



# Safe Road Transport Roadmap

**Towards Vision Zero:  
Roads without Victims**

Status: Final draft

Date: 28.02.2019

ERTRAC Working Group:  
Road Transport Safety & Security



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## 2. EXECUTIVE SUMMARY

In its Vision for 2050, the European Road Transport Research Advisory Council (ERTRAC) provides long-term objectives for the improvement of road transport in the coming three decades. Being safe and secure at any time when using the European road transport system is included as an important objective in this vision. However, 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 since 2013. As a consequence, important European safety targets are getting out of reach. Neither will road fatalities be cut by 50% in the current decade, nor is the EU likely to move close to zero fatalities by 2050. A continuation at the current level of ca. 25,000 road fatalities and ca. 1.4 million 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 are key factors here. In this roadmap, ERTRAC proposes a set of eleven high-priority road safety research needs with a suggested timing for their inclusion in “Horizon Europe”, the next EU framework programme. These needs have been developed in intensive cooperation of experts from European industry, academia, research providers, road user associations and public authorities. Research and innovation projects addressing these needs should give ample room for citizens and road users themselves to engage.

The overall scope of the roadmap is broad, covering all elements of the road transport system, all road transport modes and all phases from preventive to post-crash safety. This document complements several other ERTRAC roadmaps, in particular the roadmap on Connected and Automated Driving, as connectivity and automation show the potential to substantially improve road safety, even if they will not avoid all crashes. Also the ERTRAC roadmap on Integrated Urban Mobility is highly complementary to this document, since many road safety issues have to be tackled on the road transport system level, rather than by focussing on its individual elements only.

The safety-related research needs from these roadmaps will best be addressed in a comprehensive safety research and innovation programme. This programme should follow the common mission of “Roads without victims” with the objective to deliver, until 2030, all the road safety measures which need to be implemented to move close to Vision Zero according to the EC political target. If such a road transport system in which no-one was killed or severely injured anymore became a reality in 2050, several hundred thousands of lives could be saved until then and socio-economic costs in the order of magnitude of 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.

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<sup>1</sup>. 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

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 and many more severe injuries over the last few years<sup>2</sup>. Since the vast majority of these crashes are caused by human error (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 roadmap than in most other ERTRAC roadmaps.

<sup>1</sup> Strategic Research Agenda, Input to 9th EU Framework Programme, ERTRAC, 23.03.2018

<sup>2</sup> Road safety evolution in the EU, based on CARE (EU road crash database) or national publications [https://ec.europa.eu/transport/road\\_safety/specialist/observatory/statistics/charts\\_and\\_figures\\_en](https://ec.europa.eu/transport/road_safety/specialist/observatory/statistics/charts_and_figures_en)

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.

## 3.2. State of the art

Horizon 2020, the EU Framework Programme for Research and Innovation, covers a period of 7 years: 2014 to 2020. Input on the topics of safety and security research were proposed in the ERTRAC Safe Road Transport roadmap dating from 2011 and by the PROS Coordination and Support Action that delivered its road safety roadmap by the end of 2014<sup>3</sup>. 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
- 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, five 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

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

<sup>3</sup> Urban, P., Op den Camp, O., Skogsmo, I. "Priorities for Road Safety Research in Europe (PROS) – final report", grant agreement No. 314427, January 2015

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 2011 to 2021, covering projects that have been running during the Horizon 2020 programme period from 2014 - 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 H2020 projects are shown with blue arrows, while green arrows indicate projects which are still running.

