

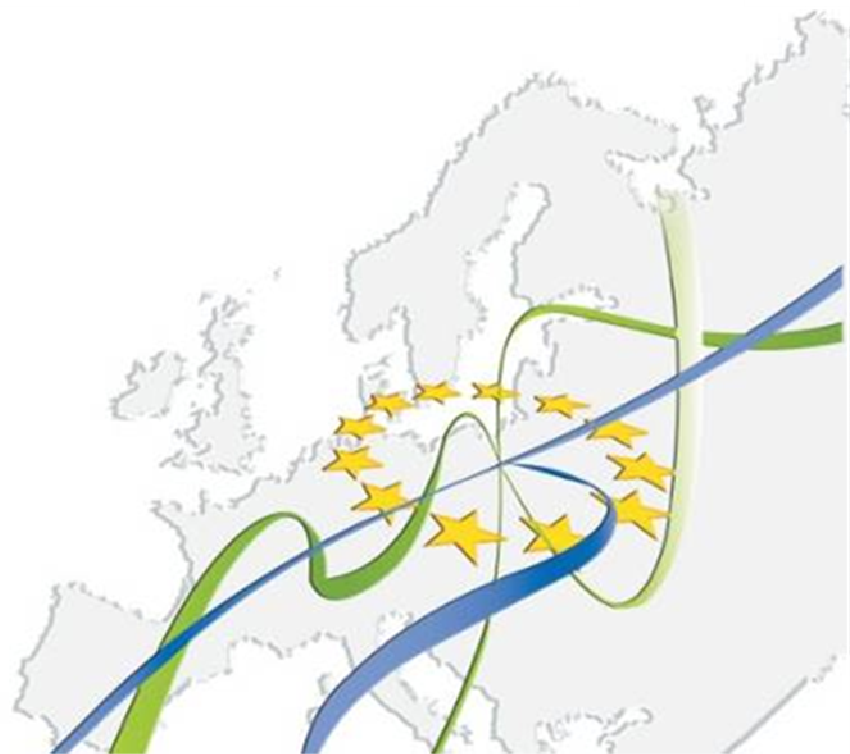


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# European Roadmap Safe Road Transport

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**ERTRAC Working Group on  
Road Transport Safety and Security**



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## 1. Executive Summary

Strong efforts have been spent by the European Commission and all Member states in the last ten years to reduce the impact of road transport in term of fatalities and injuries. The overall objective to halve the number of fatalities between 2001 and 2010 has not completely reached but significant improvements have been made. However the final target is to reduce to (almost) zero fatalities and severe injuries, at the level of a “reasonable” risk, similar to other safer transport means like rail or air transport.

As a further step towards the “zero fatalities ” objective, ERTRAC has defined an ambitious target: to reduce by 60% fatalities and severe injuries by year 2030 (baseline 2010).

To reach that safety level different approaches have to be followed, compared with the previous 10 years: continuing in research on passive and active safety and enforcement of traffic rules, strong effort in preventive safety, both at vehicle and infrastructure level, education and continuous training of drivers, strong enforcement of driving under alcohol or drug effects and protection of vulnerable road users.

Furthermore integrated and cooperative safety could provide the needed level of “protection and perception” to ensure to drive always with enough margin to be able to properly react to any sudden problem, like vehicle failure or static obstacles in the road.

## 2. Introduction

### Background

As stated in the ERTRAC Strategic Research Agenda the societal need for safety and security in road transport is on reducing fatalities and severe injuries, as well as reducing the amount of freight cargo lost due to theft and damage. The policy of reducing fatalities is a long-standing objective which reflects the ongoing efforts of the European Commission, the Member States and industry in reducing fatalities on the roads towards zero in the long term. However, ERTRAC has extended the reach of this indicator so that it now also includes the reduction of severe injuries. Considering the trend in urbanisation and in new concepts of vehicle (lightweight, full electric, etc.) vulnerable road user protection will be an important issue.

### Scope

This roadmap will cover all actions related the improvement of road safety on the vehicle, on the infrastructure, promoting a better driver behaviour, and the organization of the transport system. All different types of safety (cooperative-preventive-active, passive and after crash) will be considered, within an integrated approach.

Security in freight transport will be considered, promoting solutions that will not put in risk the professional driver of the vehicle.

The roadmap will cover actions that will improve the deployment of the solutions, since benefits will be possible only with a large penetration of solutions in the overall vehicle fleet. However specific policy (like incentives, taxes, etc.) to increase the deployment of solutions will not be considered. In some specific aspects, like prevention of driving under the effect of alcohol or drug, the roadmap will promote technology development to help the introduction of specific policy for the enforcement.

### 3. Benefits to Grand Societal Challenges

Clearly the main benefits will be on the safety target, this roadmap will be responsible to have the main impact (almost all) on the objective to reduce by 60% fatalities and severe injuries. But the reduction of accidents will have important benefits on the traffic reliability, since accidents are one of the main causes of traffic abnormalities and then congestions. Clearly the reduction of 60% of accidents with fatalities and severe injuries will have an impact on the reduction of abnormalities due to traffic accidents.

Since congestion will produce also a big increase of fuel consumption due to the very low speed followed by the vehicles (and the continuous acceleration and deceleration) a certain impact also in traffic decarbonisation is expected.

Cooperative systems will allow also a better management of the (remaining) accidents, fast intervention of emergency help, fast information to the incoming traffic to find alternative routes.

### 4. Research areas

It is generally recognised that human error are responsible of the large majority (more than 90%) of the road accidents. The strategies were directed mainly at improving road users' behaviour, mostly through education, information and enforcement strategies. But it is clear that several of the driver mistake cannot be recovered simply with the education (for example distraction, drowsiness, illness, etc.) and a more comprehensive approaches which included interventions for vehicles, roads and medical care is needed. This is clear in the Haddon Matrix, shown in Table below.

PHASE - FACTORS	Human	Vehicle	Infrastructure
<b>Prevention</b> <b>Mitigation</b>	Improved pedestrian and 2-wheeler active safety systems for accident avoidance Naturalistic Driving Studies Road user modelling and simulation Driver inattention and impairment Driver Coaching Human-Machine interaction	Vehicle dynamics monitoring and control Driver support for collision avoidance monitoring and support Automated systems	Intelligent traffic systems for VRU safe mobility management Real time road status monitoring Towards zero maintenance roads Self-explaining roads Conception and design for elderly, vulnerable and users with specific needs Automated road

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<b>Crash</b>	Biomechanical models and injury prediction	Safety systems for the protection of (motor)cyclists in collisions with motor vehicles. Crash compatibility and improved crash-worthiness of light and/or new vehicle concepts Advanced passenger protection systems including elderly/more fragile people	Forgiving infrastructure
<b>Post Crash</b>	Road accident monitoring and investigation	Automatic crash notification systems Protection of rescue personal and first responders against risks caused by energy storage systems	Advanced Incident and Traffic management

Table 1. Haddon matrix Accident Phases- Factors

The roadmap will consider the following main research areas.

- ***Safety of vulnerable road users***
- ***Safety of new vehicles***
- ***Advanced driver support***
- ***Traffic Safety Analysis***
- ***Safe infrastructure***
- ***Cooperative systems***
- ***Secure road transportation***

#### 4.1 Safety of vulnerable road users

Vulnerable Road Users (or VRU) are defined in this document as those participants in traffic that are not protected by any mechanical system: pedestrians, motorcyclists, bicyclists, and users of mopeds. This includes road users with impairment, e.g. using a mobility aid, or children playing on the road. Car occupants, even when this refers to impaired people, senior people or children do not belong to the category of VRU according to this definition. Their specific needs are included in the roadmap referring to new vehicle developments (Safety of New Vehicles).

Although the total number of fatalities and severe injuries due to traffic accidents is decreasing, e.g. as a result of the introduction of passive and active safety systems, the number of VRU that are killed and wounded in traffic tends to decrease in a much slower pace. Measures to decrease the number of VRU casualties in traffic are dedicated to influence driver and road users to show more safe behaviour, to make infrastructure more forgiving and intuitive in order to decrease the number of accidents and accident severity, and to make motor vehicles more safe e.g. by means of driver warning systems or full autonomous safety systems as to reduce the impact of accidents on injury levels of vulnerable road users. Influencing road user behaviour is outside the scope of this roadmap, except for advanced driver assistance systems which are integrated in vehicles and used in a timeframe prior to the crash at a moment that the driver is fully in control of the situation. Autonomous systems have to take over from the driver at the time that any response from the driver is too late to avoid a potential collision, or when the driver is no longer capable to deal with the information flow regarding a potential critical situation. Intelligent systems are required that not only give information to the driver on the possible collision risk in the continuously changing environment of the vehicle, but also estimate the driver state in order to judge whether the driver is still capable to cope with the ever increasing amount of information to use this information to avoid critical situations.

The following topics are considered to be of main importance in the reduction of the number of fatalities and severe injuries among vulnerable road users in traffic:

1. Intelligent traffic systems for VRU safe mobility management
2. Improved pedestrian and 2-wheeler active safety systems for accident avoidance
3. Safety systems for the protection of (motor)cyclists in collisions with motor vehicles.
4. Safety systems for the protection of single-vehicle motorcyclist accidents.
5. Technology development to mitigate the consequences of secondary impacts after a VRU-to-vehicle collision.

Impact assessment of systems to improve the safety of vulnerable road users is dealt with in a separate roadmap (Traffic Safety analysis).

#### 4.1.1 Intelligent traffic systems for VRU safe mobility management

Especially at inner city black spots where the density of cars and vulnerable road users is high with consequentially many possible hazardous interactions, an automated guiding system for safe VRU mobility could be put into place. Such a system would have to lead to increased awareness of drivers for VRU behaviour, combined with traffic guidance for vulnerable road users and cars depending on the detected traffic flows. A combination of in-vehicle systems (active safety systems), roadside systems (e.g. camera's overlooking a crossing and identifying road users and their future paths), car-to-infrastructure and infrastructure-to-car communication, and an intelligent traffic management system should result in increased driver awareness (e.g. by sending information on pedestrians crossing the street outside the view of the driver), improved awareness for vulnerable road users on the presence of vehicles potentially crossing their path, and guidance by automated traffic guidance systems (e.g. automatically adapting their timed switch and/or the vehicle speed for optimized mobility of cars and VRU).

#### 4.1.2 Improved pedestrian and 2-wheeler detection systems for accident avoidance

Current developments in pedestrian and 2-wheeler detection systems aim at in vehicle sensors, such as a combination of camera's, radars, contact sensors and other sensor types, as these are desperately needed to avoid accidents with VRU. Developments are required to reduce the cost of these sensor systems, to make sensors smarter as to be able to identify the type of road user, and to reduce the number of false positives. There is a major concern about the growing thickness of the A-pillars for car structural resistance and the blind spots generated by the same. Reducing the weight of structural materials might even increase the problem.

In order to have sensors to provide information that add to the drivers view, the information streaming towards the driver becomes important, especially in inner cities with high numbers of road users, including VRU. When a warning is given to the driver, does the driver have the possibility to digest this information, and is he/she capable of acting accordingly? Accident avoidance systems therefore also require an estimation of driver behaviour (capabilities), and driver state, to predict delayed reactions due to fatigue or increasing age. Using this information, the trigger for autonomous action by the car could be adapted.

Apart from in-vehicle sensors, detection could be enhanced by providing pedestrians and 2-wheelers with some sort of transmitter, whose signal is easily picked up by in-car or road side systems. This could especially be used in the protection of young children, that have little notion on the dangers of traffic or for bikers approaching a heavy vehicle with important areas falling under blind spots.

The regulatory framework is very essential for a successful market introduction of accident avoidance systems, especially in the case of autonomous actions of in-car systems. Current legislation has not yet an answer to upcoming questions on responsibility for autonomous acting vehicles. Besides the developments of such systems, the regulatory frameworks well as test procedures for such systems need to be installed.



