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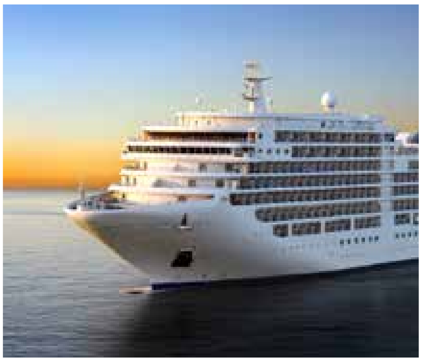

# Research Theme Analysis Report

# Transport Safety

COMMUNICATING TRANSPORT RESEARCH AND INNOVATION

www.transport-research.info

*Mobility and Transport*

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Transport Research & Innovation Portal

# Research Theme Analysis Report

# Transport Safety

# Contents

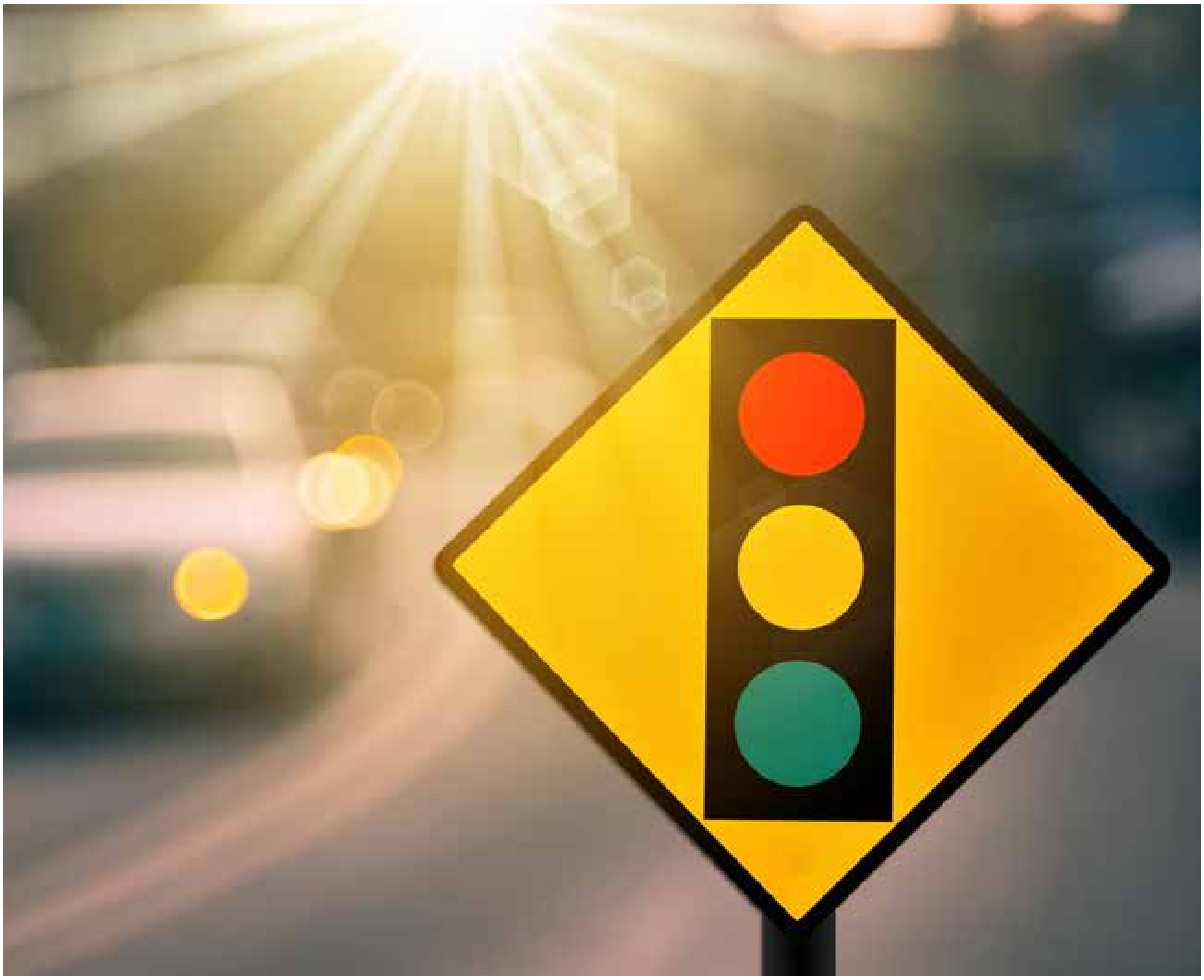

| | | |
|---|---|---|
| | **Executive summary** | **4** |
| **1.** | **Introduction** | **7** |
| **2** | **Policy context** | **8** |
| 2.1 | Transport safety in European transport policy | 8 |
| 2.2 | Transport safety in European research programmes | 10 |
| 2.3 | Research priorities and roadmaps | 10 |
| **3** | **Sub-theme assessments** | **12** |
| 3.1 | Safety in road transport | 12 |
| 3.1.1 | Introduction to the sub-theme | 12 |
| 3.1.1.1 | Overall direction of European-funded research | 12 |
| 3.1.1.2 | Overall direction of nationally funded projects | 12 |
| 3.1.2 | Research activities | 13 |
| 3.1.2.1 | Road safety management | 13 |
| 3.1.2.2 | Road users | 14 |
| 3.1.2.3 | Infrastructure | 15 |
| 3.1.2.4 | Technology | 15 |
| 3.1.3 | Research outcomes | 16 |
| 3.1.3.1 | Achievements of the research under this sub-theme | 16 |
| 3.1.3.2 | Transferability from research to practical use | 18 |
| 3.1.3.3 | Indications for future research | 18 |
| 3.1.3.4 | Implications for future policy development | 19 |
| 3.1.4 | List of projects included in the sub-theme assessment | 20 |
| 3.2 | Safety in railway transport | 24 |
| 3.2.1 | Introduction to the sub-theme | 24 |
| 3.2.1.1 | Overall direction of European-funded research | 24 |
| 3.2.1.2 | Overall direction of nationally funded projects | 24 |
| 3.2.2 | Research activities | 24 |
| 3.2.3 | Research outcomes | 27 |
| 3.2.3.1 | Achievements of the research under this sub-theme | 27 |
| 3.2.3.2 | Transferability from research to practical use | 28 |
| 3.2.3.3 | Indications for future research | 28 |
| 3.2.3.4 | Implications for future policy development | 29 |
| 3.2.4 | List of projects included in the sub-theme assessment | 29 |
| 3.3 | Safety in air transport | 31 |
| 3.3.1 | Introduction to the sub-theme | 31 |
| 3.3.1.1 | Overall direction of European-funded research | 31 |
| 3.3.1.2 | Overall direction of nationally funded projects | 31 |
| 3.3.2 | Research activities | 31 |
| 3.3.2.1 | Innovative technologies | 32 |
| 3.3.2.2 | Behavioural aspects, assessment and decision-support methodologies | 35 |
| 3.3.2.3 | Airport management and airport operations | 35 |
| 3.3.3 | Research outcomes | 36 |
| 3.3.3.1 | Achievements of the research under this sub-theme | 36 |
| 3.3.3.2 | Transferability from research to practical use | 37 |
| 3.3.3.3 | Indications for future research | 37 |
| 3.3.3.4 | Implications for future policy development | 37 |
| 3.3.4 | List of projects included in the sub-theme assessment | 38 |

3.4 Safety in maritime transport 41
3.4.1 Introduction to the sub-theme 41
3.4.1.1 Overall direction of European-funded research 41
3.4.1.2 Overall direction of nationally funded projects 41
3.4.2 Research activities 41
3.4.3 Research outcomes 44
3.4.3.1 Achievements of the research under this sub-theme 44
3.4.3.2 Transferability from research to practical use 44
3.4.3.3 Indications for future research 45
3.4.3.4 Implications for future policy development 45
3.4.4 List of projects included in the sub-theme assessment 46

**4 Conclusions and recommendations 48**
4.1 Research environment and development 48
4.2 Research activities and outcomes 49
4.3 Indications for future research 51
4.4 Implications for future policy development 51

**5 References/bibliography 53**

**6 Glossary 54**



# Executive summary

*This is the sixth and final Research Theme Analysis Report produced under the Transport Research & Innovation Portal (TRIP) continuation project for the European Commission's Directorate General for Mobility and Transport (DG-MOVE). It covers the Transport Safety research theme.*

The purpose of TRIP is to collect, structure, analyse and disseminate the results of European Union (EU) supported transport research, research financed nationally in the European Research Area, and selected global research programmes. The TRIP web portal can be found at www.transport-research.info

This Research Theme Analysis Report gives an overview of research performed (mostly) in the EU collated by TRIP, providing a view across many projects that fall under the theme title. It provides a robust and thorough assessment of the reported results from the projects and offers perspectives from scientific and policy points of view.

For the purpose of this review, the theme of Transport Safety has been divided into four mode-related sub-themes and the assessments performed within each sub-theme and across the complete theme. The sub-themes considered are linked to the transport modes:

- road;
- rail;
- aviation;
- maritime.

The key findings from a scientific perspective are:

- In relation to the safety of road users, research projects have addressed:
  - mobility experiences;
  - perceptions of safety needs by different types of road user;
  - opinions and experiences about speeding; impaired driving; and attitudes towards motorcycle riders, pedestrians and other road users.

  National projects focused on behavioural elements, the impacts of driving distractions from a multidisciplinary perspective and on the driver's visual workload and attentiveness.
- Vulnerable road users have benefited from the results of several projects dealing with assessment methodologies and protocols for integrated pedestrian protection systems (e.g. the European New Car Assessment Programme (Euro NCAP) pedestrian passive safety test protocol), sub-systems for children traveling to and from school (e.g. intelligent bus stops, new bus signs and driver support systems) and guidelines for live action role playing in education.
- Several road infrastructure projects focused on road network safety assessment. Research also targeted secondary and rural roads using specific before-and-after accident analyses. Investigations concerning visibility and comprehensibility of pictograms, signing and verbal messages and the safety of work zones were other key areas of research.
- The road safety technologies that have been investigated include advanced driver assistance systems, communication technologies to improve hazard detection, new sensor devices integrating obstacle detection and communication, traffic recognition sensors and pre-crash and blind spot surveillance. Projects on passive safety systems focused on biomechanics research, injury mechanisms and protection, vehicle restraint systems and the skid and rolling resistance of tyres.

- Research activities focusing on the safety of the railway infrastructure included the improved design of stations, supported by software to simulate the circulation of passengers in normal and emergency situations. Work has also focused on identifying means of preventing and mitigating the impacts of the main causes of derailments (especially in the freight sector). Optical rail scanners and sensors can now more easily inspect rails to identify potential flaws in their surface. Research on the safety of rail tunnels contributed to the upgrade of the 'European Fire Safety Standard' (TS45545). The Shift2Rail Joint Undertaking will continue to focus on key research priorities for achieving a single European railway area.
- The safety of rail carriage interiors in the event of a crash has been improved by analysing the latest knowledge from injury biomechanics and through the development of a toolkit for designing the interiors of carriages to reduce fatalities. The prevention of accidents from failures in railway vehicles was targeted through improvements in the inspection and diagnosis of issues relating to the axles and wheels of trains during production, maintenance and operation.
- The focus on behavioural aspects concentrated on train drivers (e.g. driver-machine interface and innovative training systems) and on trespassers and level crossing users. Level crossings have been identified as a particular weak point from the perspective of road transport safety.
- The development of innovative technologies in air transport, such as advanced on-board monitoring systems, has enabled aircraft systems to predict and to mitigate technical and operational issues, including weather events. On-board data are used to improve aircraft performance and to optimise their service lifetimes. The on-board systems may also be used to analyse available data in real time during the flight and to react to prevent accidents.
- Aviation safety risks associated with the impacts of meteorological conditions and natural hazards (e.g. fire, lightning, ice and ash clouds) have been targeted by a number of research projects. Important and relevant improvements have been achieved for detecting aircraft damage through the use of sensors and microwaves, so gaining more extensive knowledge of the topics.
- For airport management and airport operations, research projects focused on safety management systems to detect and correct safety problems before they result in aircraft accidents. Also, a shared view on how to address capacity-related issues caused by wake turbulence was achieved so that wake turbulence separation minima (i.e. minimum distances aircraft need to fly apart from each other at all times to ensure safety) can be reduced under specific conditions while maintaining current levels of safety.
- Research activities targeted at seaports focused on the welfare, behaviour and psychological perspective of employees such as crane operators and the potential to establish a 'mutually recognisable framework' for the training of port workers operating in different jobs in a port.
- Projects concerned with ships have included studies to improve their 'design for safety' in the event of an accident, deal with rough seas or improve their inspections to reduce the risk of accidents and support maintenance of ship hulls. The use of information technology and other techniques to inspect ships to ensure that they remain safe and seaworthy has been a theme under different research programmes. The structural failure that provoked the accident of the tanker 'Prestige' in 2002 raised questions and targeted research on the way repairs are undertaken.

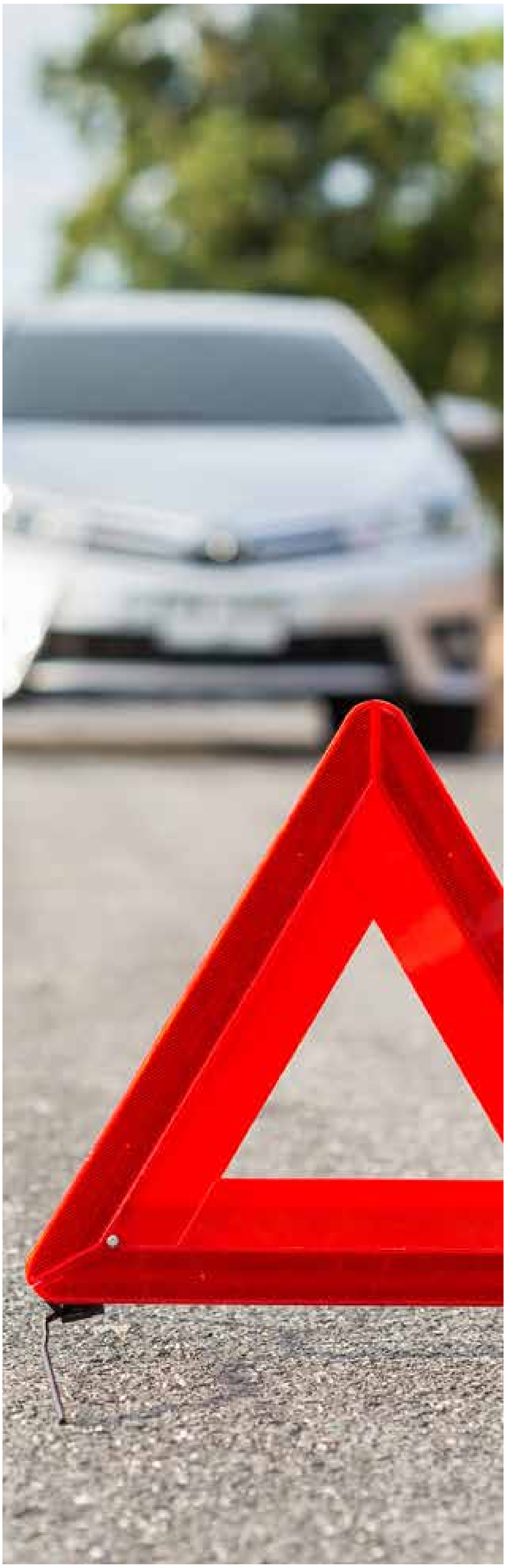
The key findings from a policy perspective are:

- The EU road safety policy is broad and largely integrated with research priorities. For the future, there is a need to continue towards full integration and real-life applications, combining infrastructure safety features, vehicle safety (including the adoption of international standards) and safer speeds. These elements must be supported by effective legislative and enforcement strategies achieving widespread road user compliance with road legislation.
- In the railway sector the new common regulatory framework introduced by the 4th EU Railway Package has set clear rules and responsibilities on the European Union Agency for Railways. Within its safety unit, the Agency will develop, promote and monitor a common EU approach to safety management and governance. There is potential to develop common approaches, based on the results of recent research activities, including those supported by the Shift2Rail Joint Undertaking.
- Policy development should be particularly targeted towards the safety of guided urban and suburban transport systems, the design of railway vehicles, and reducing the dangers associated with level crossings and the number of trespassing and suicides, through improved technologies.
- The good safety record of commercial air transport over the past few years, particularly among EU-registered operators, could be seriously affected by a single incident. The International Civil Aviation Organization has identified a reduction in runway safety events as a continuing global safety priority.
- Targeted interventions and measures promoted at a policy level from the EU may further increase awareness around the effects of pilot stress and negative personal situations, paying particular attention to the assessment of pilot health conditions and to the development of better support systems for pilots and aeromedical examiners.
- The international relevance of the research on maritime safety has often been transposed into the development of the International Maritime Organization's rules and regulations. There might be potential for EU policy to take forward the results of research projects to improve the way inspection and maintenance are undertaken for EU-registered ships and to prevent accidents occurring as a result of failures in ship structures.

- EU policy should recognise the high number of incidents that involve navigation and human error, through accelerating the uptake of research achievements into day-to-day operations.

The priority research gaps identified are:

- Research priorities on road safety have been identified in different roadmaps issued by a number of organisations, including the European Road Transport Research Advisory Council (ERTRAC), the European Road Federation (ERF) and the Forum of European Road Safety Research Initiatives (FERSI). These have been assessed and aligned with EU research programmes.
- Further efforts should focus on road safety education and human factors analysis. In addition, advantage should be taken of research advancements made in other transport modes in relation to learning practices, safety cultures, the use of new technologies, and the need of drivers and vehicles to handle critical situations.
- Research is still needed on improved technology, testing specifications and regulations. The Horizon 2020 call 'Road infrastructure to support the transition to automation and the coexistence of conventional and automated vehicles on the same network' received high levels of interest in the research community. Therefore, new projects will produce positive developments towards enhancing the safety of road transport.
- The rail industry has progressed in different areas targeted by research projects, including those of the Shift2Rail Joint Undertaking. However, the number of fatalities as a result of trespass, suicides and accidents with road users on level crossings remains high. The number of research projects in this area should be increased.
- The expansion of the high-speed rail network is likely to pose more challenges to infrastructure as a consequence of its increased use, in accident prevention and to the impacts on trains.
- Research in the domain of aviation staff and aircraft pilot training should integrate the effects of human factors such as fatigue, situational awareness and workload into a single performance safety prediction system, so enabling a proper monitoring of pilot or controller performance.
- Future research should focus on health conditions of passengers and illness/diseases that might be provoked by altitude and pressurised flight conditions.
- As there are still a significant number of maritime accidents annually in the EU, there is scope to improve safety for this transport mode, especially in the areas of human error, suggesting a need for research into tools, mechanisms and procedures to support decision-making.



# 1 Introduction

*This is the sixth and final Research Theme Analysis Report produced under the Transport Research & Innovation Portal (TRIP) continuation project for the European Commission's Directorate General for Mobility and Transport (DG-MOVE), which began in 2014. It covers the Transport Safety research theme.*

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The assessment aims to consider:

- overall trends in transport safety, including key results;
- overall trends in the funding for transport safety research;
- the alignment of the research with current policy;
- policy implications of the results from the research;
- any gaps within the research theme.

The theme for this analysis was decided in consultation with DG-MOVE.

The assessments for this analysis have been performed on four sub-themes within the theme of Transport Safety. The set of sub-themes, selected following initial assessments of the projects and in consultation with DG-MOVE, consists of:

- safety in road transport;
- safety in railway transport;
- safety in aviation transport;
- safety in maritime transport.

The projects identified have been clustered under these sub-themes. The analyses of the trends and gaps have been performed across the projects in these sub-themes and across the full Transport Safety theme. The assessments of trends and gaps are mainly based on selected projects within the TRIP database.

EU-funded projects align with EU policy through the funding and selection process. As such, the trends identified from these projects may not necessarily be representative of those from further afield.

Section 2 of this report describes the policy context of transport safety and Section 3 presents reviews of the individual sub-themes (as specified above), the research environment and development, and the research activities and outcomes. Conclusions and recommendations are then presented at the end of the report.

The preparation of this report has involved the analysis of a large number of projects related to the Transport Safety theme. To enhance readability, the text of this report refers to projects by their standard acronyms (where an appropriate one exists). More details about the projects, including the full titles, are given in the tables at the end of each sub-theme section.

# 2 Policy context

## 2.1 Transport safety in European transport policy

Safety is a cornerstone of every transport strategy because it greatly influences the efficiency and effectiveness of the transport system as a whole, and is a primary concern for travellers and companies.

The European Commission's 2011 Transport White Paper (European Commission, 2011) set an ambitious goal for the European Union (EU) to become a world leader in safety and security in all modes of transport. The overall aim of saving thousands of lives in transport has been transposed in a set of actions aimed at moving towards a 'zero-vision' on road safety (i.e. achieve close to zero fatalities by 2050). These actions streamline the rules for the intermodal transport of dangerous goods and develop comprehensive European safety policies in road, air, maritime and rail transport. They also enforce the role of the relevant safety agencies – the European Aviation Safety Agency (EASA), the European Union Agency for Railways (the former European Railway Agency (ERA)) and the European Maritime Safety Agency (EMSA).

The current road safety work of the Commission is guided by the policy framework 'Policy orientations on road safety 2011-2020' (European Commission, 2010), which is structured around two main components:

- a strategic, aspirational target for the reduction of road fatalities by 2020 (i.e. halve the number of road deaths over the decade, with 2010 as the baseline year);
- a list of 16 proposed Commission actions divided under seven focus areas ranging from legislation to soft measures and studies as described in Table 2-1.

**Table 2-1 Focus areas and 16 actions in the EU policy framework 2011-2020**

| Focus areas | EU action |
|---|---|
| Education and training of drivers | • Education/training strategy |
| Enforcement of traffic rules | • Cross-border information exchange for enforcement<br>• Enforcement strategy<br>• Enforcement implementation plans |
| Safer road infrastructure | • EU funds conditional on infrastructure safety directive principles<br>• Infrastructure safety principles on inter-urban roads |
| Safer vehicles | • Encourage active/passive safety for motorcycles<br>• Strengthening roadworthiness test rules |
| Modern technologies | • Assess safety benefits of cooperative systems<br>• Evaluate benefits of advanced driving assistance systems (ADAS)<br>• Accelerate eCall[1] deployment |
| Injuries and emergency response | • Propose strategy on road injuries |
| Vulnerable road users | • Technical standards for protection of vulnerable road users<br>• Vehicle inspections also for motorcycles<br>• Encourage safe cyclist/pedestrian infrastructure<br>• Contribute to better information to road users |

1 eCall is a European initiative intended to bring rapid assistance to motorists involved in a collision anywhere in the EU

The European Commission has established a knowledge hub though its road safety website[2], which also integrates the European Road Safety Observatory (ERSO). The latter gathers harmonised specialist information on road safety practices and policy in all EU countries.

The possibility of attaining the strategic target of halving the number of road deaths in 10 years is strongly linked to a combination of actions at local, national and EU levels, and needs a strong involvement of all actors and stakeholders (e.g. non-governmental organisations (NGOs), companies/industry and citizens).

In its Road safety study for the interim evaluation of Policy Orientations on Road Safety 2011-2020 (European Commission, 2015), the Commission analysed the completed actions concerning legislation, such as:

- the adoption of Directive 2015/413/EU facilitating cross-border exchange of information on road-safety-related traffic offences;
- the adoption of the package containing Directives 2014/45/EU on periodic roadworthiness tests, 2014/46/EU on registration documents and 2014/47/EU on technical roadside inspections.

It also considered the overall relevance of the policy framework, concluding that it remains relevant and in line with most of the other main policy objectives investigated (such as environmental, economic and social policy objectives).

The Valletta Declaration on Road Safety was endorsed in March 2017 after a stakeholder and Ministerial conference that brought together road safety experts, stakeholders, and policy makers. The event was held in Malta by the European Commission, together with the Maltese Presidency with the aim of launching a political debate and of outlining the future political direction.

The rules applicable to railways with regard to technical safety and interoperability are two core elements of the single European railway area, the internal competitive market for rail services. Both require a higher level of harmonisation at the EU level. Through the 4th EU Railway Package, a set of six legislative texts[3] designed to complete the single market and further revitalise the rail sector, the EU has established the European Union Agency for Railways. This is the European authority entitled to develop a common approach to safety on the European railway system and, from 2019 onwards, to issue single EU-wide safety certificates to railway undertakings.

The EU has been developing a common regulatory framework for railway safety through harmonisation of the content of safety rules, the safety certification of railway undertakings, the tasks and roles of the national safety authorities, and the investigation of accidents. The framework is set out in the Railway Safety Directive (Directive 2004/49/EC), which has been complemented by various, more-specific pieces of legislation. These include setting common safety indicators and targets, and common methods for a variety of assessments, including risk assessments and safety authorisations (European Commission, 2014). Directive (EU) 2016/798 on railway safety has recently recast Directive 2004/49/EC in the interests of clarity and in the light of future further amendments.

The achievements of the EU Air Transport Policy in the last 20 years have been relevant to transport safety. Up to the late 1980s, air transport was fully controlled by state governments, and over-regulated by rigid bilateral agreements and obsolete international conventions. The internal air market has allowed European airlines to expand and to engage in a process of cross-border consolidation. Many European airports have been converted from simple infrastructure providers to successful commercial businesses. Since then, the EU has progressively become a leading force and a respected policy maker in the field of air transport. It started with the liberalisation of the sector, then its action pursued other aspects, such as air transport safety. The common EU aviation policy aims to make Europe the safest airspace in the world.

