Research for
a smart and competitive
railway system
Contents

1) Challenges in rail transport ................................................................................................................................. 1
2) A more efficient and competitive railway system .................................................................................................... 3
3) Addressing environmental challenges ....................................................................................................................... 10
4) Facilitating the highest level of safety and security ................................................................................................. 17

Bibliography ........................................................................................................................................................................ 24

Glossary .................................................................................................................................................................................. 25

This publication was produced by the Transport Research and Innovation Portal (TRIP) consortium for the European Commission’s Directorate-General for Mobility and Transport (DG MOVE). The brochure was compiled by Florian Klute, Tina Bessel and Eckhard Szimba (KIT, Germany). The project team wishes to thank Helen West for reviewing the manuscript.

LEGAL NOTICE: The views expressed in this publication are the sole responsibility of the author and do not necessarily reflect the views of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of the following information.

Additional information on transport research programmes and related projects is available on the Transport Research and Innovation Portal website at www.transport-research.info.

doi: 10.2832/915127

© European Union, 2015
Reproduction of content other than photographs is authorised provided the source is acknowledged.
With inherent advantages in environmental performance, land use, energy consumption and safety, railways are an essential component of a competitive and resource-efficient transport system, in line with the Europe 2020 strategy for smart, sustainable and inclusive growth. The 2011 Transport White Paper sets goals to strengthen passenger and freight rail transport and to encourage a shift from less sustainable modes, such as road and air. Yet, the modal share of rail transport is modest, with rail accounting for only 11% of freight transport in Europe, and for just 6% of intra-EU passenger transport (EC, 2014). Key challenges in enhancing rail transport in the European Union (EC, 2013a; 2008) are:

- **Increasing efficiency and competitiveness:** Railways face fierce competition from the road sector, which offers attractive, cost-efficient, flexible, reliable, convenient door-to-door transport of freight and passengers across borders. The challenge is further heightened by the fragmented rail market, with more than 20 national systems for rail signalling and speed control operating in Europe. Interoperability is a key challenge in improving the free flow of rail traffic throughout the continent and developing an efficient and attractive rail system.

- **Reducing environmental impacts:** While comparing favourably with other transport modes in terms of lower environmental impacts, there are key challenges to be met in reducing hindrance from rail noise and vibration, particularly in urban areas, and to further reducing greenhouse gas emissions.
- **Improving safety and security**: Whilst not very frequent and causing a relatively low share of deaths in transport, rail accidents often involve large numbers of people. To maintain and increase rail safety in the EU, which is among the highest in the world, interoperability and harmonised safety standards for rolling stock and railways are required throughout the continent.

To meet these challenges, EU transport policy sets out a series of initiatives. A key goal is to establish a Single European Railway Area with an internal market for rail transport, and thus a more efficient and customer-responsive industry to encourage innovation and provision of better services (EC, 2011a; 2013a).

**Research**

Achieving these objectives involves opening rail markets to greater competition and promoting technical standardisation of rail systems in Europe (EC, 2004; 2013a). EU efforts include support for modernising and extending rail infrastructure, with a specific focus on linking rail networks in Europe and removing bottlenecks in cross-border connections. The ultimate objective is to create an integrated trans-European rail network for freight and passenger traffic (EC, 2011a; 2013b).

EU policy on improving rail transport in Europe is supported by EU research and innovation framework programmes, which have contributed to essential improvements in the sector. Research under the Seventh Framework Programme concentrated on enhancing the efficiency of rolling stock and train operations, improving rail system interoperability, and optimising railway infrastructure (EC, 2011b; 2013c).

Under the Horizon 2020 Framework Programme that runs from 2014 to 2020, the EU has substantially increased funding for rail research and innovation. A new public-private partnership, the Shift2Rail Joint Undertaking, is being set up to manage and coordinate research and innovation in the rail sector. Activities will be organised in five key Innovation Programmes:

- Cost-efficient and Reliable Trains, including high capacity and high speed trains;
- Advanced Traffic Management and Control Systems;
- Cost-efficient, Sustainable and Reliable High Capacity Infrastructure;
- IT Solutions for Attractive Railway Services;
- Technologies for Sustainable and Attractive European Freight.

