and in future with L4 vehicles should be understood. The role of cues, such as informal communicative cues (e.g. hand gestures, facial expressions…) or vehicle dynamics (braking, accelerating…), in the interaction between drivers and other road users needs to be further investigated. Guidelines for advanced and user-friendly communication interfaces and intention prediction systems in different traffic situations will also need to be developed. This is especially critical in a future when automated and non-automated vehicles will share the road.

In this context, opportunities to leverage in-cabin monitoring system information in a V2X communication context could also be explored.

For both **part A** and **part B**, some specific use cases, such as elderly drivers with declining sensing and higher sensibility to cognitive load, young and inexperienced drivers and professional drivers performing other tasks simultaneously will also need to be addressed. For these populations a key research question will be how to meet their specific needs and how to realise the best compromise between tailored vs. standardised approaches.

Also, trust is mandatory for the acceptability of these systems: precision, reliability, and transparency need to be ensured. In particular, the vehicle response to a given situation as well as the level of information to be conveyed needs to be coherent and logical. Relevant research areas to achieve this objective will be the definition of multi-modal and multi-sensorial vehicle warning and response strategies for the safe management of critical phases considering user acceptance and the severity of scenarios.

HTI systems should be upgradable both in software and in hardware with minimal disruption for the users, while ensuring that the intended effect and functionality is improved or at least maintained. A cross-fertilisation opportunity would be to investigate how other transport modes (e.g. aviation) handle upgrades/updates with minimal disruption for the user.

SSH may have relevance in the context of identifying driver acceptability criteria and pain points as well as in setting up use cases for part B.

These research needs should be addressed in coherence and continuation with the call topics HORIZON-CL5-2021-D6-01-10 and HORIZON-CL5-2022-D6-01-02.

4.4 New ways of reducing the long-term consequences of road crashes

Expected outcomes: Research is expected to contribute to the following outcomes:

- Validated mechanisms of personal injuries leading to significant long-term consequences, for all road users (pedestrians, bicyclists, motorcycle riders, car and bus drivers and occupants, etc.)
- Established system for classification of long-term injuries, including methods for follow-up of personal injuries for the required time after a crash
- Validated tools and methods for the assessment of injuries leading to long-term consequences, such as upgraded virtual human body models
- Preconditions to develop policy, regulatory, and standard requirements for the purpose of reducing long-term consequences
- A general upgrade in protection for all road users through safe and robust countermeasures and solutions

Scope:

In addition to fatal and near-fatal injuries, personal injuries with long-term consequences continue to pose a threat to personal mobility. Particularly pedestrians, bicyclists, and motorcycle riders, as well as users of new mobility devices, have a high risk to sustain personal injuries with long-term outcomes, such as brain and neck injuries. In cars, despite new collision mitigation systems, low and medium severity collisions may still cause similar permanent neurological disorders to occupants. Long-term injuries to both the upper and lower extremities are further examples, occurring among all road user types. As of today, neither any standardized nor any accepted method exists for the evaluation of solutions to reduce long-term outcomes. In addition, there is a need to include more aspects of human variability like age, sex, weight, and stature, with particular focus on long-term disability.

Several research areas, also social sciences, are required for the sake of understanding and reducing the long-term consequences fully. Cognitive capabilities could for example be impaired by physical head trauma, and there is at the same time a need for more knowledge of psychiatric impairment related to post-traumatic stress or reduced quality of life. In other words, cognitive issues and depression must be fully recognized as potential long-term consequences of road crashes.

More research is needed to establish a relevant system for classification of long-term or permanent disability that can be used for the development and design of future protective solutions as well as policies and requirements. There is a strong need for refined knowledge of the relations between initial injury and long-term consequences of personal injury, which will demand new in-depth crash data for the reconstruction of collisions combined with long-term injury follow-up. New models for measuring long-term consequences will need a lot of real-world data to become validated. In-depth analysis of data from hospitalized patients will in this perspective also continue to be needed as well as efficient means to follow up on psychiatric impairment measurables. Hence, new efforts in accident research are required, as well as the most related social sciences (economics and psychology), further to research in biomechanics, vehicle crashworthiness, and other aspects of crash dynamics. New technologies open possibilities for gathering new types of data with higher levels of detail.

Virtual testing tools are crucial for new more efficient evaluation methods, and accordingly further development of human body models (HBM) is particularly important. The effectiveness of new systems must for instance be assessed in a wide range of crash load cases, which the current test dummies cannot support, and another possibility with the use of virtual HBM will be to evaluate integrated and adaptive safety at a significantly higher level of detail. The potential of HBM to be usable for the evaluation of long-term injuries in product development is strong and will be supported by further multidisciplinary research. Research is also needed to assess any limitations in this respect.

Virtual methods with HBM should not only be developed further for passenger car safety, but for the purpose of assessing personal protection equipment, forgiving road infrastructure (including road surfaces), and the protection of motorcycle, moped and bicycle riders, as well as pedestrians and users of new micro-mobility devices against long-term injuries. Virtual HBM need to reflect human variability, and there is a particular need to focus attention on children in all different road user roles, e.g. preteens in passenger vehicles who normally are not seated in child seats, yet often too small to be fully protected by current vehicle integrated safety systems.