#### 4.1.3 Safety systems for the protection of (motor)cyclists in collisions with motor vehicles

Systems are developed for collision avoidance. If in unfortunate cases, a collision is unavoidable, then there is still time left to mitigate the impact of the collision. This could be by systems on the car that decrease the impact, by a combination of car deceleration and safety measures to reduce the severity of the contact between car and VRU. Other possibilities are protective garments for the vulnerable road user that become active when an imminent collision is detected. An active bicycle helmet or collar is a simple example of such a system. For motorcyclists such systems could be part of the motorcycle, or of the protective garment, to be activated only if and when needed. A good prediction of what will happen during the accident scenario is crucial to determine the best combination of protective measures and consequently the algorithms to deploy the protection. Moreover, systems should be very easy to handle, and should fit comfortably under all weather conditions.

Enhanced concepts for motorcycling helmets to protect the rider from neck torsion will add to motorcyclist safety.

#### 4.1.4 Safety systems for the protection of single-vehicle motorcyclist accidents

Due to the high speed reachable and the weight of the vehicle, single-vehicle accidents involving PTWs (Powered Two-Wheelers) can be fatal or lead to very severe injuries. Since in the case of a single-vehicle accident no opposing vehicle is present to absorb part of the impact and thus mitigate the collision, measures to reduce the mortality and the level of injury should be implemented on the motorcycle, in the protective garments or in the infrastructure. These systems, similar to developments for cars could follow the strategy of driver warning, collision avoidance, and collision mitigation, the latter with automatically activated protective systems.

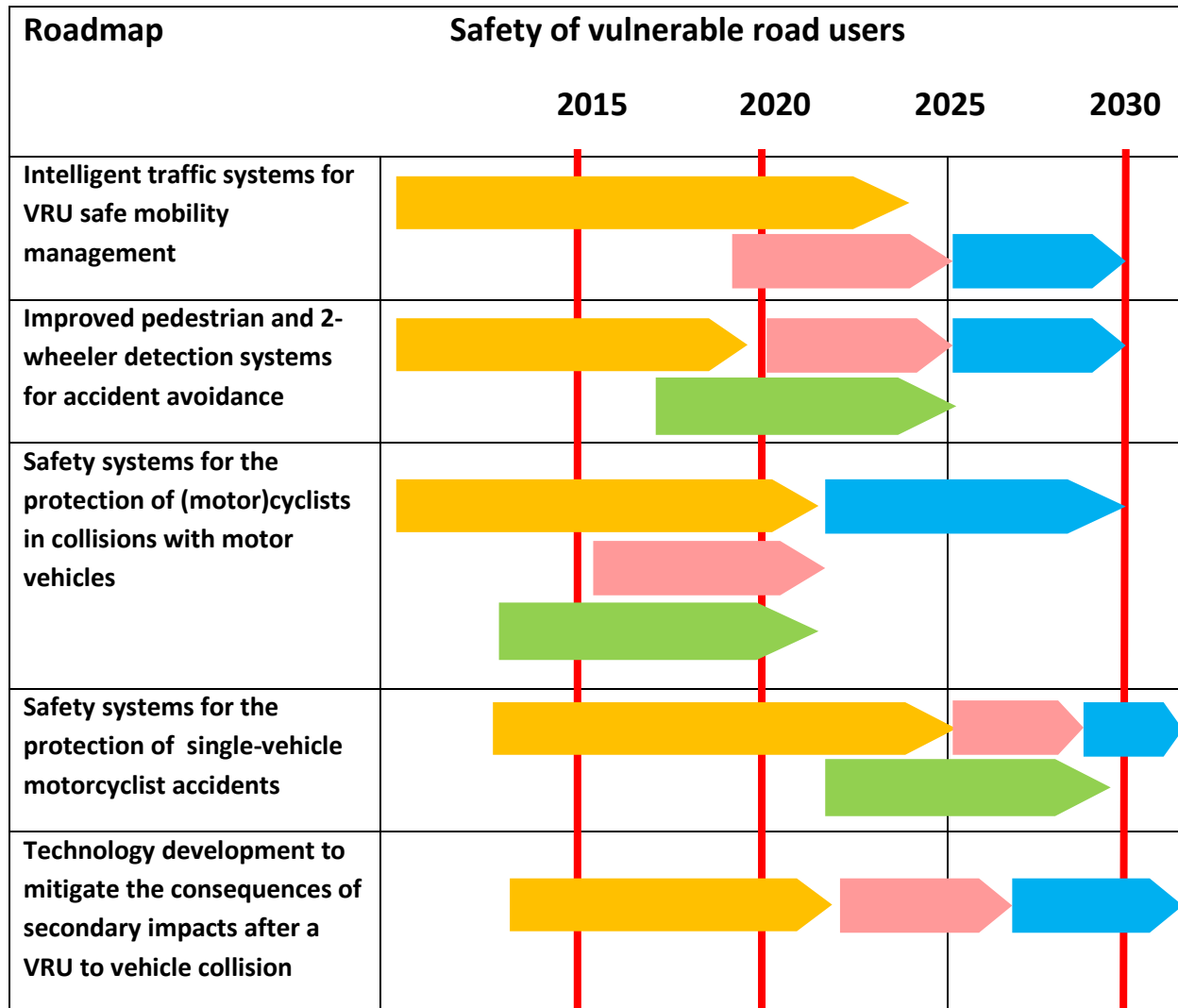
Systems like ESC for PTWs, advanced protective clothing and helmets, wearable air-bags; forgiving infrastructure design and "soft" road furniture should be considered for innovative development.

#### 4.1.5 Technology development to mitigate the consequences of secondary impacts after a VRU to vehicle collision

In most accident scenarios for the collision of a passenger car and a pedestrian, the head will make contact with the bonnet close to the windshield, the windshield, or the vehicle's A-pillars. Depending on the flexibility of the structure, the deceleration pulse of this primary contact is so high that a fatal injury might result. For this reason various protective measures are currently studied reducing the risk of fatal and severe injuries due to primary impacts.

Only very limited data is available on the secondary impact, i.e. the impact that the VRU faces when bouncing off the vehicle and hitting the road or other equipment. The severity of this contact might be as high as or even higher than that of the primary impact. Consequently

measures should be developed to prevent or soften secondary impact, e.g. retaining systems to avoid secondary impact or forgiving infrastructure/road furniture design.



#### 4.2 Safety of new vehicles

Current state-of-the-art vehicles show a very high level of active (e.g. Electronic Stability Control) and passive safety. Euro NCAP rating is often at the highest level of five stars. However, improvements are still possible and needed considering the introduction of new, smaller and lighter vehicles, and of electric vehicles. These vehicles will have new specific needs, in particular

for passive safety, but will also offer new opportunities with the availability of high electric power on the vehicle and the possibility to control the traction torque at each wheel.

In particular, electric vehicles are more flexible in their architecture compared with conventional vehicles. This aspect, together with the requirement to reduce costs and weights, will probably produce vehicles very different from the current solutions. Research is also needed to better understand the biomechanics of the vehicle occupants during crashes to enable new solutions for the passive safety of these new vehicles, solutions that will guarantee adequate levels of protection without negative impact on vehicle performance (weights and then range).

Topics for research:

1. Biomechanical models and injury prediction
2. Crash compatibility and improved crashworthiness of light and/or new vehicle concepts
3. Solutions for low acoustic perception of FEVs (Full Electric Vehicles)
4. Advanced passenger protection systems including elderly/more fragile people
5. Integrated safety concepts (hydrogen vehicles, fire...)

### **4.2.1 Biomechanical models and injury prediction**

With the convergence of active and passive safety, human-like reactions, as they would occur in the pre-crash respectively low-g phase, will play a more and more important role in the development and fine-tuning of safety systems. This should be supported by research on active human models for all kinds of road users. The bio-fidelity and injury prediction capability of these numerical representations of the human body and in particular their ability to reproduce muscular activity need further improvements. Research in biomechanics will be the basis of such advances. So far most of the knowledge in biomechanics has been focused on so-called structural effects caused by various types of impacts. However, there is an urgent need to get a better understanding about functional effects, e.g. injuries to the nervous system frequently causing long lasting or disabling injuries. This knowledge will be a prerequisite for the definition of refined injury criteria and reference values.

### **4.2.2 Crash compatibility and improved crashworthiness of light and/or new vehicle concepts**

CO<sub>2</sub> emission regulations, global anti-pollution policies, management of resources and economical development call for cars with reduced size and weight, which are ecologically friendly (emissions, material recycling, manufacturing processes), affordable and still safe. Current requirements for crashworthiness, however, set limits to the trend of “downsizing” and to the weight savings which can be achieved. On the other hand, there are classes of extra-low mass vehicles (L5e and L7e) which are largely unregulated in terms of vehicle safety. Research should therefore aim at establishing the scientific basis for harmonizing these requirements and for giving greater room to weight savings without compromising the high level of safety which even small cars offer today.

An important route to realise substantial weight reductions is the application of lightweight and particularly of composite materials in the vehicle structure. Apart from high material and processing costs, the lack of numerical crash simulation tools with truly predictive capability still constitutes a major barrier to the introduction of these materials in the virtual development processes of the motor vehicle industry. Research should bridge this gap by developing numerical tools which offer the capability to predict also the failure and the post-failure behaviour of composite materials under impact loading at high levels of confidence and which can be integrated seamlessly in the existing industrial development processes.

Apart from the general trend of downsizing, the electrification of drive trains in particular causes new challenges with regard to crashworthiness and, at the same time, offers new chances to improve the crash safety of vehicles. The bulky and heavy battery packs which vehicles will have to be equipped with in the coming years in order to offer a significant purely electric operating range might not only form a safety risk on their own when being damaged, but will also have a major influence on the full vehicle's crash deformation behaviour and on the resulting deceleration patterns. High voltage lines and hydrogen tanks for energy storage in fuel cell electric vehicles will introduce new risks which have to be tackled, too. On the other hand, new package concepts enabled by the replacement of mechanical shafts by electric power transmission and the introduction of wheel-hub motors in particular will facilitate radically new designs of crash structures and finally enable rethinking the vehicle architecture as a whole. In combination with the application of new materials, this will be the basis for major advances in the lightweight design of electric vehicles allowing for the extension of purely electric operating ranges. Research activities should cover the whole range from basic risk analyses to the development of design guidelines and test procedures which allow for a holistic safety assessment of electrified vehicles while limiting the risks immanent in the tests themselves.

Not only electric vehicles might be based on totally new architectures in the future though. Special attention is currently paid to two-seater concepts with in-line seat arrangements, for example. Such vehicles could be equipped with the full range of drive train technologies available, but will in any case show different impact kinematics than conventional passenger cars. Research should therefore explore routes to guarantee the crashworthiness of such vehicle structures in terms of energy-absorption mechanisms, deceleration patterns and survival spaces. Moreover, the adaptation of restraint systems to the requirements of such new vehicles concepts should be addressed.

Last but not least, the interaction of different types of vehicles in terms of crash compatibility should be a topic of future research, as this issue will become even more important with the trend of downsizing and the introduction of a growing number of extra-low mass vehicles. According to current safety paradigms, smaller vehicles have to be designed with stiffer structures, modifying the energy absorption characteristics and requiring more aggressive restraint systems. In addition, the introduction of new vehicle architectures might also result in issues of geometric compatibility with other vehicle types (override / underride effects etc.). Based on an in-depth analysis on what are the optimal safety features a small car should provide compared to those of a larger vehicle and making full use of the results of former projects in this field, research should be targeted towards the amendment of safety requirements for the

different types of vehicles available. This might also necessitate the modification of test and assessment methods in order to better reflect the requirements of crash compatibility.

#### 4.2.3 Solutions for low acoustic perception of FEVs

Novel acoustic characteristics of fully electric vehicles (FEVs) do not provide the same recognizable impressions regarding interior and exterior noise as conventional vehicles - particularly at low speeds. This means a perceptible sound has to be developed in order to avoid additional risks for vulnerable road users and maintain public acceptance. Significant progress towards regulations for exterior noise characteristics of quiet road vehicles has already started in the USA, Japan and Europe. However, there is still a substantial need for further research in this area of psycho-acoustic characteristics for artificial noise measures, increased driver awareness as well as novel smart system approaches to maintain the advantages of FEVs regarding the reduction of urban noise pollution. Thus the NVH-behaviour of new vehicle concepts (in particular FEVs) is an interdisciplinary research domain, also involving innovative materials and production methods. In this context also infrastructure measures could be developed in combination with in-vehicle measures. As an example, one could imagine smart systems in pedestrian paths, especially at crossroads, which generate sound and vibration to vulnerable road users. In-vehicle measures as well as infrastructure measures should be integrated with the help of innovative HMI solutions in order to generate an automated acoustic system environment for the safety of new vehicles.