At an international level, the International Civil Aviation Organization (ICAO)[4] is responsible for setting minimum aviation safety standards, but these are not binding and so compliance is mainly dependent on the goodwill of parties from the participating states. The creation of a European internal market in aviation has meant that all passengers should benefit from the same, high level of safety wherever they fly in the EU. The common European aviation safety rules[5] are based on the standards and recommendations adopted by the ICAO, but are often more stringent. They have gradually been extended to cover the entire air transport sector. Regulation (EU) No 996/2010 of the European Parliament and the Council defines common principles governing the investigation of civil aviation accidents and incidents in EU Member States.

Aviation safety data are collected by EASA, an agency of the EU and governed by European public law. EASA has established common requirements for the regulation of safety and environmental sustainability in civil aviation. It collects detailed data on aviation incidents and accidents, and performs in-depth safety-relevant analyses.

2 http://ec.europa.eu/transport/road_safety/

3 https://ec.europa.eu/transport/modes/rail/packages/2013_en

4 The ICAO is a specialised agency of the United Nations which was established under the Convention on International Civil Aviation of December 1944 (also known as the 'Chicago Convention'), to which 191 countries have now acceded. The ICAO adopts standards and 'recommended practices' which are mandatory for the States parties, but there is no binding mechanism with which to verify compliance.

5 https://ec.europa.eu/transport/modes/air/safety/safety-rules_en

An international framework of rules and regulations governs maritime transport under the responsibility of the International Maritime Organization (IMO). The IMO's international conventions on Safety of Life at Sea (SOLAS) and Prevention of Pollution from Ships (MARPOL) are implemented consistently in the EU through legislation[6]. In addition, EU legislation complements the IMO's rules by focusing on elements of the sector that are more appropriate for regional action. Legislation of potential relevance to maritime safety includes the Community vessel traffic monitoring and information system (Directive 2014/100/EU). This ensures that non-EU ships comply with relevant international law, requiring the investigation of maritime accidents and the harmonisation of safety rules relating to maritime equipment operating on EU-registered ships.

## 2.2 Transport safety in European research programmes

Since the EU's 5th Framework Programme for Research and Technological Development (FP5), which ran from 1998 to 2002, the topic of transport safety has received increasing attention from EU research in terms of financial support, and interest from public and private stakeholders. In FP6 (2002-2006), the topic of transport safety was specifically addressed by the Sustainable Surface Transport Research theme that had four broad objectives. In particular, Objective 4 'Increasing road, rail, waterborne safety and avoiding traffic congestion' investigated several topics related to transport safety. The research focused mainly on road safety strategies (research domains from 4.1 to 4.5), intelligent transport systems (research domains 4.6 and 4.7) and implementation of transport pricing (research domains from 4.8 to 4.10).

To be effective, the EU policy framework on road safety and the supporting research targeted the human, vehicle and infrastructure environment. In addition, it took into consideration the interaction between these elements, and the acceptability and cost-effectiveness of the proposed measures in a wider socio-economic context. Research focused on the economic mechanisms necessary to reward the introduction of advanced technologies with a view to their overall safety benefits, instead of the defensive approach to avert possible liability risks.

Research combined measures and technologies for prevention, mitigation and investigation of road accidents. It placed special attention on risky and vulnerable users including children, the disabled and the elderly.

Between 2007 and 2013, the main objective in the transport safety field of FP7 was to develop technologies and intelligent systems to protect vulnerable people such as drivers, riders, passengers, crew and pedestrians. Advanced engineering systems and risk analysis methodologies for the design and operation of vehicles, vessels and infrastructure were studied.

Emphasis was placed on integrated approaches linking human aspects, structural integrity, preventive, passive and active safety including monitoring systems, and rescue and crisis management. Safety was considered as an inherent component of the total transport system, embracing:

- infrastructure;
- freight (goods and containers);
- transport users and operators;
- vehicles and vessels;
- measures at policy and legislative levels, including decision support and validation tools.

Security was addressed wherever it was an inherent requirement to the transport system.

Under the Horizon 2020 Programme (2014-2020), transport safety has been included in one of the four broad lines of activities – 'better mobility, less congestion, more safety and security'. These were aimed at reconciling the growing mobility needs with improved transport fluidity, through innovative solutions for seamless, inclusive, affordable, safe, secure and robust transport systems. Horizon 2020 addressed research priorities for all transport modes, covering actions particularly in the field of transport infrastructure and vehicle/vessel design, traffic management and crash safety. Another focus is being developed on research related to human behaviour as a major cause for accidents including the assessment of changes of user behaviour as a consequence of health and demographic issues, and the introduction of new advanced transport technologies.

The topic of transport safety is investigated under Horizon 2020's 'Mobility for Growth' theme for all modes of transport, particularly road and aviation, divided into several sub-topics. The focus is principally on aviation safety challenges, protection of all road users in crashes, safer waterborne transport and maritime operations, innovation in transport infrastructure to increase safety at modal and intermodal levels (including nodes and interchanges), behavioural aspects for safer transport, and the Euro-African initiative on road safety and traffic management.

## 2.3 Research priorities and roadmaps

Based on the policy framework mentioned above, several other roadmaps and research priorities have been developed in the area of road safety over recent years. For example, in 2011, the European Road Transport Research Advisory Council's (ERTRAC) Working Group on Road Transport Safety and Security published its European roadmap 'Safe Road Transport'.

6 https://ec.europa.eu/transport/modes/maritime/safety_en

In 2013, the European Road Federation (ERF) published 'Strategic Research Priorities in the area of Road Safety 2013-2020', introducing 17 topics under 6 priority areas:

- adapting the infrastructure to meet the challenges of 21st century traffic;
- alternative tools for financing and maintaining roads;
- developing tools for more cost-effective road operation and maintenance;
- in-depth statistics into the causality of accidents;
- infrastructure and vulnerable road users;
- wider deployment and harmonisation of intelligent transport systems (ITS) solutions.

In 2014, the Forum of European Road Safety Research Institutes (FERSI) identified 'Nine key challenges for road safety research for the next decade'. According to the position paper, these should be addressed 'if Europe wants to succeed in its ambition to improve road safety and reduce significantly the number of crash victims'. These challenges are an ageing society, vulnerable road users, cultural diversity, vehicle automation and ITS, the burden of injuries, safe road design, educating and training road users, behavioural change and road safety management.

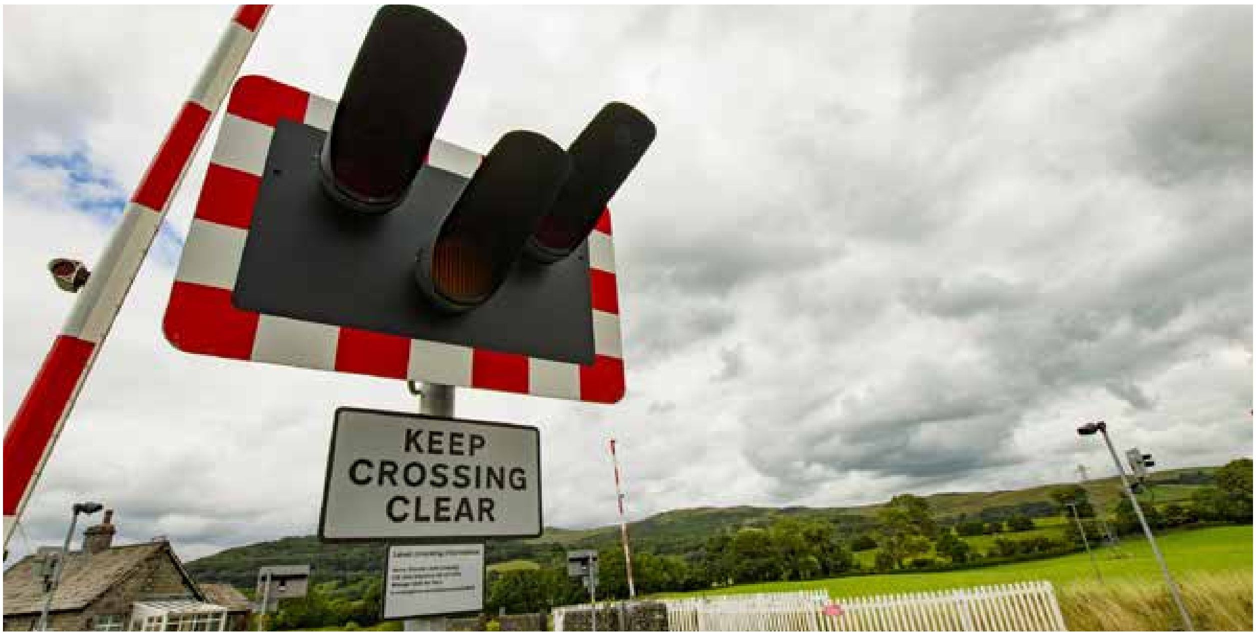
A list of priority research topics for road safety was also released in 2014 by the EU-funded project Priorities for Road Safety Research in Europe (PROS, 2012-2014). It was the first initiative in which a process for the definition of research priorities with this degree of transparency was established in a European multi-stakeholder network covering road safety research as a whole. PROS activities are now carried on under the umbrella of the ERTRAC Working Group on Road Transport Safety and Security with the ambition of integrating the basic principles of PROS in the ERTRAC approach and building on the PROS results.

Rail safety is a cross-cutting topic that is dealt with in the five key Innovation Programmes (IPs) identified in a common strategic master plan by the Shift2Rail Joint Technology Undertaking. This is a partnership established under Horizon 2020 between the EU and the private sector dealing with rail for coordinating research activities with a view to driving innovation in the rail sector in the years to come. In 2016, the European Rail Research Advisory Council (ERRAC) published the 10 FOSTER-RAIL roadmaps, aligned with the ERRAC Strategic Rail Research Innovation Agenda (SRRIA), identifying the key technology and innovation needs for rail safety. These include the replacement of personal judgment with clear pass-fail criteria, standards for cross-industry acceptance of simulation tools and general applicability of risk-based safety approaches, re-balancing active versus passive safety and improving cross-modal safety.

The Advisory Council for Aviation Research and Innovation in Europe (ACARE) released its Strategic Research and Innovation Agenda in 2012. Challenge number 4 specifically targeted safety and security issues.

The Joint Research Centre (JRC) supports EU transport safety policy in all transport modes – road, aviation, maritime and rail. The JRC has developed and manages accident and incident reporting systems for the aviation, maritime and railway domains to improve transport safety. For road safety, the JRC has a key role in assuring the security and trustworthiness of the digital tachograph. The JRC is also developing innovative radar systems for maritime surveillance and safety, and is working on innovative solutions to enhance the security of containers.

Following the successful introduction of the European Coordination Centre for Accident and Incident Reporting Systems (ECCAIRS) in the aviation domain, the JRC also developed the European Marine Casualty Information Platform (EMCIP) for EMSA, and the European Railway Accident Information Links (ERAIL) system for the former ERA.



# 3 Sub-theme assessments

*This section describes the assessments of each of the sub-themes in turn. For brevity, when discussing individual projects, the descriptions refer to those projects by their acronym (particularly for EU-funded projects, which commonly have an acronym as well as a full project title). Further information on the projects that are relevant to the sub-theme, including the full project title, is given in the tables at the end of each sub-theme section.*

## 3.1 Safety in road transport

The Transport Research & Innovation Portal (TRIP) team would like to acknowledge the invaluable contribution of Professor George Yannis (National Technical University of Athens) to the development of this sub-theme assessment.

### 3.1.1 Introduction to the sub-theme

Every year in the European Union (EU), more than 25 000 people die and more than 200 000 are seriously injured in road traffic accidents. According to the statistics, road accidents remain one of the most common causes of death for those between 15 and 25 years old. Drink-driving and speeding are responsible for a large share of all fatal road accidents.

The European Commission has adopted an ambitious Road Safety Programme that aims to cut road deaths in Europe between 2011 and 2020. There has been a steady and promising trend towards meeting this common target, but fatality reduction rates have plateaued in recent years. In 2016, 25 500 people lost their lives on EU roads, representing just a 2 % reduction over the previous year, following a 1 % increase from 2014 to 2015. Following 2 years of stagnation, 2016 marks the return of a positive trend. Over the last 6 years, road fatalities have been cut by 19 % compared with 2010.

Road safety can be approached in two main ways – attempting to prevent serious traffic accidents from happening (active safety) and attempting to reduce the severity of the accidents that cannot be prevented (passive safety). Nevertheless, road safety work is complex, with many factors playing a role. The occurrence of road traffic accidents depends on the behaviour of the road users (e.g. intentional risk-taking or unintentional mistakes), the conditions of the roads (inherent (such as safety design, maintenance and permitted speeds) or external (such as temporary weather situations)), and the condition and equipment of vehicles. The severity of the accident outcome depends on the safety and accident protection quality of roads, the vehicles and road users involved, the safety equipment and the extent of its use, and the time and quality of the emergency response.

Since there are many causal factors involved, many different types of actions are required to address the problem effectively. Some of these actions are best done at a local or national level, while others are more efficiently dealt with in cooperation across the borders and directly involve the automotive industry.

#### 3.1.1.1 Overall direction of European-funded research

A wide number of research projects have addressed the different road safety domains over time – at EU and national levels. The field of road safety is very broad and challenging. For the purpose of this review, the research projects have been clustered into four groups:

- road safety management – safety management and strategies, including data collection (safety observatories), identification of high risk groups, cost-benefit/cost-effectiveness analyses and enforcement activities;
- road users (including vulnerable road users) – analyses of behaviour, accident causation and user-focused countermeasures (such as education and training of all age groups);
- infrastructure – safe road design and safe infrastructure, including engineering measures (such as traffic calming, speed limits and roundabouts) and their evaluation, and road safety audits and inspections;
- technologies – advanced driver support, intelligent transport systems (ITS), and information and communications technology (ICT) (from data collection, through field operational tests to implementations and evaluations and, ultimately, resulting in safer vehicles (active and passive safety) and automation.

Within these four groups, 60 representative projects (43 EU and 17 national projects) were selected and reviewed – looking at their coverage, quality, the excellence of the partners and outputs.

#### 3.1.1.2 Overall direction of nationally funded projects

Probably the most significant example of a national research project based on ambitious strategies is the Swedish Vision Zero[7]. It is based on an underlying ethical principle that people must not be killed or seriously injured when moving within the road transport system. As an ethics-based approach, Vision Zero aims to guide strategy selection and not to set particular goals or targets. In most road transport systems, road users bear complete responsibility for safety. Vision Zero changes this relationship by emphasising that responsibility is shared by transport system designers and road users.

[7] http://www.visionzeroinitiative.com/

Apart from Sweden, other Member States adopted the EU strategic goal of halving the number of road fatalities. This led to the following results:

- Austria: 50 % reduction in fatalities and 20 % reduction in injury accidents by 2010 compared with the 1998-2000 average;
- Denmark: 40 % reduction in fatalities and injuries by 2012 compared with 2005;
- France: 35 % reduction in fatalities by 2012 compared with 2007;
- Hungary: 30 % reduction in fatalities and injury accidents by 2010 compared with 2001 and 50 % by 2015;
- United Kingdom (UK): 40 % reduction in fatalities and serious injuries by 2010 compared with the 1994-1998 average.

Final targets can also include specific road user groups such as children or older users. In addition to targets to reduce deaths and serious injuries, and the casualty rate for slight injuries, the UK set a target for a 50 % reduction in children killed and seriously injured by 2010 (compared with the 1994-1998 average).

Research projects closely follow the objectives described above. For example, in the UK, activities have been supported by the Department for Transport: Road Safety Research Programme (1998-ongoing), which has the following sub-themes:

- Vulnerable Road Users;
- Driver and Rider Behaviour;
- Impairment;
- Road Engineering and Speed Management;
- Statistical Analysis, Accident Causation and Policy Monitoring;
- Medical Aspects of Fitness to Drive;
- Cross-cutting Research;
- Research Support and Dissemination.

According to the Swedish innovation agency's (Vinnova) analysis 'Effects of Swedish traffic safety research 1971-2004' (Vinnova, 2007), Sweden has invested significant resources in traffic safety research during the last 50 years, which has contributed to lives saved. The Swedish car industry is developing a number of safety products and building up institutions that educate highly competent professionals within all areas of traffic safety. As a major stakeholder, the Swedish National Road Administration has funded research and contributed to the development of research institutions through separate departmental programmes and funding for investigations.

Examples of similar strategic projects from other countries include the Finnish LINTU (2002-2008) project and the Norwegian Strategic research initiative: road safety (2011-2015) project. Several projects also focused on specific risk groups (for example the Norwegian High Risk Groups in Road Traffic (2007-2010) and Finnish Road safety of elderly people (2007-2008) projects).

## 3.1.2 Research activities

As described in section 3.1.1.1, the European research projects on road safety were screened and clustered under the four main topics of road safety management, road users, infrastructure and technologies. The key projects identified in each topic are described in the following sub-sections. The PROS (2012-2014) project established a pan-European network to develop commonly agreed priorities in road safety research and overcome fragmentation in relevant stakeholder groups.

### 3.1.2.1 Road safety management

Road safety management includes decision-making on road infrastructure investments, identifying risk groups, enhancing the effectiveness of safety components, collecting data on speeding as a cause of traffic accidents, the European road safety information system, campaigning and raising awareness of safety and behaviour on roads, and drivers' psychology.

The SafetyNet (2004-2008) project is an example of a complex 'umbrella' project in this area. Its main goal was to build the framework of an EU-wide road safety knowledge system. The project integrated relevant data on accidents, risk exposure indicators and safety performance indicators, and helped to develop a decision-support system for the established European Road Safety Observatory (ERSO)[8]. The follow-up projects DaCoTA (2010-2012) and SafetyCube (2015-2018) further updated and expanded the contents of ERSO, with the latter developing an innovative road safety decision-support system. The MeBeSafe (2017-2020) project is looking to change road users' habitual traffic behaviour through an approach called 'nudging'. This concept, derived from behavioural economics, relates to a subconscious stimulus to encourage a desired choice, without undue pressure if the person wishes to do otherwise. Nudging measures are non-invasive, provide the user with choices (but predispose them to make a desired choice) and can influence behaviour early in the chain of events that might lead to a critical situation.

Important road safety measures also include enforcement and campaigns. The PEPPER (2006-2008) project focused on traffic law enforcement policies and practices, comparisons and analyses. In parallel, the CAST (2006-2009) project addressed the need for effective road safety campaigns aimed at enhancing traffic safety, and ready-to-use evaluation and design tools for fieldworkers. The SUPREME (2005-2007) project aimed to promote best practices, while the BESTPOINT (2010-2012) project established a set of recommended practices for developing effective demerit point systems. The PRAISE (2009-2012) project and initiative, coordinated by the European Transport Safety Council (ETSC), has addressed the safety aspects of driving at work and driving to work since 2010.

Data on speed, seat belt use and mobile phone use, which are considered crucial risk factors associated with driving behaviour, were collected in some national projects such as The speed of vehicles in Poland in 2015, Seatbelt and Mobile Phone Usage Survey Scotland (2014-2015) and REVEL (Spain, 2006-2008).

8 http://ec.europa.eu/transport/road_safety/specialist/erso_en

### 3.1.2.2 Road users

The issues of the protection of road users and reduction of road accidents have been analysed in a number of projects. These included studies and observations of operators, innovative tools for increased safety and training road users and future road safety experts. Key projects included the Social Attitudes to Road Traffic Risks in Europe (SARTRE) series, which encompassed four rounds and ended with the SARTRE 4 (2009-2012) project. A large survey was conducted in each EU Member State as part of the SARTRE 4 project. The survey was based on a common methodology and resulted in a shared analysis of the attitudes, opinions, self-reported behaviour and experiences of European drivers.

The PROLOGUE (2009-2011) project dealt with reducing the number of road casualties in Europe by developing and testing the naturalistic observation methodology (i.e. road-user behaviour observed unobtrusively in a natural setting for a long period of time) to obtain a better understanding of road safety. The results were used to develop a concept for an intrinsically safe road transport system, including in-car technology, self-explaining roads, driver training, etc. The project was followed by others, including the UDRIVE (2012-2016) project.

One of the major causes of road accidents is impaired driving due to the consumption of psychoactive substances such as alcohol, drugs and certain medicines. These were addressed by the DRUID (2006-2011) project, which helped to establish guidelines and measures to combat impaired driving.

Another risk factor is workload and consequent distraction – this particular aspect was addressed by the national projects ATLAS (France, 2009-2013) and Research in driver's visual workload and attentiveness (Czech Republic, 2014-2016). Accidents taking place while driving for work and commuting to work were assessed by the PRAISE project.

Safety for vulnerable road users (VRU), such as pedestrians, was studied in the ASPECSS (2011-2014) project, which developed harmonised test and assessment procedures for forward-looking integrated pedestrian safety systems. Key projects under the Horizon 2020 programme include:

- PROSPECT (2015-2018), which is looking at addressing an expanded scope of VRU scenarios and improvements to the overall system performance (e.g. earlier and more robust detection of VRUs, and proactive situation analysis);
- InDev (2015-2018);
- XCYCLE (2015-2018), which aims to develop the means to improve the treatment of cyclists in traffic, thus encouraging cycling and making it safer.

Attention was also paid to VRUs in national projects, such as the Swiss Pedestrian Crossing (Principles) (VSS2008/302, 2008-2011). Powered two wheeler (PTW) users are greatly over involved in serious and fatal crashes (and their number has more than doubled over the last two decades on European roads). They were addressed by the 2-BE-SAFE (2009-2011) project, whose main objective was to target behavioural and ergonomics research to develop countermeasures for enhancing PTW safety.

Children are another group at risk in transport, particularly when travelling to and from school. In this context, the SAFEWAY2SCHOOL (2009-2012) project designed, developed and evaluated technologies for providing a holistic and safe transport service for children commuting between home and school. It encompassed tools, services and training resources for all key actors. In a similar vein, the CASPER (2009-2012) project focused on child protection by studying child restraint systems and improving their efficiency with innovative tools. The Czech MELA (2012-2014) project developed and applied a live action role playing (LARP) teaching methodology for traffic education.

The issues of an ageing society were targeted by the CONSOL (2011-2013) project, which combined knowledge on mobility and safety with the newest evidence from basic research (such as gender studies, gerontology, findings on health and functionality with age). The safety of older people is also being addressed by the SENIORS (2015-2018) project. This aims to improve the safe mobility of the elderly, including the obese, using an integrated approach and reality-based knowledge that includes the main modes of transport and the particularities of this vulnerable road user group.

### 3.1.2.3 Infrastructure

In the RANKERS (2005-2008) project, the overall objective was to develop scientifically researched guidelines on road infrastructure safety, thus enabling optimal decision-making by road authorities to promote safer roads and eradicate dangerous road sections. In a similar vein, the RIPCORD-ISEREST (2005-2008) project focused on secondary roads, which have had much less attention to date than primary roads and motorways, even though a large proportion of fatalities in rural areas occur on secondary roads. These were also targeted in Italy by the IASP (2004-2007) project.

Important changes came in 2008 with Directive 2008/96/EC of the European Parliament and of the Council on road infrastructure safety management. It introduced the safety procedures of road safety audit, road safety inspection, network safety ranking and road safety impact assessment, which should be applied primarily on the Trans-European Transport Network (TEN-T). Member States followed the Directive, and introduced the processes on their roads and developed national guidelines to ensure gradual road safety improvements. With this focus, the Pilot4Safety (2010-2012) project aimed to apply the Directive's approaches for the training and certification of road safety experts for road safety audits and inspection procedures applied to selected secondary roads. The idea was to share good practices and define common agreed training curricula and tools for the qualification of road safety personnel. The Horizon 2020 project ECOROADS (2015-2017) examined the differences established by Directives 2008/96/EC on road infrastructure safety management and 2004/54/EC on minimum safety requirements for tunnels in the TEN-T.

Parallel national projects included the Hungarian National Road Safety Audit (2012-2014) project and the Czech Analysis of the impacts of the application of the Directive 2008/96/EC about road infrastructure safety management on the roads in the Czech republic outside the TEN-T network (2015-2016).

The BRoWSER (2013-2015) project addressed the issue of the safety of road workers and their interaction with road users. The goal was to enable national road authorities to understand how, when and where their employees (or contractors) are harmed when working on the roads. Road work zones were also focused on in the ASAP (2013-2015) project, which developed recommendations for efficient speed management.

The road infrastructure is also gradually being improved by modern measures, such as turbo-roundabouts, alternative road markings and novel bicycle infrastructure – see projects MERKUR (2011-2012), Modern turbo-roundabouts and their application in the design of transport constructions (2013-2015), Optimising profiled road markings with rumble strips for improving road safety (2014-2017).

### 3.1.2.4 Technology

Technology plays an important role in road safety – decreasing the complexities of the driving environment, reducing risk, and increasing active and passive safety. Combinations of assistance and cooperative systems, with innovative telematics services, are essential to develop a network of integrated safety systems.

The EASIS (2004-2007) project developed the technologies to enable the realisation of future integrated systems and helped to proceed from single systems to a complete network of integrated safety systems (ISS). The IN-SAFETY (2005-2008) project used intuitive cost-efficient combinations of new technologies and traditional infrastructure best practice applications to make roads more forgiving and to improve the readability of road signs. An assessment of the socio-economic effects of intelligent vehicle safety systems (IVSS) and their impact on traffic safety and efficiency was performed by the eIMPACT (2006-2008) project.

