Research for future Railway Systems

Institute of
Transportation Systems

DLR

Contents

Institute of Transportation Systems

Mobility plays a key role in our economy and society. People want to reach their destinations safely, comfortably and quickly, and goods have to be shipped cost-effectively over short or long distances. The impact of mobility is visible in environmental pollution, accidents and traffic congestion.

With a staff of about 120 researchers – engineers, psychologists and information scientists – at its two sites in Braunschweig and Berlin, the Institute of Transportation Systems carries out research and development into automotive and railway systems and into traffic management, thus contributing to improvements in the safety and efficiency of road and rail transport. In interdisciplinary teams, the institute's staff plan, develop and evaluate solutions for user-focused driver assistance systems, traffic coverage and management, and for safety, automation and dispatch in rail transport.

In their work, they consider the requirements of and effects on the whole traffic system. Thanks to the close collaboration between the individual institutes and facilities at DLR, synergies can be achieved with aerospace engineering and energy technology.

Set up in 2001 at Braunschweig's Research Airport and headed by Prof. Dr.-Ing. Karsten Lemmer, the Institute of Transportation Systems has since grown considerably and has expanded its research activities. Its scientists work together with partners and clients from industry, science and politics at the national and international levels.

The institute's work has been ISO 9001:2008 and VDA 6.2 certified for its quality. In addition, the Railway Systems division has been certified by Eisenbahn-Cert (EBC) as a subcontractor for the Notified Body Interoperability.

Railway Systems Department

Safety and efficiency on rails.

It is a clear and current demand: rail transport has to become more competitive. One key aspect in this is cost-effective and efficient control and safety technology.

As part of our work in rail automation, we develop innovative technologies, methods and concepts for the rail system, with the aim of optimising it in operational, technical and financial terms. This is our mission: to make rail transport safe, efficient and competitive, and to advance European railway harmonisation.

And these are our research and development topics, which are presented in more detail on the following pages:

- Testing and Validation
- Rail Transport for the Future
- Life Cycle Management (LCM)
- Sensors – Data – Algorithms
- Rail Human Factors
- Safety and Approval Procedures

We have a number of large-scale research facilities and unique simulation laboratories, which support our work and allow us to validate research findings in experiments:

• Railway Simulation and Testing (RailSiTe®)
• Railway Simulation Environment for Train Drivers and Operators (RailSET®)
• Railway Driving and Validation Environment (RailDriVE®)

Testing and Validation

Individually configured. Accurate. Fast.

In our accredited RailSiTe® laboratory, we test components, interfaces and operational scenarios.

Given the particular safety requirements in the rail sector, the development of control and safety technology goes hand in hand with continuous testing. This starts with the specification, includes the derivation of test cases and test environments, and ends with the acceptance of the final systems and hardware devices.

The Institute of Transportation Systems carries out research into processes, methods and their actual implementation, with the aim of optimising testing processes. Our modular RailSiTe® train laboratory provides the infrastructure for our research: complete track infrastructures can be loaded into this environment, allowing us to carry out extensive functional and operational tests even at the design stage. This helps us to identify errors in the planned message packets or detect potential safety problems on the line. We can even test and evaluate operational changes and improvements to lines that are already in operation.
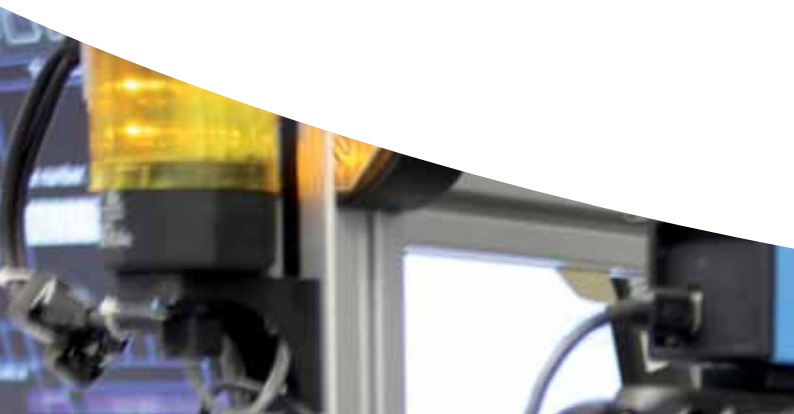
Thanks to RailSiTe®'s modular structure, individual rail system components can also be tested in simulations of functional and operational scenarios. Our work currently focuses on the compliance and interoperability testing of components for the European Train Control System (ETCS).