These large-scale research programmes support EU policy to make rail transport more attractive, more efficient, greener and safer. Highlights of research contributing to these targets are presented in this brochure.
A more **efficient** and **competitive** railway system

With an annual turnover of EUR 73 billion and employing 800,000 people, the rail sector plays a significant role in the economy of the European Union (EC, 2013a). However, rail transport still relies to a large extent on public funding and continues to lag behind other modes in terms of customer satisfaction. The efficiency, reliability and cost-effectiveness of rail operations and services are hampered by the diversity of rail infrastructure and rolling stock in Europe. For instance, gauge widths, electrification standards and safety and signalling systems vary between Member States.

EU-funded research and innovation has contributed to developing cost-efficient, interoperable rail technologies. A strong focus has been given to improving and harmonising signalling and train control systems, supporting the creation of a Single European Railway Area, and enhancing competition in the rail equipment manufacturing and services industry. Information and communication technology (ICT) has been harnessed to reduce operation and maintenance costs and to increase the capacity of the rail network.

Research highlights that have contributed to create a more efficient, competitive, integrated Single European Railway Area are presented in this chapter.
Innovative solutions and techniques have been developed to increase the capacity of the European railway network, and to improve train logistics and scheduling. These improvements contribute to reducing delays for passengers and freight, thus increasing customer satisfaction and ensuring the railway network provide a dependable, resilient and green alternative to other transport modes.

BACKGROUND

A priority in EU transport policy is to improve railway customer satisfaction by increasing capacity and reducing delays for passenger and freight. While considerable research has been carried out on timetable planning and real-time traffic management, there has been little industry involvement and practical application. A multidisciplinary consortium of railway infrastructure managers, rail industry companies and research institutions developed methods and techniques to enable railway undertakings to increase network capacity, and to improve planning and operations management.

RESULTS

ON-TIME developed advanced railway timetabling and capacity estimation methods for use in all Member States, leading to more efficient use of capacity, improved train punctuality and reduced energy consumption. New algorithms and processes for robust cross-border timetables and integrating
timetables of regional and national networks were developed to facilitate interoperability and efficient rail corridor management.

A traffic management system was developed that includes methods and tools for real-time traffic monitoring and prediction, conflict detection, and conflict resolution including train speed optimisation to provide travellers with reliable and timely information on disruptions. The system was tested on several sections of heavily trafficked rail corridors. As a basis for a new European standard, a new driving advisory system was developed for efficient automatic communication between train drivers and rail traffic control centres.

Real case studies were reviewed and benchmarked to identify approaches for further development and demonstration. Current best practices were identified and potential standards were developed for dissemination through associations and organisations, such as Rail Net Europe, the International Union of Railways (UIC) and the Union of European Railway Industries (UNIFE).
SUCCESS STORY

INESS

Integrated European Signalling System

INESS extended and enhanced the standardisation process for railway signalling systems in Europe. Specifications for a new generation of interlocking systems were defined and business models to support strategies to migrate to standards were developed. Harmonising signalling systems paves the way to a homogeneous railway system in Europe.

BACKGROUND

The creation of an integrated European railway area calls for improved interoperability and technical compatibility of infrastructure, rolling stock, signalling and other subsystems. Since 1990, the EU has been promoting modernisation of signalling subsystems under the European Rail Traffic Management System (ERTMS) programme to improve interoperable cross-border rail transport. A new generation of interlocking systems was defined and developed to extend and enhance the ERTMS standardisation process. Some 30 partners from industry, railways and universities participated in harmonising the interlocking system and reducing associated costs of production and installation.

RESULTS

A common core of functional requirements was defined and developed for a new generation of interlocking systems in line with the ERTMS standards for interoperable railway operation and safety systems.
Building on previous research, INESS developed business and cooperation models to support migration strategies for ERTMS. Reports were completed on a life cycle based cost model for interlocking systems, market-specific cost drivers, and cost-saving potential in the interlocking life cycle.