New and upgraded vehicle interiors (including non-conventional seating and new interior features) of highly automated passenger cars, shuttle buses (including mini buses), and other driverless passenger vehicles, will play an important role in the efforts to raise the road safety level further regarding passenger vehicles. Persons who are standing, for instance passengers in public transport, should also be included. Market drivers (e.g. increased automation, comfort, and infotainment) will be reinforced with safety-intended development strategies when supported by relevant research and policies regarding long-term consequences.

Research within this field is expected to recommend upgrades to concerned policies, regulatory requirements, and standards. For this reason, international cooperation is important. Findings, knowledge, and experience are encouraged to be shared with other fields, such as certain sport, recreation, and work activities, as well as with other transport modes, which may have similar issues regarding personal injuries with long-term consequences as road traffic, although a different incidence.

4.5 Establishing a framework to improve traffic safety culture in the EU

Expected outcomes: Research is expected to contribute to the following outcomes:

- Growing a positive traffic safety culture across the EU that supports the Vision Zero goal and the Safe System Approach, and which is in line with the UN Sustainable Development Goals and the 2020 Stockholm Declaration

- Remedial action against detrimental, non-temporary impacts of the COVID-19 pandemic on certain road safety risk factors

- Facilitation of a shift to increase efficiency in road safety related public spending across Europe
- Development and evaluation of strategies to transform the traffic safety culture of road users and stakeholders based on a valid model that identifies the key components defining traffic safety culture, including social norms, attitudes, perceived control, values, and system assumptions
- Concepts and guidelines to make the concept of traffic safety culture an integral part of road safety work of actors across the socio-economic systems of European societies

Scope:

A Safe System entails the understanding and managing of all elements of the transport system, including the behaviour and interplay of its actors. Comparative analysis shows persistent differences in road safety performances between EU Member States. These differences may be attributable to differences in culture, which are hard to explain with classical risk models. Efforts shall therefore be made to complement road safety initiatives by a *safety culture* perspective, i.e., the values, beliefs, priorities and viewpoints shared among groups of road users and stakeholders that influence their decisions to behave or act in ways that affect safety. This concept is already well established in organisational research. Assessing road safety cultures in different national, regional or local systems, groups and organisations is believed to help understanding and explaining different patterns of risk perception and risk taking across communities and countries – and can likewise inform tailored interventions for these (sub-)cultures, which all come with their specific norms, values, beliefs and behaviours. These interventions should address all relevant actors in the system for road transport of people and goods, and consider future developments, such as potential impacts by increasing automation levels or by the introduction of new mobility concepts in road transport.

Within this context, actions should contribute to establishing a framework for cultural transformation in road safety across the EU and thereby address the following aspects:

- Better understanding of the link between road safety outcomes and safety culture, i.e. of sociocultural factors like values, beliefs, attitudes, and norms and their effects on actual behaviour of road users (including subjective perception of safety as well as implications of value of time and institutionalised travel costs) – and the ways how these factors can be sustainably transformed
- Consideration in particular - but not exclusively - of traffic behaviour with high safety impacts, such as inadequate speed choice, distraction by communication or control devices, driving under the influence of alcohol or drugs, non-use of protective devices, and risks triggered by professional drivers' requirements to multitask and report while driving
- Assessment of safety cultures and respective activities from other transport modes such as aviation and rail and their potential for road safety
- Consideration of safety impacts of new technologies (including better understanding and use of Advanced Driver Assistance Systems (ADAS)) and emerging transport means and services
- Stocktaking of good practices from countries and companies worldwide already successfully applying cultural approaches to (road) safety work, including countries outside of the EU such as the US and Australia

- Targeting all levels of the socio-economic systems of societies in the EU, i.e. from European to national, regional and local communities, including entities such as schools and workplaces

- Clear guidance & hands-on advice on the design and evaluation of interventions to define, measure, transform and institutionalise traffic safety culture across all areas affecting road safety – for decision-makers and practitioners, with a good geographic coverage across EU institutions, Member States and Associated Countries. At the level of individual road users, such interventions may entail targeted educational and communication efforts to challenge wrong beliefs or to clarify misperceived social norms, and the use of incentives and nudging to encourage compliant behaviour. At the level of enterprises and authorities, initiatives may include the take-up of safety culture principles in sustainability reporting and encompass various activities from staff training and supervision to procurement and operations – at best permeating work culture and norms of an organisation. Advice at the level of Member States and the EU is sought on how to support such transformation such as with legislation, enforcement, and data.

- Pilot testing of selected interventions at various levels in the Member States

Actions should be based on the results of previous research in this domain, such as in the TraSaCu project. Integration of relevant expertise from SSH and international cooperation with partners from the US or Australia is considered beneficial.

4.6 Smart rescue operations

Expected outcomes: Research is expected to contribute to the following outcomes:

- Extension of eCall protocols to enable injury severity estimation and support emergency services through pre-hospital decision support systems

- Further developed communication systems and standards for emergency services

- En-route support to blue light resources based on V2X communication

- Improved injury severity prediction algorithms / tools and on-scene diagnostics making use of AI and similar data analysis tools

- Further developed rescue procedures to avoid further injuries

Scope:

A significant part of deaths and severe injuries can be related to the post-crash phase. These could be reduced by applying new and improved methods and working procedures in this phase, considering also the increased diversity in powertrains, e.g. electric, hydrogen-powered and other vehicles with specific powertrains, further developed human extrication methods and fire handling procedures.