In the Czech Republic, the PREVENT (2005-2008) project developed and implemented intelligent traffic systems to force drivers to change their behaviour in a positive manner through continuous surveillance and preventive informative activity.

Advanced driver assistance systems (ADAS) are being studied by the ADAS&ME (2016-2020) project. Within the Compass4D (2013-2015) project, the activities focused on the standardisation of systems for forward collision warning, red light violation warning and energy efficient intersection services.

The SAFERIDER (2008-2010) project demonstrated the full feasibility and effectiveness of five advanced rider assistance systems for PTWs. The activities in this research topic were also supported by cooperative networks (e.g. COOPERS (2006-2010)) and networks of excellence (e.g. NEARCTIS (2008-2013)).

To reduce the severity of run-off-the-road accidents, improvements to the road infrastructure (such as 'forgiving roadsides') need to be designed. This includes identifying where there is a need for a vehicle restraint system (VRS) and what appropriate VRS should be selected for specific locations and traffic conditions. This topic was addressed by the SAVeRS (2013-2014) project. On the other hand, the TYROSAFE (2008-2010) project was devoted to tyre/road interaction parameters. The SimuSafe (2017-2020) project is aiming to develop realistic multi-agent behavioural models in a simulated transport environment, where researchers will be able to monitor and introduce changes in each aspect, gathering data that are not available in real-world conditions.

The EuroFOT (2008-2011) project tested applications that are technologically mature, but are not yet commercially deployed, through field operational tests (FOTs) using ordinary road networks and users.

The study looked at user acceptance of existing technologies, and their potential to enhance safety and reduce environmental impacts.

The ARTRAC (2011-2014) project developed a reliable and low-cost safety system, using advanced sensors to detect other road users and to monitor road surface conditions to detect low-friction sections. The information is used to warn or adapt the vehicle electronic control systems to the change in friction conditions.

The THORAX (2009-2013) project addressed the prevention and reduction of driver and passenger injuries in the event of a traffic accident. It developed the required understanding in thoracic injury mechanisms to implement into numerical and experimental tools that enabled the design and evaluation of advanced VRS, offering optimal protection for a wide variety of car occupants. In a similar vein, the ADSEAT (2009-2013) project provided guidance on how to evaluate the protective performance of vehicle seat designs aiming to reduce the incidence of whiplash-associated disorders. Related national projects included Improving Passive Safety of Vehicles (2007-2013) and Biomechanics of Deformation Processes in Human Skeleton under Extreme Strain (2007-2013).

The issue of connected vehicles, infrastructure and their potential to improve road safety was addressed in the previous TRIP research theme analysis report on Cooperative Intelligent Transport Systems (C-ITS).

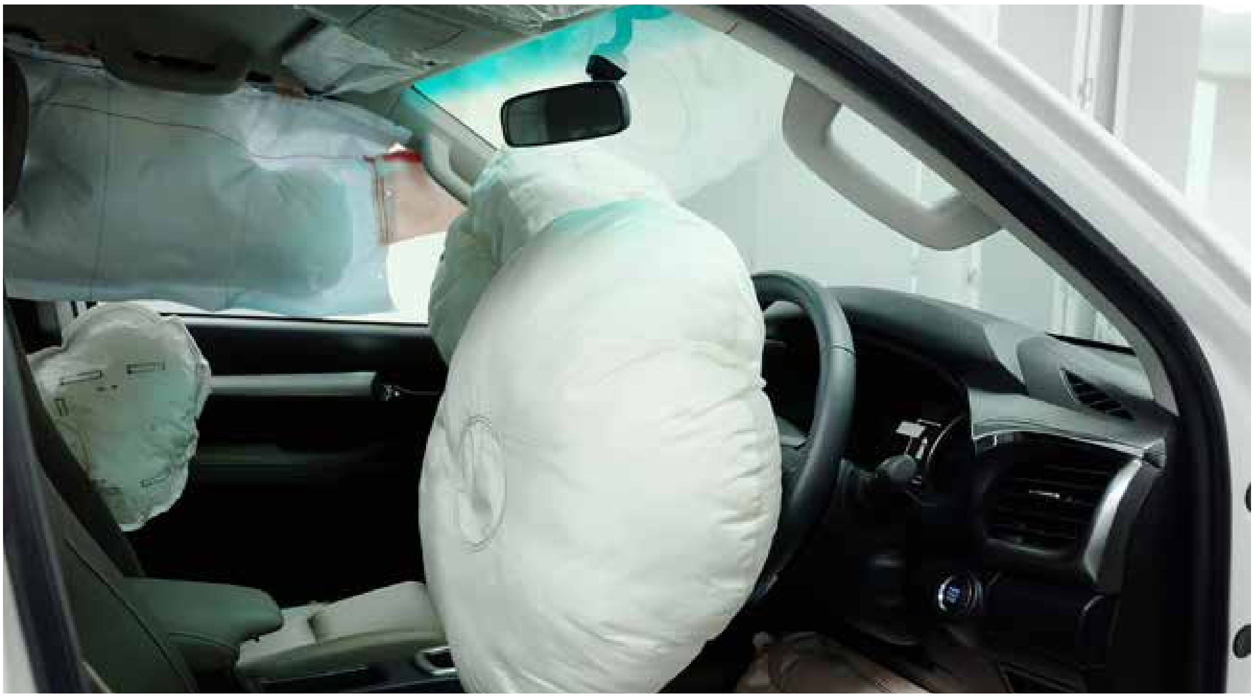
## 3.1.3 Research outcomes

### 3.1.3.1 Achievements of the research under this sub-theme

About 120 experts from more than 40 stakeholder organisations have contributed to the development of a comprehensive European road safety research roadmap within the PROS support action. Work started with a review of social trends and scenarios that affect road safety research. PROS gathered and analysed approximately 30 current national, EU and global research agendas, and examined the state-of-the-art in existing road safety research activities at EU and national levels (about 100 projects were assessed). The project identified 11 prioritised research topics to assist policymakers in defining Horizon 2020 calls.

Under the road safety management domain, the projects that have been reviewed helped to provide knowledge to support key road safety decision-makers. One of the key outcomes is ERSO. This tool enables the European Commission to monitor progress towards objectives, identify best practices, and ensure that new regulatory and other security measures lead to maximum reductions in accident rates. Another umbrella project was SUPREME, which provided user-specific information on outstanding safety measures with a view to implementation in other countries or at the European level.

Several projects enabled the collection of safety performance indicators, which are important for monitoring, evaluating and setting strategies. Others focused on preparing guidelines, such as the CAST and PEPPER projects. The key outcome of the CAST project was the ‘Manual for Designing, Implementing and Evaluating Road Safety Communication Campaigns’. This is a tool for conducting campaigns at national and international levels, containing theoretical background and practical guidelines. PEPPER developed a model for enforcement data collection systems and associated pilots for strategic enforcement monitoring databases, and innovative technologies and approaches for improving compliance with traffic laws. BESTPOINT produced a concise overview of recommended practices on demerit point systems, based on evaluation studies, psychological and learning theories, and expert experience.



In relation to the road users domain, research projects (e.g. the SARTRE series) addressed issues such as mobility experiences; perception of safety needs by different types of road user; opinions and experiences about speeding; impaired driving; and attitudes towards motorcycle riders, pedestrians and other road users.

The findings and experience in the PROLOGUE project resulted in a set of recommendations for large-scale naturalistic driving studies (NDS). The follow-up UDRIVE project has continued implementing NDS and FOTs for in-depth knowledge of driving behaviour. In addition, national projects have focused on risky behaviour, its analysis and quantification (e.g. impacts of driving distractions, multidisciplinary approaches, and research into the visual workload and attentiveness of drivers).

In parallel, the 2-BE-SAFE project was successful in running the first NDS involving instrumented PTWs. This identified key information for devising new safety measures and facilitating the production of novel safety-related technology. Regarding other vulnerable road users, the ASPECSS project provided an overall assessment methodology on a benefit-related basis as a test and assessment protocol for integrated pedestrian protection systems with automated emergency braking (AEB). This assessment methodology has been proposed to be implemented, together with AEB test protocols and the standard European New Car Assessment Programme (Euro NCAP) pedestrian passive safety test protocol.

The SAFEWAY2SCHOOL project tested various sub-systems for children travelling to and from school, such as intelligent bus stops, new bus signs and driver support systems. The CASPER project conducted field studies on the use and misuse of child restraint systems, including the completion of specific dummy models. The MELA project developed guidelines for live-action, role-playing education of schoolchildren. On the other hand, the CONSOL project produced an overview on the topic of an ageing society, in terms of mobility and safety.

The DRUID project developed a methodological framework for integrating results of experimental and epidemiological studies, based on an international database of samples collected across Europe. Outcomes included recommendations for improving medical guidelines (assessing fitness to drive for patients who take psychotropic medicines).

The focus of several infrastructure-centred projects was on the safety assessment of the road network. To this end, the RANKERS project developed a 'road safety index' and a catalogue of road infrastructure safety recommendations (ranked according to their efficiency). The project also developed an interactive online eBook to assist in the assessment of the safety of urban vulnerable road users. The RIPCORD-ISEREST project introduced best practice tools and guidelines for cost-effective road infrastructure safety measures based on accident prediction models, road-safety inspection and black-spot management. Outcomes also included a safety handbook for secondary roads. This extended focus was followed up in the Pilot4Safety project, where infrastructure safety approaches were tailored to secondary roads. With a similar focus, the IASP project conducted pilot studies on two-lane rural roads in Italy using specific before/after accident analyses and monitoring vehicle trajectories and speeds.

The introduction of tools from Directive 2008/96/EC on road infrastructure safety management in Member States was supported by national projects. A road safety audit was piloted in Hungary ('National Road Safety Audit') and an extra application on non-TEN-T roads was supported by a national study in the Czech Republic ('Analysis of the impacts of the application of the Directive 2008/96/EC about road infrastructure safety management on the roads in the Czech republic outside the TEN-T network').

The IN-SAFETY project published several results on the deployment of ITS infrastructure and cooperative systems. These included investigations concerning visibility and comprehensibility of pictograms, signage and verbal messages.

Several projects have investigated safety in road work zones, including:

- the BRoWSER project underpinned the data, information and understanding of the topic by providing the framework for a pan-European database (the European road worker casualty database (EuRoWCas));
- the ASAP project provided recommendations for efficient management of vehicle speeds at road work zones.

Implementations of novel safety features were supported by recommendations and guidelines from national projects, such as MERKUR, 'Modern turbo-roundabouts and their application in the design of transport constructions' and 'Optimising profiled road markings with rumble strips for improving road safety'.

Many technology-focused projects developed and implemented ITS systems to assess the range of applications that could contribute to road safety. The prototypes that were demonstrated included communication technologies to improve hazard detection, new sensor devices that integrate obstacle detection and communication, traffic recognition sensors, and pre-crash and blind spot surveillance. In addition, technologies to track vulnerable road users and apply automatic braking or system-initiated steering to prevent accidents were developed in the ARTRAC project. The eIMPACT project carried out socio-economic impact assessments of in-vehicle safety systems and estimated their expected impacts on traffic safety and efficiency.

Advanced driver assistance systems incorporating driver/rider state, situational/environmental context and adaptive interaction to automatically transfer control between a vehicle and driver/rider are being explored further by the ADAS&ME project. In the EASIS project, a safe speed function for trucks was developed. The SAFERIDER project ran several tests with PTWs and developed specific on-bike information systems.

Regarding passive safety systems, the THORAX project improved understanding of the thoracic injury mechanisms, which is required for the design and evaluation of advanced restraint systems. The ADSEAT project developed a virtual dummy female model to evaluate enhanced whiplash injury protection (previous similar models were for an 'average male'). In addition, the SAVeRS project focused on VRS, producing several practical tools, such as life cycle cost models or guidelines for the selection of the most appropriate VRS. Passive safety was also studied in national projects 'Improving Passive Safety of Vehicles' and 'Biomechanics of Deformation Processes in Human Skeleton under Extreme Strain', leading to the development of models and practical recommendations. The TYROSAFE project optimised three key road properties – skid resistance, rolling resistance and tyre/road noise emissions.

To help a wider uptake of ITS, FOTs have been conducted. The EuroFOT project focused on the impact of driver assistance systems in Europe. It revealed a link between these systems and improvements in driver behaviour, fuel efficiency, traffic safety and overall cost savings.

#### 3.1.3.2 Transferability from research to practical use

A number of research outcomes mentioned in the previous sections can be transferred easily to practical use. The projects related to road safety management are examples – in particular for decision support systems, and cost-benefit and cost-efficiency analyses of road safety measures, which also include science-based evaluations and recommendations regarding road safety campaigns, traffic law enforcement, and the impact of drugs and medicines.

Tangible transferable outcomes have also been produced thanks to attitude surveys (SARTRE 4), naturalistic driving studies and FOTs in projects 2-BE-SAFE, PROLOGUE or UDRIVE. The data obtained led to new product designs and enhanced industry competitiveness. Similarly, ITS projects (such as PREVENT, SAFERIDER, EASIS, IN-SAFETY, Compass4D, ADAS&ME and eIMPACT) provided know-how for assessing drivers' acceptance and safety impacts, which may be used for harmonisation at a European level and for planning market penetration.

The THORAX and ADSEAT projects helped to improve passive safety testing and innovative restraint systems. The virtual testing approach that was developed provides an opportunity for a broader scope of safety evaluation in vehicle regulations without excessive requirements on manufacturers. Also, national projects gave valuable recommendations for implementation in practice. TYROSAFE helped to identify the needs for future research on skid resistance, rolling resistance and tyre/road noise emissions.

In the field of safety assessment of road network infrastructure, research projects such as RANKERS, RIPCORD-ISEREST, IASP and Pilot4Safety helped to implement practical tools, including road safety audits, inspections and impact assessments with the use of accident prediction models. These were successfully supported by specific national activities, such as 'National Road Safety Audit' and 'Analysis of the impacts of the application of the Directive 2008/96/EC about road infrastructure safety management on the roads in the Czech republic outside the TEN-T network'. In parallel, practical guidelines were developed for road work zones (the BRoWSER and ASAP projects) and several innovative infrastructural features were supported by national projects.

#### 3.1.3.3 Indications for future research

While the research projects described above have made significant contributions towards addressing the road safety challenges outlined in Section 2.2, there is still room for improvement. A large gap exists in the field of safety education and human-factors analysis. Guidance should be sought from practices in the rail, water and air transport sectors, where a controlled environment and professional training have clear benefits. There are possibilities to take some of the high-quality learning from these sectors (in conjunction with developing technologies, vehicle automation, and the needs of drivers and vehicles) to handle critical situations. In this regard, driver-state monitoring is an evolving field that addresses distraction or fatigue issues. Evaluating a driver's fitness combined with appropriate mitigation measures can increase awareness and decrease reaction times.

Automation, which has now arrived at the forefront of research, has a high potential to increase safety by minimising or eliminating the human error factor and by reducing driver stress and workload. Existing in-vehicle technologies have started to take over some of the driver tasks. With the coming of higher automation levels, machine-only responsibility will become a reality for transport. However, significant research is still needed in terms of technology, testing specifications and regulations. Moreover, any developments need to be checked and assured regarding insurance, liability and data security. The loss of specific driving skills, as automation routinely takes control of the vehicle, should be considered. Lessons may be learned from rail and air transport, where automation is more advanced.

A study to compare research in road safety in regions with similar population densities and cultures to Europe (e.g. USA and Canada) should be initiated. This could identify new knowledge and practices that are already proven elsewhere. The comparison could point to new processes and potential research topics.

The requirements for the qualification of car drivers should be explored further. There are no current requirements for systematic continuing development of driving skills and education in safety, changes in legislation, etc. Improvements in safety may be feasible by keeping drivers' skills up-to-date with the latest technology.

Additionally, further research is required into cyber security in relation to the development of ICT in road transport and automation.

Further topics that could be researched and applied in practice include:

- the safety of new types of fuel;
- modelling the risks in the field of road safety;
- limitations of human factors could be examined more deeply;
- reporting and analysing near-miss situations in road safety;

- investigating the safety risks connected with multimodal transport routes (mode changes, infrastructure where passengers are waiting for connection, etc.);
- 'Big Data' analysis to identify locations – safety risks posed by accident black spots on the road network.

### 3.1.3.4 Implications for future policy development

Within road transport safety, the 'Safe System' approach (such as the Swedish Vision Zero) marks a shift from a sole focus on crash reduction to the elimination of death and serious injury.

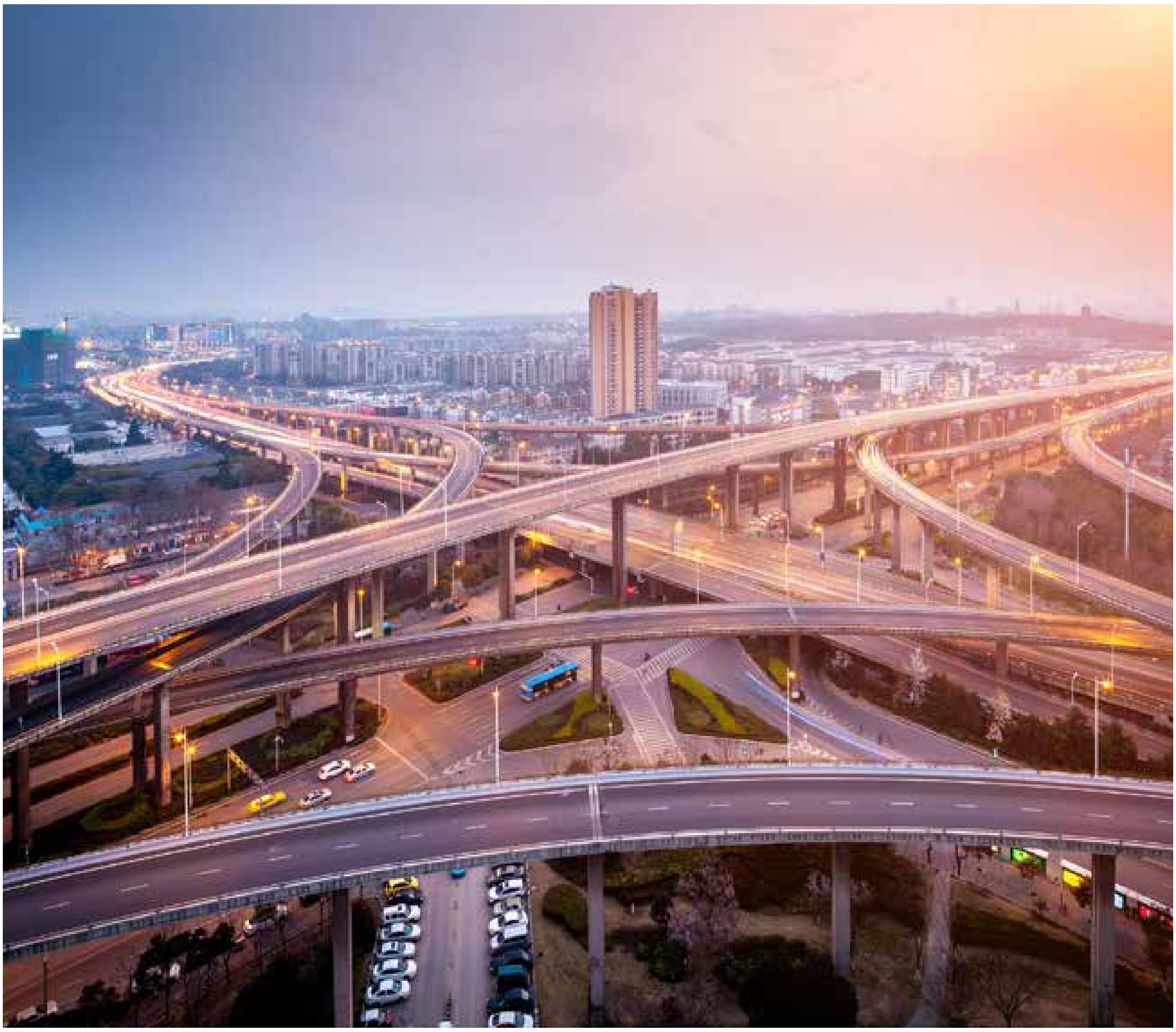
The necessary future step is to proceed from theory to real-life applications, using a combination of infrastructure safety features (including self-explaining roads and forgiving roadsides), vehicle safety features (including adopting international vehicle safety standards) and safe traffic speeds. These must also be supported by effective legislative and enforcement strategies that achieve widespread user compliance with road rules and laws. Better data for surveillance and monitoring are critical. This includes tackling under-reporting, international unification of injury severity scales, and linking police data with hospitals and other registries.

In addition, as driving behaviour is constantly evolving, the related risk, incidents and accidents are changing through time. Therefore, policy tools need to be continually adapted and their impacts should be evaluated and monitored periodically – followed by revised strategies and action plans.

Road safety is most commonly evaluated by the occurrence of fatalities, but injuries can also have serious impacts on a person and society. Therefore, there needs to be a shift towards gaining a holistic view of these impacts by evaluating and preventing the consequences of road accidents.

Road safety is still widely considered an infrastructure problem, but it is also influenced by the behaviour of the road users. A greater focus should be given to the psychological aspects of road safety issues.

Considering the number of people who are affected by road transport (fatalities, injuries and long-term after-effects), road safety should be considered a public health issue with all the attention and consequences that classification brings.



### 3.1.4 List of projects included in the sub-theme assessment

Table 3-1 lists the projects included in this sub-theme assessment.

**Table 3-1 Projects reviewed in the road transport safety sub-theme**

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| 2-BE-SAFE | 2-wheeler behaviour and safety<br>https://goo.gl/hbcF9B | 2009-2011 | EU (FP7-TPT) |
| ADAS&ME | Adaptive ADAS to support incapacitated drivers Mitigate Effectively risks through tailor made HMI under automation<br>https://goo.gl/oFE1J8 | 2016-2020 | EU (Horizon 2020) |
| ADSEAT | Adaptive seat to reduce neck injuries for female and male occupants<br>https://goo.gl/LmFfDl | 2009-2013 | EU (FP7-TPT) |
| ARTRAC | Advanced Radar Tracking and Classification for Enhanced Road Safety<br>https://goo.gl/LLNuHu | 2011-2014 | EU (FP7-TPT) |
| ASAP | Appropriate Speed Saves All People<br>https://goo.gl/EhiXvy | 2013-2015 | EU (ERA-NET) |
| ASPECSS | Assessment methodologies for forward looking Integrated Pedestrian and further extension to Cyclists Safety Systems<br>https://goo.gl/kvALo3 | 2011-2014 | EU (FP7-TPT) |
| ATLAS | Impacts of driving distractions: multidisciplinary approach<br>https://goo.gl/IfrKov | 2009-2013 | France |
| BESTPOINT | Criteria for Best Practice Demerit Point Systems<br>https://goo.gl/iVJquL | 2010-2012 | EU (DG MOVE) |
| BRoWSER | Baselining Road Works Safety on European Roads<br>https://goo.gl/up3yv6 | 2013-2015 | EU (ERA-NET) |
| CASPER | Child Advanced Safety Project for European Roads<br>https://goo.gl/33C7ku | 2009-2012 | EU (FP7-TPT) |
| CAST | Campaigns and Awareness-raising Strategies in Traffic Safety<br>https://goo.gl/IlcTMy | 2006-2009 | EU (FP6-SUSTDEV) |
| Compass4D | Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment<br>https://goo.gl/QOONNy | 2013-2015 | EU (Competitiveness and Innovation Framework Programme) |
| CONSOL | Road safety in the ageing societies – Concerns and solutions<br>https://goo.gl/xzXJwg | 2011-2013 | EU (DG MOVE) |
| COOPERS | Co-operative Networks for Intelligent Road Safety<br>https://goo.gl/K13dht | 2006-2010 | EU (FP6-IST) |
| DaCoTA | Road safety Data Collection, Transfer and Analysis<br>https://goo.gl/V9fIkW | 2010-2012 | EU (FP7-TPT) |
| DRUID | Driving Under the Influence of Drugs, Alcohol and Medicine<br>https://goo.gl/oG9g6I | 2006-2011 | EU (FP6-SUSTDEV) |
| EASIS | Electronic Architecture and System Engineering for Integrated Safety Systems<br>https://goo.gl/4n8BOL | 2004-2007 | EU (FP6-IST) |
| ECOROADS | Effective and COordinated ROAD infrastructure Safety operations<br>https://goo.gl/r7kuaE | 2015-2017 | EU (Horizon 2020) |