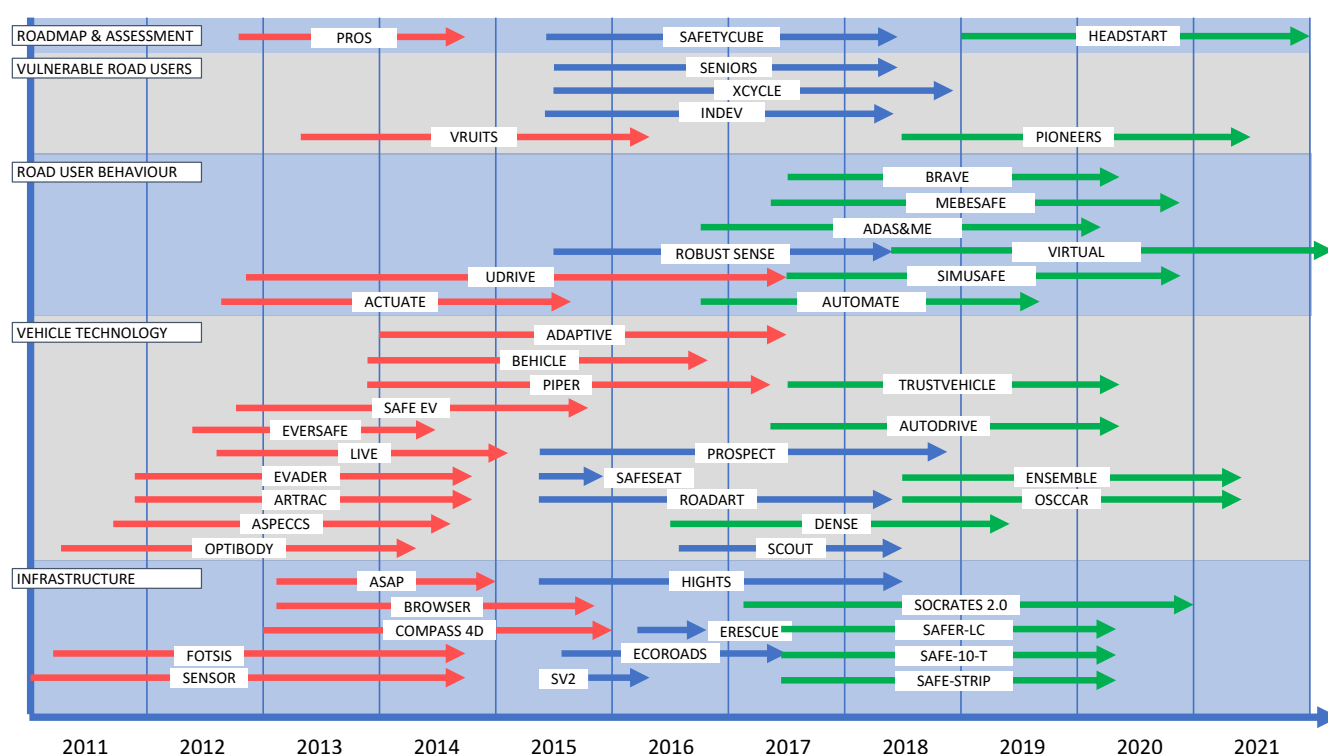


Figure 1: Overview of EC funded projects dedicated to road safety

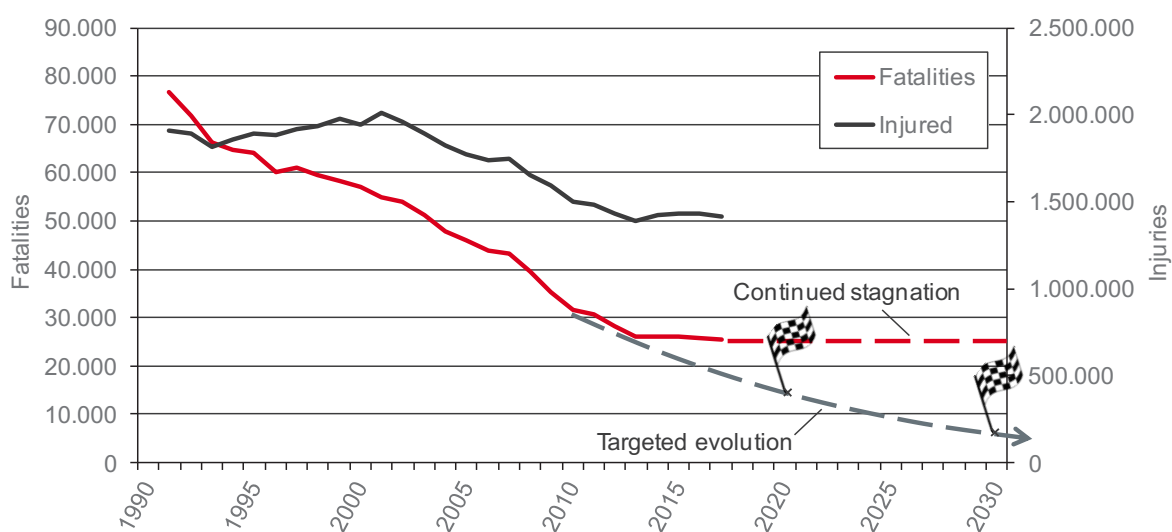
In the Horizon 2020 Framework Programme, projects have evolved from technological research and development towards innovation with a focus on the interaction between all road users, considering the impacts of new developments on human behaviour and user acceptance as well as the added value of the proposed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

### 3.3. Policy context, challenges and objective

With 1.35 million fatalities in 2016, 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<sup>4</sup>. With good cause, road safety is therefore well reflected in the UN Sustainable Development Goals (SDGs) set in 2015, in particular in SDG 3.6 ("By 2020, halve the

number of global deaths and injuries from road traffic accidents”) and SDG 11 (“Make cities and human settlements inclusive, safe, resilient and sustainable”). Unfortunately, the goal of halving the global number of road fatalities by 2020 is unlikely to be met, but global road fatality figures are still growing.

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 since 2013 resulting in an increasing gap versus the EC long-term targets, as indicated by the dashed lines in Figure 2. 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. Most probably, road fatalities will not be cut by 50% in the current decade until 2020, as called for in the EC Policy Orientations on Road Safety 2011-2020. Extrapolating the current 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 sets the interim target of minus 50% between 2020 and 2030, which seems very ambitious in view of the current trend, as well.



**Figure 2: Road safety evolution in the EU<sup>5</sup>**

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 25,300 lives of EU citizens in 2017 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 120 billion are a major burden to the European economy<sup>6</sup>. Clearly intensified efforts therefore have to be made by all relevant stakeholders not to completely miss the long-term objective of “Vision Zero”, meaning a transport system in which human life is the paramount concern and no-one is killed or severely injured anymore.