Based on identifying safety constraints related to interfaces to adjacent signalling systems, recommendations were made for viable migration strategies to the new system, and on how the system should be implemented. A handbook on best practices was prepared for testing the interlocking system. An open source software support tool was developed to reduce time and money in signalling while enhancing safety, thus paving the way to harmonising signalling and interlocking systems in Europe.
Adoption of advanced automation, inspection, maintenance and planning techniques could result in up to 40% reduction in maintenance downtime on rail networks. Reducing maintenance downtime could substantially increase capacity utilisation to meet the ever-increasing demand on rail networks in Europe.

BACKGROUND

The maintenance requirements for railway infrastructure have risen simultaneously with the increase in rail traffic in the EU over the last decade. However, maintenance downtime restricts the operation of additional trains especially for freight. Thus, improvements are required in track inspection and maintenance in order to increase capacity utilisation and to generate additional capacity on rail networks. This was the key objective of the AUTOMAIN project, a consortium of infrastructure managers, contractors, train operators, research organisations and the railway component industry.

RESULTS

Based on maintenance as required as opposed to schedule-driven maintenance strategies, best practices were adapted from highway maintenance management, and the aerospace industry. Solutions were developed for advanced automation, inspection and maintenance planning for railway infrastructure.
Automating and optimising maintenance planning and scheduling was shown to increase the availability of the rail network and to reduce time required for maintenance work. These measures are estimated to reduce maintenance downtime by up to 40%. Automated inspection techniques reduce inspection work carried out on or near the track and contribute significantly to track worker safety.

To improve the efficiency of track monitoring, track failure prediction algorithms were developed to estimate time remaining before track failure, and integrated into a monitoring planning and scheduling tool.
Addressing **environmental challenges**

Rail transport’s energy efficiency comes mainly from the low rolling resistance of locomotives, railcars and wagons running on dedicated tracks, and the controlled, regulated driving pattern. Rail can therefore offer significant environmental advantages to the transport system.

Nevertheless, railways have a considerable environmental impact in terms of noise and vibrations, which is an issue particularly in freight transport and in urban areas. As diesel locomotives are still commonly used, air pollution also needs to be tackled.

EU policy encourages eco-innovation in rail transport by supporting development and deployment of energy efficient and quieter trains, and by establishing innovative rail network infrastructure. The goal is to further reduce environmental impacts to make rail a key pillar of sustainable mobility in Europe (EC, 2011a). EU policy is supported by targeted research, which has tackled innovations in traction technologies, improving rolling stock, and smarter management of rail infrastructure and operations.

Highlights of EU-funded research on improving the environmental performance of the railways are presented in this chapter.
Even though about 80% of rail transport volume in the EU is hauled on the electrified network, diesel traction is the backbone of railway operations in countries, such as Estonia, Greece and Ireland, where little of the network is electrified. Changes to the scope of EU Directive 2004/26/EC require compliance of diesel engines with the requirements of stage IIIB of the Non-Road Mobile Machinery (NRMM) European Directive. CLEANER-D demonstrated the in-service feasibility and reliability of railway rolling stock powered by diesel engines compliant with the directive. The project had two key components. The operational component tested significant applications of rolling stock to give engine manufacturers the opportunity to test concept engines to migrate from IIIA to IIIB compliance within the short time frame under the directive. The scientific component investigated innovative solutions, including hybrid applications for further NRMM implementation phases and emission limits beyond IIIB.

Low emission, competitive rolling stock will enhance rail sustainability and attractiveness compared to other transport modes. CLEANER-D developed and integrated emission reduction technologies in diesel engines and evaluated hybrid solutions to further reduce CO$_2$ emissions.

**BACKGROUND**

**Project reference:** FP7-234338  
**Status:** Completed  
**Total cost:** EUR 12,924,840  
**EU contribution:** EUR 7,787,411  
**Coordinator:** Union of European Railway Industries (UNIFE), Belgium  
**Website:** [www.cleaner-d.eu](http://www.cleaner-d.eu)

Low emission, competitive rolling stock will enhance rail sustainability and attractiveness compared to other transport modes. CLEANER-D developed and integrated emission reduction technologies in diesel engines and evaluated hybrid solutions to further reduce CO$_2$ emissions.
RESULTS

Significant emission reductions were demonstrated in diesel engines repowered with low emission engines. Three demonstrations were carried out. The first was on a class 842 railcar operated by Czech Railways and equipped with two low power engines in very restricted space, and with a Diesel Multiple Unit on the narrow rail gauge in the UK. The second was on a heavy haul locomotive with high power engines (>1,800 kW) in maintaining weight per axle under the infrastructure limits. The IIIA compliant Vossloh EURO4000 diesel-electric locomotive was equipped with 3,000 kW diesel engine to make it IIIB compliant. The third was on a mainline lightweight V225 DB diesel hydraulic locomotive for freight service with 1,500 kW traction power with different load factors.