Research is needed for improvements of eCall service quality, supporting the extension to possible heterogeneous connectivity technologies and the worldwide interoperability considering the variety of rescue structures in the different countries.

Moreover, the research focus should address the development of eCall protocols to support emergency services in many different countries with rapid, more accurate and complete information for health care of people involved in crashes, as well as for the protection of rescue and police operators. Rapid and improved medical support will lead to reduced fatality and impairment rates, less human suffering, faster rehabilitation and reduced total socio-economic costs.

The research should include improved and extended eCall functionalities, smarter and more appropriate call-taking, blue light dispatching, en-route support, and triage methods for critical injuries like traumatic brain and thorax injuries, as well as improved working conditions and secure environment for rescue personnel. Finally, the research activities should also focus on the application of new technologies (e.g. AI, sensors, drones...) for the post-crash diagnosis and rescue, in particular including AI-based severity prediction algorithms for on-scene diagnosis

International cooperation is recommended, in particular with projects or partners from the US. The involvement of SSH aspects is a fundamental requirement for these research activities.

4.7 Road safety analysis supporting road safety management

Expected outcomes: Research is expected to contribute to the following outcomes:

- Guidelines for (crash) data collection based on good practise and methods using combinations of data sources to realise pan-European harmonised information on fatalities, serious injuries and Key Performance Indicators (KPIs)
- Open access European in-depth crash database with long-term funding concept
- New data analysis methods and development of policies that include data on KPIs and/or multi-criteria analyses that cover other public values (e.g. environment, health, liveability)
- Recommendations for and best practises of accurate crash data and case handling that allow a fair and just treatment of crash victims, including the long-term effects of injuries

Scope:

The aim of this research is to improve road safety management by providing better *information* and *analysis methods* to select and implement more successful *measures* that result in a safe, fair and just road traffic system following the Safe System Approach.

The quality standard of registration and analysis of fatal road crashes varies widely across Europe and regionally across EU Member States. There are many good examples of professional road crash recording in Europe. To make this knowledge available and to enable greater standardisation of accident investigation throughout Europe, it is necessary to compile this knowledge and make the minimum standards mandatory in a European guideline. Data acquisition and definitions of crashes, injuries, quality of roads, costs of measures etc. differ (a lot) among European countries for reasons that are not easily overcome. Research on combining various existing data sources such as police records, hospital data, vehicle data (from event data recorders (EDR)) is a promising approach to build pan-European databases with comparable information. The need for this has increased substantially now there is a European road safety target for serious injuries and KPIs are used. Results of this research will also show where harmonisation from the start is unavoidable or additional data acquisition is needed to realise sufficient harmonisation.

Detailed information from in-depth crash reports has great added value to define countermeasures or provide ex ante evaluations of the effects of these measures. The costs, however, are high and in-depth information on crashes and pre-crash scenarios is available for very limited numbers of crashes per year. Combining information from different (national) databases is difficult because of privacy issues (GDPR), but promising approaches have been demonstrated such as IGLAD. Another possibility is the combination of different data sources to a 'light' version of in-depth data. Furthermore, the application of new data acquisition technologies could lower the costs of in-depth data. Existing experience and technologies of accident research initiatives like GIDAS and TASC should be taken into account to adapt further research to these standards and to develop this to a European level. Pre-crash scenarios provide the information necessary for developing relevant active and passive safety measures. In-depth crash data acquisition shall be statistically representative to enable an extrapolation to the country-wide situation. A harmonized classification of key parameters such as crash situations, severities and injuries as well as pre-crash and in-crash information shall be pursued.

Various EU projects (e.g. SafetyNet, DaCoTA, SafetyCube, ERSO) have delivered methods to analyse road safety data and formulate policy or select measures. The risk-based approach using KPIs adds a new element to this. Another new angle is the need for multi-criteria analyses: road safety has to go hand-in-hand with or be weighed against other public values like environment, health, liveability, accessibility. Both KPIs and multi-criteria analyses need to be incorporated in existing or totally new analysis methods.

Preventing road crashes is an ethical issue (Vision Zero). The traffic system should be fair, just and unbiased to all road users, but many road traffic victims experience it differently. This is, for instance because crash information is not accurate or detailed enough to fully compensate their loss (financially) or the case handling to assist them and their bereaved families is not adequate. More insight is needed on the European level to identify best practises. A specific research aspect (see chapter 4.4) are the long-term effects of injuries that are (still) largely unknown.

This research requires the inclusion of relevant expertise in social sciences and humanities (SSH) and will benefit from international cooperation, e.g. with the International Traffic Safety Data and Analysis Group (IRTAD) at OECD.