But the testing of systems is not limited to ETCS. Since the layers in the individual modules can be replaced, other control and safety systems can also be implemented and tested. This includes, for instance, the quick and efficient testing of new user interfaces for electronic interlocking control centre, or new interface concepts for additional control and safety system components.

The tests carried out in the RailSiTe® laboratory can also be used for system validation. A comprehensive range of methods is available for the derivation of test cases from specifications, the transfer of test cases to laboratory scenarios, and the automated implementation, logging and analysis of scenarios.

The Institute of Transportation Systems thus has extensive expertise and knowledge in testing and validation, particularly in the areas of conformity and interoperability testing, as well as a flexible test infrastructure.

You may also be interested to know that the DLR RailSiTe® train laboratory was accredited in early 2012 for the functional compliance testing of ETCS on-board units (ERA Subset-076) in accordance with DIN EN ISO/IEC 17025:2005.

Rail Transport for the Future

Our research focuses on rail transport for the future: energy efficient, powerful, noiseless.

Efficient and competitive rail transportation is crucial for achieving environmental and economic goals. To ensure the necessary efficiency and quality, infrastructures must be extended according to requirements and bottlenecks must be eliminated. Greater energy efficiency will further enhance the environmental benefits of rail transport. And new systemic approaches can help limit noise pollution, particularly caused by freight transport, to a level that ensures no adverse health effects for residents.

Our rail transport research supports this process with the following areas:

• Business economic research
• Identification and development of solutions for low-emissions rail transport
• Improvement of technical and operational measures to reduce noise levels in rail transport

Planning an infrastructure that meets requirements and optimising timetables requires an assessment of the capacity of individual lines or whole networks and timetable reliability. At DLR, we use simulation tools from a range of providers and based on different simulation methods for this purpose. This allows us to identify the impact of different operational and technical solutions on the operational quality of nodes, lines and networks. For high-capacity lines, particularly the increasing hinterland traffic volume to the North Sea ports, we develop and assess solutions for the short-term, medium-term and long-term elimination of line bottlenecks.

Factors that are becoming increasingly important include high track capacity and timetable reliability, as well as an energy-efficient mode of operation that helps reduce emissions and cut operating costs. In this context, DLR prepares recommendations for network operators concerning train movements and timetable design. Based on microscopic simulations of rail operations, dynamic operational tests are carried out and different scenarios for dispatching strategies and operations are assessed. DLR supports the railway industry and rail operators in the development of driver assistance systems for energy-saving operation.

The noise resulting from rail transport has a negative effect on its positive environmental balance. This aspect must not stand in the way of the move towards rail transport. New ways have to be found of reducing noise efficiently through use of an integrated approach to the rail transport system. Our contribution consists particularly of operational solutions that help ensure technical measures can be used to optimum effect. DLR also has unrivalled expertise in the noise impact chain, namely the emission and distribution of sound, the effect of noise, and technical solutions for noise reduction.

Life Cycle Management

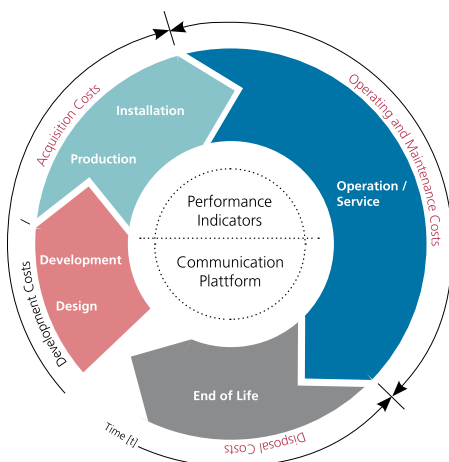**We look at the whole package: economic efficiency throughout the life cycle.**

The actors in rail transport are currently experiencing growing competition between the modes of transport and an increasing focus on ecological topics such as noise immission. To be able to compete in such a business environment in the long term requires sustainable business decisions. This is the context in which we carry out research into life cycle management, focusing on the following three areas in the life cycle of the railway infrastructure:

• Development: early identification of cost saving potentials
• System design: integrated assessment taking into account economic, ecological and social aspects
• Infrastructure asset management: condition-based maintenance

DLR provides support to the manufacturers of railway technology in the development of cost-efficient systems. Using system analysis, system description and life cycle costing methods, we identify cost saving potentials, support their implementation, and estimate the economic effects of innovative technology and procedures on the complex overall system.