Sustainable emission reduction measures were identified, and recommendations were made for future emission reduction approaches and strategies. Recommendations and best practices were also presented on integrating low emission technologies in diesel engine and power packs and rolling stock performance. To tackle emission reduction by reducing energy consumption, recommendations were presented on brake-energy storage systems for reuse in traction.
While noise is an environmental issue in all transport modes, ground vibration and vibration-induced noise caused by rail services can have a significant impact on people living nearby rail infrastructure. Various EU-funded research projects have tackled noise reduction from railways and have led to the development and implementation of noise mitigation techniques that are now in use throughout the EU. This work continued in the RIVAS project to develop techniques to reduce rail vibration in residential areas to the threshold of perception, or even below this threshold.

**RESULTS**

The research demonstrated that the effectiveness of vibration mitigation measures is closely related to the type of train, its speed, type of track, soil conditions and even to the type of buildings alongside the rail track. These factors were taken into account in developing mitigation measures and a system approach to control vibration.
Technologies were developed to control vibration at the source, and included improved track, wheel and rolling stock maintenance and vibration mitigation measures on the transmission path. Based on simulations of combinations of train speed and axle load, the unsprung mass and wheel out-of-roundness were found to be the key vehicle-related parameters in generating ground-borne vibration. Reducing the unsprung vehicle mass by up to 35% together with regular wheel maintenance can reduce ground-borne vibration by up to 20 decibels.

Guidelines on reducing the unsprung mass were developed to include alternative wheelset designs with optimisation of geometry, material and production process, and a design concept and suspension for the mechanical drive system.

Innovative technologies have been developed to effectively reduce low frequency vibration from railways, caused mainly by freight traffic. These technologies are also applicable to suburban, regional and high-speed operations. A methodological approach was developed for measuring and assessing ground-borne vibration, and recommendations and guidelines prepared for the design of infrastructure and rolling stock.
One approach to counteracting the rise in railway noise as a result of traffic growth is to restrict the permissible noise emission per train. EU regulations, such as Technical Specifications for Interoperability (TSIs), set limit values for noise emitted by individual rolling stock. By gradually introducing lower limit levels in the TSI Noise, the supply industry is encouraged to develop quieter products. TSI Noise also promotes interoperability because compliance with noise limits means rolling stock can operate on the Trans-European Network.

However, the TSI Noise testing procedure is time consuming and costly, thus reducing and delaying the potential impact of the legislation. The ACOUTRAIN consortium developed procedures to streamline the acoustic authorisation procedure for new rolling stock.

**RESULTS**

A certification procedure was developed that incorporates elements of virtual testing. As a result, virtual certification has been introduced to replace part of the noise testing procedure with reliable simulations.

---

**SUCCESS STORY**

The noise certification procedure for new railway rolling stock has been streamlined to incorporate elements of virtual testing. The new virtual testing procedure supports railway operators and manufacturers to comply with noise limits required under EU legislation, while reducing costs and time-to-market for new quieter trains in Europe.
Furthermore, a method was established to distinguish noise contribution from infrastructure and from rolling stock, and contributes to harmonising the procedure to identify noise from rolling stock. Standardised procedures were developed and virtual certification introduced and will be incorporated in the next revision of the TSI Noise. In addition, a methodology to validate pass-by noise and standstill noise predictions was developed so that these predictions can be incorporated in future certification.
Facilitating the highest level of safety and security

Rail is among the safest transport modes, for example in 2012, there were just 36 rail fatalities in the EU (EC, 2014a), though unfortunately this does not include suicide and track worker fatalities. Rail safety has continued to improve in the last decade. EU transport policy gives top priority to maintaining high safety standards and to harmonising safety requirements and measures (EC, 2013a; 2008) so that railways in Europe are among the safest in the world. A key goal is to strengthen security measures to prevent unlawful interference with passengers, freight and transport infrastructure to give confidence to use rail services.