4.8 Leveraging a predictive safety assessment framework

<u>Expected outcomes</u>: Research is expected to contribute to the following outcomes:

- Approaches for well-founded predictive analyses of the requirements for future safety measures, to deal with the changes in the transport system as a result of new means of road transport and higher levels of CCAM systems, the introduction of new technologies (e.g. Artificial Intelligence (AI)), regulatory changes, and safety culture changes

- A harmonized virtual simulation methodology to enable the virtual sign-off of future safety systems in vehicles, including a procedure for model validation using a selection of physical tests

- Continuous safety validation methodology to monitor the safety state of the vehicle in operation during its service life, following a virtual sign-off
- Harmonized stochastic approaches, methods and tools, to increase understanding and acceptance of statistics on risks, that are computed as a result of predictive safety assessment

Scope:

Safety assessment considers the validation of safety measures, whether these are regulatory and behavioural changes, solutions in the infrastructure or safety systems on-board vehicles.

In the coming years, the road transport system will undergo large changes as a result of the introduction of new technologies (especially AI) and the introduction of higher levels of CCAM systems that supposedly lower the role of the human driver in traffic. Moreover, regulations will continue to change and also changes in safety culture (Vision Zero) are foreseen. Consequently, a predictive analysis of the requirements setting for future safety solutions is needed. How will the transport system change, what different traffic scenarios are to be expected and how will expectations evolve regarding the safety that higher levels of automation need to offer?

With these changing requirements to safety solutions and technologies, the predictive safety assessment framework (as to be developed in answer to call HORIZON-CL5-2022-D6-01-06) is expected to determine the impact on safety as a result of the introduction of such new technologies, new means of transport, and of specific safety measures or solutions. Safety assessment includes the projection of results to the broader perspective, i.e. the traffic level and the level of regions and countries.

Due to the fast increasing functionality and complexity of safety systems on-board vehicles, type approval of such systems is no longer feasible through performing a limited set of physical tests only. Large efforts are being made to develop type approval procedures that are mostly based on validated virtual simulations. Virtual safety assessment makes a prediction of system performance in the large range of relevant traffic scenarios with all realistic occurrences and their variations, with a large variety of human driver interactions with the vehicle and the safety system, under a large variety of weather and lighting conditions. To quantify safety risk as a metric for the safety performance of vehicles, statistical methods that can deal with the stochastic description of those variations are required.

Future safety validation requires a system and methodology to *continuously monitor* the safety performance of a vehicle throughout its operational lifetime, also after (virtual) type approval has been granted. This is of particular importance for systems with the possibility of performing over-the-air software updates – i.e. the system is altered compared to the system for which type approval has been granted. In addition to interfacing to a vehicle system and arranging wireless data transfer, technology needs to be developed to interpret the vehicle signals. Research needs to analyse which signals are needed, which signals can be made available for continuous validation and how validation is performed. Approaches for continuous validation of the operational safety of a vehicle should be provided. References for safe and social driving are required to judge the acceptability of observed vehicle performance in relation to the scenario that the vehicle is in.

Projection methods of the results of safety assessment towards different regions or countries, should not only be applicable to determine the impact of safety solutions but also to assess the impact of greening of road transport and electrification on road safety. Continuous safety validation throughout a vehicle's operational lifetime will provide inputs to quantify the extent to which foreseen changes in the transport system actually take place, which will strengthen capabilities to make such predictions and projections.

4.9 Predicting and avoiding road crashes based on AI and big data

Expected outcomes: Research is expected to contribute to the following outcomes:

- Knowledge on high-risk locations along the road network becoming available, before crashes actually occur, enabling road authorities to deploy appropriate countermeasures pro-actively
- Predictive identification of safety-critical situations based on data from multiple sources and enabling real-time interventions to avoid crashes
- Additional information on traffic flow and particularly on critical situations enabling more effective traffic management

Scope:

One of the principles of the Safe System Approach is to turn from mainly re-active to pro-active management of road safety, i.e. not to derive needs for intervention primarily from crash investigations, but to intervene before serious crashes happen. The ubiquitous gathering of ever-growing amounts of data and their processing in the digital transport system support this idea providing valuable information on traffic situations and events. Potential data sources include amongst others: smart phones, wearables, connected vehicles, drones, road-side cameras etc. Progress in computing power, in the accuracy of location services and in video analytics are further enablers in the processing and analysis of such data in order to identify safety-critical situations or conflicts based on surrogate safety metrics. Artificial intelligence may also help to identify underlying risk factors and their combinations that correlate with the occurrence of safety-critical situations. The observation of these risk factors may then allow predicting such situations at quantifiable risk levels and finally avoid crashes based on targeted, pro-active interventions, as proposed amongst others by the International Transport Forum at the OECD[21]. Ideally, such interventions would be feasible in real time and increase the safety of all road users.

Research should address the following aspects:

- Analyse in detail the technical challenges associated with the acquisition of the big data from multiple sensors in the road transport system, as needed to identify and quantify road safety-related risk factors, and develop concepts to overcome these challenges
- Develop methods and tools to predict safety-critical traffic situations at quantifiable risk levels based on such data
- Avoid biases in the related algorithms and in the data used for analysis and/or for the training of tools, so that the safety of all road users will be improved effectively in a fair, non-discriminatory way

[21] New Directions for Data-Driven Transport Safety, report by the International Transport Forum, 2019, https://www.itf-oecd.org/new-directions-data-driven-transport-safety-0

- Analyse in detail also the non-technical challenges associated with this approach and the inherent need to collect and share large amounts of data that can be used to identify and quantify road safety-related risk factors. Ethical, legal and economic issues should be considered and concepts be developed to overcome these challenges in terms of privacy concerns, questions of data ownership, organisational barriers etc.