Thus there are important challenges in the next two decades which demand holistic R&D approaches. In the first stage an initial research and demonstration phase has to be initiated. The major aims of this first phase are:

- Sound (and vibration) functionality and generation devices are developed at a prototype and/or pre-series-production level (mainly in-vehicle measures)
- Sensing strategies and HMI-integration (Human Machine Interaction) for acoustic solutions are developed (in-vehicle but also infrastructure measures)
- Demonstration / field testing (mainly vehicle level but also infrastructure measures)

This refers to a small scale application of technical systems and methods regarding effective solutions for the low acoustic perception of FEVs. First R&D projects on these aspects are running or currently being started.

In the second stage, the validation and integration of these acoustic solutions for a preventive vulnerable road user protection is a major aim. As a major future aim, a holistic automated acoustic system environment for collision avoidance, mainly in terms of vulnerable road user protection, has to be established. This involves economically advantageous and validated applications at large scale.

#### 4.2.4 Advanced passenger protection systems including elderly/more fragile people

Already more and more systems are penetrating the market where passenger protection systems are electrically driven instead of mechanically driven, this trend will continue in the future due to the availability of a higher voltage battery also in conventional vehicles. The availability of even higher electric power in electric or hybrid vehicles opens possibilities to redefine passive safety

systems altogether. Not only restraint systems can be redefined to more dynamically and less aggressively (taking into account the different statures of occupants) respond to dangerous situations, but also the supply of power can be used to trigger crash mitigation systems like dynamic changes to the structure of the vehicle. A strategy should be developed how the demands of different actuators should be handled by such a power system. Also, questions of energy management arise in the event of a crash: actors need to be generally redefined. Do the protection systems have sufficient power and may there be a demand for power supply after the crash? How will this power supply be secured without endangering the occupants or first responders? These questions have to be answered to (re)define the passenger protection systems in the overall safety concept.

### 4.2.5 Integrated safety concepts (HV, fire...)

Vehicles with an alternative propulsion system, like battery operated vehicles and hydrogen and fuel cells driven vehicles, put higher demands on traditional safety systems. The use of these new energy storage systems in combination with the changed characteristics of the vehicle asks for an integrated safety approach encompassing primary, secondary and tertiary safety systems. These systems should be directed at the energy storage system itself (battery or hydrogen tank), the vehicle as a whole and the environment of the vehicle. Additional safety challenges as discussed in the following paragraph should be compensated by improved primary and secondary safety systems. Since these vehicles will be introduced first in urban environments also specific safety systems directed at the protection of vulnerable road users should be considered.

Also post-crash, the alternative powertrain components (battery, hydrogen storage, high voltage lines) pose new challenges for rescue teams. Emergency personnel must be able to identify the specific type of vehicle it is dealing with and secure the scene so rescue work can begin. They also need to know when to call for trained personnel equipped with proper protective gear for assistance. First arriving emergency responders should be protected as well as the occupants of the vehicles and bystanders at the scene.

For the electric vehicle the so-called electronic crush zone is even more important not least due to the different architectural designs (2-seaters, in-line etc). Therefore, further research on reliable sensing is a must. The reliability of the sensing systems has to be increased in order to be able to use the signals for the deployment of collision mitigation systems.

Research activities should be aimed at a holistic approach looking at prevention, avoidance, protection, rescue and care. Firstly a profound analysis is needed of the specific safety requirements of the different new vehicle concepts (battery, hydrogen). Primary safety systems should be redefined in order to focus these systems on urban environments and vulnerable road users. Safe vehicle dynamics is a further area that needs extensive research for the different new vehicle concepts, including 2- and 3-wheelers. For the secondary safety systems, pre-triggered occupant protection systems need to be elaborated, adapted actuator concepts which take into account the diversified crash behaviour. Furthermore, improvement of tertiary safety systems is needed taking into account fire, leakages of chemical materials and high voltage.

Roadmap	Safety of new vehicles			
	2015	2020	2025	2030
Biomechanical models and injury prediction	Research and Development		Regulations and Standards	
Crash compatibility and improved crashworthiness of light and/or new vehicle concepts	Research and Development		Demonstration	Market introduction
Solutions for low acoustic perception of FEVs	Research and Development		Demonstration	Market introduction
Advanced passenger protection systems including elderly/more fragile people	Research and Development		Regulations and Standards	Market introduction
Integrated safety concepts (HV, fire...)	Research and Development			Market introduction



### 4.3 Advanced driver support systems

In-depth accident analysis and naturalistic driving studies have consistently demonstrated that the great majority of road accidents involve some form of driver error, in particular related to inattention. The key purpose of advanced driver support systems is to prevent such errors or mitigate their consequences by providing drivers with information or warnings on potential hazards, or even intervening by automatic steering and/or braking. In addition, some functions partly automate the driving control task. Also, enhanced logging capabilities have enabled driver coaching functions that provide drivers with performance feedback, during or after the trip, with the general purpose to obtain long-term behavioural change. Today, several advanced driver support systems have entered the market but the penetration rate is still relatively low.

To accelerate deployment, it will be of key importance to reduce development costs. This will require an increased level of integration both on the sensor and on the actuator/HMI side. Future technological developments will include improved perception capabilities, also utilising short-range communication enabled by cooperative system technologies. This will also enable a higher level of automated driving, which will require new regulatory frameworks. Increased integration of the suspension, braking, steering and propulsion systems will enable new forms of vehicle dynamics support functions. There are also key challenges for the design of the human-machine interface to manage the rapid growth of functions interacting with the driver, minimise distraction and ensure a high level of acceptance and adoption of new functions.

The following main research topics have been identified:

1. Vehicle dynamics monitoring and control
2. Driver support for collision avoidance
3. Driver inattention and impairment monitoring and support
4. Automated systems
5. Driver Coaching
6. Human-Machine Interaction

#### 4.3.1 Vehicle dynamics monitoring and control

A key future trend in this area is increased chassis integration, that is, integration of the suspension, braking, steering and propulsion systems to provide safer functionality by combined management of these systems. Thus, future active safety systems will be able to directly act on the vehicle dynamics.

Road transports of tomorrow, especially heavy goods vehicles, face challenges in increasing their transport efficiency and reducing their environmental footprint. One viable future option is to design longer modular transport systems than agreed in Directive 96/53 EC within long haul and regional distribution. Research is needed on how these vehicle combinations should be managed



in safety critical situations and how safe corridors can be detected and evaluated to choose an optimal driving path for high speed situations as well as low speed including reversing. To secure the right level of control with energy and cost efficient systems an integrated approach of propulsion, braking and steering is needed.

Coordination of legislation and development of common standards is also needed to facilitate the development of integrated chassis systems.

### 4.3.2 Driver support for collision avoidance

Today, several types of collision warning systems exist on the market, primarily in premium segment vehicles. Recently, vehicle manufacturers took the next step to further enhance safety by introducing systems like Automatic Emergency Braking which autonomously takes control over the brakes when necessary to mitigate rear-end collisions. In the near future, active safety will be increasingly deployed in lower-cost segments. To achieve this, research needs to be directed at systems with multiple functions, with high accuracy / reliability, and reduced cost. Deployment in heavy goods vehicles and buses will be accelerated by 2013/2015 legal requirements on mandatory CMbB and LDW systems.

On the sensor side, accuracy and reliability will be further enhanced, in particular regarding the detection of vulnerable road users (as addressed in more detail in section 4.1). Moreover, in the near future, short-range communication technologies (V2V, V2I) will function as additional sensors. In combination with digital maps and e-Horizon, this will substantially enhance the robustness and predictive capacity of today's collision warning systems, thus minimizing false warnings and enabling automatic intervention across a wider range of scenarios. Enhanced predictive capabilities is also essential for systems supporting green driving, so synergies between those two application areas may be exploited.

The development of integrated information, warning and intervention (IWI) strategies for multiple functions is another key challenge. Yet another future trend will be proactive information (e.g., based on digital maps, traffic information and/or V2V, V2I communication) supporting drivers' anticipation of potentially critical events, thus enabling more "foresighted" driving. Finally, there will be a trend towards increased integration of active and passive safety functions where, for example, collision prediction is used to optimise protection systems prior to impact.

### 4.3.3 Driver inattention and impairment monitoring and support

Driver inattention and impairment monitoring systems have started to appear on the market. These systems analyse different information on driving behaviour (lane keeping, steering and braking patterns, etc), and/or information from a interior cameras, to mitigate inattention (e.g., eyes off road) or physiological impairment (e.g., alcohol intoxication or drowsiness). In the case of alcohol, solutions that will disable the possibility to use the vehicle are foreseen. This may even include stopping a vehicle in motion, which requires a high level of accuracy and reliability.

Of key importance will also be to reduce the intrusiveness of some technologies (e.g., alco-locks), and to increase the real-world detection accuracy and reliability of others (e.g., distraction and drowsiness mitigation). Future inattention and impairment detection systems will combine signals from multiple (driver-, environment- and vehicle) sensors. Moreover, inattention and

impairment monitoring systems will be integrated into the general onboard perception platform and used for enabling a wide range of functions including inattention warning, driver coaching (see below) as well as driver state-adaptive collision avoidance.

Driver state monitoring will also be important for ensuring that the driver is in the loop during mode transitions in semi-automated driving.

#### 4.3.4 Automated systems

From a technological perspective, fully automated driving is a reality today. However, the deployment of fully automated road vehicles will require more precise, reliable and extended environment perception and situation understanding. Here, positioning and qualified map data and short-range communication (V2V and V2I) will be of key importance. It may be foreseen that, within the time-frame of the present roadmap, full automation will be limited to specific contexts (e.g., platooning or dedicated lanes) where the driver will maintain the overall responsibility for safe driving, although in a monitoring role. A key issue here is thus the development of automation strategies, e.g., for handling transitions between automatic and manual control modes. As discussed in Section 4.5, the infrastructure design will also play a key role in enabling automated driving and a systems perspective needs to be adopted.

Finally, legal and regulatory frameworks for automated driving need to be developed in order to enable large scale deployment.

#### 4.3.5 Driver Coaching

The general idea behind driver coaching is to improve driving performance by means of feedback. This may involve improvements in safety as well as driving efficiency, and performance feedback may range from immediate feedback provided while driving to post-trip reports summarising performance over a longer time period (e.g., a drive, a week or a month).

Driver coaching may be based on relatively cheap aftermarket video data recorders or more advanced onboard logging and communication systems which are also used for other purposes (such as vehicle uptime monitoring, vehicle optimisation and accident/incident analysis). These systems log inappropriate behaviours (e.g., hard braking, speed violations, close following, drowsiness/distraction episodes) and this information may then be used by a fleet manager to coach the driver towards safer and/or more efficient driving behaviour, using different forms of incentives. For private drivers, the information may be linked to incentives such as reduced fuel consumption or insurance premiums.

As the required logging technologies are relatively mature today, the main challenge for future development of driver coaching concerns the implementation and deployment strategies. A critical issue is incentive schemes sufficient to motivate long-term behavioural change. For commercial fleets, it may be foreseen that driver coaching will to an increasing degree form part of general safety management strategies, and be combined with other measures, such as driver education and training. Technologically, driver coaching system will merge with other driver support systems. For private driving, new business models will emerge involving incentives, possibly linked to insurance and dynamic pricing (e.g., pay-as-you-drive). Another potential application, of increasing importance due to current European demographic trends, is the coaching of elderly drivers.