The EU has funded research ranging from surveillance systems for railway stations to advanced inspection systems for rail track. Best practices and solutions have been identified and implemented to increase the resilience of rolling stock and railway stations to safety and security threats, such as fire and terrorist attack.

Highlights of research to contribute to a safe and secure railway system in Europe are presented in this chapter.
To improve the safety and security of metro and train stations against terrorist attack, a Constructive Design Handbook has been developed to support cost-effective integration of security measures in station design and refurbishment. The handbook is based on extensive risk assessment of disaster scenarios, such as fire and bomb blast, and assessment of the countermeasures to be incorporated in station design.

BACKGROUND

The Madrid bombings in 2004 and the attacks on London public transport in 2005 underlined the vulnerability of crowded public open spaces as targets for terrorist attack. Thus, potential security threats need to be considered in the initial stages of the design and refurbishment of passenger railway facilities. Funded under the Seventh Framework Programme, SECURESTATION assessed security in train stations and terminals to establish ways of increasing resilience to the impacts of bomb blasts, fires and chemical, biological, radiological attacks. Building on previous and parallel EU research on rail safety and security, the project developed a quantitative risk assessment method and design guidelines for railway station security.

RESULTS

Data generated from modelling explosions, fires and chemical dispersal, and simulations of passenger evacuation in various types of
attack were used as input to a quantitative risk assessment methodology for railway terminals and stations. This methodology enables cost-benefit comparison of countermeasures, such as security equipment, to risks in various attack scenarios to be calculated.

A specific tool, SARA (SECURESTATION Attack Resilience Assessment), has been developed to implement this methodology. The tool supports railway corporations and key stakeholders, such as the International Union of Railways (UIC) and the International Association of Public Transport (UITP), in assessing security and safety risks.

The results of the risk assessment were consolidated in guidelines and best practices for each stage of the architectural design process to improve the resilience of railway stations and terminals to terrorist attack. The guidelines and best practices were integrated in the SECURESTATION Constructive Design Handbook for railway station design, construction and refurbishment to ensure that security is considered and implemented in the earliest stages of design processes to create safer stations and terminals while considering the cost-benefit of the measures implemented.
SUCCESS STORY

2TRAIN

Training of Train Drivers in Safety Relevant Issues with Validated and Integrated Computer-Based Technology

Project reference: FP6-31324
Status: Completed
Total cost: EUR 3 731 742
EU contribution: EUR 2 198 219
Coordinator: University of Wuerzburg, Germany
Website: http://www.transport-research.info/

European standards for cost-effective, computer-based, safety training for train drivers were proposed and tested in simulator pilots, and the effectiveness of a common EU training programme was demonstrated to enhance safety and to improve crisis management.

BACKGROUND

Skilled and well-qualified train drivers are a pivotal factor in the safety, interoperability and competiveness of railways. There are well over 133,000 train drivers in the European Union at the human interface with technical developments and cross-border operations. Thus, a European standard for training train drivers is an increasing priority in improving rail safety. 2TRAIN ensured close collaboration between train operators, manufacturers and research institutes in developing and evaluating best practices in computer-based training for train drivers, as well as training scenarios to increase driver competences in crisis management.

RESULTS

The project delivered best practice guidelines for efficient and cost-effective use of computer technologies in training train drivers and assessing their competencies and performance. The first step was to benchmark training programmes and methods used in various
countries in Europe in order to specify the common requirements for computer based training for train drivers. Based on these requirements, common elements of the training content were prepared, especially for crisis management and action in rarely occurring hazardous situations.