Table 3-1 (continued) Projects reviewed in the road transport safety sub-theme

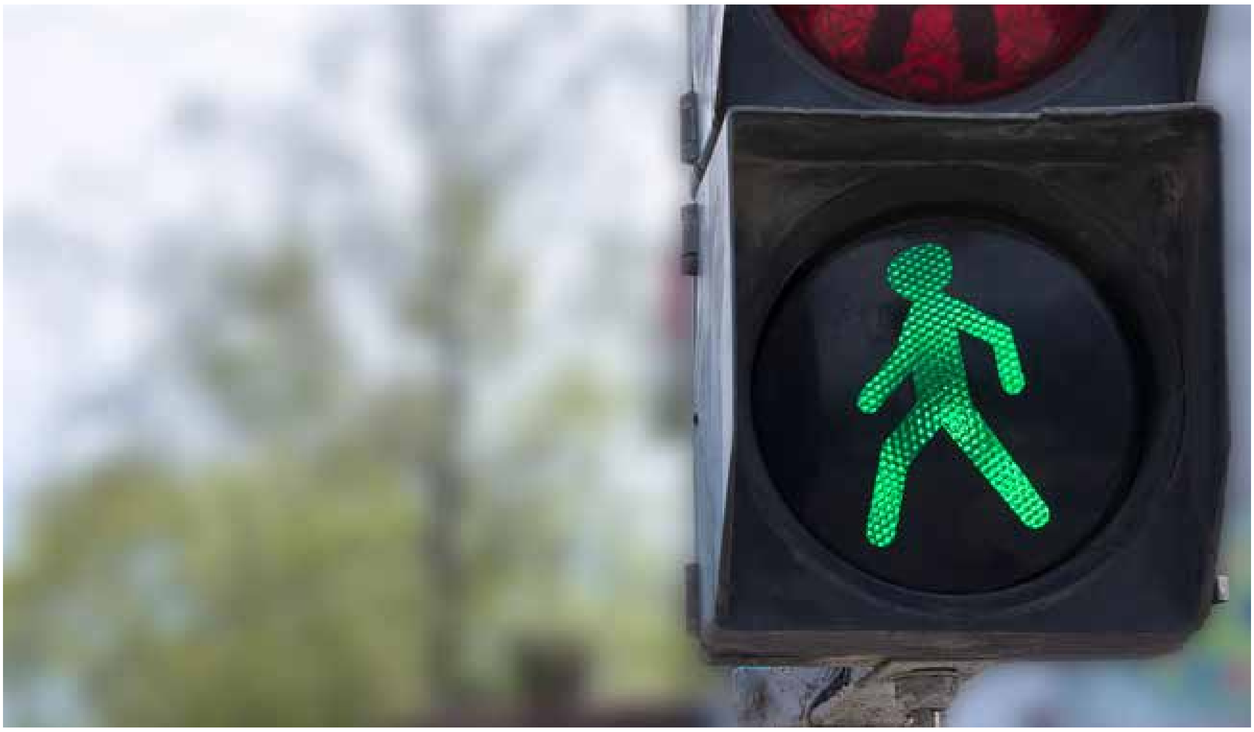
| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| eIMPACT | Assessing the Impacts of Intelligent Vehicle Safety Systems<br>https://goo.gl/EZDTRR | 2006-2008 | EU (FP6-IST) |
| EuroFOT | European Large-Scale Field Operational Test on Active Safety Systems<br>https://goo.gl/HcPQSt | 2008-2011 | EU (FP7-ICT) |
| IASP | Identification of Hazard Location and Ranking of Measures to Improve Safety<br>https://goo.gl/YGzxj2 | 2004-2007 | EU (DG TREN) |
| InDev | InDeV: In-Depth understanding of accident causation for Vulnerable road users<br>https://goo.gl/wlIc8T | 2015-2018 | EU (Horizon 2020) |
| IN-SAFETY | Infrastructure and Safety<br>https://goo.gl/qybEwK | 2005-2008 | EU (FP6-SUSTDEV) |
| LINTU | Long-term Research and Development Programme for Road Safety<br>https://goo.gl/WICcEc | 2002-2008 | Finland |
| MeBeSafe | Measures for behaving safely in traffic<br>https://goo.gl/zHSCyg | 2017-2020 | EU (Horizon 2020) |
| MELA | LARP Method in Traffic Education<br>https://goo.gl/tpAFGh | 2012-2014 | Czech Republic |
| MERKUR | Effects of the developments in the market for e-bikes on risks, conflicts and accidents on the bicycle infrastructure<br>https://goo.gl/bQwfmO | 2011-2012 | Austria |
| NEARCTIS | Network of Excellence for Advanced Road Cooperative Traffic Management in the Information Society<br>https://goo.gl/mSo6Pw | 2008-2013 | EU (FP7-ICT) |
| PEPPER | Police Enforcement Policy and Programmes on European Roads<br>https://goo.gl/eQ4lto | 2006-2008 | EU (FP6-SUSTDEV) |
| Pilot4Safety | Pilot project for common EU curriculum for road safety experts<br>https://goo.gl/44g5in | 2010-2012 | EU (DG TREN) |
| PRAISE | Preventing Road Accidents and Injuries for the Safety of Employees<br>https://goo.gl/ORv5uj | 2009-2012 | EU (ETSC) |
| PREVENT | Automatic system for detection and punishment of the violations<br>https://goo.gl/6ZjncG | 2005-2008 | Czech Republic |
| PROLOGUE | Promoting Real Life Observations for Gaining Understanding of Road Behaviour in Europe<br>https://goo.gl/jD5xeD | 2009-2011 | EU (FP7-TPT) |
| PROS | Priorities for Road Safety Research in Europe<br>https://goo.gl/85XiDs | 2012-2014 | EU (FP7-SST) |
| PROSPECT | PROactive Safety for PEdestrians and CyclisTs<br>https://goo.gl/JXXFUB | 2015-2018 | EU (Horizon 2020) |

Table 3-1 (continued) Projects reviewed in the road transport safety sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| RANKERS | Ranking for European Road Safety<br>https://goo.gl/2HdMNZ | 2005-2008 | EU (FP6-SUSTDEV) |
| REVEL | A methodology to update speed limits<br>https://goo.gl/OJ6QSn | 2006-2008 | Spain |
| RIPCORD-ISEREST | Road Infrastructure Safety Protection – Core Research and Development for Road Safety in Europe<br>https://goo.gl/4SR9T8 | 2005-2008 | EU (FP6-SUSTDEV) |
| SAFERIDER | Advanced Telematics for enhancing the safety and comfort of motorcycle riders<br>https://goo.gl/bWwrgh | 2008-2010 | EU (FP7-ICT) |
| SafetyCube | Safety Causation, Benefits and Efficiency<br>https://goo.gl/QBS70b | 2015-2018 | EU (Horizon 2020) |
| SafetyNet | The European Road Safety Observatory<br>https://goo.gl/G9Yeq3 | 2004-2008 | EU (FP6-SUSTDEV) |
| SAFEWAY2SCHOOL | Integrated System for Safe Transportation of Children to School<br>https://goo.gl/CWMX94 | 2009-2012 | EU (FP7-TPT) |
| SARTRE 4 | Social Attitudes to Road Traffic Risks in Europe<br>https://goo.gl/YvYVoC | 2009-2012 | EU (DG TREN) |
| SAVeRS | Selection of Appropriate Vehicle Restraint Systems<br>https://goo.gl/kBVOk6 | 2013-2014 | EU (ERA-NET) |
| SENIORS | Safety-ENhancing Innovations for Older Road userS<br>https://goo.gl/ddfKPj | 2015-2018 | EU (Horizon 2020) |
| SimuSafe | Simulator for Behavioural Aspects of Road Safety<br>https://goo.gl/1gmWU8 | 2017-2020 | EU (Horizon 2020) |
| SUPREME | Summary and publication of best practices in road safety in the EU member states<br>https://goo.gl/0Zaii5 | 2005-2007 | EU (DG TREN) |
| THORAX | Thoracic Injury Assessment for Improved Vehicle Safety<br>https://goo.gl/CP9hyp | 2009-2013 | EU (FP7-TPT) |
| TYROSAFE | Tyre and Road Surface Optimisation for Skid resistance and Further Effects<br>https://goo.gl/l9kkG5 | 2008-2010 | EU (FP7-TPT) |
| UDRIVE | European Naturalistic Driving and Riding for Infrastructure & Vehicle Safety and Environment<br>https://goo.gl/4vUDxZ | 2012-2016 | EU (FP7-TPT) |
| VSS2008/302 | Pedestrian Crossing (Principles)<br>https://goo.gl/sTHhZg | 2008-2011 | Switzerland |
| XCYCLE | Advanced measures to reduce cyclists' fatalities and increase comfort in the interaction with motorised vehicles<br>https://goo.gl/tcVLgw | 2015-2018 | EU (Horizon 2020) |
| N/A | Analysis of the impacts of the application of the Directive 2008/96/EC about road infrastructure safety management on the roads in the Czech republic outside the TEN-T network<br>https://goo.gl/WTKJUJ | 2015-2016 | Czech Republic |

Table 3-1 (continued) Projects reviewed in the road transport safety sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| N/A | Biomechanics of Deformation Processes in Human Skeleton under Extreme Strain<br>https://goo.gl/CfntiX | 2007-2013 | Czech Republic |
| N/A | High Risk Groups in Road Traffic<br>https://goo.gl/WFJckH | 2007-2010 | Norway |
| N/A | Improving Passive Safety of Vehicles<br>https://goo.gl/xOvrdh | 2007-2013 | Czech Republic |
| N/A | Modern turbo-roundabouts and their application in the design of transport constructions<br>https://goo.gl/OGwEjY | 2013-2015 | Czech Republic |
| N/A | National Road Safety Audit<br>https://goo.gl/BCCkBx | 2012-2014 | Hungary |
| N/A | Optimising profiled road markings with rumble strips for improving road safety<br>https://goo.gl/uu2xSj | 2014-2017 | Czech Republic |
| N/A | Research in driver's visual workload and attentiveness<br>https://goo.gl/iA9IM4 | 2014-2016 | Czech Republic |
| N/A | Road safety of elderly people<br>https://goo.gl/wYdsEP | 2007-2008 | Finland |
| N/A | Seatbelt and Mobile Phone Usage Survey Scotland: 2014<br>https://goo.gl/mRocHF | 2014-2015 | UK |
| N/A | Strategic research initiative: road safety<br>https://goo.gl/rNvxQB | 2011-2015 | Norway |
| N/A | The speed of vehicles in Poland in 2015<br>https://goo.gl/zsMVFg | 2015 | Poland |



## 3.2 Safety in railway transport

### 3.2.1 Introduction to the sub-theme

The number of casualties resulting from accidents on the EU railway network is small compared with the number of casualties from accidents on EU roads. This makes rail one of the safest modes of transport. Generally, fewer than 100 rail passengers – often many less – are killed each year in railway accidents in the EU (European Union Agency for Railways, 2016). Indeed, in 2014, the number of rail passengers killed on the EU's rail network (only 15) was the lowest figure ever recorded. However, passenger casualties are only a small proportion of the 1 000 or so people who are killed by trains each year, the majority of which are trespassers. Accidents on level crossings account for around 30 % of these additional deaths, although these numbers have been declining in recent years. Additionally, there are around 3 000 suicides on the EU's railways each year, but these are not included in the total figures for railways as they are not considered to be a railway incident.

Even though the number of fatalities is relatively small, there are still around 2 000 significant accidents on the rail networks of EU Member States each year, which incur annual costs of over EUR 1.4 billion. The majority of these accidents are as a result of collisions between rolling stock in motion and people, while around 5 % of accidents involve a derailment and a further 5 % a collision. In addition, there are many accidents and incidents with less serious consequences (European Union Agency for Railways, 2016).

The European Union Agency for Railways recognises that the industry must do better. This is particularly important in light of the goal of the European Commission's 2011 Transport White Paper (European Commission, 2011) to ensure that the EU is a world leader in transport safety. Consequently, there is a need for research to identify efficient and effective ways of improving the safety of rail transport.

#### 3.2.1.1 Overall direction of European-funded research

Research funded by the EU's 6th and 7th Framework Programme for Research and Technological Development (FP6 and FP7) covered many of the different aspects of rail safety. As a result, identifying trends is challenging, particularly given the large number of potential research areas and the various different elements of the rail system that are important for safety. One trend that is identifiable is a move away from more general 'operational' projects, such as AVATARS (2005-2007) and INTERGAUGE (2006-2008), towards projects focusing on more specific elements, particularly wheelsets and axles under more recent calls, such as SAFERAIL (2008-2011), EURAXLES (2010-2013) and MAXBE (2012-2015).

It is also noticeable that many more rail safety projects began in 2006 – five of those identified – with only one, or sometimes two, being funded each year since. The projects generally cover different elements of the railway system. However, given their high contribution to the overall number of fatalities on the railway, only one project was identified that concerned trespassers and suicides (RESTRAIL (2011-2014)), and one that concerned level crossings (SELCAT (2006-2008)).

#### 3.2.1.2 Overall direction of nationally funded projects

Comparatively few national projects have been identified. Those that were identified tended to focus on operational elements associated with improving the safety of the overall system or on specific railway lines. National projects also tended to be very practical, in that they were developed for, and tested on, specific railway lines.

### 3.2.2 Research activities

The research activities can be separated into those that focus on the infrastructure, those for which the main concern is with the railway vehicle (i.e. the railway locomotive and the carriages) and those that are more behavioural in nature – including driver behaviour and the behaviour of actors from outside the railway system.

The activities that focus on infrastructure cover topics from station design to track inspection and the integrity of the infrastructure. The way in which railway stations are designed, focusing on how people move around stations in different circumstances, was the subject of AVATARS. Traditionally, stations were designed with a focus on their aesthetics. However, in an era of intensive use of railway stations, and the threats posed by terrorism and natural disasters, designing stations to facilitate their use, reduce overcrowding and enable their evacuation in emergency situations has become increasingly important. The aim of AVATARS was to develop software to simulate the circulation of passengers in normal and emergency situations to support the design of railway stations. The tools were tested and refined using data from actual stations to ensure their applicability in the real world.

The approach to safety in the European urban guided transport sector (e.g. trams, underground rail and light rail systems) had previously been relatively under-researched. The MODSafe (2008-2011) project, which involved major transport operators (including London Underground, Régie Autonome des Transports Parisiens (RATP, Paris) and Metro de Madrid) aimed to address this. Different guided systems tended to have different requirements and to apply different certification schemes with respect to how they deal with risk. MODSafe provided a coherent analysis of the challenges that such systems faced by bringing together and testing the knowledge of the different participants. This led to the development of a common process and a layout for generic proofs for the safety systems of urban guided transport systems.

The aim of the D-RAIL (2011-2014) project was to develop approaches and standards to reduce the incidence and economic cost of derailments in the European rail freight sector. The project analysed the causes, consequences and potential means of preventing freight train derailments, which cost the industry EUR 200 million per year. Ways of preventing and mitigating the impacts of the main causes of freight derailments were assessed, and monitoring techniques and standards were developed and evaluated on test tracks in the UK and the Czech Republic.

Potential ways to integrate these techniques into broader monitoring systems that are used in the rail sector were also assessed.

The development of an inspection system that can evaluate the structural integrity of rail tracks was the subject of the INTERAIL (2009-2012) project. As the rail networks are becoming ever busier and axle loads are increasing, it is becoming increasingly important to be able to inspect and evaluate rail tracks quickly and efficiently to ensure that they remain safe to use. INTERAIL developed and successfully validated a number of related systems. A high-speed inspection system was developed, containing three modules that were combined into a single architecture – automated visual inspection, alternating current field measurement (ACFM) and ultrasonics. This was complemented by the development of manual detection and verification technologies, which could be used to inspect joints, switches and crossings. The technologies used ACFM and ultrasonics, as well as high frequency vibration analysis.

The early detection and assessment of damaged rails was the aim of the Austrian fractINSPECT (2009-2011) project. As a result of the type of steel used to make rails, and the traction force of railway engines and their carriages, it was considered to be no longer sufficient to rely on visual inspection to identify rail breakages. The aim of the project was to develop an optical rail scanner that could inspect rails to identify potential flaws in their surface that might lead to greater damage at a later date.

A number of projects have looked at the safety of rail (and road) tunnels, particularly in relation to the risk of fire. The TRANSFEU (2009-2012) project aimed to contribute to filling some gaps in the development of the European Fire Safety Standard (TS45545) and to develop engineering solutions to improve the performance of tunnels when a fire occurs. In addition to tunnels, the project looked at fires inside trains more generally. One part of the project tested and classified the toxicity of effluents from fires, while another developed a fire safety engineering methodology, along with various tools, that could be used to inform the design of rail vehicles and tunnels. These would, for example, facilitate the evacuation of people and assess the integrity of the structures in the event of a fire.

The Tunnelsafe2020 (2015) project was funded by the Horizon 2020 small and medium-sized enterprise (SME) instrument and supported a Danish fire extinguishing solutions company to study the feasibility and test potential fire extinguishing solutions for rail (and road) tunnels. The prevention of failures in rail (and road) tunnels more generally was the concern of the ROBO-SPECT (2013-2016) project. This drew on the latest developments in robotics, computer vision and non-destructive sensing to develop an autonomous robotic inspection and assessment system for tunnels. The autonomous system that was developed was successfully tested on a motorway tunnel in Greece[9].

The INTERGAUGE project had a relatively narrow focus, but was nonetheless important – the development of technology to enable the safe and secure movement of hazardous goods between railways of different gauges. The project developed new technology, including a railway vehicle with adjustable wheelsets, an automatic track gauge switching station and new technology for switching stations. The track system at Dorohusk on the Polish-Ukrainian border was adapted to test the technology developed within the project, the effectiveness of which was subsequently examined and verified.

The projects in which the focus was on railway locomotives and carriages included one that investigated improvements to the safety of carriage interiors in the event of a crash, and several on the performance of wheelsets and axles.

The SAFEINTERIORS (2006-2010) project looked at how to reduce fatalities and injuries in the event of an accident by improving the interior of passenger carriages. It built on the already well-developed structural crashworthiness of carriages by drawing on knowledge of injury biomechanics directly associated with ‘secondary collisions’ (i.e. those between passengers, and passengers and other objects, that take place after a train has crashed). The project developed a tool kit to assess potential passenger injuries that might result from a crash, as well as models for designing carriage interiors to reduce the risk of fatalities and injuries in the event of an accident.

A number of FP7 projects focused on enhancing safety by improving the inspection and diagnosis of issues relating to the axles and wheels of trains. Failures associated with these are a major source of accidents. SAFERAIL aimed to reduce wheelset failures through the development of systems to improve the inspection of wheels and axles on moving trains, and when wheelsets are manufactured and maintained. The trackside system to inspect moving trains was based on high frequency vibration analysis and compared the results of the inspection with historical data to identify potential issues. The two probes developed to inspect, respectively, wheels and axles, used ACFM technology.

EURAXLES looked at various ways to improve the safety performance of axles. First, it aimed to understand the stresses that axles are subject to and then to design an approach to estimate the probability of a failure as a result of fatigue in the course of service. It also developed better coatings, and improved the cohesion of such coatings, to protect axles from corrosion. Finally, it developed and assessed non-destructive methods for inspecting axles.

The focus of MAXBE was on addressing the safety threats posed by defects in axle bearings. It developed concepts, strategies and guidelines that could be used across the EU to support railway operators in monitoring axle bearings and in identifying potential problems before they become an issue. The monitoring system developed in the project was tested on lines in Portugal, Belgium and the UK.

Of those projects that focused on behaviour, some were concerned with the role of train drivers in safety, while others were interested in the interaction of non-railway users with the railways (for example, trespassers and level crossing users).

9 http://www.robo-spect.eu/Newsletters/6th_ROBO-SPECT_Newsletter.pdf

The SAFEDMI (2006-2008) project aimed to design and develop a driver machine interface (DMI) for on-board automatic train control systems that integrated safety considerations, which previous DMIs had not addressed. The aspiration was that the DMI should at least achieve Safety Integrity Level 2 of the specifications developed by the European Committee for Electrotechnical Standardisation (CENELEC). The project demonstrated that such an aspiration was feasible, and that it was feasible to maintain the DMI using safe and secure wireless communication.

The focus of the 2TRAIN (2006-2009) project was on the development and evaluation of computer-based training systems for train drivers. While it is not possible to completely harmonise the technology used for training and the content of training, the project aimed to strengthen the approach to train driver training across the EU by making the most of the latest developments. It produced European good practice guidelines for the efficient and cost-effective use of modern technologies that enhance safety, which covered the training of train drivers, and continuing competence and performance assessment.

The collection and analysis of data and approaches to reduce the number of accidents at level crossings was the purpose of the SELCAT project. Level crossings have been identified as a particular weak point from the perspective of road transport safety and accidents involving level crossings make up a significant proportion of the fatalities caused by the operation of railways. In 90 % of cases, the primary cause of the accident is inappropriate human behaviour, which poses a particular challenge. The project brought together and analysed a large amount of data, and made this available on a website (which no longer appears to exist). It also made recommendations for appraising the risks associated with level crossings, the technologies that might be used to reduce risks and the elements to be included in campaigns to increase the awareness of the risks among drivers.

The RESTRAIL project focused on a different type of interaction between railway vehicles and non-rail users (suicides and trespassers), which account for the majority of fatalities associated with railways each year.

The project examined evidence from around the world on the factors that contribute to suicides and trespass, and good practice for reducing suicides, preventing trespassing and mitigating the impacts of these for rail operations. It explored soft measures, (e.g. media campaigns) and harder measures, including technical solutions. It produced an online toolbox[10], which can be used by infrastructure managers to reduce the numbers and consequences of such incidents.

Some national projects have focused on developing better systems for rail safety, with an emphasis on operational elements. The Austrian CHECKPOINT (2003-2006) study supported the development for Austrian railways of a new safety supervision system. The new system replaced visual inspections and was implemented using an automated system based on sensors. As well as reducing the number of staff, the project aimed to increase the number of checks that took place as a result of the placement of sensors at trackside locations. The prototype was tested on the railway line operating between Vienna and the border with Hungary. The development of a signalling system to improve safety on regional railways in the Czech Republic was the aim of the Railway Traffic Safety improvement on Regional Lines Making Use of Satellite Systems (2014-2016) project. The approach that was developed was based on the block system using radio communication. The Slovak Quantitative safety integrity level evaluation of control systems in railway application (2012-2014) project evaluated safety-related control systems to ensure that risks were reduced to an acceptable level. Another Czech project, Active safety system for object spatial localization between railway vehicles and in the front of vehicles (2013-2015), aimed to develop on-board safety systems using optical and acoustic signals.

The coordination and support action FOSTER RAIL (2013-2016) supported the work of the European Rail Research Advisory Council (ERRAC) for the European Commission. It aimed to strengthen and support research and innovation cooperation strategies in the European rail sector. By expanding on the results of a previous project, ERRAC-ROADMAP, FOSTER RAIL defined strategic research and innovation needs, including 11 challenge areas where railway safety will benefit from the application of technology and innovation.

Finally, a number of projects addressing the safety aspects of railways have been initiated under the scope of the Shift2Rail Joint Technology Undertaking, funded by the Horizon 2020 programme, but have not yet produced any results. These projects are:

- GoSAFE RAIL (2016-2019) – a global safety management framework for rail operations;
- PLASA (2016-2018) – dealing with railway planning, relevant data and safety issues;
- SAFE4RAIL (2016-2018) – for modular integration and certification of all safety-, time- and mission-critical train functions.

### 3.2.3 Research outcomes

#### 3.2.3.1 Achievements of the research under this sub-theme

The various projects reviewed in this section have contributed to the development of knowledge and expertise in various elements of rail safety. Together, they provide many different potential mechanisms and approaches to improve the safety of the EU's railway network.

A number of projects have focused on the prevention of accidents resulting from failures in infrastructure, including tracks (INTERAIL) and tunnels (ROBO-SPECT). The fact that the systems developed in these projects were tested successfully suggests that they could pave the way for the wider development and application of such systems.

Other projects have focused on the prevention of accidents from failures in railway vehicles. As noted previously, there has been a particular focus on preventing wheelset and axle failures (e.g. in the SAFERAIL, EURAXLES and MAXBE projects). These three projects progressively narrowed down the focus of attention, through the trackside monitoring of wheelsets and axles in moving trains in SAFERAIL, to a focus on axles only in EURAXLES and finally a focus on monitoring axle bearings in MAXBE. This suggests a development of the understanding of the problem and progress towards a solution. The monitoring systems developed in SAFERAIL and MAXBE, as well as the focus on anti-corrosion coatings for axles in EURAXLES, have the potential to provide a toolkit for preventing failures on these parts of locomotives and carriages.

The concern of other projects was on what happens in the immediate aftermath of an accident. For example, the SAFENTERIORS project used the latest knowledge from injury biomechanics to develop a toolkit for designing the interiors of rail carriages to reduce fatalities as a result of accidents. The TRANSFEU project specifically focused on fires, from the perspectives of evacuating passengers, and maintaining the integrity of carriages and tunnel structures in the event of a fire.

Two earlier projects focused on improving the control of trains from the perspective of safety:

- SAFEDMI integrated safety considerations into on-board automatic train control systems;
- 2TRAIN developed computer-based systems to train drivers and to assess their subsequent competence and performance.

A number of projects have looked at particular types of accident or incident, including derailments of freight trains (D-RAIL), trespassers and suicides (RESTRAIL) and level crossings (SELCAT).

10 http://www.restrail.eu/toolbox/

### 3.2.3.2 Transferability from research to practical use

Many of the project partners had an active involvement in the area of railway safety and this has facilitated the transfer of the results into practical use. The involvement of transport operators and companies that help to design stations in the AVATARS project helped to ensure that lessons learnt from the project, and potentially the software that was developed, have subsequently been used in practice. The involvement of major urban transport operators in MODSafe suggests that the project's findings are likely to have influenced the activities of the various operators. Similarly, the inclusion of infrastructure managers, including Portugal's National Railway Network (REFER) and Brussels Société des Transports Intercommunaux de Bruxelles (STIB-MIVB), in the INTERAIL project indicates that its findings will have informed practice.

Many of the projects involved major rail operators, so it is likely that the findings would have been taken on board in practice to some extent. In particular, the French national railway company (SNCF) and Germany's Deutsche Bahn AG were involved in the D-RAIL, 2TRAIN and SAFEINTERIORS projects. SNCF was also involved in the SAFERAIL project. Some of these projects also involved the International Union of Railways (UIC) (e.g. D-RAIL), which would have helped with the wide dissemination of the results.