- Analyse what real-time countermeasures can be taken to reduce instantaneous risk levels for all road users complementary to existing Intelligent Transport Systems (ITS) services

- Demonstrate the feasibility of such risk predictions and targeted interventions

- Build consensus among relevant stakeholders on possible routes for deployment in coordination with other ITS services

Ways to leverage valuable complementary data, e.g. from crash databases, should also be explored as well as links to initiatives for European data spaces.

Research is expected to develop recommendations for updates to relevant standards and legal frameworks. International cooperation is advised, in particular with projects or partners from the US, Japan, Canada, South Korea, Singapore and Australia. Knowledge and experience from other modes where similar approaches are followed in much more controlled environments should be leveraged.

4.10 Safety of bicyclists and users of other micro-mobility devices

Expected outcomes: Research is expected to contribute to the following outcomes:

- Improved road safety, especially for (e-)cyclists and users of other micro-mobility devices

- An advanced understanding of the safety needs of (e-)cyclists and other users of micro-mobility devices, with guidance for design approaches for such devices as well as safe and forgiving infrastructure

- Increasing use of active modes of transport, in particular (e-)bikes and other micro-mobility devices, in all age groups

- Enhanced safety due to fewer conflicts between automated vehicles and (e-)cyclists as well as users of other micro-mobility devices, built on validated safety measures at the vehicle side as well as at cooperative infrastructure for (e-)bikes and other micro-mobility devices

- Harmonised validation methodologies and tools for safety assessment with integrated behavioural components

Scope:

In many regions, the share of trips made by active modes of transport is increasing, which is very much in line with the UN Sustainable Development Goals, but at the same time a development that needs to be supported by increasing the safety of these road users, taking into account e.g. age differences and cultural differences. To decrease the number of road fatalities and severe injuries, major actions regarding the protection of (e-)cyclists and other users of micro-mobility means are needed. Actions should include crash risk analysis to determine underlying mechanisms and baseline scenarios.

The safety of both completely unprotected and partially protected road users riding (e-)bikes and other types of micro-mobility devices needs to be continuously and properly addressed. The increasing use of communication technologies can be an enabler, as can be improved human-technology interaction technologies and methodologies.

For the interaction between motor vehicles and users of any micro-mobility devices, it will be important to focus on the one hand on detection by motor vehicle-based sensor systems, and on the other hand on V2X based detection of these types of road users, in line with e.g. the MeBeSafe and the SAFE-UP projects. The inclusion of behavioural aspects is also essential and an aspect that needs further research, including the area of safety coaching features (nudging). This research should also lead to dedicated measures for automatic conflict resolution and protective safety measures for crash mitigation and a forgiving infrastructure. It shall result in new and advanced safety measures both from a technological and a behavioural perspective, while limiting the costs. The safety potential as well as the effectiveness of these measures should be evaluated with new assessment methodologies. Both fatalities and injury severity reduction should be taken into account in such methodologies, while considering the maturity of existing (self-)certification and differentiating between the various types of mobility devices. An FOT approach is suggested here to validate the chosen approach.

The risks of both single crashes as well as crashes with other micro-mobility devices and the underlying mechanisms should be evaluated. This can include also an insight in the limitations of riding skills of elderly people with the increased use of (e-)bikes and similar types of vehicles. This, together with the aforementioned assessment methodologies, should be used in new conceptual designs of these and other micro-mobility devices, as well as in the underlying development of a draft European regulatory framework on e.g. type-approval of these devices or self-certification based on harmonized standards as is the case for e-bikes.

Research should also address the option to broaden the current scope of geofencing technologies towards application in the road safety domain. Effective means of implementing geofencing for micro-mobility users' safety, opportunities and validation should be shown in relevant use cases.

This research requires the inclusion of relevant expertise in social sciences and humanities (SSH), focussing on human-technology interaction and behavioural aspects.

4.11 Safer behaviour in road traffic

<u>Expected outcomes</u>: Research is expected to contribute to the following outcomes:

- Valid, reliable and easy-to-use methods to provide a better indication of the prevalence and risk of certain behaviours (like distraction, drug-impairment)
- Determinants of multiple offending and suggestions for countermeasures to improve safety, health and social issues related to these determinants (e.g. addiction, anger, lack of moral sense)
- Increased insight in the relevance of contemporary health issues (like dementia, attention deficit hyperactivity disorder (ADHD), depression, obesity) and road safety

- A strategic and practically feasible approach to road safety education underpinned by evaluations of targeted education programmes that show effectiveness and efficiency on relevant, observed behavioural changes
- Innovative and effective enforcement approaches or methods that take into account new technologies, social media etc. as an opportunity or threat

Scope:

In a Safe System Approach, safety must partly be realised by a road infrastructure and vehicles that are forgiving for human errors and mistakes, but also the risky behaviour itself has to be targeted. We need to know how road users behave, which behaviours are causally linked to crashes, what determines that road users exhibit risky behaviour and which (combinations of) measures are effective in preventing risky behaviour.