A modular software platform was developed to integrate the latest computer-based technologies into training environments throughout Europe. The harmonised and integrated computer-based training system was implemented in simulator pilots in the Czech Republic, Germany, Spain and France. In total, 113 test drivers participated in the training sessions and simulator exercises. Feedback from drivers, instructors, and training managers demonstrated that the 2TRAIN training system could be implemented on various simulators currently in use. The comprehensive training content is suitable for improving driver competence in dealing with safety hazards.
In 2013, trespassing was the cause of nearly 60% of all deaths and accidents on the railways in Europe. Railway suicides are reported separately and are not counted under railway safety statistics. There were 2,819 suicide fatalities recorded on EU railways in 2013 (ERA, 2014). In an effort to reduce the number of suicides, trespasses and service disruptions, the RESTRAIL project was launched to identify, test and evaluate suicide and trespass prevention measures on railway property.

**Project reference:** FP7-285153  
**Status:** Completed  
**Total cost:** EUR 3 868 393  
**EU contribution:** EUR 2 816 243  
**Coordinator:** International Union of Railways (UIC), France  
**Website:** www.restrail.eu

Efficient and cost-effective measures to prevent and mitigate the consequences of rail suicides and trespassing accidents have been identified and tested at railway stations in several Member States. A dynamic online toolkit of suicide and trespass preventive measures has been compiled and is readily available to support railway decision makers.

**BACKGROUND**

In 2013, trespassing was the cause of nearly 60% of all deaths and accidents on the railways in Europe. Railway suicides are reported separately and are not counted under railway safety statistics. There were 2,819 suicide fatalities recorded on EU railways in 2013 (ERA, 2014). In an effort to reduce the number of suicides, trespasses and service disruptions, the RESTRAIL project was launched to identify, test and evaluate suicide and trespass prevention measures on railway property.

**RESULTS**

Reasons for railway suicides and trespasses and countermeasures were identified based on analysis of the latest research findings and best practices. New approaches were developed for complementary railway safety education programmes. The most effective measures were collected in a dynamic online toolkit to support decision-makers in reducing the incidence of suicides and trespasses, and to put in place preventive measures and measures to manage the consequences of such events. The
user-friendly toolkit contains over 70 measures grouped in three categories:

- Organisational and procedural measures, such as identification of trespass hotspots, communication strategies, and suicide patrols;
- Physical and technological measures, such as fencing platform ends and lighting linked to movement sensors;
- Public awareness and education measures, such as awareness campaigns to prevent suicide, and risk and safety education in schools.

The effectiveness of the countermeasures was evaluated in field tests at railway stations in Belgium, Finland, Spain, Sweden, Turkey, the UK, Germany, the Netherlands and Israel. Awareness campaigns in combination with infrastructure measures reduced railway trespass by 78% within three months of implementation in Belgium.

To disseminate the research findings, a website containing the toolkit was launched, which also serves as a knowledge exchange platform for rail infrastructure managers, railway operators, rail experts and other stakeholders. Newsletters and conferences were used to publish the project findings on measures to prevent railway suicides and trespasses. Future research will build on these results to reduce accidents on railway property.
Bibliography


# Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>ERA</td>
<td>European Railway Agency</td>
</tr>
<tr>
<td>ERTMS</td>
<td>European Rail Traffic Management System</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>NRMM</td>
<td>Non-Road Mobile Machinery</td>
</tr>
<tr>
<td>TRIP</td>
<td>Transport Research and Innovation Portal</td>
</tr>
<tr>
<td>TSI</td>
<td>Technical Specification for Interoperability</td>
</tr>
<tr>
<td>UIC</td>
<td>International Union of Railways</td>
</tr>
<tr>
<td>UITP</td>
<td>International Association of Public Transport</td>
</tr>
<tr>
<td>UNIFE</td>
<td>Union of European Railway Industries</td>
</tr>
</tbody>
</table>
With inherent advantages in environmental performance, land use, energy consumption and safety, railways are an essential component of a competitive and resource-efficient transport system. Yet, the modal share of rail in the EU is modest. To enhance the attractiveness of rail transport, the challenge is to increase the efficiency and competitiveness of railways while reducing environmental impacts and maintaining high levels of safety and security.

Highlights of research to generate innovative and competitive rail transport solutions are presented in this publication produced by the Transport Research and Innovation Portal (TRIP). The Portal provides access to the results and best practices of transport research in the European Research Area.