The involvement in research projects of manufacturers (e.g. in SAFEINTERIORS and EURAXLES) and maintenance companies (e.g. in MAXBE) indicates that lessons from these projects will have been available to be integrated into the design and maintenance of railway vehicles. Some of the results of TRANSFEU have been incorporated into the relevant European standard – EN 45545-2 (Railway applications – Fire protection on railway vehicles – Part2: Requirements for fire behaviour of materials and components).

The involvement of national rail companies in some of the national projects means that it is likely that the results of these projects will have informed practice and may have led to changes in practice if the projects were successful. For example, the fractINSPECT project led to the successful development of a device that enabled the early detection of flaws in rails before major damage was caused, which facilitated the improved monitoring of an extensive part of the Austrian rail network.

The projects that aimed to reduce the occurrence and consequences of incidents between railway vehicles and non-rail users, (e.g. RESTRAIL and SELCAT), also involved relevant stakeholders. This suggests that some of the lessons about reducing suicides and trespassing, and incidents at level crossings, will have been put into practice. Deutsche Bahn AG was involved in both projects, while ProRail (which is responsible for the railways in the Netherlands) was involved in the former and Bulgarian National Railways was involved in the latter.

### 3.2.3.3 Indications for future research

As the European Union Agency for Railways noted in its 2016 safety report[11], there still remains a lot for the industry to do to improve its safety record, which can be supported by research. In spite of the research that has been targeted at the subject, the number of derailments, collisions and fires on-board trains have remained relatively constant in recent years, while the number of fatalities as a result of trespassers and suicides, and in accidents with road users on level crossings remains relatively high.

Another trend in the EU is the increasing number of high-speed rail lines. These are also likely to pose more challenges to the infrastructure (as the stresses imposed by railway vehicles increase) and to accident prevention (due to the high speeds involved). On the other hand, technology is developing rapidly, so there is likely to be the potential for the rail sector to benefit from developments in other sectors.

11 https://erail.era.europa.eu/documents/SPR.pdf

#### 3.2.3.4 Implications for future policy development

Given the aim of developing a common regulatory framework for rail safety in the EU involving the development of common methods and approaches for a variety of assessments, the results of recent research activities provide a basis for a potential further development of the assessment methodologies. For example, the common processes for the safety of guided urban and suburban transport systems developed in the MODSafe project, and the monitoring techniques and standards to prevent freight derailments from D-RAIL or INTERAIL's track inspection system, could be translated into common EU-wide approaches.

Additionally, there might be scope for the development of common approaches to the design of railway vehicles. This could include taking account of the findings of the SAFEINTERIORS project to improve the design of carriage interiors or the findings of the SAFERAIL, EURAXLES and MAXBE projects with respect to axles and wheelsets.

Given the high level of fatalities associated with incidents involving level crossings, some of the conclusions of the SELCAT project might be relevant. The project made various recommendations for the appraisal of risks associated with level crossings and for technologies that might be used to reduce them. It proposed the harmonisation of risk assessment methodologies across the EU to ensure that risks are appropriately assessed and that the necessary technologies are applied. It also recommended that a cross-sector strategy be developed to identify and coordinate the roles and responsibilities of the players. Similarly, consideration might be given to developing a common framework of action based on the results of the RESTRAIL project to reduce the number of incidents associated with trespass and suicides.

### 3.2.4 List of projects included in the sub-theme assessment

Table 3-2 lists the projects included in this sub-theme assessment.

Table 3-2 Projects reviewed in the safety in rail transport sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| 2TRAIN | Training of Train Drivers in Safety Relevant Issues with Validated and Integrated Computer-Based Technology<br>https://goo.gl/qrlrrs | 2006-2009 | EU (FP6-SUSTDEV) |
| AVATARS | Advanced Virtual Agents for Testing the Accessibility of Rail Stations<br>https://goo.gl/DBLAvL | 2005-2007 | EU (FP6-SUSTDEV) |
| CHECKPOINT | Integration of Checkpoint Systems into Solid State Interlockings for automatics train supervision<br>https://goo.gl/29i6zp | 2003-2006 | Austria |
| D-RAIL | Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment<br>https://goo.gl/OMC9N2 | 2011-2014 | EU (FP7-TPT) |
| ERRAC ROAD MAP | ERRAC Road Map<br>https://goo.gl/ZAqrYY | 2009-2012 | EU (FP7-TPT) |
| EURAXLES | Minimizing the risk of fatigue failure of railway axles<br>https://goo.gl/FSSMN1 | 2010-2013 | EU (FP7-TPT) |
| FOSTER RAIL | Strengthening the research and innovation strategies of the transport industries in Europe<br>https://goo.gl/56xvoi | 2013-2016 | EU (FP7-TPT) |
| fractINSPECT | Early detection and prognosis of rail breaks through complex surface inspection<br>https://goo.gl/CHFWqY | 2009-2011 | Austria |
| GoSAFE RAIL | Global Safety Management Framework for RAIL Operations<br>https://goo.gl/EQRPrZ | 2016-2019 | EU (Shift2Rail, Horizon 2020) |
| INTERAIL | Development of a Novel Integrated Inspection System for the Accurate Evaluation of the Structural Integrity of Rail Tracks<br>https://goo.gl/muPGkJ | 2009-2012 | EU (FP7-TPT) |

Table 3-2 (Continued) Projects reviewed in the safety in rail transport sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| INTERGAUGE | Interoperability, Security and Safety of Goods Movement with 1435 and 1520 (1524) mm Track Gauge Railways: New Technology in Freight Transport including Hazardous Products<br>https://goo.gl/E2uK2W | 2006-2008 | EU (FP6-SUSTDEV) |
| MAXBE | Interoperable Monitoring, Diagnosis and Maintenance Strategies for Axle Bearings<br>https://goo.gl/0jLx9n | 2012-2015 | EU (FP7-TPT) |
| MODSafe | Modular Urban Transport Safety and Security Analysis<br>https://goo.gl/Wi418x | 2008-2011 | EU (FP7-TPT) |
| PLASA | Smart Planning and Safety for a safer and more robust European railway sector<br>https://goo.gl/PEJ1Gn | 2016-2018 | EU (Shift2Rail, Horizon 2020) |
| RESTRAIL | Reduction of Suicides and Trespasses on RAILway property<br>https://goo.gl/Go6vWE | 2011-2014 | EU (FP7-TPT) |
| ROBO-SPECT | ROBotic System with Intelligent Vision and Control for Tunnel Structural INSPECTion and Evaluation<br>https://goo.gl/Of5sZv | 2013-2016 | EU (FP7-ICT) |
| SAFE4RAIL | SAFE architecture for Robust distribute Application Integration in roLling stock<br>https://goo.gl/q6beVn | 2016-2018 | EU (Shift2Rail, Horizon 2020) |
| SAFEDMI | Safe Driver Machine Interface for ERTMS Automatic Train Control<br>https://goo.gl/H3KD6d | 2006-2008 | EU (FP6-SUSTDEV) |
| SAFEINTERIORS | Train Interior Passive Safety for Europe<br>https://goo.gl/4ocXla | 2006-2010 | EU (FP6-SUSTDEV) |
| SAFERAIL | Development of Novel Inspection Systems for Railway Wheelsets<br>https://goo.gl/UVzmvH | 2008-2011 | EU (FP7-TPT) |
| SELCAT | Safer European Level Crossing Appraisal and Technology<br>https://goo.gl/RvwIHV | 2006-2008 | EU (FP6-SUSTDEV) |
| TRANSFEU | Transport Fire Safety Engineering in the European Union<br>https://goo.gl/O4GNK7 | 2009-2012 | EU (FP7-SST) |
| Tunnelsafe2020 | Road and rail tunnel fire protection<br>https://goo.gl/fsSe5a | 2015 | EU (Horizon 2020 SME Instrument) |
| N/A | Active safety system for object spatial localization between railway vehicles and in the front of vehicles<br>https://goo.gl/zZsYXr | 2013-2015 | Czech Republic |
| N/A | Quantitative safety integrity level evaluation of control systems in railway application<br>https://goo.gl/i2wTeT | 2012-2014 | Slovakia |
| N/A | Railway Traffic Safety improvement on Regional Lines Making Use of Satellite Systems<br>https://goo.gl/AAiaiV | 2014-2016 | Czech Republic |

## 3.3 Safety in air transport

### 3.3.1 Introduction to the sub-theme

According to the European Commission, aviation supports close to 5 million jobs and contributes EUR 300 billion or 2.1 % to European gross domestic product, making the sector strategically important for the EU's overall economy and employment. Despite the financial crisis and some difficult years following 2008, global air transport over the long term is expected to grow by around 5 % annually until 2030. As traffic increases so do concerns about safety.

Detailed data collected by the European Aviation Safety Agency (EASA) show a good safety record for commercial air transport over the past few years, particularly among EU-registered operators. However, a single accident can seriously affect the generally positive image. In 2015, a total of 348 people died in accidents occurring on EU territory involving aircraft registered in the countries of the EU – 150 of these were killed in the Germanwings crash in France. This tragic crash alone accounted for nearly all of the fatalities occurring in commercial air transport (155 in total). The majority of the rest of the 348 fatalities were recorded in general aviation and, more specifically, in light aircraft (essentially small aeroplanes, gliders, 'microlights' and balloons).

#### 3.3.1.1 Overall direction of European-funded research

In total, 47 projects on the topic of safety in air transport have been identified and clustered from the TRIP database, of which 44 were EU funded. This review analysed, in particular, the most recent Framework Programmes for Research and Technological Development (FP6 and FP7), and research activities under Horizon 2020.

Research has progressed with an extensive coverage of a wide number of topics. These include the development and further use of innovative technologies ranging from on-board tools to ground-based navigation aids, from materials used in aircraft to emergency response within the overall airport management procedures.

Coordination and support actions (CSAs) also played an important role. The Episode3 (EP3) (2007 2009) project was initiated by the European Commission to undertake a detailed first assessment of the Single European Sky ATM Research (SESAR) programme, validating the operational concept for medium-term deployment (2020). The emphasis was on obtaining a system-level performance assessment of the concept's ability to meet the targets defined by SESAR.

Another CSA, OPTICS (2013-2017), has been launched with the aim of delivering a global vision of the aviation safety research landscape, offering strategic recommendations and support to establish safety research priorities. To support this process, OPTICS provides a comprehensive evaluation of relevant safety research and innovation in aviation and air transport, aiming to provide a complete picture of how research is performing. This includes confirming that the right research is being conducted and that research is delivering the expected benefits to society, drawing conclusions, and providing recommendations for consideration by the EU and other stakeholders. OPTICS is performing an extensive survey of relevant research and innovation activities in the field of aviation safety to establish current state-of-play conditions. The survey results are published in a repository, tracing the activities and main results of research and innovation. The OPTICS initiative created also an interactive map highlighting the funding origin of selected projects and their partners.

The Future Sky Safety (2015-2018) project is an EU-funded transport research initiative, aiming to develop new tools and new approaches to aviation safety, initially over a 4-year period that started in January 2015. The 1st phase focuses on four main topics:

- building ultra-resilient aircraft and improving the cabin safety;
- reducing risk of accidents;
- improving processes and technologies to achieve near-total control over the safety risks;
- improving safety performance under unexpected circumstances.

The project will also help to coordinate the research and innovation agendas of several countries and institutions, and will create synergies with other EU initiatives in the field (e.g. SESAR, Clean Sky 2).

#### 3.3.1.2 Overall direction of nationally funded projects

Only three projects focused on safety in air transport have been selected at a national level. These are from the Czech Republic, Poland and the United Kingdom. They have been analysed in conjunction with the respective topic areas.

The main reason behind a limited number of projects conducted at a national level is probably linked to the consolidated international character of the air transport sector, and the diffusion over a wide scale of the technical solutions and policy measures adopted.

### 3.3.2 Research activities

Air transport safety has improved significantly over the last decades thanks to better aircraft design, engineering and maintenance; the evolution of navigation aids; and improved and extended safety protocols and procedures. Progress has been achieved in parallel with a constant and steady growth in air traffic connections.

Research projects have been clustered according to research advancements in terms of:

- innovative technologies;
- behavioural aspects, assessment and decision-support methodologies;
- airport management and airport operations.

#### 3.3.2.1 Innovative technologies

Advanced on-board monitoring systems allow the aircraft and the air transport system as a whole to predict and mitigate technical and operational issues, including weather, before they arise. On-board data are also used to improve aircraft performance and to optimise their service lifetimes. The distinctive feature of aircraft condition monitoring systems (ACMS) is that they collect a wide range of data. As such, ACMS enable the monitoring and control of the status of on-board systems and equipment, and variations in flight conditions and equipment operation.

The main objective of the HASTAC (2005-2008) project was to increase safety in all in-flight situations, particularly in low-visibility conditions, by improving the transducers used in air data computers (ADC) for aircraft applications. This was one of the major challenges identified on the Strategic Research Agenda for European aeronautics, particularly referring to incidents such as the 11 September 2001 attacks in the US, the SAS plane accident at Linate airport (October 2001) and the mid-air collision at Überlingen, Bodensee (July 2002). Similar intentions were pursued by the HISVESTA (2009 2011) project, aiming to develop a new-generation altimetry module, suitable for fixed-wing and rotary-wing applications.

The aim of the ONBASS (2005-2007) project was to propose, analyse and develop an innovative principle for active system safety (PASS) for aviation. Rather than just recording data during an aircraft's flight to enable post-crash analyses to be carried out, ONBASS proposed the analysis of available data in real time during the flight and reactions to them with the aim of accident prevention.

In aviation, experience has shown that accidents are often preceded by safety-related incidents and occurrences, which reveal technological failures, human factors issues and organisational deficiencies. However, they also show that solely reactive interventions have limited effect. The SKEMAS (2014 2015) tool enabled SMEs to comply fully with existing regulations and to enrich their usually scarce datasets to provide a more complete and realistic safety analysis.

The increased level of automation has been addressed by some more projects. Situations related to difficult flight conditions, system failures or cockpit crew incapacitation can lead to peak workload conditions. The amount of information and actions to process may then exceed the crew capacity. Therefore, systems alleviating crew workload can improve safety. The ACROSS (2013-2016) project developed new applications and human-machine interface systems (HMI) in a cockpit concept for all crew duties from gate to gate. Human factors, safety and certification drove this approach.

Meteorological conditions and natural hazards (fire, lightning, ice, ash clouds, etc.) play an important role in air transport safety.

Lightning strikes to aeroplanes are very common and, on average, every aircraft is hit by lightning once a year. Occasionally, the strike causes exterior damage – a superficial entry or exit wound – or minor damage to the aircraft's electrical systems. However, in most cases, a strike leaves little or no evidence.

The first objective of the ILDAS (2006-2009) project was to develop and validate a concept prototype capable of in-flight measurements of the parameters of lightning strikes. Such a system would, in due course, provide a better knowledge of these parameters that could be used to improve aircraft lighting protection. Based on the reconstructed attachment points and amplitudes of the in-flight lightning strike in real time, the second objective was to enable the development of tailored and efficient maintenance inspection procedures to be applied after a recorded strike.

Safety regulations control aircraft materials and the requirements for automated fire safety systems. Usually, these requirements take the form of required tests. The tests measure the flammability of materials and toxicity of smoke. When the material or system fails a test, it is on a prototype in an engineering laboratory rather than in an aircraft.

The simulation of fire propagation and evacuation in aircraft suffered from a lack of data on material properties and fire behaviour. Therefore, the AIRCRAFTFIRE (2011-2013) project aimed to increase passenger survivability during major fire scenarios such as in-flight fires and post-crash fires. The project focused on the next generation of aircraft as composite materials and other combustible materials have increasingly been used to reduce the weight of the aircraft or to improve passenger comfort. However, these materials have raised the fire load significantly. Although these materials have passed the existing certification tests, it has been necessary to study and assess fire risks for specific zones of the aircraft and for the entire aircraft.

Ice and snow can be major factors in aircraft accidents. Even a small amount of icing or coarse frost can greatly impair the ability of a wing to develop adequate lift, which is why regulations prohibit ice, snow or even frost on the wings or tail prior to take-off.

Building on electro-thermal de-icing technology (now widely used in helicopters), the objective of the ON-WINGS (2009-2012) project was to develop a smart, autonomous, composite electro-thermal de-icing system for fixed wing, helicopter rotor blade and engine inlet applications. The system incorporated, for the first time, ice detection sensors integrated within the structure that are capable of reliably detecting the presence, thickness and type of ice accreted on the surface. The sensors control the operation of the electro-thermal heater blankets, thus ensuring optimum de-icing performance while minimising power demand. This technology is compatible with future-generation aircraft, in which composite materials will be used extensively, and differs from approaches using hot gas diverted from the engines as used in large aircraft.

Ash clouds pose great danger to aircraft and can lead to engine failure. The fine, abrasive particles erode metal, clog fuel and cooling systems, and melt to form glassy deposits. Flight instruments, windows, lights, wings and cabin air supply can also be affected.

The eruptions of the Eyjafjallajökull volcano in Iceland in April and May 2010 caused enormous disruption to air travel across western and northern Europe for several weeks. The shutdown had a knock-on impact on the economy and cultural events across Europe, with the cancellation of more than 100 000 flights across the EU.

The VAMOS SEGURO (2011-2013) project developed an automatic system for monitoring and forecasting volcanic ash dispersal between Sicily and Malta. New instruments were installed to gather important data on explosive activity and volcanic particles, and the use of tephra dispersal models enabled the locations and height of the volcanic clouds to be forecast.

Fire, ice and system failures are typical safety hazards associated with fuel systems. Even if they only represent 2 % of accidents, they continue to be a concern for air safety. The project SAFUEL (2012-2015) aimed to develop the next generation of safer fuel systems that are able to deal with more extreme temperatures, stronger temperature gradients, higher humidity and more frequent exposure to lightning. They were also intended to offer the opportunity to reduce the current over-dependence on patented United States technology.

The HAIC (2012-2017) project allowed the European aeronautical industry to improve aircraft operation and enhance international flight safety when flying in mixed phase and glaciated icing conditions. To do so, appropriate detection and awareness technologies were fitted on aircraft. These alerted the flight crew or enabled the adaptation of the flight path well in advance so as to avoid flying in such weather conditions.

A further topic investigated by some projects is related to the quality, duration and stress of materials used for aircraft. The need to contain operating costs, develop aircraft able to reduce fuel consumption and reduce greenhouse emissions is pushing air operators and aircraft manufacturers to identify and implement new technical solutions, and to use new materials and components. The continued growth in air traffic has placed an increasing demand on the aerospace industry to manufacture aircraft at lower costs, while ensuring that the products are efficient to operate, have less of an environmental impact and maintain the required level of safety.

The AISHA II (2008-2011) project developed advanced monitoring systems for the structural state of aircraft using extended sensor networks. Aircraft design is normally based on a damage tolerance approach and time-based inspection cycles. The large costs associated with these can be drastically reduced by switching to a condition-based maintenance schedule. The same issue was also investigated by the DOTNAC (2010-2013) project, which targeted the development of a safe, contact-free, high-resolution and, potentially, on-site non-destructive testing tool based on terahertz (THz) waves, which will be easy to integrate into industrial facilities. A similar approach was taken by the AERONEWS (2004-2008) project. This focused on non-linear elastic wave spectroscopy (NEWS), and related acoustic and ultrasonic methods, as innovative non-destructive techniques that provide extreme sensitivity in detecting and imaging incipient damage in the form of microcracks or delaminations, weakening of adhesive bonds, and thermal and chemical damage of aircraft components and structures. Both tools allowed the detection of surface, subsurface and in-depth defects in a variety of composite materials used in aircraft.

The COCOMAT (2004-2008) project focused its attention on the reduction of the structural weight of aircraft, while expanding the limits of safe design. The European aircraft industry demands a reduction in development and operating costs by 20 % and 50 % in the short and long term respectively. The project demonstrated considerable reserves in primary fibre composite fuselage structures by conducting an accurate and reliable simulation of collapse. The project developed a substantially extended database on material properties and on the collapse of undamaged and pre-damaged structures subject to static and cyclic loads. The project also developed degradation models, improved slow and fast computation tools for statically loaded structures, and design guidelines. Although the project was orientated towards an application in fuselage structures, the results are also transferable to other parts of the airframe.

The SMIST (2005-2008) project was aimed at developing and validating monitoring technologies able to deliver savings in maintenance costs, and to enable innovative structural designs for metallic and composite structures. Its main objective was to allow the most advanced sensing technologies to become an integral part of the aircraft structure and thus implement structural health monitoring (SHM) into aircraft structural design to minimise maintenance costs, increase aircraft availability and minimise weight.

The CELPACT (2006-2009) project developed cellular materials and twin skinned sandwich structures made from hybrid composites and metals. It focused on basic research for implementation by industry in an 8 to 12-year timescale. The research included next-generation manufacturing techniques for composite hybrid and metal cellular materials and structures. A wide range of candidate materials and geometries were considered, such as cellular hybrid composites, cellular metal with closed cell cores and selected laser-melted lattice cores.

Three research projects specifically addressed safety issues in helicopters. The HELISAFE TA (2004 2007) project aimed to improve the survivability of helicopter occupants in the event of a crash and to minimise the risk of severe injuries in the cockpit and cabin. The scientific issues concerned a better understanding through full-scale tests and computer modelling of helicopter crash dynamics to improve the knowledge of human body limits and injury criteria.

The HELI4RESCUE (2012-2014) project set out to advance heavy-payload aircraft for use during emergencies. The use of air assets in environmental and man-made disasters ensures speedy deployment of rescue services. The project bridged the gap between user needs and air transportation systems suitable for emergency usage and last-mile rescue. During disasters, equipment and personnel must be deployed quickly and perhaps into areas where conventional infrastructure is unavailable. Aircraft have the greatest potential, yet most aircraft are not built for, and consequently not suited to, emergency use.

The Czech project, System for improvement of helicopter safety during landing and taking-off in an unknown terrain (2013-2015), was intended to increase helicopter safety during landing and take-off phases, especially when landing in an unknown and potentially dangerous environment, and in poor visibility. The project developed an innovative system capable of detecting a wide range of obstacles in the vicinity of the helicopter, providing the crew members with an appropriate audio or visual alert to help them avoid the collision.

Recent airliner accident and incident statistics show that about 16 % of the accidents between 1993 and 2007 can be attributed to loss of control in flight (LOC-I) caused by pilot error, technical malfunctions or unusual upsets due to external disturbances.

The ADDSAFE (2009-2012) project aimed to develop and apply fault detection and diagnosis (FDD) methods for civil aircraft to increase aircraft safety and reduce development/maintenance costs. It helped the scientific community to develop the best-suited FDD methods capable of handling the real world challenges raised by industry, while ensuring acceptance and widespread use of these advanced theoretical methods by the aircraft industry.

The goal of the RECONFIGURE (2013-2015) project was to investigate and develop aircraft guidance and control technologies that facilitate the automated handling of abnormal events, and optimise the aircraft status and flight while maintaining, or even improving, its safety level. Similarly, the SOFIA (2006-2010) project developed improved flight reconfiguration functions (FRF). This is a technological response from the aviation industry to the social demand of increasing the security of air transport after the 11 September 2001 terrorist attacks. The FRF will take the control of the aircraft and will manage its safe return to the ground in a security emergency, disabling the control and command of the aircraft from the cockpit.

VISION (2016-2019) is a Europe-Japan collaborative research project, which is developing and validating smarter technologies for aircraft guidance, navigation and control by integrating on-board vision systems, advanced fault detection and resilient systems. The project supports the global civil aviation goal to reduce aircraft accident rates. It targets critical flight situations, especially during the final approach and landing phases where nearly half of fatal accidents in the last decade have occurred.

Some projects addressed specifically the topic of passenger health and comfort. Aircraft seat cushions should be replaced every 4 to 5 years to maintain their safety and comfort characteristics. However, cushion replacement is expensive (about EUR 600 each) and, when original replacements are no longer in production, the whole seat must be replaced (about EUR 1 300 per seat). Cushions need to be certified along with the seat through expensive crash tests. Therefore, airlines delay cushion replacements resulting in passengers traveling on unsafe and uncomfortable seats. The 16gAirTest-Phase2 developed a test method (approved by EASA) for certifying monolithic cushions against the 16g (16 times the acceleration due to gravity) requirement, independently from the crash test on the whole seat.

Concerns have been expressed about the impact of flying on the health and wellbeing of passengers. Changing passenger demographics, the advent of ultra-long-haul services and specific health issues (such as deep vein thrombosis (DVT) and severe acute respiratory syndrome (SARS)) are some of the most relevant aspects being considered. The objective of the ICE (2005-2008) project is to provide airframe manufacturers and airlines with step-change knowledge and innovations to address the concerns about the unknown combined effects of cabin environmental parameters (including cabin pressure for the first time) on the health of passengers in commercial aircraft.

The ADLAND (2003-2006) project dealt with evaluating the options for adaptive shock absorbers to be applied in aircraft landing gears. Typically, shock absorbers are designed as passive devices with characteristics adjusted either to the most frequently expected impact loads or to ultimate load conditions.

The research focused on active adaptation of energy absorbing structural elements, where a system of sensors recognises the type of impact loading and activates energy absorbing components in a fashion that guarantees optimal dissipation of impact energy.

The national UK project WRIGHT (2003-2005) was a multi-centred, multi-study project investigating the association between travel and venous thromboembolism (VTE), a term which covers DVT and pulmonary embolism (PE). It was designed as a series of inter-related studies to determine if the risk of VTE is increased by air travel, the magnitude of this risk, the effect of other factors on the association and to clarify the causal mechanisms. The combined results from this group of studies provided a consistent picture, in-line with previous medical literature on travellers' VTE However, these more recent data strengthen this picture since a greater number of examples have been taken into account.