<sup>5</sup> Road safety evolution in the EU, based on CARE (EU road crash database) or national publications [https://ec.europa.eu/transport/road\\_safety/specialist/observatory/statistics/charts\\_and\\_figures\\_en](https://ec.europa.eu/transport/road_safety/specialist/observatory/statistics/charts_and_figures_en)

<sup>6</sup> Safe Mobility: A Europe that protects, factsheet, The European Commission, 2018

Research and innovation are key factors in such efforts, and connected and automated road transport 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 fact that human error is a major factor in more than 90% of road crashes<sup>7</sup>. By increasing the automation of vehicles, the reduction of the need of human intervention should decrease the risk of collisions. The first applications of higher automation levels which are on the verge of reaching the market, however, address relatively safe traffic scenarios and, therefore, will only have limited influence on the number of road fatalities and seriously injured. 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, where many severe crashes occur today. 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 to a data collecting network. Moreover, a limited number of collisions may even be caused by failures of automated driving functions or by imperfect hand-over of control between vehicle and driver.

In the end, it is not one single technological solution, but the combination of innovations targeting all elements of the road transport system, including the control and management of vehicles and infrastructure, and all road users which may bring Europe closest to Vision Zero. The EC therefore follows the internationally recognised “Safe System Approach”, which accepts that people make mistakes and aims to ensure that this does not lead to fatalities or serious injuries. As a consequence, the safety of all parts of the system needs to be improved – vehicles, road infrastructure and the behaviour of all road users – so that if one element fails, another one will compensate.

In addition to the implementation of known measures, clearly intensified efforts in a comprehensive safety R&I programme are therefore needed. This programme should follow the common mission to drastically improve road safety towards Vision Zero. This mission is also referred to as “Roads without victims”. It clearly fulfils the criteria for missions in Horizon Europe from the so-called Mazzucato report<sup>8</sup> in being bold, inspirational with wide societal relevance, requiring cross-disciplinary, cross-sectoral and cross-actor innovation and giving room for multiple bottom-up solutions. As a clearly targeted and ambitious, but realistic objective of such a comprehensive R&I programme, ERTRAC proposes to deliver, until 2030, all the road safety measures needed to achieve this mission and finally move close to Vision Zero according the EC political target.

Primarily in this roadmap and complemented by its roadmaps on Connected and Automated Driving and Urban Mobility, ERTRAC puts forward a set of high-priority R&I topics following the ambition described above.

**A comprehensive R&I programme on road safety is needed.**  
 The programme should follow the **mission** of “Roads without victims”.  
 As an **objective**, it should deliver, until 2030, all the road safety measures which need to be implemented to move close to Vision Zero according the EC political target.

<sup>7</sup> Maurer, M., Gerdes, J.C., Lenz, B., Winner, H., “Autonomes Fahren – Technische, rechtliche und gesellschaftliche Aspekte”, Springer Open, ISBN 978-3-662-45853-2, 2015 (based on data from the German In-depth Accident Study GIDAS)

<sup>8</sup> Mazzucato, M., “Missions-oriented R&I in the EU”, February 2018



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
- Increasing the acceptance and leveraging the potential of connected and automated driving in improving safety

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 the beginning of the next decade onwards, a cumulative total of more than 400,000 lives could be saved and ten 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.

### 3.4. 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 the identified challenges to reach the ambitious goals set for the European Union and for its individual member states. With the current development in many parts of Europe, where the numbers of fatalities and serious injuries no longer decrease, but, in certain countries, even increase, it is even more important that the correct measures are taken and that resources are used wisely.

The specific challenges identified should lead to targeted efforts in research and innovation. ERTRAC calls for pre-competitive collaboration among European industry, academia and research providers. The key role of public authorities is also highlighted, in particular 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 elements of the road transport system (users, vehicles and their environment), all road transport modes and all phases of safety from preventive to post-crash safety.

Chapter 4, which is the main part of the roadmap, outlines in detail the most important needs for road safety R&I in Europe, structured according to the following headlines for each R&I need:

- Specific challenge
- Scope
- Expected impact

This gives the reader a clear view of the identified areas, including a clarification of the proposed timing of the corresponding R&I activities.

### 3.5. Complementarity between ERTRAC roadmaps

The Safe Road Transport roadmap is strongly connected to several other ERTRAC roadmaps, especially the roadmaps on Connected and Automated Driving and Urban Mobility. Within the Connected and Automated Driving roadmap, there is for instance the key challenge “Safety validation and roadworthiness testing”, with direct implications on the Safety roadmap, calling for a systematic approach when it comes to testing and verification of vehicles at different levels of automation, also taking into account the self-learning aspects of these vehicles. Also with regard to the connection to infrastructure and human technology interaction, the roadmaps complement each other. More specifically, the concepts of Operational Design Domains (ODD)<sup>9</sup> and Infrastructure Support Levels for Automated Driving (ISAD)<sup>10</sup> 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.

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 pedestrians and two-wheelers with a varying degree of connectivity and information is one of the top challenges requiring cross-thematic approaches.

These three roadmaps interplay and create a solid foundation for the research needed to reach the afore-mentioned goals, with the R&I described in the Connected and Automated Driving roadmap providing the framework and boundary conditions for automated driving including cyber security aspects. Safety is, of course, a cornerstone in this context. The Integrated Urban Mobility roadmap sets the scene on a higher system level with priorities for a sustainable and reliable transport system in urban areas with high accessibility, while the R&I described in the Safety roadmap is to make sure that these transport modes and systems will be designed and finally be used by all types of users on roads without victims, i.e. without crashes causing fatalities or severe injuries.