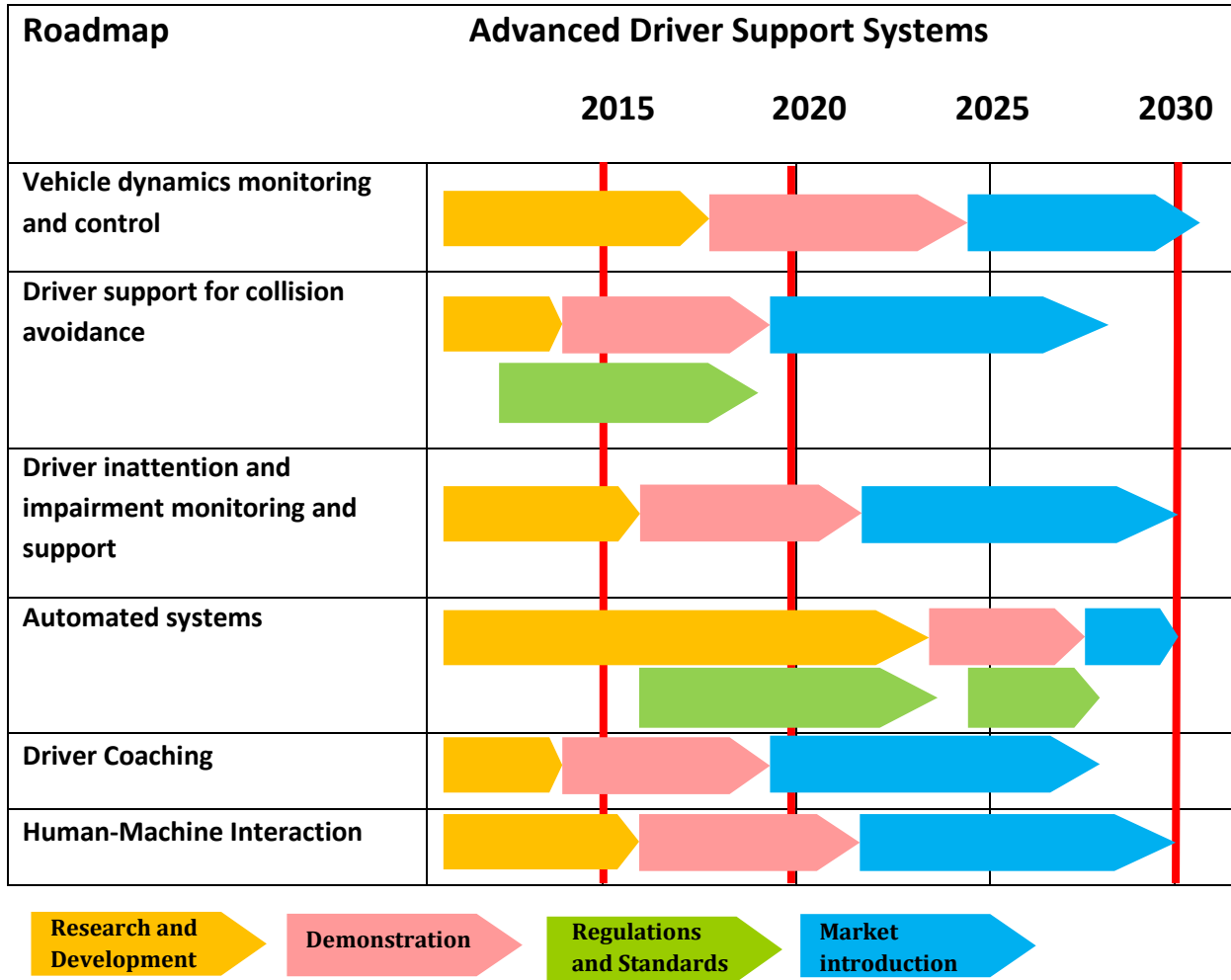
Finally, as the level of automation increases, so will the requirement for driver coaching. Future systems may thus focus more on drivers' monitoring, as opposed to operational driving, performance.

#### 4.3.6 Human-Machine Interaction

Drivers experience advanced driver support functions through the human-machine interface. Hence, the Human-Machine Interaction (HMI) design critically determines the level of user acceptance and adoption and is thus key factor for successful deployment.

A general future challenge for automotive HMI design is to handle the rapid growth of functions interacting with the driver. In addition to factory-fitted and aftermarket functions, this will soon include cooperative system functions as well as downloadable third-party applications. Today, driver support systems are still, to a large extent, interacting with the driver independently of one another, but this situation will quickly become infeasible as the number of functions increases. Thus, there is a need for more holistic approaches to automotive HMI design.

In-vehicle HMI technologies will develop towards increasingly intuitive and distraction-free driver support systems, involving in particular more advanced speech-based interfaces, based on natural speech understanding, which minimise the need to take the eyes off the road. A key concern today is the great distraction potential of consumer electronics systems not designed for use while driving. To some extent, integration of third-party applications into the vehicle HMI is already available in modern premium vehicles. This development is expected to continue towards increasingly seamless integration solutions. This may also involve more advanced methods for workload management, including, for example, dynamic scheduling and lock-out of information. A key step for enabling this development is new business models involving vehicle OEMs, consumer electronics OEMs and application developers. Due to the ageing of the European population, a further important topic concerns the potential to adapt the in-vehicle HMI to better suit elderly drivers.



#### 4.4 Traffic Safety Analysis

There are explicit visions in many countries that aim at reducing the number of fatalities and serious injuries in traffic to zero within a few decades. To achieve this, a combination of increased knowledge and improved technology is required. The main source to obtain the knowledge required is field data. Awareness of the value of field data to make the right priorities, understand the underlying mechanisms of accidents and injuries, and to evaluate the safety potential of new system, has gradually increased over the years and is today a natural part of the development process of safety on roads.

In recent years, new technologies have opened new possibilities for understanding the causes of accidents. Data logs from the vehicle, the driver, and the surrounding environment, where data is collected continuously during normal driving, will greatly improve understanding of accident causation, but also implicate major challenges in the development of methods for collection, storage, and analysis of data.

Crashes are rare events and therefore are not always practical to measure due to (1) small sample sizes and (2) lack of details regarding crash failure mechanisms and especially the driver crash avoidance behaviour. Therefore surrogate (crash-substitute) measures of safety are required. A surrogate measure is (a) based on an observable non-crash event that is physically related in a predictable and reliable way to crashes, and (b) uses a method that converts the non-crash events into a corresponding crash frequency and/or severity. Many methods (such as those outlined below) use surrogates as a way of improving efficiency of analysis.

Road User Modelling and Simulation of traffic may be expected to become an increasingly important tool in the traffic safety analysis on several levels, from large scale traffic simulations to case analyses of accident and injury causation. Development of knowledge and method in the area of Impact Assessment, where estimations can be done how a certain safety intervention affects road safety, will be essential to have the possibility to measure the effect of action taken and also for cost benefit estimations.

In order to achieve the goals we seek, a further development of databases and methods for data analysis is an obvious prerequisite. Data from the Investigation of Accidents and from Naturalistic Driving Studies must be combined to provide optimal value. Further development of methods and tools for analysis and simulation must be given high priority.

In the future, accident analyses will be cost-efficient and use integrated data sources. The future analysis system includes data from accident (and injury) investigations, naturalistic driving studies, data from cheap after-market data recorders, and event data recorders. This integrated future dataset will significantly improve explanatory power and cost-efficiency.

Topics for research:

1. Road accident monitoring and investigation
2. Naturalistic Driving Studies
3. Road user modelling and simulation

4. Impact assessment and cost benefit

**4.4.1 Road accident monitoring and investigation**

Road accident research in terms of accident investigations has been an important and fundamental input to traffic safety analysis for decades. During previous and ongoing research throughout the world standardisation and harmonisation of the methodologies for accident investigations has been developed, e.g. in the FP7 project DaCoTA. With the harmonised methodologies in place the accident investigation system can be implemented to allow researchers to gain access to real-world data across Europe. Important issues for the future are to understand how the decreased number of fatalities affects the injury outcome including the long term consequences. The aim is to make the investigations more cost-effective by e.g. developing methods for merging incident and accident data from naturalistic driving studies (NDS) with other data sources and make use of information from site based as well as vehicle based monitoring (such as Event Data Recorder data) in the investigations. With these methods the road user behaviour can be approached in several ways. However the accident data always need to be linked to injury data for usage in impact assessment and cost benefit analyses.

Data from hospital or insurance sources could be compared to accident data to know precisely the causes of accidents and consolidate accident statistics.

Another important issue is to find statistical methods how to generalise in-depth data from streamlined investigation locations in a few European countries to the whole European road accident situation. Methods for using reconstructions of accidents for risk modelling and to predict accident outcome needs to be developed and confirmed with real-world data.

**4.4.2 Naturalistic Driving Studies**

Safety countermeasures can best be developed if causes and contributing factors for accidents are well-understood. In Naturalistic Driving Studies (NDS) various recording devices (typically of video and vehicle kinematics data) capture objective, detailed recordings of the events preceding real accidents and safety critical events. These detailed recordings enable risk analyses of many driver-, vehicle- and environmental characteristics that have not previously been possible. The need for in-depth pre-crash knowledge combined with the need for a statistically large enough sample of accidents for analysis is best satisfied by studies with high-fidelity continuous data recordings and larger studies with low-cost event data recorders (with video).

Since accidents are rare events, research on surrogate safety measures (crash-substitute measures) such as near-crashes or incidents is greatly needed. The link between lower severity crash-relevant events and accidents needs to be determined and validated. If this relationship between crashes and surrogates is well-understood, these surrogate measures become tools to speed up countermeasure development, deployment and evaluation.

An integrated approach where Naturalistic Driving Studies are used to collect data simultaneously for safety, efficiency, mobility and environment research and evaluation purposes should be encouraged. Understanding driver behaviour and driving patterns is also essential for solving environmental issues in the Transport area. NDS data, in combination with in-depth knowledge of driver, vehicle, and road and infrastructure features, will enable the development and statistical validation of countermeasures.

#### 4.4.3 Road user modelling and simulation

Computer simulation of traffic may be expected to become an increasingly important tool in traffic safety analysis, from simulation of entire infrastructure networks over a long time, to specific near-crash scenarios involving one or a few road users during a few seconds. Large-scale traffic simulations do exist today, but further research is needed in order to make these fully useful in the study of safety effects of e.g. Cooperative systems and future infrastructure solutions. One specific need in this context is improved surrogate safety measures for the analysis of simulation output. For near-crash simulation, the main need is high-fidelity models of road user behaviour in near-crash situations. Regardless of simulation time scale, models are needed of behaviour in relation to active safety systems (both immediate reactions and longer-term behavioural adaptations), and modelling should also be expanded beyond the current focus on passenger car drivers, to include all types of road users. Further, scientifically sound conceptual models of road user behaviour are needed, on which to base the quantitative models. The diversity of users have to be integrated in the models (age, driving experience, health status, ....). In all of the above, inter-individual variance is a crucial factor to consider.