How road users behave and how this is quantitatively linked to road crashes (risk) is largely known for well-defined behaviours like speeding and drink-driving (e.g. from the DRUID project). Distraction, inattention, drugs, fatigue etc. are not always clearly defined (what type of distraction? which drug?) and measured in simple units. There is a need for innovative, valid and reliable indicators that can link classes of behaviour (like distraction, drug use) to road crashes in order to determine their risk and relevance. They should also be easy to use by the police, hospitals etc.

A few percent of road users frequently speed, drink-drive etc., and this group of multiple offenders - with an extremely high risk - is almost immune for traditional treatment like fines. It is likely that their deviant behaviour (alcohol abuse, anger etc.) is not limited to road use and links to other research fields (health, social issues). Dedicated research will give insights into the determinants of multiple offending and will subsequently help to identify countermeasures.

Ageing in itself is not a disease, but deteriorating cognitive and physical skills, dementia, cataract etc. are. These and other health issues like depression or ADHD (may) affect the ability to drive, ride and walk and thus affect road safety as well as the quality of life, if they also affect mobility (social inclusion). Understanding how these health issues relate to road safety is essential to define countermeasures.

The purpose of education is to motivate and provide skills to act safely. A strategic and practically feasible approach to road safety education is needed, not based on beliefs and opinions, but on scientifically sound evaluations that prove safety relevant behavioural changes (speeding, drink-driving, distraction etc.). This programme may apply to specific target groups of road users.

Enforcement is usually focussed on specific roads (motorway segment, intersection, school area) and behaviours (drink-driving, texting, seat belt wearing). It is likely that combinations have added value, but sound evaluations of observed behavioural change levels are needed. New technologies like face recognition, network of cameras or social media offer new opportunities, but there are ethical and privacy issues. An approach that integrates combinations of different enforcement measures and takes account of new technologies, effects of social media etc. will render the largest effects on road safety.

This research requires the inclusion of relevant expertise in social sciences and humanities (SSH) and will benefit from international cooperation, e.g. with the International Council on Alcohol, Drugs and Traffic Safety (ICADTS).

4.12 Additional research needs within the scope of the CCAM Partnership

Operational safety; new methods for AI-based systems

Expected outcomes: Research is expected to contribute to the following outcomes:

- Increased user acceptance of CCAM technologies and services, based on increased operational safety and system robustness enabled by AI technologies
- A clear understanding of the capabilities and the limitations of AI for enhancing road safety, including enhanced compatibility of AI components and requirements for a safety proof of AI enabled CCAM
- Accelerated AI development for CCAM, especially with a focus on safety with a clear outlook on sustainability effects, enabled by a relevant set of real as well as synthetic data and scenarios, while avoiding algorithmic biases
- Guidelines for safe integration of AI-based technologies in the road transport system

Scope:

For higher levels of CCAM, and consequently for related advancements in transport management, the application of AI-technology is indispensable. The full potential and limits of AI in this field are not yet well understood. Research is needed to create such an understanding, both on the AI potential as well as on the limitations or further development needs, residual risks and nominal performance.

For AI systems used in safety-critical traffic situations, advanced situational awareness is critical. Research is needed to develop context and ODD aware perception systems, allowing a proper system response.

One particular topic for research follows from the need for methods that are able to assess and validate the operational safety of AI-based systems. This also links to the need for AI to be explainable and trustworthy to enhance the user acceptance of such systems.

AI enabled CCAM technologies will need a deeper analysis in the design of the control architecture, based on different performance indicators and beyond the existing testing framework for validation. It needs to be determined to what level functional safety standards (ISO 26262) and Safety of the Intended Functionality (ISO 21448) are applicable to components and systems that make use of AI technology. How to design fail-aware, fail-tolerant, and fail-operational components that ensure the appropriate performance of such systems of future vehicles in case AI technology is on-board? Assessment tools and methodologies are needed, as well as demonstration of the equitability of AI, in e.g. avoiding race and gender biases.

Furthermore, the work should lead to a clear benchmark and development of performance measures for AI in road safety for specific use cases and applications (object detection, trajectory planning etc.).

The requirements for a proof of safety of AI-based function modules for highly automated driving should be developed within the framework of a generally accepted safeguarding strategy, which should also be taken into account in future vehicle approval but corresponding standards. Accordingly, accepted metrics for the evaluation of AI algorithms are required.

The focus should be on the development of explainable and trustworthy AI, and context aware AI. In safety assessment it is of vital importance to address the robustness of the AI algorithms (how the AI responds to a situation that it has never experienced before, i.e. which is outside its training set, or outside, but adjacent to its ODD) and the specificity of the AI algorithm (how well the AI performance, predictions and decision making are aligned with the ODD scope). New Machine Learning capabilities will be key here, e.g. in interpreting complex and unpredictable traffic situations – including rare special cases – and then developing and implementing the right driving strategy.

The use of AI means that algorithms must be trained with many different data sets of traffic events and scenarios until a function or module reaches a required level of robustness. Relevant sets of real and synthetic scenarios are needed to serve the metrics for a safety proof. This should lead to a common reference scenario database.