<sup>9</sup> “the specific conditions under which a given driving automation system or feature thereof is designed to function” [SAE J 3016-2018]

<sup>10</sup> 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](http://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 a series of workshops in 2017 and 2018, elaborated by a group of experts in the specific areas, and further refined based on electronic feedback loops.

Road safety research should start from the human road user, who needs protection, in particular if travelling as a largely unprotected road user (pedestrian, cyclist, powered two-wheeler rider). Therefore, the safety of unprotected road users needs special research attention (paragraph 4.2). The starting point for a comprehensive approach towards road safety from a human perspective, however, is a cultural one: A framework to improve traffic safety culture in the EU should be built up (paragraph 4.1). The way that humans interact with other elements of the road transport system, i.e. vehicles and infrastructure, is currently already undergoing change and will do so even more in a future of connected and automated road transport. Road user capabilities, therefore, need to be assessed in future scenarios of road transport (paragraph 4.3) and safe human-technology interaction to be ensured in a digital traffic system (paragraph 4.4). The latter will see new means of transport, which need to be included safely (paragraph 4.5), and the safety of highly and fully automated vehicles is a research topic of particular interest in this context (paragraph 4.6). Still, crashes will continue to occur, so that their consequences need to be mitigated. New ways of understanding and reducing long-term injuries are needed to this end (paragraph 4.7) as well as advanced care and rescue measures to minimize long-term effects (paragraph 4.8).

Finally, infrastructure safety must be addressed to make use of the room for improvement in all elements of the road transport system (paragraph 4.9). With an increased speed of technological development, but relatively slow penetration of innovations in the traffic system, existing ex post assessment methods of the impact of new solutions are not sufficient anymore, and a predictive safety assessment and validation framework is urgently needed (paragraph 4.10). While all this research is intended to contribute to a drastic reduction of fatalities and injuries in Europe, the road safety challenge is even much more massive in other parts of the world and in particular in middle- and low-income countries. Therefore, last but not least, there is also a specific need for research on the radical improvement of road safety outside Europe and OECD countries (paragraph 4.11).

Based on a survey among ERTRAC experts, the afore-mentioned research needs have been assigned to different time periods taking into account criteria such as the urgency, the complementarity and the technological feasibility of different research activities (Figure 3). Detailed descriptions of the specific challenges, scopes and expected impacts of the individual topics are given in the following paragraphs.

Research Need		Time period		
		2021-2022	2023-2024	2025-2027
1	Building a framework to improve traffic safety culture in the EU		x	
2	Safety of unprotected road users	x		
3	Assessment of road user capabilities in future scenarios of road transport		x	
4	Safe human-technology interaction in the digital traffic system	x		
5	Safe inclusion of new means of transport into the traffic system	x		
6	Safety of highly and fully automated vehicles			x
7	New ways of understanding and reducing long-term injuries			x
8	Care and rescue measures to minimize long term effects		x	
9	Infrastructure safety		x	
10	Predictive safety assessment and validation framework	x		
11	Radical improvement of road safety outside Europe and OECD countries			x

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

## 4.1. Building a framework to improve traffic safety culture in the EU

### Specific challenge:

Road safety figures across the EU are stagnating and comparative analysis shows persistent differences in safety performances between Member States, which are hard to explain with “classical” means of analysis. It seems that well-established approaches to prevention do not deliver further improvement. Efforts have recently been made to complement road safety initiatives by a safety culture perspective, a concept already well established in organisational

research. Assessing 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 – and can likewise lead to tailored countermeasures for these (sub-) cultures, which all come with their specific norms, values, beliefs and behaviours. This should address all relevant actors in the road transport system and take into account potential impacts by increasing automation levels in road transport, in particular in relation to artificial intelligence (AI) being deployed in vehicle control.

#### Scope:

An action framework for cultural transformation in road safety across the EU should:

- devise and discuss a European theoretical model for traffic safety culture, considering interrelations such as of values, beliefs, attitudes, norms as well as of habits, willingness and intention and their influence on actual behaviour of road users
- provide hands-on advice for different target groups how to define, measure, transform and institutionalise traffic safety culture
- collect, collate and make known to all relevant stakeholders good practices from countries and companies worldwide already successfully applying cultural approaches to (road) safety work
- advise how to design and evaluate targeted measures and interventions during the change process with a view to informing national road safety strategies
- cover in particular – but not exclusively – behavioural areas of road safety with substantial impact on severe outcomes (fatalities and serious injuries) such as: inadequate speed choice, driving under the influence of alcohol or drugs, non-use of protective devices, and distraction by modern communication technology
- tackle 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
- actively involve citizens in the development of easily acceptable and thus effective measures
- oversee pilot testing of selected measures
- establish a web-based repository of knowledge and ready to use measures
- devise a dissemination strategy to reach all relevant road safety stakeholders both in the Member States and at EU level

Integration of relevant expertise from social sciences, including partners from the US, would be considered beneficial.