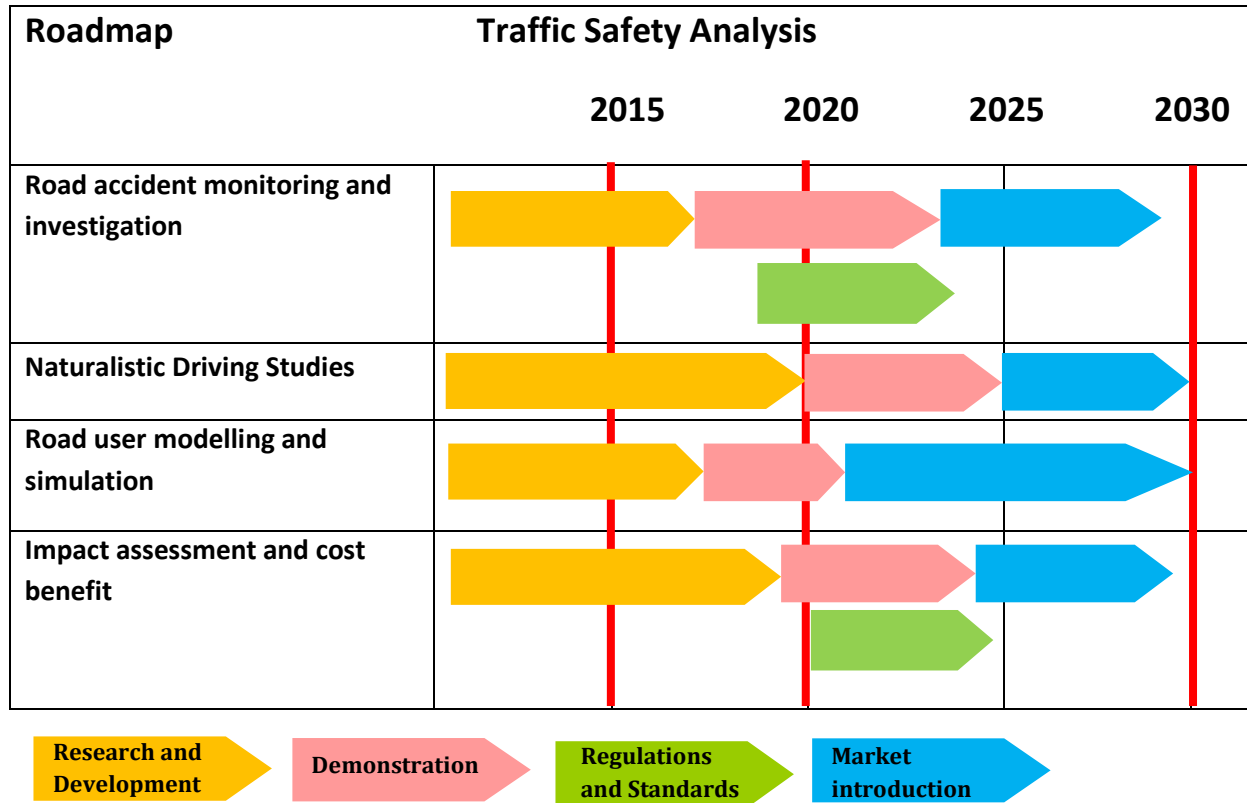
#### 4.4.4 Impact assessment and cost benefit

The goal of safety impact assessment is to estimate the effect of certain safety intervention on road safety. While the most straightforward approach is simply to compare the situation before and after the intervention was introduced (e.g. in terms crash frequency or crash severity), it is of great value to be able to predict prior to introduction what the safety impact will be. This involves the development of risk models which define the mathematical/statistical relation between a safety intervention and its impact to a specific road safety measure. One approach is to relate parameters in statistical accident databases (e.g., speed limit, road surface condition) directly to crash risk or crash severity. Increasing the precision of such models requires improved quality of accident data and the development of new mathematical models, also taking into account regional differences as well as influence over time.

Field Operational Tests (FOTs) potentially yield a more detailed understanding of how a safety system influences behaviour/performance. However, since real crashes are rarely captured in FOTs, the effects of a system in critical situations ("crash relevant events") needs to be extrapolated to its effects on actual crash risk and crash severity. In order to bridge this gap, FOTs and statistical accident data may be combined. This may be further aided by simulation of pre-crash and crash scenarios, based on advanced biomechanical and behavioural models. A complementary approach is to use traffic-level simulations which integrate all aspects in traffic safety (vehicle, infrastructure, driver behaviour and traffic) on a systems level. This will be particularly important for assessing the benefits of system-level interventions such as traffic management and the introduction of cooperative systems. In the future, it may be foreseen that simulation will partly replace large-scale FOTs as the basis for impact assessment. Here, it is important that the behaviour diversity relating to geographical and cultural differences is taken into account.

In order to finally bridge the gap between incidents and accidents, large amounts of detailed data on real crashes as well as incidents are needed. Naturalistic driving data has a great potential to provide this information, which can then be used to develop detailed models that map from microscopic changes in driver behaviour (e.g. eyes-off-road time) to crash risk. As mentioned above, this type of data may be collected at a relatively low cost, through cheap aftermarket data recorders.

A further step is to relate the cost of a safety intervention to the financial benefit of the reduced impact. Today, such calculations focus mainly on societal costs of fatalities and injuries. However, long-term consequences of injuries need to be better accounted for and calculation methods need to be harmonized between countries. Moreover, secondary costs related, for example, to congestion, material damage, vehicle uptime, should also be taken into account. Sufficiently precise calculation methods may also be used as the basis for creating new business models for safety systems involving multiple stakeholders (e.g., drivers, OEMs, authorities, insurance companies, etc.), and thus help accelerating market deployment.





## 4.5 Safe infrastructure

Road infrastructures have an important role in traffic safety, accident reduction and accident impact mitigation. Further, society is not accepting an unsafe transport system and therefore constantly improvement of road quality and strengthening of inherent infrastructure safety aspects is of political interest. In this context the status of the road network is an important performance criterion and aids in determining road infrastructure's safety level. Research is needed to precisely define the "safety rank" of the road network considering all safety aspects and developing cost-effective solutions to improve the safety performance of the existing road network. As a consequence, critical road sections are identified and available resources and budgets are distributed to improve the road network.

Road monitoring and maintenance are important parts in providing a reliable and safe infrastructure. However, these tasks require alignment with the societal needs for mobility and sustainability. Research and development on real-time road status monitoring and on evolving towards zero maintenance roads is needed to avoid disruption of traffic.

Road infrastructure can help the driver by either explaining a proper use (adapted speed profile) or by mitigating consequences of erroneous behaviour. These concepts are called self explaining roads and forgiving roads. Research is needed to evaluate and understand both concepts with the aim of cost-effective and targeted deployment. An integrated approach of both is needed to streamline results as effects might have opposing impact.

Vulnerable road users, elderly people and people with specific needs are important groups in road safety due to accident severity. Further, the societal challenge of ageing society requires preparing the road transport system for future needs. Current roads and road design do not consider these groups particularly. The challenge is to adapt the current system to the specific needs and increase the level of protection. Research is needed on how to achieve this adaptation in a cost efficient way.

A long-term objective in road transport research (beyond 2025) is to gain a certain level of automation in the transportation system. Assuming that all security and liability issues are solved the automated road will support efforts in traffic safety to achieve vision zero. Coordinated research efforts with ITS related topics (see cooperative systems) are needed towards better integration of the infrastructure, infrastructure related databases, traffic management centres and control centres. Better incident management is one research item which requires coordination of all involved stakeholders. Future ITS solution shall support this process. Economic benefits from such improved systems are among others reduced congestion and reduced risk of secondary accidents.

Topics for research:

1. Real time road status monitoring
2. Towards zero maintenance roads
3. Self-explaining roads
4. Forgiving infrastructure

5. Advanced Incident and Traffic management
6. Conception and design for elderly, vulnerable and users with specific needs
7. Automated road

#### 4.5.1 Real time road status monitoring

The road status and the road condition are significant in the interrelation of accidents and infrastructure. Currently, road sections with higher risks (accident blackspots) are identified by accident statistics. The challenge is to identify dangerous sections beyond accident blackspots related to the road status. In this context it is important to have continuous information (road data, traffic condition, weather information, visibility etc.) both in spatial terms and time wise. Research is needed to develop techniques for in-situ monitoring (sensors and communication) and condition monitoring under traffic speed conditions to avoid disruption. Specifically on the secondary road network where funds are limited and monitoring on a regular basis is not feasible, concepts need to be developed to increase information quality. Probe vehicle concepts making use of extended floating car data communicated in a cooperative system might be a reasonable and cost efficient approach. Road safety on secondary roads is even more relevant as accident statistics show a considerable higher accident risk compared to urban roads or motorways.

#### 4.5.2 Towards zero maintenance roads

Construction and maintenance works on roads (highways and motorways) reduce the level of service. Besides the associated higher chance of congestion, construction areas exhibit a higher accident risk (especially rear end collision, side impact and accidents with oncoming traffic). It is therefore a reasonable objective for road transport safety to reduce downtime due to construction and increase the level of service. Research includes concepts to increase durability and reduce maintenance interventions and costs by advanced asset management approaches. The challenge is to unify expectations in lifecycle cost reduction by at the same time increasing availability, quality and reliability of the road infrastructure network. This and traffic safety concepts especially in road construction areas will aid in reducing accident risks. Safety road workers and concepts to reduce the risk of accidents involving road workers are of specific interest.

#### 4.5.3 Self-explaining roads

Self-explaining road design aims at preventing drivers from errors while driving [...]. It is an important tool to adapt user behaviour to road safety level. The road design and landscape stimulate the drivers to choose the proper speed and safe driver behaviour. These concepts support calming of road traffic and reducing road user mistakes.

One of the major challenges is to develop the concept for each kind of network (secondary road, motorway, etc.) and to provide helpful rules to design or rebuild the roads.

Self-explaining road design needs consolidation with forgiving roads principles to evaluate effects on traffic safety in an integrated approach. This is necessary as effects might be contradicting.

#### 4.5.4 Forgiving Infrastructure

Forgiving roads mitigate consequences of accidents. The first priority of forgiving roadsides is to reduce the consequences of an accident caused by driving errors, vehicle malfunctions or poor roadway conditions. The main objective of forgiving infrastructure is to bring errant vehicles back

onto the lane to reduce injury or fatal run-off-accidents. If the vehicle still hits a roadside element, the second priority is to reduce the severity of the crash. In other words, the roadside should forgive the driver or vehicle erroneous driving by reducing the severity of run-off-road accidents. The challenge is unifying considerations to preserve the landscape with risk reduction efforts due to roadside obstacles. Consequently, self-explaining road and forgiving road concepts require consolidation. Research is needed to evaluate risk reduction effects in a unified concept as separated consideration might yield controversial results.

#### **4.5.5 Advanced incident and traffic management**

Traffic safety and congestion are influencing each other bidirectionally. And both challenges have a major economical impact. For cost-effective solutions it is necessary to manage European roads in a sustainable way and improving the use of the existing road network. The challenge is to support road authorities by identifying cost-effective solutions and assessing the impact of ITS in traffic management. One of the first research priorities is related to a better incident management including all stakeholders. Incidents often resulting in congestion need a comprehensive management system. This will increase the level of safety and reduce secondary costs (congestion and secondary accidents). Research is needed to obtain valid and good quality data to anticipate incident. Concepts like extended floating car data should be integrated. Further incident management should accelerate post accident rescue and lifesaving. Especially in the transition phase for new vehicle based safety technologies (e.g. eCall, cooperative systems) it is important to properly prepare the infrastructure (infracall). Research is needed on how and where the infrastructure can support non-equipped vehicles in a proper and cost-efficient way.

#### **4.5.6 Conception and design for elderly, vulnerable and users with specific needs**

Of specific interest is the protection of VRU, elderly people or people with specific needs. In this context safe infrastructure design, construction and technologies play a significant role. Ageing society makes it even more important to act soon on reviewing and preparing the road infrastructure for the needs of elderly people. The future in road transport safety will strongly depend on how elder and vulnerable road users as well as their needs are better integrated in the systems safety considerations. Research and development specifically considering the needs of this user group and improving protection for VRU or prevention of VRU accidents is required. Further research is needed to review current regulatory framework and design guidelines to identify gaps and suggestions for improvement.

#### **4.5.7 Automated road**

A certain level of automation of the road transport system will aid in increasing the level of service, the level of safety and energy efficiency. This includes concepts of platooning in freight transportation (demonstrated in the EC SARTRE and Citymobil projects) and advanced control functionality through cooperative systems. By 2025 the developments towards automation of the road transport system progress to a certain level (including considerations on liability and legal framework) where infrastructure needs to be prepared for that step change.