### 3.3.2.2 Behavioural aspects, assessment and decision-support methodologies

The ASICBA (2005-2007) project highlighted that, despite the important efforts on safety data sharing at an international level, aviation stakeholders proceed, at best, with limited access to these data because of the lack of adequate tools. The small number of tools available tend to focus on data collection rather than data use. The safety approach of the ASICBA project consisted of a methodology enabling aviation stakeholders to assess the effects of their technical, managerial and political decisions at a safety level, together with the associated costs and benefits. The approach supported decisions, such as whether or not to introduce a safety measure, by making priorities for investments in safety based on the most beneficial outcome.

The HILAS (2005-2009) project developed a 'system life-cycle' model for human factors, in which knowledge is generated about the human aspects of the system at the operational end. This is then transformed into an active resource for the design of more effective operational systems and better, more innovative, use of technologies.

The objective of the HUMAN (2008-2011) project was to develop a methodology with techniques and prototypical tools, based on a cognitive model of crew behaviour, to support the prediction of human errors in ways that are usable and practical for human-centred design of systems operating in complex cockpit environments. The methodology was developed and tested in the frame of a flight management system (FMS) case study to understand the human factor and predict potential pilot errors early in the design process. This enabled a considerably improved human-centred design of cockpit systems.

The objective of the SUPRA (2009-2012) project was to develop simulator technologies that allow for better upset recovery training. Current flight simulator technology is incapable of reproducing upset conditions, and aviation professionals are conservative in advocating the use of simulators for upset recovery training because of the risk of negative transfer of training.

Other projects, such as ASCOS (2012-2015) aimed to develop more effective certification of safety enhancements and PROSPERO (2012-2015) addressed its efforts towards a modern understanding of potential risks involving air traffic systems (ATS).

### 3.3.2.3 Airport management and airport operations

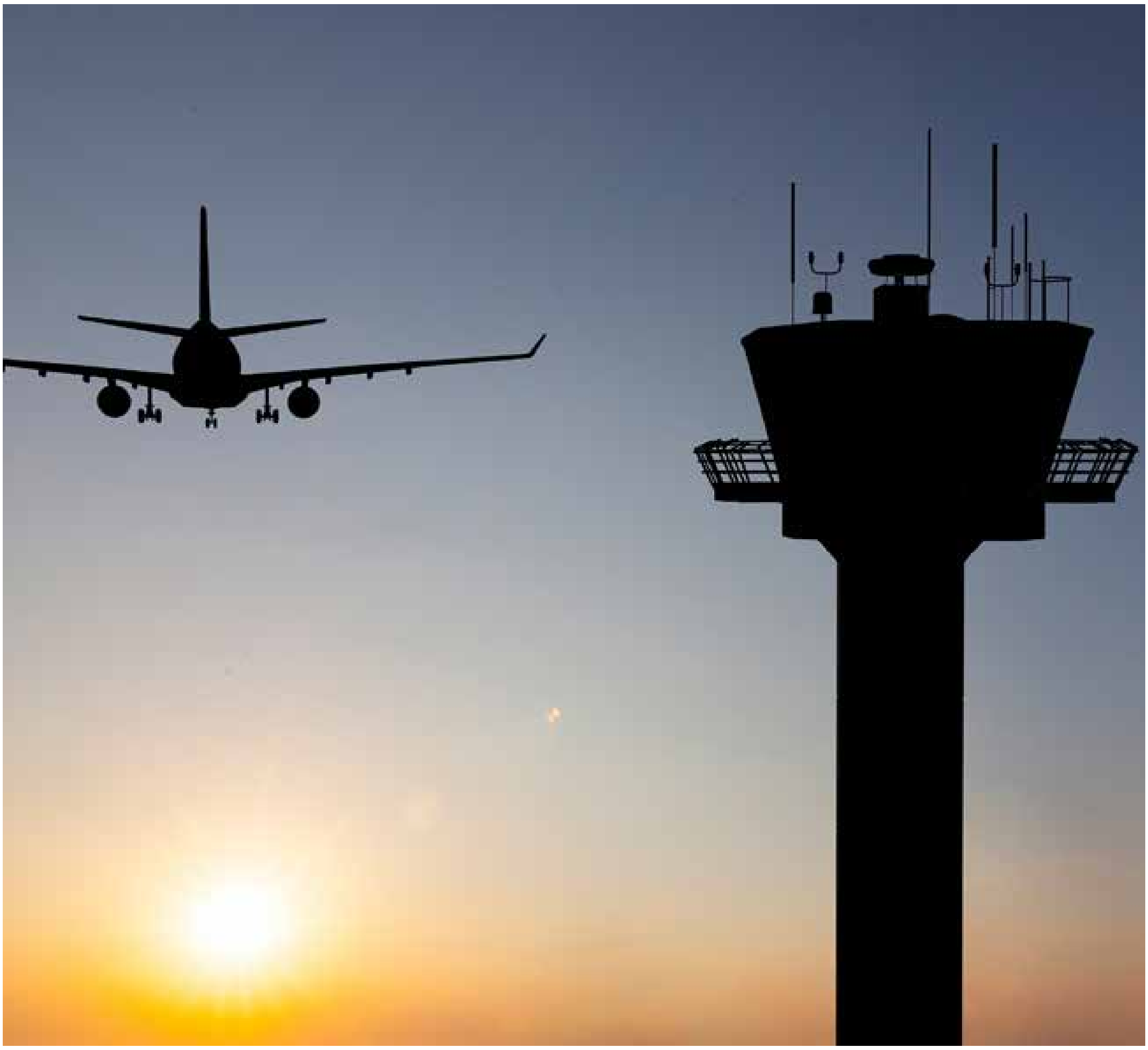
As noted above, air traffic is expected to grow consistently in the future. In particular, some airports and hubs are expected to face significant increases in traffic. Moreover, it is important to consider that many airport facilities were built in a period where the current and future trends in growth, and the increase of low-cost carriers across Europe were not considered.

As a consequence, airport facilities and airport management are facing new operational challenges to keep safety requirements to adequate levels and standards. The use of safety management systems at airports can contribute to this effort by helping airports detect and correct safety problems before they result in aircraft accidents.

The AAS (2008-2011) project aimed to develop, implement and investigate the implications of a high technology system for comprehensive monitoring and controlling of all ground support equipment (GSE) vehicles and movements around the apron area. The overall objective was the enhancement of safety and efficiency on the apron. Furthermore, AAS aimed to significantly improve environmental sustainability by decreasing movements and fuel consumption.

Safe separation distances, prescribed to avoid potential hazards by aircraft encountering a preceding aircraft's wake vortex, are limiting airport capacity growth. Increasing airport congestion, the increasing diversity of aircraft types (e.g. the advent of very light jets), the introduction of new large aircraft and the availability of new technologies have promoted extensive wake vortex investigations in recent years. The Coordination Action WAKENET3-EUROPE (2008-2012) promoted multidisciplinary exchanges between research and operational specialists in the field of wake vortex turbulence. It enabled the development of a shared view on how to address capacity-related issues caused by wake turbulence. It continued the Thematic Networks WAKENET and WAKENET2-EUROPE.

The CREDOS (2006-2010) project evaluated the feasibility of the use of conditional reduced separations for departures under certain meteorological conditions. Recent research suggested that the current wake turbulence separation minima (i.e. minimum distances aircraft need to fly apart from each other at all times to ensure safety) can be reduced under specific conditions while maintaining current levels of safety. The project built on the results of the S-WAKE project that indicated that, with crosswind speeds above a certain threshold, vortices are blown out of the flight corridor and pose no further threat to following aircraft. Similar objectives were pursued by the parallel RESET (2006-2009) project that investigated the reductions in separation minima that could be realised so that they contribute towards a growth of air traffic over Europe, without compromising the current levels of safety.



The SINBAD (2007-2010) project started from similar assumptions. However, in this case, the research focused more on the necessity to monitor air traffic in a rapidly growing density scenario, complicated by the foreseen increase of 'non-cooperative targets' (i.e. aircraft that do not respond to directions from air traffic control). A new monitoring system capable of sending an alert to endangered aircraft or other, ground-based, assets, in case of a confirmed collision risk, is a crucial element in significantly increasing aircraft safety and security, especially in an airport control terminal zone. To meet these challenges, a new technology has emerged over the past years – the multistatic primary surveillance radar (MSPSR). The SINBAD project was based on passive MSPSR using digital television broadcast (DVB-T) opportunity transmitters.

The Polish Multi-criteria planning of safety systems for air traffic and passengers in the airport area (2002-2004) project defined a mathematical model, together with simulation model, for simulating the process of services that take place at the airport relating to aircraft. The model took into account all phenomena relating to aircraft traffic.

## 3.3.3 Research outcomes

### 3.3.3.1 Achievements of the research under this sub-theme

Most of the projects performed on the topic of air transport safety focused their attention on innovative technologies, applied to on-board monitoring systems, aircraft materials and the prevention of accidents provoked by natural hazards. As an example, one of the most significant projects, HASTAC had a significant impact on the avionics industry, allowing manufacturers of high-performance instrumentation to achieve better accuracy and stability in their final system products (about 800 sensors were developed).

Important and relevant improvements have been achieved for the detection of aircraft damage through the use of sensors and microwaves (AISHA II, AERONEWS and DOTNAC), contributing to a more extensive knowledge on the topic. The biggest advantages of such technologies are not only to allow more accurate controls and monitoring, but also to increase efficiency and safety, and detect potential damage that the human eye cannot see.

Testing and application have contributed to the development of new innovative technologies, and identifying materials and alloys that reduce the weight of aircraft and their fuel consumption, without compromising safety standards (COCOMAT and SMIST). The diffusion of innovative solutions in this field is likely to have a positive impact on aircraft manufacturers and operators, considering the importance of such issues to reduce operating costs and improve overall efficiency.

#### 3.3.3.2 Transferability from research to practical use

The wider potential for application is mainly associated with the development of sensors for application in on-board tools. The HASTAC and HISVESTA projects developed a considerable number of sensors and transponders that are likely to have had a positive influence on the sector.

The direct involvement of aircraft manufacturers in some projects (SMIST, COCOMAT and DOTNAC) carried out between 2004 and 2013 dealing with the development and testing of new materials suggest that their outcomes are likely to have found practical applications.

Similar conclusions may be drawn in relation to airport management and operations, where it is expected that the involvement of airport authorities is facilitating the acceptance of new operational systems. This conclusion is reinforced by the observation that many of them have been developed in close synergy with previous initiatives (WAKENET3-EUROPE) and in-line with the objectives pursued by the EU SESAR programme.

#### 3.3.3.3 Indications for future research

The following research topics dealing with human factors and health conditions could further support progress in research on air safety:

- Research in the domain of staff and pilot training should integrate the effects of various human factors (fatigue, situation awareness, workload, etc.) into a single performance prediction approach. This will enable the monitoring and prediction of pilot or controller performance, and the identification of degradation to a level that is unsafe.
- The second main human factors area that should be addressed is better automation. New systems and advances are often putting more automation in front of the pilot, the controller and other operatives. Too often, the human factors of such automation have not been thought through – ignoring knowledge and processes to make the automation a good fit to the task.
- Few projects have been focused on the health conditions of passengers and illness/diseases that might be provoked by altitude and pressurised flight conditions.
- As the capabilities of data science for analysing Big Data improve, there will be a need to do so in a more efficient way and to transform data into 'safety intelligence' that can be acted upon rapidly and, ultimately, in real-time.
- The safe integration of drones into civil airspace and, for example, their potential use in and around airports is a current issue. There are challenges for research to keep pace with technological developments and the development of ever-smaller models.

#### 3.3.3.4 Implications for future policy development

According to the International Civil Aviation Organization (ICAO), runway safety events were identified as one of the main high-risk accident categories, along with controlled flight into terrain (CFIT) and LOC-I. While much progress has been made in the last years, these three high-risk accident categories continue to be global safety priorities.

In 2015, the tragic events of Germanwings flight 9525 and Metrojet flight 9268 showed that aviation safety is being challenged by new threats and emerging risks. As underlined by EASA in its report 'Task Force on Measures following the accident of Germanwings Flight 9525'[12], pilots, like other professionals, are susceptible to the effects of stress or negative personal situations, and may sometimes be reluctant to seek help and support for a number of reasons. Targeted interventions and measures promoted at a policy level from the EU may further increase awareness of the issue, paying particular attention to the assessment of pilot health conditions, and to the development of better support systems for pilots and aeromedical examiners.

Another issue that will be relevant in the future relates to the expected growth in air traffic. Such increasing trends are already relevant and visible in specific airports, especially those with high levels of flights by low-cost carriers. Air traffic is expected to grow rapidly in some cases, while infrastructure facilities needed for adaptation and adjustment will take more time to be conceived, planned and built. The main challenge ahead is to continue to foster research in this sector, aimed at assuring the highest safety standards for passengers and people working at airports.

12 https://ec.europa.eu/transport/sites/transport/files/modes/air/news/doc/2015-07-17-germanwings-report/germanwings-task-force-final-report.pdf

### 3.3.4 List of projects included in the sub-theme assessment

Table 3-3 lists the projects included in this sub-theme assessment.

**Table 3-3 Projects reviewed in the safety in air transport sub-theme**

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| 16gAirTest-Phase2 | Innovative EASA certified dynamic test method for 16g aircraft seat cushions<br>http://goo.gl/dfZBW1 | 2016-2017 | EU (Horizon 2020) |
| AAS | Integrated Airport Apron Safety Fleet Management<br>https://goo.gl/fTkUiX | 2008-2011 | EU (FP7-TPT) |
| ACROSS | Advanced Cockpit for Reduction Of StreSs and workload<br>https://goo.gl/E6o8SH | 2013-2016 | EU (FP7-TPT) |
| ADDSAFE | Advanced fault diagnosis for safer flight guidance and control<br>https://goo.gl/LkSLs9 | 2009-2012 | EU (FP7-TPT) |
| ADLAND | Adaptive Landing Gears for Improved Impact Absorption<br>https://goo.gl/jVA97c | 2003-2006 | EU (FP6-AERO) |
| AERONEWS | Health Monitoring of Aircraft by Nonlinear Elastic Wave Spectroscopy<br>https://goo.gl/z8Hxdy | 2004-2008 | EU (FP6-AERO) |
| AIRCRAFTFIRE | Fire risks assessment and increase of passenger survivability<br>https://goo.gl/FPDH9A | 2011-2013 | EU (FP7-TPT) |
| AISHA II | Aircraft Integrated Structural Health Assessment II<br>https://goo.gl/x677bm | 2008-2011 | EU (FP7-TPT) |
| ASCOS | Aviation Safety and Certification of new Operations and Systems<br>https://goo.gl/AM67my | 2012-2015 | EU (FP7-AAT) |
| ASICBA | Aviation Safety Improvement using Cost Benefit Analysis<br>https://goo.gl/v9FSZR | 2005-2007 | EU (FP6-AERO) |
| AVITRACK | Aircraft Surroundings, Categorised Vehicles & Individuals Tracking for Apron's Activity Model Interpretation & Check<br>https://goo.gl/Xu7S6x | 2004-2006 | EU (FP6-AERO) |
| CELPACT | Cellular Structures for Impact Performance<br>https://goo.gl/zS4l3z | 2006-2009 | EU (FP6-AERO) |
| COCOMAT | Improved Material Exploitation of a Safe Design of Composite Airframe Structures by Accurate Simulation of Collapse<br>https://goo.gl/AHZCGm | 2004-2008 | EU (FP6-AERO) |
| CREDOS | CROSSWIND-Reduced Separations for Departure Operations<br>https://goo.gl/czVAiY | 2006-2010 | EU (FP6-AERO) |
| DOTNAC | Development and Optimization of THz NDT on Aeronautics Composite Multi-layered Structure<br>https://goo.gl/DCCX3p | 2010-2013 | EU (FP7-TPT) |
| EPISODE 3 (EP3) | Single European Sky Implementation Support through Validation<br>https://goo.gl/hNsijC | 2007-2009 | EU (FP6-AERO) |

Table 3-3 (continued) Projects reviewed in the safety in air transport sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| Future Sky Safety | Future Sky Safety<br>https://goo.gl/3SfimD | 2015-2018 | EU (Horizon 2020) |
| HAIC | High Altitude Ice Crystals<br>https://goo.gl/c7GjfL | 2012-2017 | EU (FP7-TPT) |
| HASTAC | High Stability Altimeter System for Air Data Computers<br>https://goo.gl/Bsg4Yk | 2005-2008 | EU (FP6-AERO) |
| HELISAFE TA | Helicopter Occupant Safety Technology Application<br>https://goo.gl/Eo5vi7 | 2004-2007 | EU (FP6-AERO) |
| HELI4RESCUE | Heavy Payload Helicopter for Last Mile Rescue<br>https://goo.gl/ehhczq | 2012-2014 | EU (FP7-SEC) |
| HILAS | Human Integration into the Life-cycle of Aviation Systems<br>https://goo.gl/aRbUAB | 2005-2009 | EU (FP6-AERO) |
| HISVESTA | High Stability Vertical Separation Altimeter Instruments<br>https://goo.gl/PSZ7G8 | 2009-2011 | EU (FP7-TPT) |
| HUMAN | Model-based Analysis of Human Errors During Aircraft Cockpit System Design<br>https://goo.gl/ummhyE | 2008-2011 | EU (FP7-TPT) |
| ICE | Ideal Cabin Environment<br>https://goo.gl/sV2cMM | 2005-2008 | EU (FP6-AERO) |
| ILDAS | In-flight Lightning Strike Damage Assessment System<br>https://goo.gl/ryWX9y | 2006-2009 | EU (FP6-AERO) |
| ONBASS | Onboard Active Safety System<br>https://goo.gl/1p8LAz | 2005-2007 | EU (FP6-AERO) |
| ON-WINGS | ON Wing Ice DetectioN and MonitorinG System<br>https://goo.gl/R98Xue | 2009-2012 | EU (FP7-TPT) |
| OPTAG | Improving Airport Efficiency, Security and Passenger Flow by Enhanced Passenger Monitoring<br>https://goo.gl/SyodWM | 2006-2009 | EU (FP6-AERO) |
| OPTICS | Observation Platform for Technological and Institutional Consolidation of research in Safety<br>https://goo.gl/NsDIyy | 2013-2017 | EU (FP7-TPT) |
| PROSPERO | PROactive Safety PERformance for Operations<br>https://goo.gl/JJQPqc | 2012-2015 | EU (FP7-TPT) |
| RECONFIGURE | REconfiguration of CONtrol in Flight for Integral Global Upset Recovery<br>https://goo.gl/H6WwnG | 2013-2015 | EU (FP7-TPT) |
| RESET | Reduced Separation Minima<br>https://goo.gl/Pgnt9z | 2006-2009 | EU (FP6-AERO) |
| SAFUEL | The SAfer FUEL system<br>https://goo.gl/qtLDDN | 2012-2015 | EU (FP7-TPT) |
| SINBAD | Safety Improved with a New concept by Better Awareness on airport approach Domain<br>https://goo.gl/5pzFqH | 2007-2010 | EU (FP6-AERO) |

Table 3-3 (continued) Projects reviewed in the safety in air transport sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| SKEMAS | Share Knowledge for Effective Management of Aviation Safety<br>https://goo.gl/qbP6Un | 2014-2015 | EU (Horizon 2020) |
| SMIST | Structural Monitoring with advanced Integrated Sensor Technologies<br>https://goo.gl/UKsbmv | 2005-2008 | EU (FP6-AERO) |
| SOFIA | Safe Automatic Flight Back and Landing of Aircraft<br>https://goo.gl/HyaRXw | 2006-2010 | EU (FP6-AERO) |
| SUPRA | Simulation of Upset Recovery in Aviation<br>https://goo.gl/zR7N7m | 2009-2012 | EU (FP7-AAT) |
| VAMOS SEGURO | Volcanic Ash Monitoring and FOrecaSting between Sicilia and Malta arEa and sharinG of the resUlts foR aviatiOn safety<br>https://goo.gl/8KRlRY | 2011-2013 | EU (INTERREG IVA) |
| VISION | Validation of Integrated Safety-enhanced Intelligent flight cONtrol<br>https://goo.gl/Ft2wid | 2016-2019 | EU (Horizon 2020) |
| WAKENET3-EUROPE | European Coordination Action for Aircraft Wake Turbulence<br>https://goo.gl/wUhVwC | 2008-2012 | EU (FP7-TPT) |
| WRIGHT | Air Travel & Venous Thromboembolism<br>https://goo.gl/fgsr9E | 2003-2005 | United Kingdom |
| N/A | Multi-criteria planning of safety systems for air traffic and passengers in the airport area<br>https://goo.gl/zGj3LS | 2002-2004 | Poland |
| N/A | System for improvement of helicopter safety during landing and taking-off in an unknown terrain<br>https://goo.gl/ooaVSe | 2013-2015 | Czech Republic |

## 3.4 Safety in maritime transport

### 3.4.1 Introduction to the sub-theme

Between 2011 and 2015, 12 500 marine incidents were reported in EU waters or involved EU ships, which resulted in 477 fatalities and 12 500 injuries (European Maritime Safety Agency (EMSA), 2016). The incidents were reported in the European Marine Casualty Information Platform (EMCIP), through which, since mid-2011, marine incidents are required to be reported in accordance with Directive 2009/18/EC – the Accident Investigation Directive – (EU, 2009). As the requirement to use the EMCIP is relatively recent, it is anticipated that the figures have been under-reported, although the missing data are expected to relate mainly to minor incidents. For example, in 2015 around 3 300 marine casualties were reported in EMCIP, whereas other sources suggest that the annual figure is probably nearer 4 000.

As a result, EMSA's latest marine casualty report should be seen as an indication of the type, incidence and severity of recent incidents rather than as a comprehensive overview. Of the incidents reported in EMCIP, 45 % involved cargo ships and 23 % involved passenger ships[13]. Around one third of the reported incidents only involved injury to a person – with the ship, its equipment or its cargo being affected in the remaining incidents. Of the latter, half were linked to issues to do with navigation, as these were contacts, collisions or groundings (EMSA, 2016).

Only 3 % of the incidents affecting a ship were classified as 'very serious', meaning that they resulted in the loss of a ship or severe damage to the environment, whereas a further 20 % were classified as 'serious' as they resulted in significant damage to the ship concerned. The cause of over 60 % of casualties and incidents was human error, with around 20 % due to equipment failure. Around 80 % of the fatalities reported over the period were members of crew with most of these occurring on cargo vessels. However, the number of fatalities – for crew and passengers – in any one year can be heavily influenced by one or two significant accidents (EMSA, 2016).

#### 3.4.1.1 Overall direction of European-funded research

The review has identified a number of common themes that appear in two or more projects, with the main difference often being the way in which technology is being applied, with a trend towards intelligent and smart technology. For example, with respect to ship inspections, the focus of research moved from the use of information technology (IT) in the CAS (2005-2008) project to the provision of real-time information using intelligent sensors in the INCASS (2013-2016) project. With respect to ship evacuation, the SAFECRAFTS (2004-2009) project assessed ship evacuation systems and developed concepts for improving life-saving appliances. The LYNCEUS2MARKET (2015-2018) project plans to apply different types of smart technology to assist with the location of passengers to facilitate evacuation.

Other common themes focus on different aspects of the operation of ships in specific conditions (e.g. iced seas and rough weather). Ship design is also a common theme, with projects such as SAFEDOR (2005-2009) and FIREPROOF (2009-2012) targeting ways in which ship design could be improved from the perspective of safety. Very serious accidents (those resulting in a significant loss of life or severe environmental damage) also help to initiate research where new problems are identified, as in the case of the ALERT (2006-2008) project, which was a response to the 2002 accident involving the tanker Prestige.

#### 3.4.1.2 Overall direction of nationally funded projects

Only one national project was identified in the course of the review. This is perhaps not surprising given that maritime transport is largely an international mode of transport, particularly in Europe. Consequently, it is not possible to identify an overall direction for such projects.

### 3.4.2 Research activities

As with the other modes, the discussion on research activities is split between those that focus on infrastructure, those that are mainly concerned with ships themselves and those that relate more to behavioural issues, including how ships are used and the activities of port workers.

Unlike for some of the other modes, there are fewer research activities focusing on infrastructure, as the only infrastructure that needs to be constructed for maritime transport are the ports. However, even for ports, the relevant research activities were more concerned with the welfare and behaviour of employees, so are arguably also 'behavioural' projects.

Crane operators are subject to stressful working conditions from the physical perspective (including the vibration of the cabin) and psychological perspective (in particular, as a result of a need to pay constant attention to the sway of the cargo being moved). A potential solution would be to operate cranes remotely, but one of the challenges of such remote operation has been to monitor the cargo adequately when it is being moved, particularly in relation to reducing its sway. The SECURCRANE (2005-2009) project aimed to address these concerns by developing a remote control system that included cargo monitoring and anti-sway modules. The three-dimensional, real-time system that was developed comprised cameras and other monitors that enabled operators to control cranes without sitting in the cabs. The system was successfully tested in a crane in the French port of Le Havre.

The focus of the EU-PORTRAITS (2013-2016) project was on the training of port workers more generally, particularly the potential to establish a 'mutually recognisable framework' for the training of workers operating in different jobs within the port.

13 The other categories covered were: 'Fishing vessels', 'Service ships' and 'Other ships'.

The project included a review of current training practices, an assessment of future needs in the context of the development of the sector, and the identification and prioritisation of relevant health and safety issues. National workshops and international conferences were held during the project to facilitate dialogue and consensus-building among key stakeholders.