#### Expected impact:

- Contribute to making the concept of traffic safety culture an integral part of road safety work of actors across the socio-economic systems of European societies
- Raise the efficiency in road safety related public spending across Europe and contribute to the long-term road safety goals of the EU
- Strengthen the EU position as an attractive business location with the safest roads globally

## 4.2. Safety of unprotected road users

### Specific challenge:

Urbanisation leads to a dense population that needs accessible homes, shops and work places, clean air and a liveable environment. Changing to smaller vehicles and using collective, active or electrified modes of transport can deliver this and that is also why road users and (local) policy makers increasingly favour cycling and walking. The arrival of new micro-mobility devices such as electric scooters adds new challenges on urban roads in particular. A consequence of this, however, is an increasing share of unprotected road users (pedestrians, cyclists and powered two-wheeler riders) in crash statistics. Almost half of all European road fatalities concern (powered) two-wheelers and pedestrians<sup>11</sup>. Where reliable statistics are available, the share of unprotected road users is even larger in severe injuries than it is in fatalities<sup>12</sup>. Riders and pedestrians have a relatively high risk because they have less safety solutions available compared to other road users. Therefore, the most promising safety measures will address infrastructure and road user behaviour, these unprotected road users' single vehicle crashes, as well as their crash opponent when there is one.

### Scope:

In order to meet this challenge, the following aspects should be addressed:

- Factors and causes of crashes involving unprotected road users
- Human factors related to risky behaviour (distraction, fatigue, impairment, breaking of traffic rules such as speeding etc.)
- Effective training, education and enforcement
- Protective wear (helmets, clothes) that is effective, user-friendly and capable to trigger higher usage rate
- Safety measures on the unprotected road users' vehicles which improve stability, help prevent crashes by other means (intelligent/advanced braking assistance systems...) or even offer crash protection
- Improved detection of unprotected road users by other road users, e.g. making use of vehicle-to-vehicle (V2V) and/or vehicle-to-infrastructure (V2I) communication
- Safety issues and countermeasures for personal light electric vehicles (PLEV), especially operating in an urban environment (including mobility or electric scooters)
- Safe routes and infrastructures for walking and cycling addressing the needs of the elderly and children, potentially including urban planning and also exploring possibilities to utilise apps as a tool for unprotected road users
- Powered-two-wheeler-friendly infrastructures, including barriers and pavements
- Preparation of innovative road safety policies which take account of specific challenges regarding unprotected road users as well as sustainable transport objectives

<sup>11</sup> [https://ec.europa.eu/transport/road\\_safety/specialist/observatory/analyses/basic\\_facts\\_en](https://ec.europa.eu/transport/road_safety/specialist/observatory/analyses/basic_facts_en)

<sup>12</sup> E.g. Netherlands <https://www.swov.nl/en/facts-figures/factsheet/serious-road-injuries-netherlands>

#### Expected impact:

- Reduction of at least 10% (with respect to 2016 figures) in injuries and fatalities in road crashes with unprotected road users by 2030
- Facilitating a substantial modal shift to active and clean modes of transport, improving the health of road users and the quality of urban environments
- Facilitating inclusiveness by offering the elderly and children a safe and accessible mode of transport
- Strengthen the competitiveness of the European transport industry (PLEV, infrastructures) by adding a competitive edge in this age of worldwide urbanisation and ageing societies

### 4.3. Assessment of road user capabilities in future scenarios of road transport

#### Specific challenge:

Substantial research has already been done to assess the capabilities of road users in various situations. However, the automation and the electrification of road transport are bringing up new challenges for all types of road users especially if demographics are considered as well. For drivers, more potential synergies with experience from automation concepts in particular in the aviation sector have to be evaluated. Moreover, different factors contributing to an individual's driving skills such as physical capabilities, reaction time, cognitive and perceptual motor abilities along with visual acuity especially at night time are currently being evaluated. However, with increasing automation, other driver skills might be required, which have not been investigated sufficiently yet. Additionally, the electrification of all types of vehicles will change the behavioural interaction between road users. As a matter of fact, those impacts have never been assessed thoroughly, either.

#### Scope:

The following questions need to be addressed by future research:

- How can the potential degradation of driver capabilities due to the daily use of automated driving mode (L4) be avoided?
- 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?
- Are the same skills required for elderly drivers and can this be assessed by a L4 vehicle?
- How can the natural learning process of becoming an experienced driver be kept in place?
- How can automated driving be permitted in a flexible way in the spatial and temporal dimensions?
- How to differentiate between professional and non-professional users?
- How can skills of operators be evaluated for remote driving of vehicles?
- How much will road safety be affected by electrification?
- What will be the impact of those new technologies to an ageing society?
- Are there any new training processes required as a road user?

**Expected impact:**

- The above 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 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.

## 4.4. Safe human-technology interaction in the digital traffic system

**Specific challenge:**

With technological devices in road transport becoming connected and making use of AI analysing vast amounts of data inputs, the human is no longer the only operator of transport systems, but provides a partial input to the control system and becomes an inclusive part of it. This has large implications in terms of human-technology interaction with potentially high impact on human safety in road transport with connected vehicles in an automated road transport environment. As every human is different, adaptive systems have to be further explored, not only for driver-vehicle interaction, but for any human-technology interaction in road transport. Such systems should consider long-term mental and physical capacity (including disabilities and disorders) as well as instantaneous limitations in capabilities (drunkenness, drowsiness, etc.).