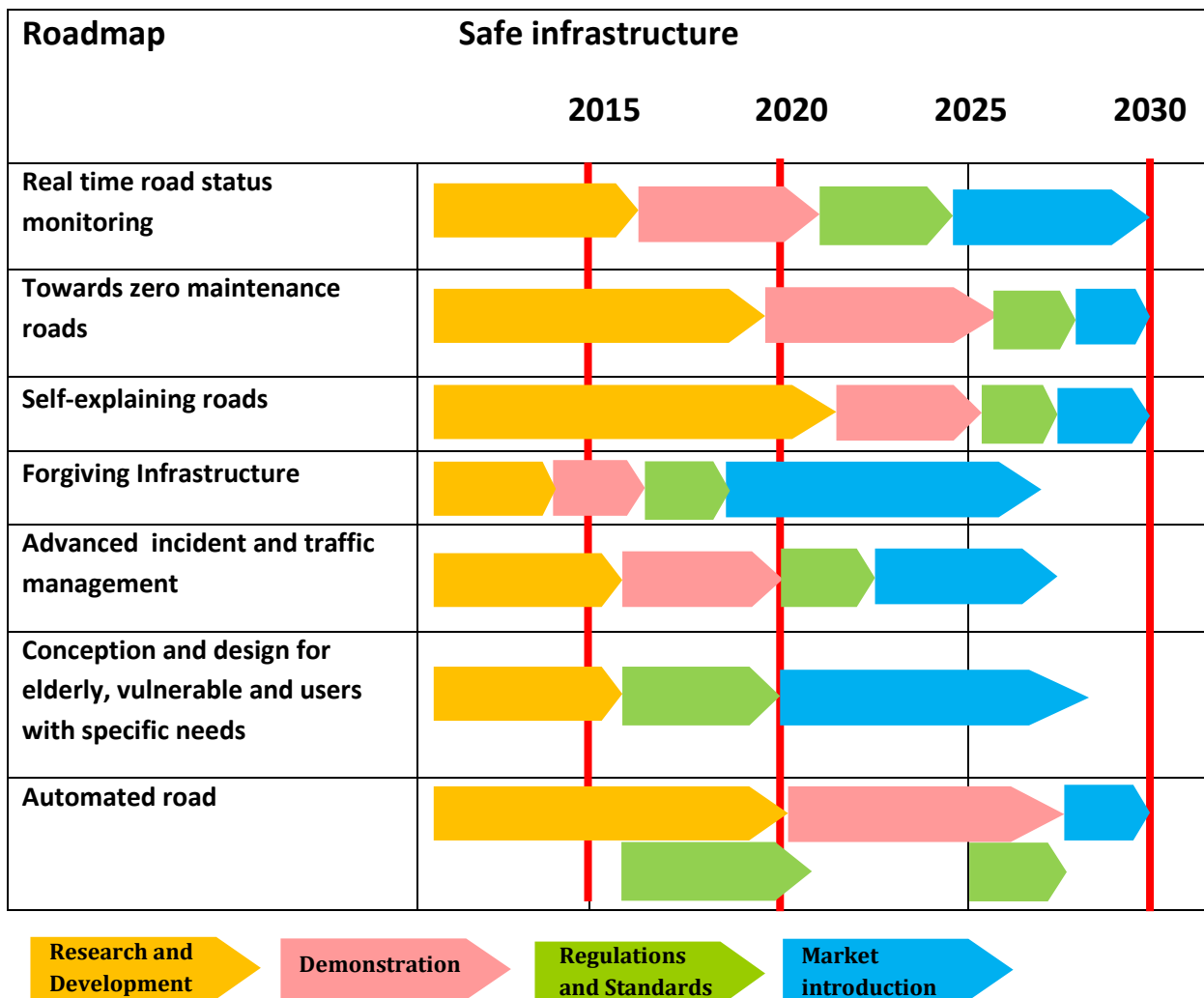
The Automated Road will integrate road side intelligence with ICT applications in the vehicle, the services and the operator. The sensory and communications technology involved will enable the deployment of advanced (e.g. dynamic) guidance and management systems tailored to respond to in situ requirements, in effect improving reliability and efficiency of the network management.

## ERTRAC Research and Innovation Roadmaps

It is therefore inevitable to connect infrastructure, databases, traffic control centres in the development process. Virtual or physical separation of traffic is required to proceed with automation of road transport. Demonstration projects need to elaborate this system orientated approach towards automated driving.

Another challenge due to the complexity and sensitivity of automated driving is more fundamental: accurate positioning to allow fail-safe lateral and longitudinal vehicle control. The research steps will concentrate on on-site sensor systems monitoring and control algorithms. A systems approach is needed combining vehicle, infrastructure and driver to develop roads towards automation.

Comprehensive, interoperable communications system linking driver, vehicle, road and operator is required. This enables future vehicle to highway guidance, speed control and direction guidance and in-road vehicle guidance using to change lane usage and traffic management.



## 4.6 Cooperative systems for road safety and security

It should be emphasized that the concept of cooperative systems is very broad. The common view today is that it covers modern and innovative use of Information and Communication Technologies as a basis for functions and applications that facilitate and improve the quality of the mobility for people and goods in general terms.

This chapter will only cover needed research and development aspect to facilitate cooperative system like communication technologies and the closely connected standardization. These are prerequisite and enablers for a broad implementation of co-operative systems. It is worth mentioning that the communication technologies will not only support road transport safety and security issues which this road map deal with, but also other challenges like environmental issues and transport efficiency. The communication technologies are fundamental to all applications and will be used for a broad variety of them.

This chapter emphasise as well the necessity of Field Operational Test as an important step to validate the technologies, models and developments on the way to large scale implementation and deployment.

Road safety is expected to gain from the cooperation between vehicles (V2V) and between vehicles and infrastructure (V2I) and it is clearly the approach that allows moving close to the final target of “zero accidents”. There are still several aspects to cover in research: standardisation, cost-effective hardware and software solution for communication between vehicles and with the infrastructure, precise relative localization and proper management of non equipped vehicles and road users. Due to cooperative systems and the connection between vehicles and to the infrastructure, advanced safety support functions are possible. The applications supporting drivers range from warning systems for low friction surface, congestion warning and intelligent speed adaptation. Research is needed to bring forward support applications with impact on road safety based on the previous project results considering the standardised communication routines. Subsequent to the research and development of algorithms and applications large field operational tests are required to assess safety impacts, user acceptance, cost benefit and driver behaviour in order to correctly design all components and the entire system.

Another research question is to what extent and how are Powered Two Wheelers (PTW) other Vulnerable Road Users (VRU) integrated in cooperative systems given their above average involvement in severe crashes. Risk compensation by drivers may undo the advantages of cooperative systems if drivers too heavily rely on a system that leaves the most vulnerable road users uncovered.

Topics for research:

1. Communication protocols, standards, ...
2. Safety of co-operative systems
3. Security of co-operative systems
4. Field Operational Test (FOT)

#### 4.6.1 Communication protocols, standards, ...

Ongoing standardisation work in different bodies (ETSI, CEN) provides a sound basis for communication between vehicles and from vehicles to the infrastructure and reverse. This work is related to communication standards and the services.

The previous EC-funded R&D projects have been the major contributors to European standardisation in the ITS area.

The main focus of the standardization activity carried on by each of the main organizations is different. Each is developing separate sets of standards, tailored to their specific focus:

- ISO mainly focuses on multiple media management
- IEEE focuses on lower layers (802.11) and a “simplified” architecture for just 5.9GHz communications
- ETSI focus is currently mainly car-to-car multi-hopping and geo-networking
- CEN is focusing on standards for messaging, protocols, architecture etc. for cooperative mobility applications.

In general, proliferation of incompatible ITS standards is very inefficient and works against the conditions for actual deployment of cooperative ITS solutions. Such fragmentation can lead to increased cost and deployment delays and, most importantly, can increase the risk of compromising the achievement of safety and efficiency benefits.

Unfortunately, since no real interoperability has been actually guaranteed in current specification work, large overlaps and a substantial amount of duplicated effort has developed. In addition, the standardisation groups have not been taking advantage from a collective cooperation

Based on the previous considerations, during the last year, the shared awareness that global cooperation and vision is ultimately needed has been increasingly developing among all the different actors, such as:

- Standard Development Organizations (SDOs)
- ITS-related government entities (DoTs)
- ITS R&D projects

This cooperation has eventually started to happen among the SDOs in the form of official liaisons and cross member participation to the different committees and ETSI TC ITS is particularly active in this harmonization activity that needs continuous backing and support.

The results of the activity performed in the frame of the main EU R&D projects are now being effectively transferred into the standardization process in the ETSI TC ITS and CEN TC 278 domains and the overall scenario seems now adequate to achieve a stable set of standards able to support the market take up of the cooperative ITS solutions. This direct link between research project and standardisation should be intensified. However, the rigorous approach of the standardisation experts

might be needed at one point to create a structured approach leading to conformance testing and certification procedure.

### 4.6.2 Safety of co-operative systems

Quite a few of the applications based on cooperative system technologies require a high degree of overall system safety, assuring a minimum of systems breakdown of a type that jeopardize the traffic safety. Such applications can be found dealing with cooperation between vehicles e.g. Cooperative forward collision warning as described in ETSI TR 102638 V1.1.1 (2009-06). This and many similar applications require use of well validated models standards and technologies to be able to provide a failsafe system. The system on each node must have a supervisory application that is permanently running in parallel and is checking the relevance of the input data and calculated results which in the end generates a signal to an actuator affecting in the case of Cooperative forward collision warning the speed regulator and or the brake. This fail safe functionality is already implemented among the OEMs when it comes to other ADAS systems e.g. lane keeping assist, but is important to mention in practical terms and in this context. When it comes to co-operative systems the failsafe issue is of a much higher dignity than in autonomous ADAS and needs special focus in research and development agendas.

In developing systems towards autonomous driving as a tool for e.g. platooning the importance of safety issues in communication, in standards etc for cooperative systems will be even higher.

As the communication safety issues related to cooperative systems are very broad due to the variety of applications and their different demand, it is not meaningful to point out any specific subject. Instead the important horizontal issues relevant for all applications are:

- Fail safe communication link
- Validated standards
- Validate communication link in a big variety of traffic composition, density etc.
- Field Operational Tests to consolidate and validate the communication functionality

To get national, regional and local road authorities as well as commercial road operators involved there must be convincing evidence from large scale FOTs. Secondly to get cross-border functionality there is a need for cooperation between road operators and road authorities or between organizations that represents them to a common agreement on how to proceed.

### 4.6.3 Security of co-operative systems

Security of the cooperative systems deals with designing and ensuring a communication system that is resistant against cyber attacks, false messages etc. Privacy is also connected to security and a system has to ensure a certain level of security for user acceptance. A challenge for future research is to improve the security level without any negative impact on the efficiency or lowering capacity of the system.

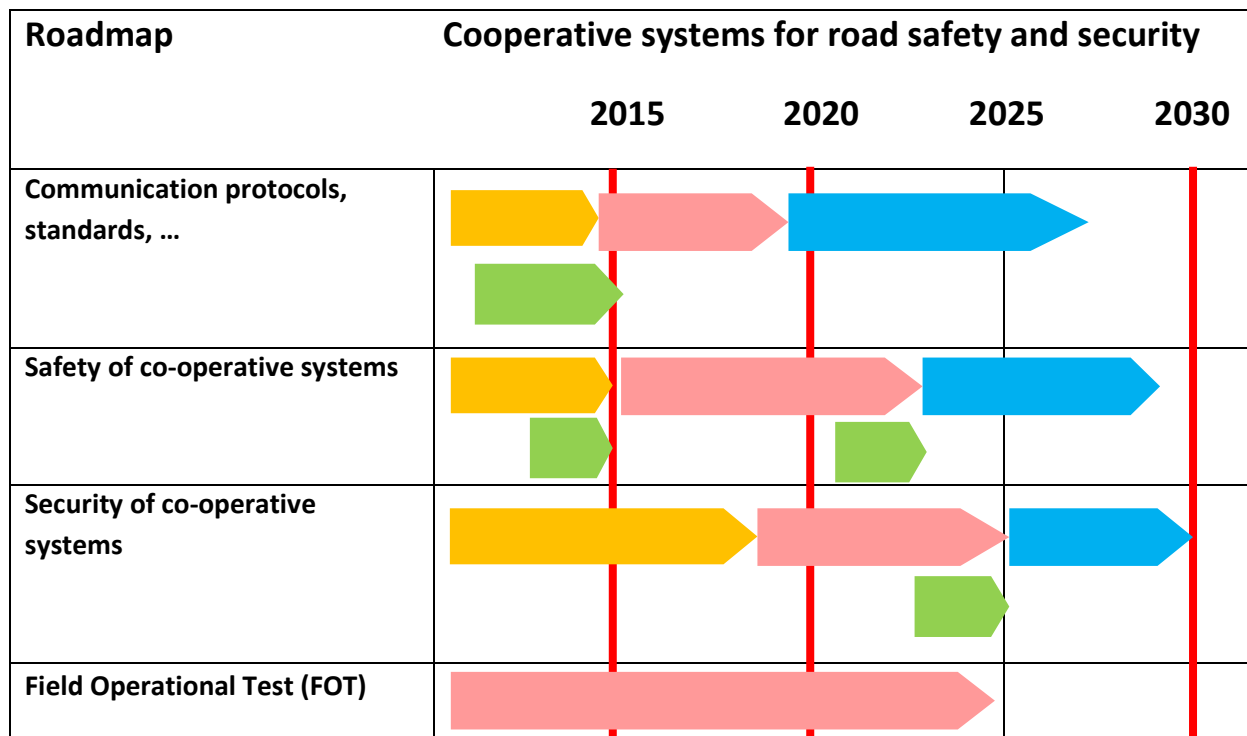
The security of co-operative systems has been well addressed in the deliverable D31 European Communication Architecture from COM eSafety support action.