This research will benefit from international cooperation and, besides cooperation amongst AI developers, it requires the inclusion of relevant expertise in social sciences and humanities (SSH), focussing on AI and ethics as well as on human behaviour.

Assessment of road user capabilities in future scenarios of road transport

Expected outcomes: Research is expected to contribute to the following outcomes:

- The research will provide input for civil law framework and for future training of road users.
- Human-machine interfaces can be designed according to the future road users' skills and capabilities.
- The research will provide insight how driver education can be formally harmonized within Europe.
- The adaptation of driver skills to future scenarios of road transport will ensure today's high level of driver capabilities in collision avoidance also in the future context of automated and electrified mobility.
- The research will allow to setup a framework on how various modes of transport need to interact in mixed traffic conditions.

Scope:

Extensive research has already been carried out to assess the capabilities of road users in different situations. However, the automation, electrification and increased connectivity of road transport are bringing up new challenges for all types of road users, especially when demographics are also taken into account. For drivers, more possible synergies need to be evaluated with experience from automation concepts in other areas, especially in the field of aviation. Moreover, different factors contributing to an individual's driving skills such as physical capabilities, reaction time, cognitive and perceptual-motor abilities as well as visual acuity, especially at night, are currently being evaluated. With increasing automation, further driver skills will be required that have not yet been sufficiently investigated. In addition, the electrification of all vehicle types is changing the behavioural interaction between road users. This is in particular true for the interaction and use of electrified bicycles (e-bikes). The impacts on road safety, especially for elderly riders, but also the increased use of this transport mode in the pandemic have not yet been sufficiently researched.

The following questions need to be addressed by future research:

- How much will road safety be affected by electrification?
- What will be the impact of those new technologies in an ageing society, e.g. e-bike riders?
- Are there any new training processes required for road users?
- How will driving skills deteriorate in time with increasing automation?
- How to differentiate between professional and non-professional users?
- How can the natural learning process of becoming an experienced driver be kept in place?
- How much of driving skills is required by future drivers if they mainly use automated driving mode? Would it be enough to have a limited number of practical driving skills in manual mode, incl. the use of rural roads?
- How can the potential degradation of driver capabilities due to the daily use of highly automated driving be avoided?
- Are the same skills required for elderly drivers and can this be assessed by an automated vehicle?
- How can automated driving be permitted in a flexible way in the spatial and temporal dimensions?
- How can skills of operators be evaluated for remote driving of vehicles?

Field operation tests will be necessary to develop the basics of driver-vehicle interaction, in particular if new modes of transport are considered.

Reliability of safety-critical systems and components in future vehicles

Expected outcomes: Research is expected to contribute to the following outcomes:

- Continue to advance in passenger safety in the context of circular economy (safety of reused parts)
- Enable safe remote control and monitoring of safety-critical systems
- Ensure a cost-effective level of redundancy of critical components
- Provide the most suitable sensors to assess the reliability of critical components
- Suitable methodologies for the reliability assessment and risk analysis of systems and components in future vehicles

Scope:

The reliability of safety-critical systems and components is a key factor to prevent or minimize the risk of road crashes due to possible system failures. This factor will become more important in future vehicles and, in general, in the future transport system, considering the increased interaction between vehicles and infrastructure, new transport modes or preferred vehicle use like vehicle sharing, in the context of circular economy for greening transport.

Research activities on the reliability of safety-critical systems should take into account all possible hardware, software and human aspects of the system.

In particular, the research should address the safety and reliability of reused components and materials of vehicles and infrastructures, including the remote control and monitoring of safety-critical systems.

Considering all types of future highly automated vehicles (e.g. cars, buses, trucks and other commercial vehicles, shuttles…), research needs to develop of cost-effective redundancy of critical components and sub-systems, as well as sensors and algorithms to monitor and assess in advance the reliability of such systems or possible critical behaviour and performance.

Moreover, research should also focus on the development of suitable methodologies for the reliability assessment and risk analysis of systems and components in future vehicles.

International cooperation is recommended for these research activities, in particular with projects or partners in the US and in Brazil.

Preparing the regulatory framework for safe, secure and inclusive operation of CCAM

Expected outcomes: Research is expected to contribute to the following outcomes:

- Harmonised update of traffic rules enabling the smooth inclusion of highly automated vehicles in mixed traffic while offering legal certainty and security to persons responsible for their behaviour in traffic
- Common usage rules for driverless vehicles defined and accepted by legislative bodies and by the operators of such vehicles and supporting the user acceptance of new mobility services
- Code of behaviour in driverless vehicles designed and promoted by their operators / service providers and other relevant stakeholders
- Suitable technical solutions available against criminal threat scenarios and for conflict avoidance in shared driverless vehicles

Scope:

In addition to new approval schemes and related technical standards for CCAM systems, also the wider regulatory framework will need to be adapted under which highly automated vehicles can operate safely and securely and contribute to the inclusiveness of road transport. In particular, traffic rules need to be addressed as well as usage rules for driverless vehicles, while recommendations for approval schemes and homologation are expected from research to be funded under the call HORIZON-CL5-2021-D6-01.