Another challenge for the digitalised transport systems and services is their even more intensified integration with various other digital systems and services of life, which can have positive and negative impacts on safety. For example, overload of all kinds of information from various sources might lead to increased driver, rider and pedestrian distraction, while the automated optimisation of travelling to reach the next destination without unnecessary rush may be beneficial for road safety.

**Scope:**

In particular, the following aspects should be considered by future research:

- Development of unobtrusive human vitals and behaviour monitoring for fitness to drive, driver state and health assessment taking into account privacy and ethical issues, targeting applications in automated driving as well as in acute and long-term health monitoring (also for unprotected road users)
- Design of reliable, seamless and adaptive interfaces between human and technology in road transport (e.g. automated driving functions) not relying on trained knowledge and abilities, but based on comprehensive knowledge and models of human individual behaviour and capabilities and of communication methods used in road transport
- Testing methods for the validation of such adaptive systems
- Design of external interfaces taking into account the characteristics (for instance speed, direction) of all road users in order to be readable, possible to interpret and understandable by all of them.
- Safety repercussions from the integration of the digitalised road transport system with all other digital systems of life



#### Expected impact:

- The distraction of drivers, riders, pedestrians and other road users as an important factor in road crashes is reduced or safely handled. Users are informed perfectly and unobtrusively about the distribution of control roles and expected actions at any time even if there are none, reducing substantially human error as the by far most important factor in road crashes.
- Safe mobility is ensured even for users who show impaired mental and physical capacity.
- Homologation and testing/validation processes adopt the adaptability of new vehicle systems.
- System models implement the human as an integral part of control systems, thus providing necessary background for design and management guidelines of adaptive automated systems.
- New technology positively stimulates and utilizes human abilities.

## 4.5. Safe inclusion of new means of transport into the traffic system

#### Specific challenge:

With the deployment of automated driving in other environments than confined areas and highways, automated vehicles will have to interact with non-automated, non-connected and in particular with unprotected road users. While automated vehicles will have to be trained to cope efficiently and co-operatively with the extreme multitude of possible traffic situations, road safety may benefit from also training humans to cooperate with these new forms of road transport.

Apart from the automation of land vehicles, recent technological advances bring closer the introduction of flying vehicles (vertically taking off and landing vehicles - VTOLs) into the ground-based transport systems of the future. Managing this new air traffic is an undoubtedly large challenge. Moreover, there is an important repercussion on road traffic and safety not only at the air-ground interface, but also with regard to the incorporation of these new types of vehicles into the road traffic.

#### Scope:

The following questions need to be addressed:

- How will the traffic system change with increased automation and how will this affect scenarios related to safety?
- What solutions can be applied to improve the perception of (non-automated) unprotected road users including robust predictions of their future behaviour? How to avoid undesired interaction between automated vehicles and other road users, considering safety and acceptance criteria?
- What solutions can be developed to make unprotected road users nodes in the cooperative intelligent transport system and enhance their conspicuity?
- How can potential extreme behaviour of non-connected users, such as crossing suddenly in front of automated vehicles, be handled reliably by automated driving functions and control strategies?

- How can the safety of automated systems in coping with non-automated users be assessed?
- How can humans be trained and educated to cooperate with automated vehicles on different automation levels?
- How can a safe air-ground interface be designed for the take-off and landing of VTOLs fully integrated in road traffic flows? What does this imply for the further development and design of VTOLs?
- How can air and road traffic be managed co-operatively taking into account potential safety hazards in particular to unprotected road users?

**Expected impact:**

- Concepts and systems for safeguarding unprotected and non-connected users' safety in mixed flows with automated vehicles
- Training and educational schemes for of all stakeholders to optimise the implementation of mixed fleets and traffic flows
- Concepts and systems for VTOLs integration into road transport

## 4.6. Safety of highly and fully automated vehicles

**Specific challenge:**

Many use cases are conceivable for highly and fully automated vehicles with their specific safety issues. Users of public shared automated vehicles such as robot shuttles, for example, may not wish to buckle up, but move around freely in such vehicles as known from other means of public transport. Conditions under which this may be acceptable should be investigated as well as appropriate alternatives to conventional restraint systems for these use cases. Moreover, the need for a code of behaviour in highly and fully automated vehicles and potential access regulations in particular to driverless vehicles should be analysed from a road safety perspective taking into account security issues, as well.

Independent from the specific use case, increasing levels of automation also demand higher reliability of critical vehicle systems. While mechanical components such as brakes, steering system, suspension and propulsion may be provided with sensors to assess their level of serviceability and reliability, for highly connected automated and remotely controlled vehicles, it is necessary to provide fail-operational critical in-vehicle systems that allow a safe and secure completion of the driving task even in case of failure of control systems or loss of communication in complex traffic situations. At the same time, V2V and V2I communication offers great potential to improve road safety in situations which vehicle-individual systems cannot handle. The extent of this benefit should be established and sensible preconditions defined to give advice on the most effective and efficient functions of such communication.

For automated vehicles, situations are even conceivable in which disobeying a traffic rule might serve the paramount objective of human life and wellbeing, e.g. in case of medical emergency. Moreover, traffic rules may have to be disregarded in some situations in order to avoid traffic breakdowns, e.g. crossing a continuous lane line because of a static obstacle on the road ahead. Relevant situations and corresponding needs for adaptations of existing rules should be analysed in detail.