### 4.6.4 Field Operational Test (FOT)

Field Operational Test is an important tool to validate models and calculations made to estimate the functionality and impact of applications based on cooperative systems. Validation is needed of

simulation models for communication and other models that have been developed for cooperative systems. Those models have been validated in research projects containing a small number of vehicles. Large scale Field Operation Tests are now needed to validate the models in a greater context to ensure the functionality. Another reason is to convince road operators and politicians, local and regional officials responsible for the public road network. Therefore the FOTs need to have a critical mass of vehicles/users to give relevant answers. Other objectives in FOTs are related to impact assessment specifically any the safety impact, the user acceptance and the cost/benefit of the tested systems. This is necessary to develop adequate business models and support large scale deployment. So the FOTs have many objectives where proving and consolidate the communication functionality is one.

There is an ongoing discussion among the infrastructure stakeholders if the impact of a cooperative system (especially V2I) is of such magnitude justify the implementation costs. It is important to remember that investments in cooperative systems compete with many other traditional measures where the cost/benefit is well known. The existing recommendations concerning V2I implementation priorities from different stakeholder groups currently lack this information. Those recommendations are not yet based on impact assessments performed during/within large scale Field Operational Test.





## 4.7 Secure road transportation

Economic growth is always accompanied with an increasing amount of freight and passenger transport which challenges the infrastructure and vehicles not only to keep pace with the increasing traffic volume but also to ensure security standards being met. Major challenges in the area of stolen or lost goods, vehicle theft, driver security, data security as well as protection against manipulation shall be addressed.

A study published by the European Parliament in 2007 has shown economic losses due lost or stolen goods in the European Union to amount of 8,2 Billion Euro annually . According to TAPA (Transported Asset Protection Association) this number is only a fracture of the economic damage as it doesn't account all costs the industry suffers (e.g. replacement goods, re-shipping etc). A report from EUROPOL, published in 2009, also states various modus operandi like curtain slashing, jump up thefts, load diversion, use of fraudulent documents as well as use of gas or explosives to incapacitate the driver. Therefore countermeasure solutions shall be developed and promoted to reduce the amount of lost, stolen or damaged goods to ensure free trade and economical competitiveness. These measures will also help reducing illegal freight transport (drugs, weapons, etc.) or illegal boarder crossing in freight compartments.

There is also a continuous challenge to prevent vehicles from being stolen or broken-up. Technological improvements over the last decades have increased the complexity to manipulate anti-theft systems. This leads to the situation that criminals are better organized and use more sophisticated methods to disable remote access or immobilization systems. Trafficking with stolen vehicles has become to a regular field for economic activity of criminal organisations and is often accompanied with other criminality. Novel systems will have to be developed to hinder, discourage and prosecute thieves as well as increase the recovery rate of stolen vehicles and goods.

Along with the emergence of vehicle telematic (ITS), cooperative traffic, co-modality and particularly vehicle tracking systems, data security questions will need to be solved to ensure user acceptance and avoid data misuse.

The following research topics for new generation road transport security systems need to be addressed:

1. Secure road transport facilities
2. Tamper-proof identification and access systems
3. Advanced alarm and tracking systems for vehicles and goods
4. Cooperative systems to increase security level in the freight transportation
5. Data security in road transport systems

### 4.7.1 Secure road transport facilities

Freight distribution centres, park&ride areas and resting places for trucks will need to be equipped with secure and intelligent surveillance, alarm and access systems. The deployment of systems that use or combine optical technologies (camera, infrared) will prevent attacks to parked trucks and may be operated manually or (semi-) automatically. Solutions in connection with future ITS systems allowing truck drivers to identify and reserve free and secure parking places, where incoming and

outgoing traffic is monitored, are highly desired and will need to be integrated in traffic management centres.

#### **4.7.2 Tamper-proof identification and access systems**

Secure and reliable identification and authentication is the baseline for every security system and their design is always a balance between the level of security and available time. Requirements for short identification times always suffer cut-backs in security and vice versa. Therefore developments in the area of identification technologies (e.g. RFID, smart labelling, etc.) require continuous effort as new technology always open benefits in efficiency and/or comfort. For access- or immobilization systems, new technology will allow reliable protection against vehicle theft or malice intrusion. It will allow reliable, novel ICT connectivity functions like smart phone or handheld interfaces. Hidden or secret identification systems will help to detect fraudulent documentation (e.g. spare parts from stolen vehicles, waybills) but will require pan-European (or even worldwide) harmonization of databases and methods. Access systems to freight distribution areas or roads that are dedicated to specific vehicles, will need to have sufficient protection against trespassing along with efficient usability. Supply chains and freight delivery with seamless cargo monitoring (incl. on-board) down to continuous single parcel identification will allow significant reduction in stolen or lost goods and improves correct sender/receiver identification. The profitable and comprehensive implementation of such systems will require continuous improvement of current identification technology as well as new approaches.

#### **4.7.3 Advanced alarm and tracking systems for vehicles and goods**

Advanced localization and tracking systems will enjoy growing popularity for fleet and freight management as they help to increase not only efficiency but also security. Following an incident where a vehicle or a piece of good has been stolen these systems may be embedded in a powerful emergency chain of alarm systems and containment measures that avoid trafficking with stolen vehicles and goods and will increase the chance to identify offenders. The first step of this emergency chain are reliable and tamper-proof alarm systems that detect malice intrusion (or intrusion attempts) in vehicles, cargo compartments or containers using various types of sensing technologies (e.g. infrared, ultrasonic, microwave, vibration, narcotic gas detectors, etc.). Key features of these systems are a close-to-zero false alarm ratio and an effective alarm scenario that should include automatic emergency message to police or law enforcement agencies. To protect the driver from violence or threat the system will need to have arming/disarming mechanisms that do not require his action or involvement. In a second step systems that localize stolen goods or vehicles will allow continuous persecution. To prevent the systems from manipulation or re-moving they need to be securely mounted or hidden. The systems shall be able to work also in a degraded mode with redundant power supply, communication channels and alternative localization techniques (jammed or no GPS/Galileo). As a third and last step systems shall be able to stop a vehicle to prevent continuation of unauthorized movement. This needs to be done without endanger other road users and avoiding dangerous situations (e.g. blocked vehicles on railway crossings or in tunnels). The systems will enjoy quick market penetration when economic benefits are offered (lower insurance rate or taxes).

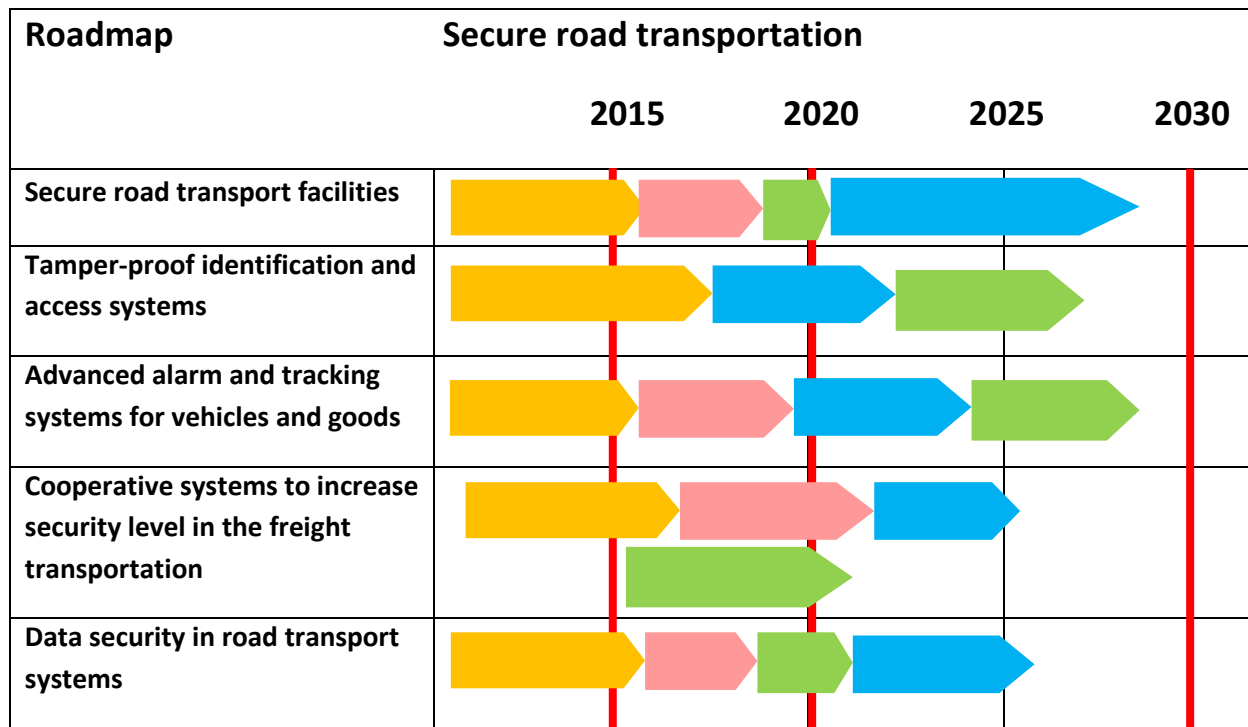
#### **4.7.4 Cooperative systems to increase security level in the freight transportation**

Future ITS Solutions and cooperative systems aid in protecting people and goods in road transportation. This is very relevant for dangerous or sensitive goods but also for freight transport in

general. Innovative technologies and functionality for tracking/tracing of vehicles and goods shall be integrated. Satellite based positioning (GPS, Galileo) in combination with V2X and ITS is a key element to enable redundancy of systems. Within a cooperative system, other vehicles and drivers may be warned after a reported theft. Dangerous and sensitive goods transports will be the first ones equipped with these applications. Demonstration activities are needed to show full vehicle and infrastructure based tracking/tracing with cooperative systems. Integration of road infrastructure based sensors for tracking, speed and weight monitoring, tolling, etc. is required. Another aspect is the security of drivers. In this context systems are necessary to authenticate information given to driver about unscheduled route changes (prevention of ambush attacks after route deviation) making use of cooperative systems. The network of goods (integrated smart sensor networks or RFID tags) allows creating ubiquitous awareness for goods and connecting them in the cooperative systems. This aids in immediately identifying any unauthorized position change or any physical or environmental (temperature, humidity, etc.) damage of the freight. Demonstration activities should incorporate pan-European activities towards harmonization of identification systems, tracking systems and (electronic) freight letters. Large demonstration activities or field operational trials with cooperative systems (see cooperative systems roadmap) shall include services for security of people and goods as well as protected data storage and transmission (see data security).