A number of projects were concerned with ships themselves, particularly with respect to improving their design to fare better in the event of an accident or to improve their inspection to reduce the risk of accidents in the first place. The focus of SAFEDOR was to apply the 'Design for Safety' concept to the design of five main types of ship, in which safety is seen as a design objective rather than a constraint. One of the aims of the project was to develop a regulatory framework, and to develop appropriate design methods and tools, that gave more freedom to ship designers. In this way, regulators would set the target safety performance of the new ship, with quantified risk acceptance criteria, and ship designers would then be able to design the ship cost-effectively to meet the specified level of safety. Thus, innovation would be enabled, which it was argued was constrained by the regulatory system. For each type of ship considered within the project, a prototype design was developed and a formal safety assessment was conducted.

The apparent constraints of the existing regulatory system on ship design were also the subject of FIREPROOF, but with the focus specifically on fire risks on passenger ships. In a similar way to SAFEDOR, FIREPROOF proposed a means of maintaining safety, while making the regulatory framework less prescriptive. The regulatory framework developed within the project was based on probabilistic and numerical models of the way in which fires start, how they spread and what their impacts were.

Designing ships to deal better with rough seas was the aim of the EXTREME SEAS (2009-2012) project. The project sought to understand the impacts of 'rogue waves' on ships and their structures using an understanding of the properties of such waves. Experimental and field data were analysed, and supported by simulations of the impacts of such waves on different types of ship, in different seas and in different types of location. The results provided information that was used to improve the design of ships to enable them to withstand rough seas better. Warning criteria were also developed that could be used as part of a decision-support system to inform operators of potential issues with the structure of the ship.

The use of IT and other techniques to inspect ships to ensure that they remain safe and seaworthy has been a theme in different research programmes. CAS focused on the development of IT support for the inspection and maintenance of ship hulls, in particular the measurement of their thickness. To enable this, the project partners, which included representatives of the major stakeholders, developed a standard exchange database called 'Hull Condition Model'. Based on this, simplified three-dimensional models were developed to support monitoring and inspection, which were demonstrated at the Lisnave shipyard in Portugal. INCASS aimed to take ship inspections further with the use of robotic platforms that provided real-time information on a ship's structure using intelligent sensors and risk analysis.

The approach to ship inspection taken by the respective authorities more generally is the subject of the SAFEPEC (2014-2017) project. While ships are inspected by different authorities, there has been little attempt to assess the effectiveness of the various inspection regimes. The project aims to take a risk-based approach and develop a 'unified risk-based framework', based on an analysis of historical data on casualties, near misses and deficiencies identified in the course of inspections. It also aims to develop prototype software that will enable the interoperability and coherent interpretation of the various data sources.

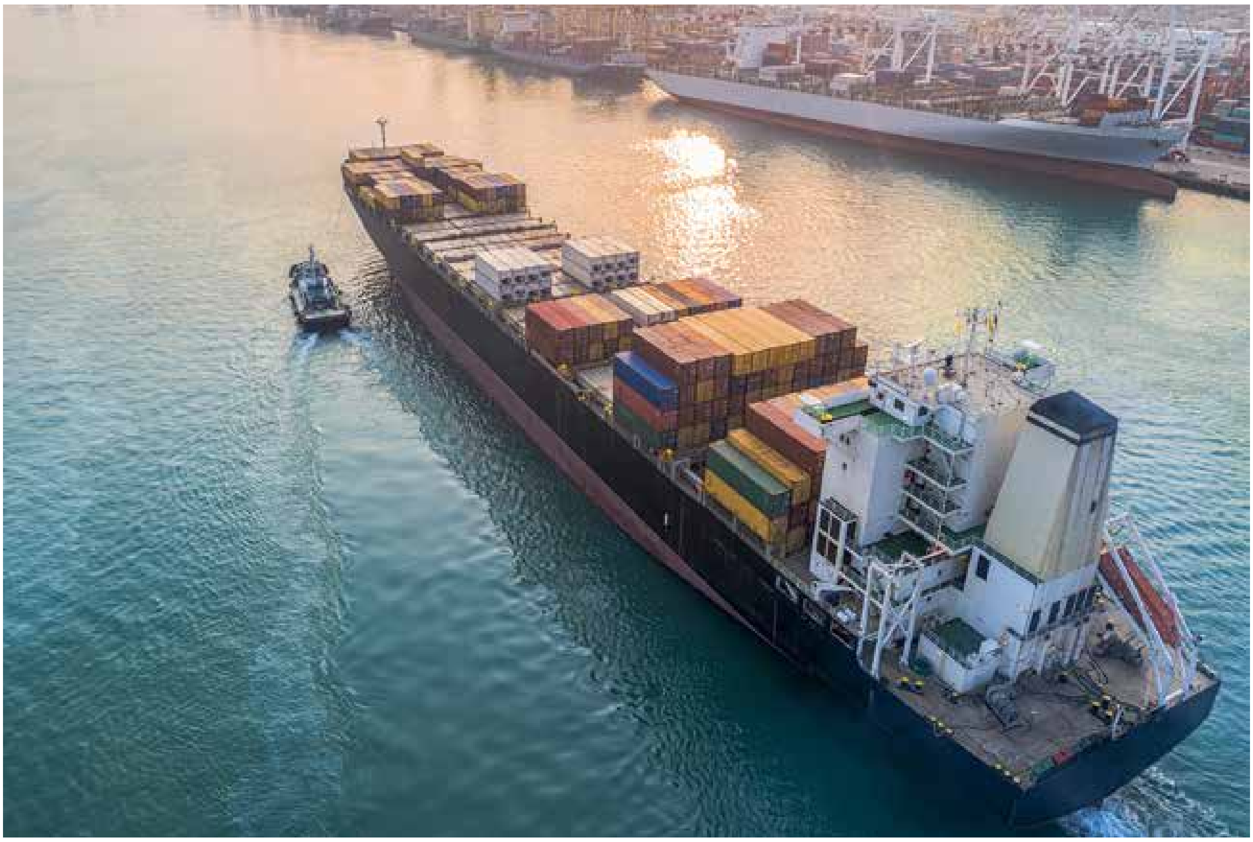
The origins of the ALERT project were in the 2002 accident involving the tanker Prestige, which suffered a structural failure even though it had undergone extensive repairs 18 months previously. This raised questions about the way in which repairs were undertaken, which were explored within the project. Ship repair practices were examined, while a review was undertaken of the existing and emerging technologies that were potentially appropriate for ship repair. The project also examined the way in which the structural strength of tankers was assessed to help inform the development of a framework to determine the extent of any repair work needed. It also studied how to improve the way in which tanker structures were managed through their lifetime.

The traditional approach to inspecting tanker hulls to ensure their structural integrity required ships to be taken out of service, and even put in dry dock, at a cost of hundreds of thousands of euros. The aim of the ROTIS II (2004-2007) project was to develop and test a system that could remotely inspect the hulls of tankers and other double-hulled ships, thus reducing costs. The system had three main components:

- a small, remotely operated vehicle (ROV) equipped with ultrasonic sensors and six cameras;
- a unit supplying energy to the ROV;
- a portable control system with an easy-to-use human interface.

The system was successfully tested in a real-world situation.

The majority of research activities on the safety of maritime transport focus on operational aspects generally or on the operational aspects of emergency situations. Two projects have investigated the specific issues involved with travelling in ice-bound seas. The SAFEICE (2004-2007) project aimed to reduce the risks to shipping of using icebound waters by analysing data and developing models to explore the impact of ice on ship hulls in different operational scenarios and ice conditions. As a result, the project developed a framework for the development of design codes and regulations for the plastic, rather than elastic, design of ships.



One of the challenges of navigating seas in winter is understanding the behaviour of ice and learning how to navigate such seas. Addressing such concerns was the focus of the SAFEWIN (2009-2013) project, which developed a system to forecast ice compression and ice dynamics in the Baltic Sea. Such a system was considered to be important to assist ship crews operating in iced seas, who would otherwise lack the necessary experience to operate in such environments.

Another project, HANDLING WAVES (2007-2010), aimed to support decision-making in rough seas, as these can adversely affect a ship's performance and therefore its efficiency. In the course of the project, research was undertaken to better understand various factors and how they affect ships, including the motion of the bow and shifting structural loads, and the probabilities and effects of rogue waves and large amplitude rolling motions. This knowledge was combined with a system to monitor ship acceleration in real-time to produce an on-board decision support system.

As a result of the increase in shipping globally, the seas are becoming more congested. This, along with the increased risk of terrorism, means that more attention is being paid to the movement of ships. The aim of the FLAGSHIP (2007-2011) project was to capitalise on the improvements in satellite communication and the internet to gather and analyse data to improve the day-to-day operations of ships and how they respond in emergency situations. A number of monitoring tools were developed, including one to assess hulls in real time and one to monitor fuel efficiency. In addition, a support system for day-to-day operations was developed to increase the speed of decision-making. A prognosis and assessment tool was also developed to improve the speed of decision-making in emergency situations, while an alarm filtering tool was developed to reduce the cascade of alarms that often sound on the bridge in emergency situations. The EfficienSea 2 (2015-2018) project addresses many of the same concerns as FLAGSHIP, but with a focus on the latest developments in communication technologies, including the development of a 'Maritime Cloud'.

The vast majority of cargo is transported in containers, but this approach is not as safe as it might be because the way in which containers are constructed does not facilitate scanning or tracking. FP7's SME instrument supported the development of a container door in the ISOTRACK (2008-2011) project that addressed these problems. The door was transparent to radio frequencies and incorporated sensors that were able to detect various safety and security risks. It was also fitted with a tracking and telemetry system to enable the container to be easily located.

Once a ship has become disabled for any reason, there are many risks involved for the ship itself and for any tugs sent to tow it. If not handled properly, the economic and environmental impacts could be extensive. The aim of the SAFETOW (2004-2007) project was to develop tools to assist the masters of the ships involved (that is, those of the disabled vessel and of the tug(s)), with the aim of reducing the risks from towing stricken vessels. The project involved representatives of all of the main stakeholders, including ship owners, a salvage company and a port authority. Three tools were developed: a manoeuvring aid, a towing aid and a lines monitor. The manoeuvring aid was targeted at disabled tankers and provided support to the master in making decisions when a vessel is drifting. The other two tools supported the masters of the tugs involved.

Increasing knowledge to support decision-making on stricken passenger ships was the subject of two projects supported by FP6 in 2009. The aim of the FLOODSTAND (2009-2012) project was to improve understanding of the way in which water flooding into a passenger ship affected its stability and the chances of its survival. The project also developed a method that enabled the quick classification of the severity of the risk that a stricken vessel faced from flooding. The GOALDS (2009-2012) project was also concerned with the impacts of flooding, but on ships that have suffered a breach in their hulls as a result of a collision or having run aground. Again, modelling and simulation were used to estimate the probability of a ship's survival and the potential for an orderly evacuation. Both projects had implications for the way in which ships are designed.

The focus of the SAFECRAFTS project was on improving the way in which passenger ships are evacuated in the event of an incident. The challenge in this respect is that passenger ships are continually getting larger and so existing approaches to evacuation and life-saving appliances may no longer be appropriate. The project first identified a way of assessing existing ship evacuation systems. It then used this information to develop two concepts for improving life-saving appliances that are used on passenger ships. The LYNCEUS2MARKET project aims to develop a system for evacuating passengers using methods that help to identify the location of passengers, including through locatable lifejackets, bracelets and cabin keycards, supported by smart smoke detectors and other sensors. Together, these will provide information to those coordinating any rescue operation to enable evacuation to be undertaken as safely and as efficiently as possible.

The maritime sector has lagged behind the aviation sector in terms of putting tools and methodologies in place to deal with instances of human error within the system. The aim of the SEAHORSE (2013-2016) project was to identify what the maritime sector might learn from practices in aviation. It began by reviewing good practice that the aviation sector uses to manage 'errors and non-standard practices', then reviewed practice in the maritime sector to identify any gaps that exist. The project developed and validated a framework to improve the resilience of individuals, teams and other actors involved and, finally, the organisation more generally.

In the 1990s, the International Maritime Organization (IMO) adopted the international safety management (ISM) code with the aim of improving maritime safety. The aim of the Finnish project, METKU (2008-2010), was to evaluate the impact of the ISM code on the maritime safety culture in Finland. The study demonstrated that the legislation and safety management systems, where they existed, were fragmented and consequently there was a need to develop an integrated safety management system for ports. On the positive side, the study suggested that a stronger safety culture was beginning to emerge and that personnel were generally more aware of safety considerations than before the ISM code had been put in place.

Two projects have also looked at the safety aspects of maritime transport. The aim of the S@S (2004-2007) project was to harmonise the risk management strategies applied in the North Sea and included relevant administrations from the countries concerned. The CHEMSAR (2016-2019) project is aiming to create operational plans and standard operational procedures for search and rescue operations in the Baltic Sea that involve hazardous and noxious substances.

## 3.4.3 Research outcomes

### 3.4.3.1 Achievements of the research under this sub-theme

Much of the research on maritime safety has been on issues of direct importance to European and international shipping. As such, it is often of international relevance, as demonstrated by the aim of many projects to present their findings at the IMO, including SAFECRAFTS. Other projects have had a direct impact on the IMO's development of its rules and regulations. The IMO's Sub-Committee on Ship Design and Construction took account of the results of the FLOODSTAND and GOALSD projects when amending Chapter II-1 of the International Convention for the Safety of Life at Sea (SOLAS)[14]. The formal safety assessments (FSAs) of the risk-based ship designs developed in the SAFEDOR project were presented to the IMO's Maritime Safety Committee or the IMO's Marine Environment Protection Committee in the case of the FSA on crude oil tankers, between 2007 and 2009. The IMO established an FSA Experts Group to review these FSA studies and to recommend any subsequent action that might be needed[15]. As part of the EXTREME SEAS project, a joint workshop was held in Geneva with the IMO and the World Meteorological Organization[16].

Many of the projects also substantially increased the knowledge in a specific area. For example, the research undertaken in the SAFEICE project significantly increased the knowledge and understanding of the ice load distributions on ship hulls. As it involved many relevant research partners and maritime administrations from northern Europe and beyond, it is likely that this knowledge will have benefited subsequent research into the design of ships. The remote crane operating system developed in the SECURCRANE project has the potential to be widely applicable, but needed further refinement before it could be fully commercialised.

### 3.4.3.2 Transferability from research to practical use

Engagement with the IMO has also led to the results of projects being transferred to practical use. For example, the two novel concepts for life-saving appliances for passenger ships that were developed in the SAFECRAFTS project have subsequently been developed and are close to being approved by the IMO[17]. The results of the SAFEWIN project have been integrated into IBNet – the management system for icebreaker operations on board Finnish, Swedish and Estonian icebreakers operating in the Baltic.

14 http://www.imo.org/fr/MediaCentre/MeetingSummaries/SDC/Pages/SDC-2.aspx
15 http://www.imo.org/en/MediaCentre/MaritimeNewsMagazine/Documents/2009/IMO-News-03-2009.pdf#search=safedor
16 https://safewaters.wordpress.com/tag/imo/
17 http://readmt.com/news/article/2015/03/30/imo-welcomes-new-life-saving-appliance-for-passenger-ships/

Other projects have led directly to the commercialisation of the results. The partners involved in the FLAGSHIP project were commercialising a number of the results of the project, including products to monitor the performance of engines, facilitate the analysis of hazards, reduce the cascade of alarms that often occur in an emergency situation and facilitate container scheduling[18]. The container door developed in the ISOTRACK project, which facilitated the scanning of the container's contents and included a tracking system, was also being commercialised by the project partners. Containerships, a short sea shipping company based in Finland, has tested the prototype door developed in the project in real-world situations[19].

Other projects involved key stakeholders, which suggests that their results are likely to have influenced, or even been taken up, in practice. For example, the ALERT project involved relevant stakeholders, including the maritime authority responsible for the ship whose accident led to the project. Therefore, it might be expected that its findings informed practice. The involvement of training institutes directly linked to ports suggests that the results of the EU-PORTRAITS project will have been taken up in practice. The tools that were developed in the course of the SAFETOW project can be expected to have informed practice as the project involved representatives of the main stakeholders involved in towing disabled vessels.

### 3.4.3.3 Indications for future research

As there are still a significant number of accidents annually in the EU, there is scope to improve maritime safety. The fact that a database of maritime accidents (such as EMCIP) exists is important because it will enable the review of accident reports to identify causes and potential research needs. This will complement any research needs identified as a result of any serious future incidents.

Even though the majority of incidents are not serious, around a third of all reported incidents are linked to some form of navigational issue and over 60 % are the result of human error. This suggests there remains a need for research into tools, mechanisms and procedures to support decision-making to improve safety in day-to-day operations. This is perhaps already recognised as the EfficienSea 2 project aims to apply the latest developments in communication technologies to day-to-day operations on board ships.

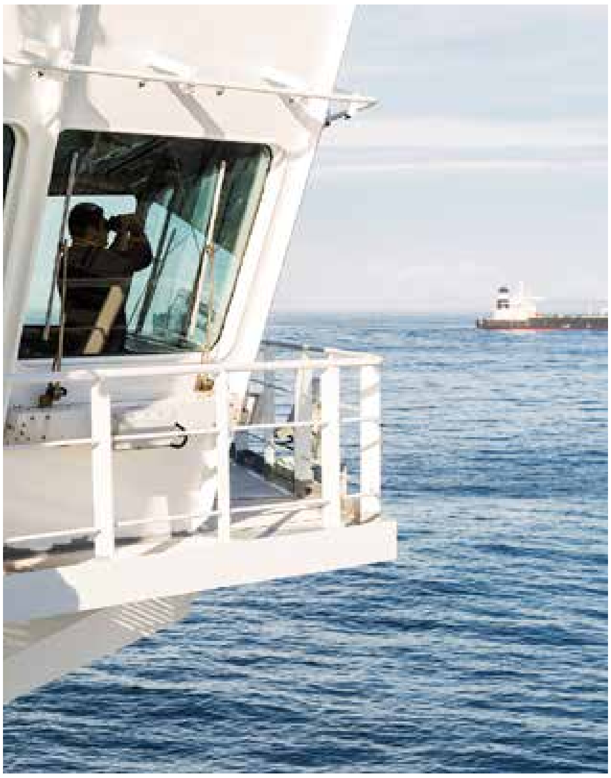
The challenges faced by the maritime and aviation sectors are similar, as recognised by the SEAHORSE project, which aimed to take lessons from aviation with respect to managing and avoiding human errors. Other areas in which maritime transport could potentially learn from aviation is how best to support crews in dealing with the increasing amount of automation and increased connectivity that both sectors are experiencing. In aviation, cultural differences within crews have been found to have led to miscommunication, resulting in accidents. It is likely that the maritime sector has experienced similar issues, which might benefit from additional research.

### 3.4.3.4 Implications for future policy development

As a result of their influence on the rules and regulations of the IMO, many projects have already had a direct effect on policy. Where the results of the EU-supported research activities are relevant more generally or need to be applied internationally, engagement with the IMO and its various committees is the appropriate means of influencing policy.

On the other hand, some other projects potentially have direct relevance for the way in which ships operate in EU waters or on the way in which EU-registered ships operate elsewhere in the world, which might have implications for EU policy. There might be potential for policy to take forward the results of projects (such as CAS, INCASS, ALERT, ROTIS II and SAFEPEC) to improve the way in which inspection and maintenance are undertaken for EU-registered ships and prevent accidents occurring as a result of failures in ship structures. While the number of incidents involving such failures is small compared with the number of other types of incident, these accidents can have particularly serious impacts for the environment or on human life.

Given the particularly high number of incidents that involve navigation and human error, there might be implications for policy from projects such as EfficienSea 2, which aims to support day-to-day maritime operations, and SEAHORSE, which focused was on reducing and managing human error. It might be useful to review the operation of the Community vessel traffic monitoring and information system in light of the findings of such projects.



18 http://www.transport-research.info/sites/default/files/project/documents/20121009_143020_83316_deliverable-d3.5.pdf

19 http://www.lloydsloadinglist.com/freight-directory/adviceandinsight/Isotrack-offers-security-and-business-benefits/761.htm#.WNqLVGd1rcs

### 3.4.4 List of projects included in the sub-theme assessment

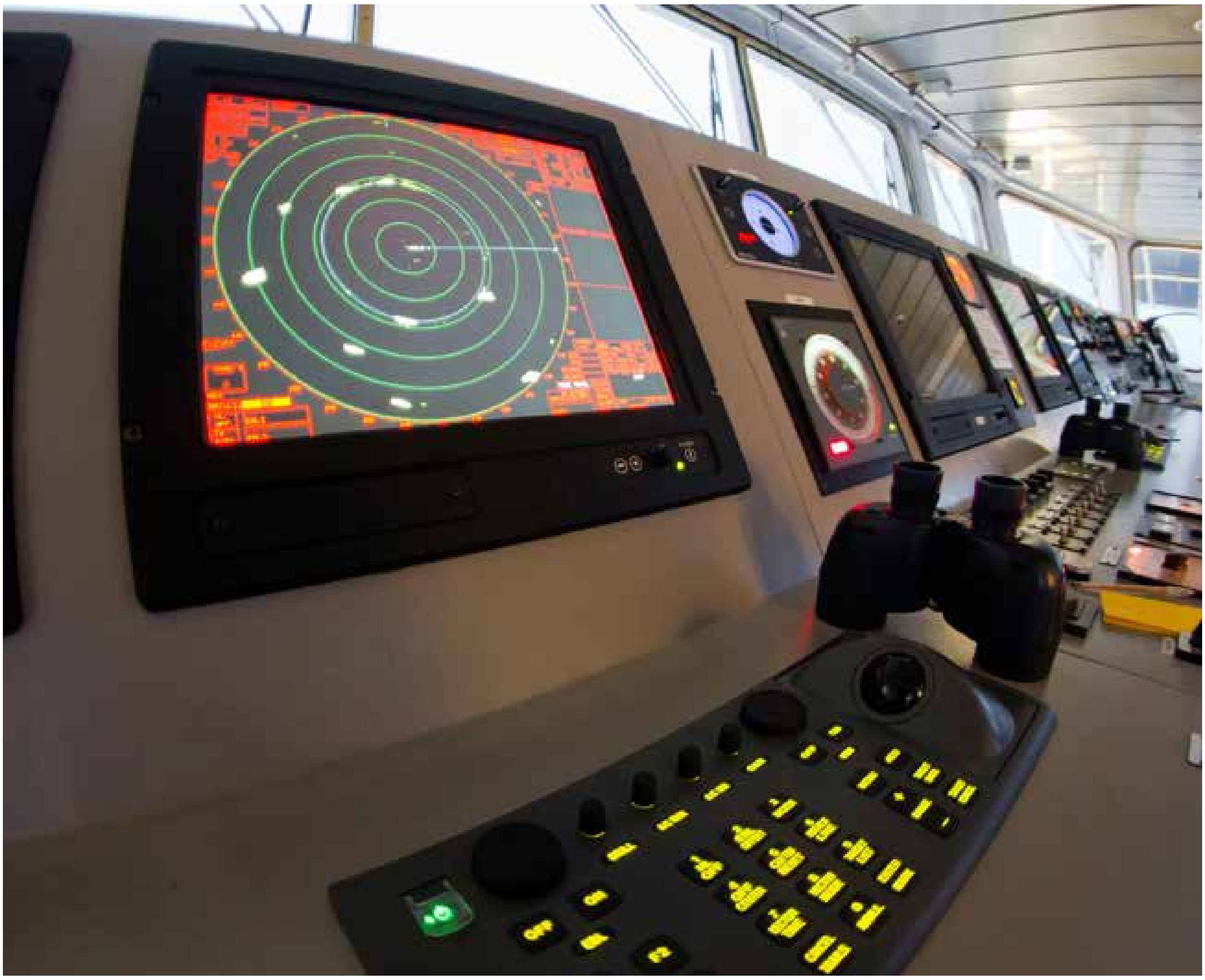
Table 3-4 lists the projects included in this sub-theme assessment.