#### Scope:

Research will need to address the following issues:

- Under what conditions may occupants be allowed to remain unbelted or even move around freely in highly and fully automated vehicles? What safety systems may be required for this?
- How should a code of behaviour for the use of such vehicles look like and how should appropriate access regulations to driverless vehicles be designed?
- What is the adequate and cost-effective level of redundancy of critical components and the level of reliability of the redundancy management systems? What are the required reliability levels of in-vehicle systems to assure a safe remote control of automated vehicles?
- What sensor systems are most suitable to assess the serviceability and reliability of critical mechanical components?
- How and to what extent can V2X communication enable new safety functions and extend road user protection beyond existing limits? To what extent do safety and security requirements for the cooperative infrastructure need further development?
- Under which conditions could specific traffic rules be relaxed for automated vehicles?

#### Expected impact:

- Increased acceptance of highly and fully automated vehicles
- Reduced human suffering and burden for the health care system, while making best possible use of the potential safety benefits of road automation.

## 4.7. New ways of understanding and reducing long-term injuries

#### Specific challenge:

Car occupant fatal and severe injuries keep decreasing, but not the more frequent non-life threatening injuries with long-term consequences. Unprotected road users such as bicyclists frequently sustain such non-life threatening injuries. In cars, residual low severity collisions causing long-term injuries – like whiplash associated disorders – are expected, despite new collision avoidance/mitigation systems. Injuries to the upper extremities are other examples, occurring for all road users. As of today, no standardized methods for evaluation exist. In addition, there is a need to include more aspects of variability like age, gender, size and stature of in-vehicle and external road users, in particular taking into account completely new types of mobility solutions entering the market.

Technology advancements also affect the “tool” side, and Human Body Models (HBMs) have the potential to provide input for design guidance and for the assessment of future advanced protection systems. The effectiveness of these systems must be assessed in a wide range of load cases, not only in the singular cases which current dummy-based testing offers.

#### Scope:

The following research needs should be addressed:

- The robustness of road safety measures for the wide range of age, gender, size and stature
- Assessment procedures to validate the effectiveness of improved protection for this wider range of road users
- Improved HBMs with new biomechanically based injury criteria and detailed biofidelity

- Development and verification of injury mechanisms of non-life threatening long-term injuries
- New biological experimental work linking initial injury and long-term sequels
- Collection of new in-depth accident data for accident reconstruction and long-term injury follow-up to help establish injury criteria
- Adaptation of HBMs to evaluate personal protection and forgiving road infrastructure for unprotected road users.

**Expected impact:**

Sharply reduced number of costly non-life threatening injuries in new vehicles due to improved safety assessment methods, which incorporate virtual testing including biofidelic HBMs with new injury assessment criteria representing a wide range of road users in a wide range of crash situations.

## 4.8. Care and rescue measures to minimize long-term effects

**Specific challenge:**

A significant part of deaths and severe injuries occur in the post-crash phase. These should be reduced by applying new and improved methods and working procedures in this phase. This includes better and improved eCall functionalities, smarter and more appropriate call-taking and blue light dispatching, en-route support to blue light resources, better on-scene diagnosis and triage methods for critical injuries like traumatic brain and thorax injuries, improved work and secure environment for rescue personnel, improved extrication and fire handling procedures etc. Moreover, there is an urgency to investigate the extension of eCall to the most vulnerable and unprotected users.

**Scope:**

The following aspects need to be considered:

- Further development of communication systems and standards for emergency services and pre-hospital actions
- En-route support to blue light resources based on V2X communication
- Deployment of AI and similar data analysis tools to improve injury severity prediction algorithms and on-scene diagnostics
- Analysis of how the human body is affected through extrication methods and similar activities to avoid further injuries and further develop rescue procedures
- Extension of eCall functionality to other categories of vehicles, such as heavy goods vehicles, buses and coaches, powered two-wheelers, and agricultural tractors
- Extension of eCall functionality to other unprotected road users
- Extension of eCall protocols towards maximum forces and accelerations recognition and estimation of injury severity to support emergency services through pre-hospital decision support systems
- Definition of threshold values in the alerts to emergency services to avoid overload and unnecessary reactions

#### Expected impact:

Drastically reduced number of deaths and severe injuries using:

- Innovative solutions, concepts and algorithms for eCall extension towards other types of vehicles and road users beyond cars and light commercial vehicles as well as extended eCall functionalities for all types of road users
- More rapid and accurate information of emergency services on road crashes, improved rescue procedures and better medical support for reduced fatality and impairment rates, less human suffering, reduced psychological impacts, lower burden for the health care system, faster rehabilitation and reduced total socio-economic costs

## 4.9. Infrastructure safety

#### Specific challenge:

Road infrastructures are often not up to date and deteriorating, increasing the risk of crashes and other incidents as well as crash severity. Consequences of this will be amplified in a connected transport system where automated or partially automated vehicles rely on the infrastructure features to perform as expected. In addition, road infrastructure is sometimes not providing clear guidance towards desirable road user behaviour, which may lead to confusion and unpredictable behaviour, and as a consequence to 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 on the surrounding territory is extremely relevant. Low cost and low impact interventions need to be studied for these roads.