Traffic rules deserve attention, as 100% strict obedience to all existing rules by automated vehicles may not always be compatible with the objective of supporting smooth and safe traffic flow. In some situations of mixed traffic, such behaviour might even cause safety risks, as it would be hard to anticipate by other road users. In some situations, like obstacles on the road, strict obedience to all traffic rules may also mean that a vehicle may not be able to continue its journey, until the situation is resolved by others. New road transport devices enabled by automation, e.g. delivery robots, should also be considered to the extent to which their operation requires the adaption of traffic rules. The same applies to the perspective of remote operation of road vehicles.

Usage rules will be needed in particular for shared driverless vehicles, as security concerns will emerge from the driver missing as an independent authority to intervene in case of conflicts between individual passengers or to even take action in case of punishable acts. In relatively small shuttle-type vehicles, also the possibilities to relocate within the vehicles for conflict avoidance or to turn to other passengers for help will be limited. The use of shared driverless vehicles by children and the use of protective devices in such vehicles may have to follow new rules in future, as well.

In particular, the following aspects should be addressed:

- Identification of current non-future-proof traffic rules which need to be adapted for smooth and safe inclusion of highly automated vehicles in mixed traffic and for their remote operation
- Identification and assessment of conflict and criminal threat scenarios in future shared driverless vehicles (e.g. robo-shuttles) taking into account the needs of all user groups and investigation of corresponding technical solutions. The perception of security and its variation with factors like age and gender should be taken into account, as well as knowledge and experience from other modes, in particular from rail transport.
- Identification of conditions under which children in particular can use shared driverless vehicles in a safe and secure way
- Analysis of particular regulatory needs for the use of protective devices in such vehicles
- Preparation of proposals for rulemaking, enforcement and, if required, for technical standardisation addressing the aspects above in a harmonised European approach based on scientific evidence
- Based on previous research on societal and citizen expectations (incl. projects to be funded under HORIZON-CL5-2021-D6-01-05, Area B), analyse how to design a code of behaviour in driverless vehicles

Due consideration of the human factors dimension both with regard to occupants and with regard to other traffic participants will be necessary, and the inclusion of SSH expertise will be essential to produce meaningful and significant results. Links to large-scale demonstration projects need to be established to leverage their relevant outputs effectively and to efficiently feed results back into such demonstration projects.

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6 Annex

6.1 Current EU funded R&I projects related to road safety

Acronym	Full project title and website
Drones4Safety	Inspection drones for ensuring safety in transport infrastructures *https://drones4safety.eu/*
FITDRIVE	Monitoring devices for overall fitness of drivers
HADRIAN	Holistic approach for driver role integration and automation allocation for European mobility needs *https://hadrianproject.eu/*
HEADSTART	Harmonised European solutions for testing automated road transport *https://www.headstart-project.eu/*
Hi-Drive	Addressing challenges toward the deployment of higher automation *https://www.hi-drive.eu/*
i-DREAMS	Safety tolerance zone calculation and interventions for driver-vehicle-environment interactions and challenging conditions *https://idreamsproject.eu/*
LABYRINTH	Unmanned traffic management 4D path planning technologies for drone swarm to enhance safety and security in transport *labyrinth2020.eu/*
MEDIATOR	Mediating between driver and intelligent automated transport systems on our roads *https://mediatorproject.eu/*
PANACEA	Practical and effective tools to monitor and assess commercial drivers' fitness to drive *https://panacea-project.eu/*
SAFE-UP	Proactive safety systems and tools for a constantly upgrading road environment *https://www.safe-up.eu/*
VIRTUAL	Open access virtual testing protocols for enhanced road users safety *https://projectvirtual.eu/*

6.2 Table of figures

6.3 List of Abbreviations

Abbreviation	Meaning
ADAS	Advanced Driver Assistance Systems
ADHD	Attention Deficit Hyperactivity Disorder
AI	Artificial Intelligence
CCAM	Connected, Cooperative and Automated Mobility
EC	European Commission
EDR	Event Data Recorder
ERTRAC	European Road Transport Research Advisory Council
EU-28	European Union plus the United Kingdom
FOT	Field Operational Test
FP7	7th Framework Programme for Research and Technological Development
GDPR	General Data Protection Regulation
GIDAS	German In-Depth Accident Study
HBM	Human Body Models
HTI	Human-Technology Interaction
ICADTS	International Council on Alcohol, Drugs and Traffic Safety
IGLAD	Initiative for the Global Harmonization of Accident Data
IRTAD	International Traffic Safety Data and Analysis Group
ISAD	Infrastructure Support Level for Automated Driving
ISO	International Organisation for Standardisation
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
L0	SAE Level 0 of automated driving: No automation
L3	SAE Level 1 of automated driving: Conditional automation
L4	SAE Level 4 of automated driving: High automation
ODD	Operational Design Domain
OECD	Organisation for Economic Co-operation and Development
R&I	Research and Innovation
RFID	Radio-frequency Identification
SAE	Society of Automotive Engineers
SDG	Sustainable Development Goal
SRIA	Strategic Research and Innovation Agenda
SSH	Social Sciences and Humanities
TASC	Traffic Accident Scenario Community
UNECE	United Nations Economic Commission for Europe
V2I	Vehicle to Infrastructure
V2X	Vehicle to Everything