**Table 3-4 Projects reviewed in the safety in maritime transport sub-theme**

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| ALERT | Assessment of Life-cycle Effect of Repairs on Tankers<br>https://goo.gl/7xVGZw | 2006-2008 | EU (FP6-SUSTDEV) |
| CAS | Cost effective Inspection and Structural Maintenance for Ship Safety and Environmental Protection throughout its Life Cycle<br>https://goo.gl/I5Qvbc | 2005-2008 | EU (FP6-SUSTDEV) |
| CHEMSAR | Operational plans and procedures for maritime search and rescue in HNS incidents<br>https://goo.gl/ezxt2p | 2016-2019 | EU (Interreg IVB, North Sea) |
| EfficienSea 2 | Efficient, Safe and Sustainable Traffic at Sea<br>https://goo.gl/6vshBC | 2015-2018 | EU (Horizon 2020) |
| EU-PORTRAITS | EUropean PORTWorkers TRAIning Scheme<br>https://goo.gl/6pE40m | 2013-2016 | EU (FP7-TPT) |
| EXTREME SEAS | Design for Ship Safety in Extreme Seas<br>https://goo.gl/TwVeed | 2009-2012 | EU (FP7-TPT) |
| FIREPROOF | Probabilistic Framework for Onboard Fire-safety<br>https://goo.gl/9j8r2q | 2009-2012 | EU (FP7-TPT) |
| FLAGSHIP | European Framework for Safe, Efficient and Environmentally Friendly Ship Operations<br>https://goo.gl/NghvsE | 2007-2011 | EU (FP6-SUSTDEV) |
| FLOODSTAND | Integrated Flooding Control and Standard for Stability and Crises Management<br>https://goo.gl/uHnhIB | 2009-2012 | EU (FP7-TPT) |
| GOALDS | Goal Based Damage Stability<br>https://goo.gl/w7Bv6x | 2009-2012 | EU (FP7-SST) |
| HANDLING WAVES | Decision-Support System for Ship Operation in Rough Weather<br>https://goo.gl/eXDXde | 2007-2010 | EU (FP6-SUSTDEV) |
| INCASS | Inspection Capabilities for Enhanced Ship Safety<br>https://goo.gl/Ige19P | 2013-2016 | EU (FP7-TPT) |
| ISOTRACK | ISO Shipping Container Tracking and Monitoring System<br>https://goo.gl/mV0LZ6 | 2008-2011 | EU (FP7-SME) |
| LYNCEUS2MARKET | An innovative people localisation system for safe evacuation of large passenger ships<br>https://goo.gl/vs05Lz | 2015-2018 | EU (Horizon 2020) |
| METKU | Developing Maritime Safety Culture<br>https://goo.gl/BjaI47 | 2008-2010 | Finland and EU (ERDF) |
| ROTIS II | Remotely Operated Tanker Inspection System II<br>https://goo.gl/03l1UJ | 2004-2007 | EU (FP6-SUSTDEV) |
| SAFECRAFTS | Safe Abandoning of Passenger Ships – Improvement of Current Lifesaving Appliances Systems<br>https://goo.gl/CLJRhL | 2004-2009 | EU (FP6-SUSTDEV) |

Table 3-4 (continued) Projects reviewed in the safety in maritime transport sub-theme

| Project acronym | Project name | Project duration | Source of funding |
|---|---|---|---|
| SAFEDOR | Design, Operation & Regulation for Safety<br>https://goo.gl/tfA8CQ | 2005-2009 | EU (FP6-SUSTDEV) |
| SAFEICE | Increasing the Safety of Icebound Shipping<br>https://goo.gl/Pzduso | 2004-2007 | EU (FP6-SUSTDEV) |
| SAFEPEC | Innovative risk-based tools for ship safety inspection<br>https://goo.gl/my4nnb | 2014-2017 | EU (FP7-TPT) |
| SAFETOW | Strategic Aid for Escort Tugs at Work<br>https://goo.gl/cGvCN8 | 2004-2007 | EU (FP6-SUSTDEV) |
| SAFEWIN | Safety of winter navigation in dynamic ice<br>https://goo.gl/PZem7i | 2009-2013 | EU (FP7-TPT) |
| S@S | Safety at Sea<br>https://goo.gl/Nwq296 | 2004-2007 | EU (Interreg IVB, North Sea) |
| SEAHORSE | Safety Enhancements in transport by Achieving Human Orientated Resilient Shipping Environment<br>https://goo.gl/17dApQ | 2013-2016 | EU (FP7-TPT) |
| SECURCRANE | Design of an Innovative System for the Drive and Control of Port Cranes for Safe Remote Operation<br>https://goo.gl/YHJQjY | 2005-2009 | EU (FP6-SUSTDEV) |



# 4 Conclusions and recommendations

## 4.1 Research environment and development

The European Commission has recently released the Traffic Safety Synthesis 2016, prepared by the European Road Safety Observatory (ERSO) with the contribution of National Technical University of Athens (NTUA)[20]. The collection includes 22 key traffic safety topics and summarises the advancements made at policy and research levels.

Research projects targeted several road safety domains over the years in European Union (EU) and national research programmes. The Horizon 2020 programme pays special attention to road transport due to the high number of accidents and fatalities compared with other transport modes. This aspect was the core of the 2014 call 'Traffic safety analysis and integrated approach towards the safety of Vulnerable Road Users' that inspired a number of projects. Road transport safety was also addressed by the 2015 call 'Safe and connected automation in road transport' and inspired the 2017 call 'Protection of all road users in crashes' with the aim of conducting new research to anticipate potential threats arising from advanced technologies like autonomous driving.

Under the 5th and 6th Framework Programmes for Research and Technological Development (FP5 and FP6), research and innovation projects addressed different aspects of railway safety. Fragmentation and inefficiencies of the European rail sector is being progressively removed by the EU broader policy goals of completing the Single European Railway Area (SERA) through proper legislation and coordination. This has helped the market uptake and further impact of research activities over the industry and the railway system as a whole, which remains among the safest in the world.

Identifying trends is not an easy task considering the large number of potential cross-cutting research areas and the different elements of the rail system that are equally important for safety (e.g. interoperability and rail traffic management). From 2006 on, the number of rail safety research and innovation projects increased. At an EU level, the focus of these projects became less operational and more linked to specific safety elements (e.g. wheelsets and axles). Operational elements (e.g. signalling systems) continued to characterise national projects that were often developed for, and tested on, specific lines.

In 2014, the Shift2Rail Joint Undertaking (JU) was established as a new public-private partnership to stimulate and better coordinate EU research and innovation investments in the rail sector. The Shift2Rail JU manages the entire budget for rail research under Horizon 2020. Three calls for proposals have been launched since 2015 with at least three funded projects specifically or partly addressed to safety issues (GoSAFE RAIL, PLASA and SAFE4RAIL), with an EU contribution reaching EUR 8.3 million.

Research progressed extensively in covering a wide number of topics under the aviation safety domain in previous FPs. These ranged from innovative on-board tools to ground-based navigation aids, from materials used in aircraft to emergency response within the overall airport management procedures.

A global vision of the aviation safety research landscape, including a comprehensive evaluation of the relevant safety research done so far, has been built up recently by the coordination and support action OPTICS. The project assessed the contribution of safety research towards achieving the Advisory Council for Aviation Research and Innovation in Europe (ACARE) Flightpath 2050 goals and evaluated the overall social and market impact of the safety research.

Maritime transport safety research experienced a growing trend towards intelligent and smart technology – from the simple integration of technologies to the provision of real-time information using intelligent sensors. Research also targeted ship evacuation systems and developed concepts for improving life-saving appliances, including the use of smart technology to assist with the location of passengers to facilitate evacuation.

Other common research domains focused on aspects of operating ships in specific conditions (e.g. iced seas and rough weather) and on safety-improved ship design.

20 https://www.nrso.ntua.gr/european-commission-traffic-safety-synthesis-2016/

## 4.2 Research activities and outcomes

Research activities on road safety management enabled policy makers at EU and national levels to monitor progress towards objectives, identify best practices, and ensure that new regulatory and other security measures lead to maximum reductions in accident rates. Several projects improved the collection of relevant data and key safety performance indicators, while others focused more on practical guidelines and tools for conducting road safety campaigns.

In relation to the road-user domain, research projects addressed:

- mobility experiences;
- perceptions of safety needs by different types of road user;
- opinions and experiences about speeding; impaired driving;
- attitudes towards motorcycle riders, pedestrians and other road users.

National projects focused on behavioural elements by concentrating on impacts of driving distractions from a multidisciplinary perspective, and on the driver's visual workload and attentiveness. Vulnerable road users benefited from the results of several projects dealing with assessment methodologies and protocols for integrated pedestrian protection systems (e.g. European New Car Assessment Programme (Euro NCAP) pedestrian passive safety test protocol), sub-systems for children traveling to and from school (e.g. intelligent bus stops, new bus signs and driver support systems) and guidelines for live action role playing (LARP) education. On the other hand, the topic of an ageing society has been targeted by projects that combine road safety with the latest evidence from basic research (such as gender studies, gerontology, and findings on health and functionality with age or aspects like obesity).

Several road infrastructure projects focused on road network safety assessment (i.e. road safety index, catalogue of road infrastructure safety recommendations, cost-effective road infrastructure safety measures based on accident prediction models, road safety inspection, and black-spot management). Research also targeted secondary and rural roads using specific before-and-after accident analyses. Cooperative intelligent transport systems (C-ITS), investigations concerning visibility and comprehensibility of pictograms, signing and verbal messages, and safety of work zones were other key areas of research.

Road safety technologies included advanced driver assistance systems, communication technologies to improve the hazard detection, new sensor devices integrating obstacle detection and communication, traffic recognition sensors, and pre-crash and blind spot surveillance. Regarding passive safety systems, projects focused on biomechanics research, injury mechanisms and protection, vehicle restraint systems (VRS) and skid and rolling resistance of tyres.

Research activities focusing on the safety of railway infrastructure covered topics such as:

- improved design of stations to facilitate their use, supported by software to simulate the circulation of passengers in normal and emergency situations;
- ways of preventing and mitigating the impacts of the main causes of derailments (especially in the freight sector);
- inspection systems based on automated visual inspection;
- alternating current field measurement (ACFM) and ultrasonics that can evaluate the structural integrity of rail tracks.

In addition, optical rail scanners and sensors can now more easily inspect rails to identify potential flaws in their surface. Research on the safety of rail tunnels contributed to the upgrade of the European Fire Safety Standard (TS45545).

Improving the efficiency and interoperability of railways also has direct impacts on safety. The research performed has led to the development of new technologies allowing adjustable wheelsets and for switching stations to secure the movement of hazardous goods between railways of different gauges. The safety and risk assessment of trams, underground rail and light rail systems received attention within the MODSafe project that involved major urban transport operators from London, Paris and Madrid.

The safety of carriage interiors in the event of a crash has been improved by analysing the latest knowledge from injury biomechanics and through the development of a toolkit for designing the interiors of rail carriages to reduce fatalities as a result of accidents. The prevention of accidents from failures in railway vehicles was targeted to improve inspection and diagnosis of issues relating to the axles and wheels of trains while trains are moving and in relation to their production (e.g. anti-corrosion coatings for axles), maintenance and operation.

The focus on behavioural aspects concentrated on train drivers (i.e. driver-machine interface and innovative training systems), and on trespassers and level crossing users (including suicides), which represent the majority of the 1 000 people killed by trains yearly. Level crossings have been identified as a particular weak point from the perspective of road transport safety. Efforts focused on the analysis of a large amount of data and on technologies that might be used to reduce the risk. In addition, factors that contribute to suicides and trespass, and good practices for preventing and mitigating the impacts of these events for rail operations have been explored.

The development of innovative technologies in air transport, such as advanced on-board monitoring systems, enables aircraft systems to predict and to mitigate technical and operational issues, including weather events, before they arise. On-board data are also used to improve aircraft performance and optimise their service lifetimes.

The on-board systems may also be used to analyse available data in real time during the flight so that, in the event of an abnormal occurrence, action can be taken to avoid an accident. Scarce datasets have been enriched for more complete and realistic safety analysis.

Aviation safety risks associated with meteorological conditions and natural hazards (e.g. fire, lightning, ice and ash clouds) have been targeted by a number of research projects. Important and relevant improvements have been achieved for detecting aircraft damage through the use of sensors and microwaves, so gaining more extensive knowledge of the topics.

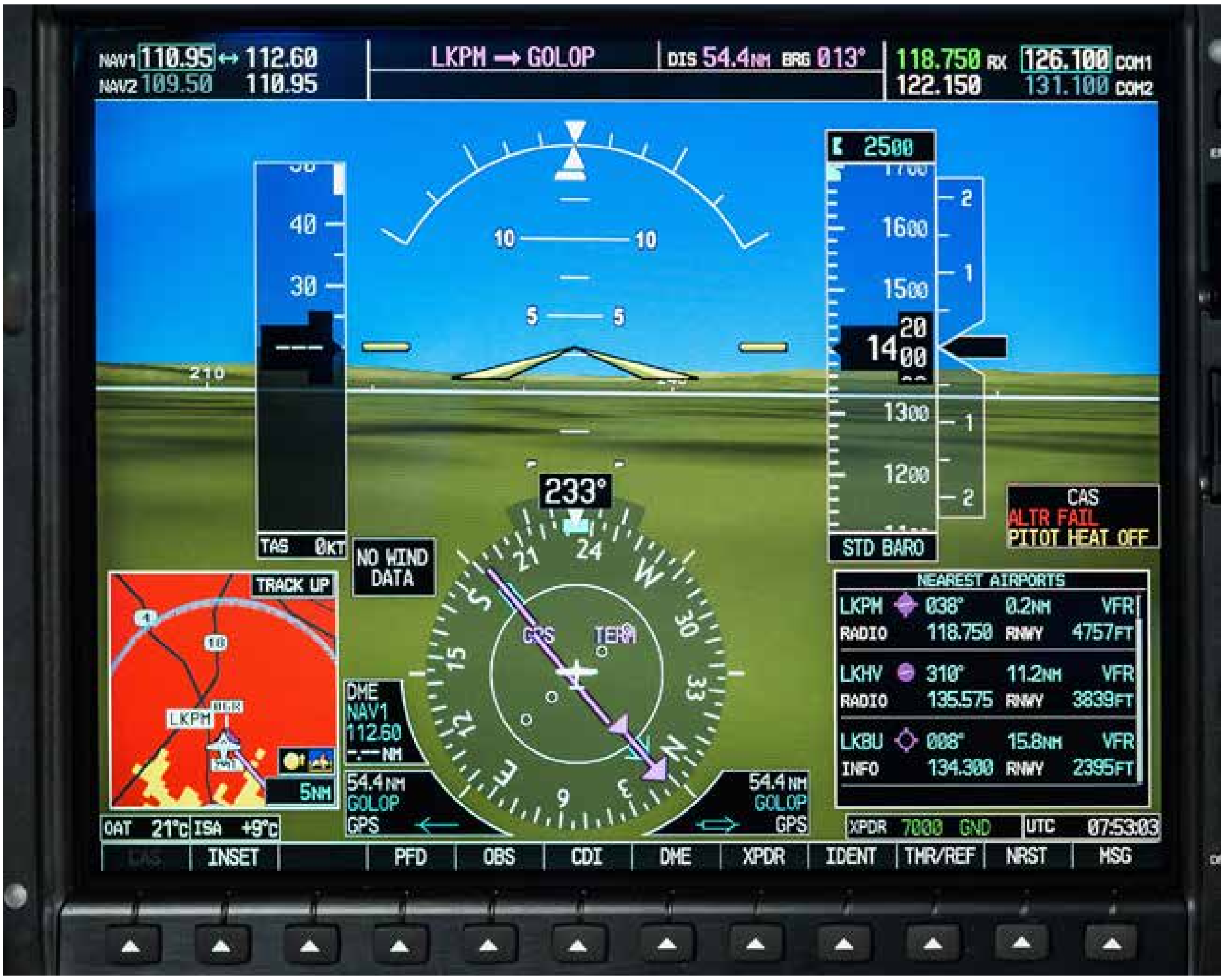
Some projects specifically addressed the impact of flying on the health and wellbeing of passengers. Others concentrated on the human aspects of the system at the operational end. These aimed to understand the human factors aspects, to predict potential pilot errors and to develop the training of aviation professionals though the use of advanced simulators.

In the domain of airport management and airport operations, research projects focused on safety management systems to detect and correct safety problems before they result in aircraft accidents. Also, a shared view on how to address capacity-related issues caused by wake turbulence was achieved so that wake turbulence separation minima (i.e. minimum distances aircraft need to fly apart from each other at all times to ensure safety) can be reduced under specific conditions while maintaining current levels of safety.

Research activities targeted at seaports focused on the welfare, behaviour and psychological perspective of employees such as crane operators (i.e. assessing the potential of remote crane operations through the use of real-time information technology (IT) systems and monitoring solutions) and the potential to establish a 'mutually recognisable framework' for the training of port workers operating in different jobs in a port.

Projects concerned with ships have included studies to improve their 'design for safety' in the event of an accident, deal with rough seas or improve their inspections to reduce the risk of accidents and support maintenance of ship hulls. The use of IT and other techniques to inspect ships to ensure that they remain safe and seaworthy has been a theme under different research programmes. The structural failure that provoked the accident of the tanker Prestige in 2002 raised questions and targeted research on the way repairs are undertaken. Assessment frameworks and IT/sensor-based, remote inspections of the hulls of tankers and other double-hulled ships were other relevant research domains.

Operational aspects of maritime transport safety addressed different aspects, such as the impact on a vessel of travelling in ice-bound seas, the way in which water flooding into a passenger ship affects the ship's stability and chances of its survival, and the way in which passenger ships are evacuated in the event of an incident.



## 4.3 Indications for future research

Road safety research projects contributed substantially to addressing research and policy challenges outlined in Section 2. Research priorities have been identified in different roadmaps issued by a number of organisations, including the European Road Transport Research Advisory Council (ERTRAC), the European Road Federation (ERF) and the Forum of European Road Safety Research Initiatives (FERSI). These have been recently assessed and aligned with EU research programmes and initiatives following a transparent, participatory and multi-stakeholder process within the PROS project. Therefore, research needs are well aligned with strategies.

From the perspective of this review, further efforts should focus on road safety education and human factors analysis. In addition, advantage should be taken of research advancements made in other transport modes in relation to learning practices, safety cultures, the use of new technologies, and the need of drivers and vehicles to handle critical situations. Synergies and cross-fertilisation of safety research advancements among transport modes should also be explored further.

Research is still needed in terms of technology, testing specifications and regulations. The Horizon 2020 call 'Road infrastructure to support the transition to automation and the coexistence of conventional and automated vehicles on the same network' received high levels of interest in the research community. Therefore, new projects will produce positive developments towards enhancing the safety of road transport.

The policy implications of different research advancements at all levels and the way public authorities should improve the involvement of different departments (i.e. developing and applying an inter-departmental approach) are also other key elements for further research.

The safety of railways has improved significantly in recent years – the frequency of derailments, collisions and fires on board trains is not considered a critical issue.

The rail industry has progressed in different areas targeted by the research projects (system management, infrastructure and train-related safety), but the number of fatalities as a result of trespassers, suicides and accidents with road users on level crossings remains relatively high. The number of research projects should be increased in this area.

In addition, the success of high-speed rail is likely to pose more challenges to infrastructure as a consequence of its increased use, in accident prevention and to the impacts on trains.

Research in the domain of aviation staff and aircraft pilot training should integrate the effects of human factors such as fatigue, situational awareness and workload into a single performance safety prediction system, so enabling a proper monitoring of pilot or controller performance. The second main human factors area that needs to be addressed is better automation.

Future research should also focus on health conditions of passengers and illness/diseases that might be provoked by altitude and pressurised flight conditions.

'Safety intelligence', though the better use of Big Data, is another relevant research domain, as is the safe integration of drones into civil airspace, and their potential use in and around airports.

There are still a significant number of maritime accidents annually in the EU. Therefore, there is scope to improve safety for this transport mode, especially in the area of human error, suggesting a need for research into tools, mechanisms and procedures to support decision-making.

## 4.4 Implications for future policy development

The European Commission created a one-stop-shop web portal on road safety[21] that includes research tools and key projects, national road safety strategies and action plans.

The EU road safety policy is broad and largely integrated with research priorities. For the future, there is a need to continue towards full integration and real-life applications, combining infrastructure safety features (e.g. self-explaining roads and forgiving roadsides), vehicle safety (including the adoption of international standards) and safer speeds. These elements must be supported by effective legislative and enforcement strategies achieving widespread road user compliance with road rules and laws. Surveillance and monitoring data, tackling underreporting, international unification of injury severity scales, and linking police data with hospitals and other registries are also fundamental policy objectives.

In the railway sector, the new common regulatory framework introduced by the 4th EU Railway Package has set clear rules and responsibilities upon the European Union Agency for Railways. Within its safety unit, the Agency will develop, promote and monitor a common EU approach to safety management and governance. There is potential to further develop common approaches based on results of recent research activities.

In particular, policy development should be targeted towards the safety of guided urban and suburban transport systems, the design of railway vehicles, and reducing the dangers associated with level crossings and the number of trespassing and suicides, through improved technologies.

The good safety record of commercial air transport over the past few years, particularly among EU-registered operators, could be seriously affected by a single incident. The International Civil Aviation Organization has identified a reduction in runway safety events as a continuing global safety priority.

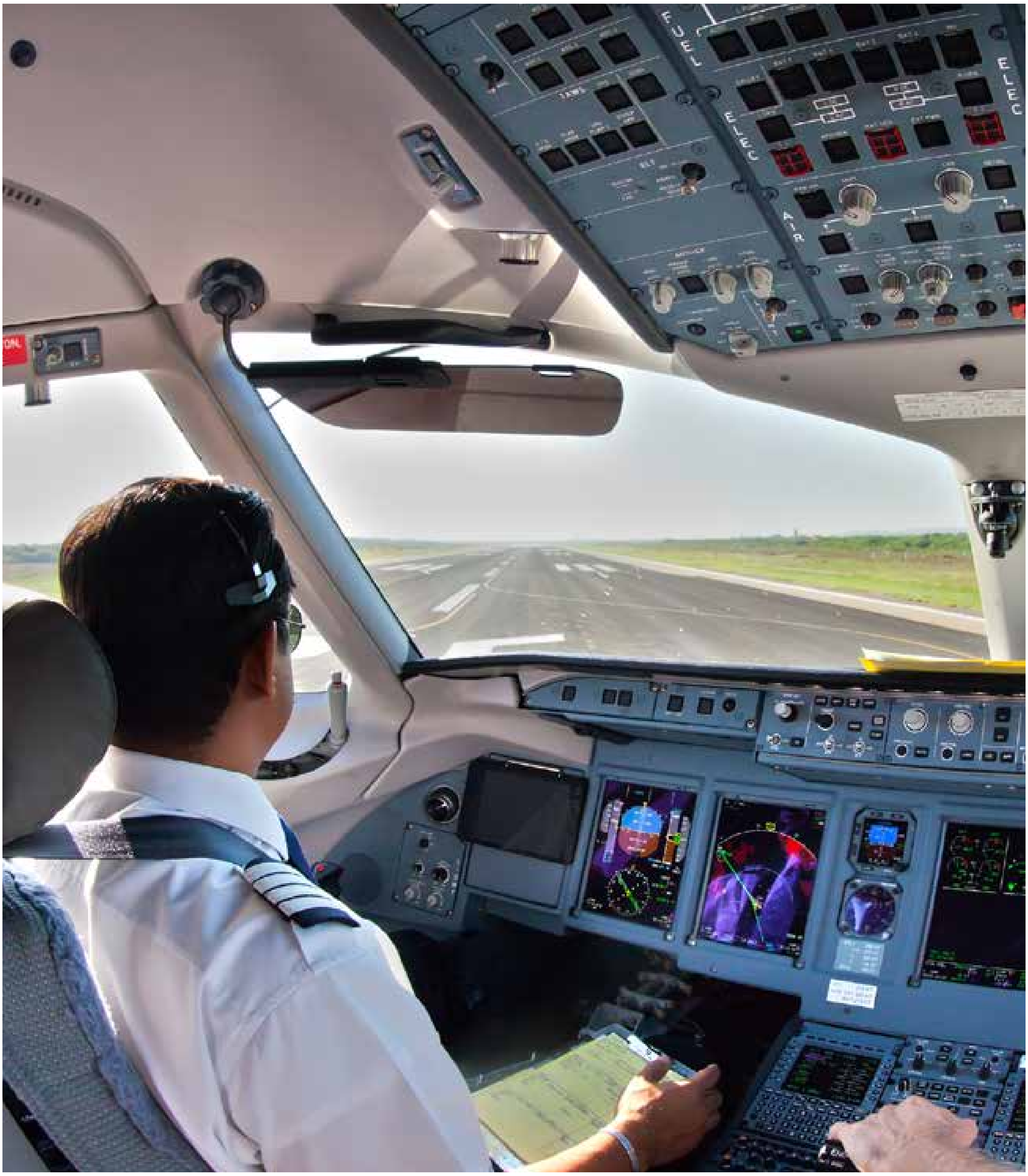
21 http://ec.europa.eu/transport/road_safety/home_en

Targeted interventions and measures promoted at a policy level from the EU may further increase awareness around the effects of pilot stress and negative personal situations, paying particular attention to the assessment of pilot health conditions and to the development of better support systems for pilots and aeromedical examiners.

The highest safety standards for passengers and people working at airports should be guaranteed in parallel with the growing rates of air traffic, especially in those airports characterised by the presence of low-cost carriers. Research should continue to look at this trend and the challenges it brings.

The international relevance of the research on maritime safety has often been transposed into the development of International Maritime Organization's (IMO) rules and regulations. There might be potential for EU policy to take forward the results of research projects to improve the way inspection and maintenance are undertaken for EU-registered ships and to prevent accidents occurring as a result of failures in ship structures.

The high number of incidents that involve navigation and human error might influence EU policy in accelerating the uptake of research achievements into day-to-day operations.



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# 6 Glossary

*The following abbreviations have been used in this review.*

| | |
|---|---|
| ACFM | Alternating current field measurement |
| EASA | European Aviation Safety Agency |
| EMCIP | European Marine Casualty Information Platform |
| EMSA | European Maritime Safety Agency |
| ERA | European Railway Agency |
| EU | European Union |
| ERSO | European Road Safety Observatory |
| FOT | Field operational test |
| FP | Framework Programme on Research and Technology Development |
| ICT | Information and Communications Technology |
| IMO | International Maritime Organization |
| IT | Information technology |
| ITS | Intelligent transport system |
| LOC-I | Loss of control in-flight |
| PTW | Powered two wheeler |
| SARTRE | Social Attitudes to Road Traffic Risks in Europe |
| SESAR | Single European Sky ATM Research |
| SME | Small and medium sized enterprises |
| TEN-T | Trans-European Transport Network |
| TRIP | Transport Research & Innovation Portal |
| VRS | Vehicle restraint system |

www.transport-research.info

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