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

#### Scope:

Topics 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.
- Development of new low impact maintenance techniques for road equipment (including but not limited to roadside safety features, signs and marking, lighting)

- Integration of safety and V2I issues in asset management to ensure that the infrastructure is capable at all times to provide the minimum required level of performance to provide safe travel conditions for automated vehicles (ISAD concept)
- 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

**Expected impact:**

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.

## 4.10. Predictive safety assessment and validation framework

**Specific challenge:**

The road traffic system is changing with increasing automation and communication and so will scenarios which are relevant for safety. Such scenarios are not yet captured in accident databases, and traditional analysis methods and road studies can no longer predict the impact of new developments and new measures on road safety. Also for already developed safety measures, scenarios need to be provided which cover more complex transport system levels where safety can be described in terms of risk and probability due to interplay between societal and technological driving forces as well as different stake-holder and user needs. Field operational tests and naturalistic driving studies, vehicle- or infrastructure-based, are needed to get an insight in mixed conventional and automated traffic and to understand the scenarios with all types of road users when higher levels of automation are introduced. The number of scenarios which have to be considered in future safety assessments is increasing drastically in order to be able to assess the response of systems for all relevant situations, conditions, system interactions and interactions with other road users.

Virtual simulation allows for fast and extensive evaluation of safety measures even in scenarios which do not exist in real traffic yet. With growing computer power, safety assessment methods should therefore be extended to potential future scenarios and to the transport system level also allowing for the evaluation of socio-economic benefits. Such predictive assessment requires appropriate simulation environments and realistic models of all elements of the transport system (incl. human behaviour and traffic flow), which need to be validated by physical testing and harmonised to make them available for regulatory and consumer assessment.

With the increasing automation of vehicles, techniques based on AI or machine learning are gaining increasing relevance. Machine learning is among other things also applied to predict road user behaviour and train decision and control logic algorithms of automated driving systems. Such systems will even continue to learn during the application of the systems on the road, which is an additional challenge in terms of their safety assessment.

#### Scope:

- New methods are needed to efficiently predict the effects of road safety improvements by technology, infrastructure or behavioural changes up to the level of socio-economic benefits.
- How will the application of new technologies such as AI affect the remaining road safety burden in the medium to far future? How will traffic and crash scenarios change with the introduction of these technologies and with their market penetration taking into account self-learning capabilities?
- How to derive appropriate test scenarios using less critical but more frequent events than collisions? How to determine how well a selection of scenarios covers all possible scenarios a system might need to respond to on the roads of the future?
- The assessment framework should allow for the virtual prototyping of systems based on self-learning technology and AI. How to provide a sign-off of such systems? When is the system sufficiently trained without having experienced all possible situations?
- A self-learning system is principally dynamic, as its properties will change with time and with in-creasing experience on the road. How to perform a continuous safety validation of such vehicle systems?

#### Expected impact:

- Harmonization of a prospective assessment and validation framework for road safety solutions will allow all stakeholders to compare different measures for decision making.

## 4.11. Radical improvement of road safety outside Europe and OECD countries

#### Specific challenge:

Today, more than 90% of road traffic fatal crashes occur in low- and middle-income countries outside Europe. These countries will not necessarily follow the fast technological development in Europe.

Automated vehicles with their potential to improve road safety will be a reality in Europe and in other developed countries in the near future and will become a reality in other parts of the world, as well. Connected and automated driving is expected to improve road safety, but globally, the penetration of automated vehicles is likely to remain quite limited in the next 20 years. It will thus be unlikely to see safety benefits coming from automation in the next decade in less developed countries. However, when the technology arrives, there will be crucial needs to understand what such technologies will mean for the road transport systems in those countries and especially in terms of safety. The development of specific infrastructure will become important, and this is one of the biggest issues regarding road safety in these countries. The point concerning interaction between conventional vehicles and automated vehicles will also be even more important in these countries, as conventional vehicles will most probably continue to represent a large part of the vehicle fleet for a longer time period than in more developed countries.

Some fast developing countries like BRICS (Brazil, Russia, India, China and South Africa) will need a specific focus. Some of them are becoming massive global competitors in the automotive sector. Observing their evolutions related to automation would be very useful and provide some important feedbacks concerning less developed countries.

### Scope:

In order to address this challenge, the following questions need to be addressed:

- As unprotected road users remain a major concern for safety in non-OECD countries, how can this issue best be taken into account in the design of future road transport systems?
- How will low- and middle-income countries be able to develop “automation-ready” infrastructures to welcome automated vehicles even if the penetration rate increases later on? Will they even be able to skip a step (first improve their infrastructures to reach the current European standard)?
- What European solutions could be applied in terms of traffic system management in these countries? How to transfer these best practices and to implement them according to local specificities?
- How can Europe remain competitive and develop solutions for successful deployment also in other parts of the world, including BRICS countries, which in some cases may have very ambitious plans for automation?
- How will BRICS countries provide a new vision of the development of automation?

### Expected impact:

- Drastic reduction of road fatalities and crash injuries in the most affected countries
- Safe design of the future road transport systems in these countries
- Better traffic flow in big cities due to automation and less crashes, also contributing to better global air quality



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