#### 4.7.5 Data security in road transport systems

Along with the deployment of new systems in the area of vehicle tracking/tracing, cooperative systems or any other ITS the users' data privacy needs to be protected at any time. Unauthorized use of data, protection against manipulation or attack will not only cause short time danger (e.g. hacker or terrorist attack) but may also cause users to be hesitant using novel systems. The commercial success of systems like automatic road tolling or parking fee collection, access to restricted areas or entry to roads dedicated to special vehicles will depend on the user's trust in the protection of his privacy and security. Thus it will be inevitable to establish appropriate standards with pan-European (or worldwide) acceptance that define storage, handling, transfer and protection of personalized data.



## 5. Milestones

### 5.1 Milestone 2015 : Safe Green Transport

**Expected benefits** – 20% of accidents  
- 30% freight lost

Safety of low emission vehicles  
Improvement of driver assistance systems (all scenarios)  
Vulnerable road user protection  
Secure parking

### 5.2 Milestone 2020 : Full integrated safe road transport

**Expected benefits** – 30% of accidents  
- 30% freight lost

Enhanced driver assistance systems (control)  
Cooperative systems - Support  
Safe infrastructure  
Secure Transport  
Road User Behaviour improvement  
Preventive Vulnerable road user protection

### 5.3 Milestone 2030 : Towards Near Zero accident Road Transport

**Expected benefits** – 30% of accidents  
- 30% freight lost

Automated system for collision avoidance  
Cooperative systems – Control  
Cooperative - Vulnerable road user protection  
Full support for road user safe behaviour  
Dedicated road infrastructure

<b>Safety of vulnerable road users</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Intelligent traffic systems for VRU safe mobility management</b>	Systems for VRU guidance, driver awareness and VRU awareness.	Selection of demonstration sites. Installed in-vehicle systems, infrastructural detection and identification systems and smart management systems. Demonstration in well-known black spots.	Market introduction and impact analysis.
<b>Improved VRU active safety systems for accident avoidance</b>	Smart systems for VRU detection to achieve: <ul style="list-style-type: none"> <li>• increased VRU detection</li> <li>• lower system cost</li> <li>• increased reliability</li> <li>• smart use of driver workload estimation.</li> </ul> Autonomous accident avoidance system based on smart sensors.	Demonstration of most promising systems in inner cities. Definition of test protocols and adequate testing systems for VRU active safety systems. Harmonized protocols included in a regulatory framework.	Show effects of VRU active safety systems.
<b>Safety systems for the protection of (motor)cyclists in collisions with motor vehicles.</b>	Active and passive systems to decrease the collision impact between VRU and motor vehicle, both on-vehicle and protective garments. Demonstration of in vehicle measures.	Demonstration of protective garments. Market introduction of most effective systems. Regulatory framework for autonomous actions of in-vehicle systems.	
<b>Safety systems for single-vehicle motor-cyclist accidents</b>		Protective measures in single-vehicle motorcyclist accidents: both motorcycle measures, garment integrated systems and forgiving infrastructure.	Demonstrated reduction in casualties for single-vehicle accidents.
<b>Mitigation of secondary impact</b>	Definition of criteria for evaluation of secondary ground impact i.e. accident kinematics, injury parameters, scenarios, influence of	Development of adequate counteractive measures. Demonstration of most promising safety measures.	Market introduction and definition of test procedures.

	vehicle geometry and speed.	Analysis of potential for autonomous braking systems regarding secondary ground impact.	
<b>Safety of New Vehicles</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Biomechanical models and injury prediction</b>	Injury criteria for neurological deficits incl. injury criteria for elderly and other VRUs. Worldwide harmonized more biofidelic crash dummies for frontal and side impacts. Human body models for safety assessment with biofidelic kinematics and realistic injury predictions for integrated safety	Human body models suitable for multiple events. Harmonized human body models as a basis for a worldwide accepted virtual safety assessment methodology. Introduction of virtual safety assessment methodology for primary and secondary safety in global regulations and consumer testing	
<b>Crash compatibility and improved crashworthiness of light and/or new vehicle concepts</b>	Harmonised safety requirements for downsized and extra-low mass vehicles. Design guidelines for crashworthiness of electric vehicles and specific test procedures.  Crashworthy structures for two-seaters with in-line seats. Restraint systems adapted to the requirements of lightweight vehicle concepts.	Predictive numerical simulation tools for composite materials under impact loading incl. the post-failure behaviour. Requirements for crash compatibility and related test procedures harmonised worldwide.	
<b>Solutions for low acoustic perception of FEVs</b>	Sound functionality and generation devices. Sensing strategies and HMI integration for	Validated, integrated acoustic solutions for preventive vulnerable road user protection	Holistic automated acoustic system environment for collision avoidance, mainly in

	acoustic solutions.  Demonstration / field testing		terms of vulnerable road user protection
<b>Advanced Driver Support Systems</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Vehicle Dynamics Monitoring and Control</b>	First generation integrated chassis.	Driver assistance systems acting on the integrated chassis, including long vehicle combinations for heavy goods vehicles.	Distributed energy storage and propulsion (on vehicle combinations for heavy goods vehicles)
<b>Driver Support for Collision Avoidance</b>	Wide-scale deployment of active safety systems in all vehicle models and types	Enhanced perception platform, integrating onboard sensing, V2X, e-Horizon and driver monitoring; Integrated IWI strategies	Automatic intervention in a wide range of critical scenarios
<b>Driver Impairment Monitoring and Support</b>	Wide scale deployment of alcohol-locks and drowsiness mitigation systems	Integration of driver inattention and impairment monitoring into the general perception platform	Driver monitoring supporting semi-automated driving
<b>Automated systems</b>	Wide scale deployment of basic semi-automated functions (ACC Stop&Go with automatic Go, full longitudinal support and limited lateral support )	Advanced semi-automated functions (e.g. full longitudinal and full lateral support in optimal conditions)	First fully automated functions (e.g., platooning in dedicated areas)
<b>Driver coaching</b>	Stand-alone Driver Coaching systems widely deployed	Driver Coaching integrated with other driver support systems and part of general safety management programs	Driver Coaching for automated driving



<b>Human-machine Interaction</b>	Integrated HMI solutions minimising driver distraction, including centralised-workload management functionality	Seamless integration of third-party applications	Adaptive HMI solutions tailored for specific user groups (e.g., elderly drivers)
<b>Traffic Safety Analysis</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Road accident monitoring and investigation</b>	2015 Implemented accident investigation infrastructure for harmonised European in-depth data which feeds the traffic safety analysis research.	Understand the shift in injury patterns due to implementation of future safety countermeasures. Methods for cost-efficient data collection and analysis merging different types of field data.	Integrated analysis from field data including event data recorders, Naturalistic Driving studies, accident and injury data fully available for impact assessment and cost benefit analyses
<b>Naturalistic driving studies</b>	first results from established Naturalistic Driving database across EU	The relationship between accidents and surrogate (crash-substitute) measures is validated. Non-crash events are predictably and reliably related to crashes.	Integrated approach between accident/Naturalistic driving and simulators
<b>Road user modelling and simulation</b>	Off-the-shelf high-fidelity simulation models of driver behaviour in selected accident scenarios; Large scale traffic simulation validated for safety assessments	General off-the-shelf high-fidelity models of road user behaviour in all major accident scenarios, including all types of road users	Integrated, general modelling and simulation of road user behaviour on large and small time and space scales
<b>Impact Assessment and Cost benefit analysis</b>	Validated European impact assessment methods based on	Simulation-based impact assessment tools linked to continuous	More advanced, and precise, cost/benefit analysis methods for

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	combination of accident statistics and, FOT data and simulation	collection of naturalistic data	road safety (based on the previously developed impact assessment methods)
<b>Safe infrastructure</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Real time road status monitoring</b>	System specification for real-time road status monitoring	Demonstrator of a monitoring system finished	Standardisation and market introduction
<b>Self-explaining roads</b>		Self explaining roads and forgiving road consolidated and demonstrated	Integration of self explaining and forgiving design and construction in the standards, guidelines and regulation finished
<b>Forgiving Infrastructure</b>		Self explaining roads and forgiving road consolidated and demonstrated	Integration of self explaining and forgiving design and construction in the standards, guidelines and regulation finished
<b>Towards zero maintenance roads</b>		Large scale Demonstration projects	Starting Market Introduction and Implementation
<b>Conception and design for elderly, vulnerable and users with specific needs</b>	New concepts for road design developed considering VRU and elderly people or people with specific needs	Large scale testing	Standardization, Guidelines and regulations adapted to consider needs of VRU, elderly people and people with specific needs
<b>Automated road</b>		Specifications, prototype and system definitions finished	Large-scale Demonstrator of an automated road system

<b>Cooperative Systems</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Consolidation of communication standards</b>	Communication standards covering most layers of the communication stack is available.	Verification made on communication standards supporting secure semi-autonomous driving	Verification made on communication standards supporting secure full autonomous driving
<b>Large field operational tests on cooperative systems support functions.</b>	Cooperative systems support functions. Impact assessment and functional verification completed.	Cooperative systems used for support integrated functions. Impact assessment and functional verification completed.	Cooperative systems used for Semi automated systems Impact assessment and functional verification completed.
<b>Secure Road Transportation</b>			
	<b>2015 - Safe Green Transport</b>	<b>2020 - Full integrated safe road transport</b>	<b>2030 - Towards Near Zero Accident</b>
<b>Secure road transport facilities</b>	Integration of secure parking areas in large ITS FOTs	Proven concepts in market (<10% of all areas) with ongoing legislation activities	50% of all areas protected with advanced systems
<b>Tamper-proof vehicle access and immobilization</b>	Concepts for secure novel ICT vehicle connectivity and ITS integration available	Ongoing market introduction with 20% of novel vehicles equipped with ICT connectivity	Close-to-zero possibility to illegally unlock and start a novel vehicle with ICT connectivity
<b>Seamless on-board cargo monitoring</b>	Demonstration of concepts for on-board identification of individual parcels	Deployment in supply-chains for high value and sensitive goods (<10 % of all freight transport)	50% of all parcels are continuously monitored 65% reduction of stolen or lost goods compared to 2010
<b>Advanced alarm and tracking systems</b>	Integration of advanced alarm/tracking systems in ITS FOTs	All new vehicles with optional tracking systems available, pan-European service available, promotion by insurances	>65% of all new vehicles equipped with alarm and tracking systems. >80% of all freight transport protected with tracking systems.

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<b>Cooperative systems to increase security level in freight transportation</b>	“Network of goods” inclusion in large ITS FOTs	>50% of dangerous or sensitive good transports are integrated in ITS	65% reduction of stolen, lost or damaged goods compared to 2010
<b>Data Security in road transport systems</b>		Pan-European standards for ITS data security established	

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## 7. Glossary

<b>CEN</b>	- <b>European Committee for Standardization</b>
<b>CMbB</b>	- <b>Collision Mitigation by Braking</b>
<b>ERTRAC</b>	- <b>European Road Transport Research Advisory Council</b>
<b>ESC</b>	- <b>Electronic Stability Control</b>
<b>ETSI</b>	- <b>European Telecommunication Standards Institute</b>
<b>EuroNCAP</b>	- <b>European New Car Assessment Programme</b>
<b>FEV</b>	- <b>Full Electric Vehicle</b>
<b>FOT</b>	- <b>Field Operational tests</b>
<b>HMI</b>	- <b>Human Machine Interaction</b>
<b>HV</b>	- <b>Hydrogen Vehicle</b>
<b>ICT</b>	- <b>Information and Communication Technologies</b>
<b>IWI</b>	- <b>Information, Warning, Intervention</b>
<b>LDW</b>	- <b>Lane Departure Warning</b>
<b>NDS</b>	- <b>Natural Driving Studies</b>
<b>NVH</b>	- <b>Noise, Vibration and Harshness</b>
<b>PTW</b>	- <b>Powered Two Wheeler</b>
<b>RFID</b>	- <b>Radio Frequency Identification</b>
<b>V2I</b>	- <b>Vehicle to Infrastructure communication</b>
<b>V2V</b>	- <b>Vehicle to Vehicle communication</b>
<b>V2X</b>	- <b>Vehicle to infrastructure/vehicles communication</b>
<b>VRU</b>	- <b>Vulnerable Road User</b>

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