Based on an integrated analytical methodology, DLR advises manufacturers, operators and public bodies on system design. This entails studying the economic, ecological and social impact of infrastructure measures, technologies and operating concepts. We also have tools for assessing the migration capability of innovative systems and their optimised integration into existing system environments (such as ETCS).

The life cycle diagram showing: Installation, Production, Development, Design (Acquisition Costs / Development Costs), Operation / Service (Operating and Maintenance Costs), End of Life (Disposal Costs), with central Performance Indicators and Communication Plattform. Axes labelled Time [t].

To improve infrastructure asset management, DLR is researching innovative procedures and technologies for implementing customised, cost-efficient maintenance concepts. Because we understand that the maintenance of components as required by the mode of operation and the level of damage leads to greater system availability and safety. We believe that the development of maintenance strategies that take into account operational and strategic decision-making parameters forms part of infrastructure asset management.

DLR has the necessary combined expertise in rail operations, technology and business management that allows our researchers to consider and optimise the life cycle of rail infrastructure as a whole. By looking at both the technological options and economic viability, we provide an objective information base that manufacturers and operators can rely on for competitive systems and decisions. With our knowledge and expertise, and the tools we have developed, we can provide the best possible support to our partners when it comes to choosing and introducing technologies and to infrastructure asset management. The economic efficiency of the railway system is crucial for its competitiveness – and thus a prerequisite for strengthening safe and environmentally friendly transport.

Sensors – Data – Algorithms

Reliable positioning:
Professional, cost-effective, individually configurable.

The use of trackside components such as axle counters in the positioning of rail vehicles results in relatively high fixed costs for lines with low traffic densitiy. By moving the positioning function including the necessary technology to the vehicle, these costs can be lowered on regional lines, making operations more economical. This is why DLR develops vehicle-based GNSS positioning systems according to customer requirements. DLR also focuses on other applications of vehicle-based positioning systems, such as the updating of train movements to permit forecasting of future train routes, and georeferenced status information for both infrastructure and vehicles. Systems of this kind, which provide combined condition and positioning information, can be used for purposes such as improved maintenance planning and logistics, or travel information.

A framework developed by DLR synchronously logs the multiple sensor data. This permits playing back these data for a realistic simulation, to test prototype sensor-based algorithms for the positioning and status logging of rail vehicles or the track system.

DLR moreover develops the algorithms required for an online fusion of the positioning sensor data. They serve to combine GNSS and vehicle sensor data and to synchronise them with a digital route map; this is called „map matching". The algorithms also take into account rail-specific boundary conditions. Thanks to its modular system architecture, the positioning system can easily be tailored to customer requirements and the intended applications.
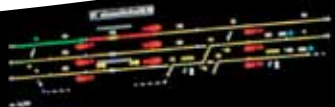
One research focus in the development of positioning systems is the derivation of conclusions about the reliability of positioning results in terms of their integrity. This is the key requirement for the integration of an innovative positioning system into safety-critical applications.

The road-rail vehicle RailDriVE®, built as a mobile testing laboratory, is equipped with positioning, communications and computing technology and can thus be used for the partly automated generation of digital route maps, or as a reference for the validation of sensors and systems of external partners or clients. It shares data with the railway simulation and testing laboratory RailSiTe® and the railway simulation environment for train drivers and operators RailSET®, thus permitting a consistent use of geodata in the three laboratories. Since digital maps are essential for the trackside-based positioning of rail vehicles, DLR is also actively collaborating in the standardisation of exchange formats for map data and the development of a concept for the life cycle management of digital route maps.

Rail Human Factors

A focus on humans.
Usability first in tomorrow's rail operations.

A comprehensive perspective in rail systems research requires an approach that does not focus solely on technology, it also considers humans as a crucial impact factor. The Institute of Transportation Systems defines the human as the starting point for its interdisciplinary research on the overall rail system. Whenever we examine the workplace of a train driver, a rail traffic manager or a control centre operator, we take into account humans with all their strengths and weaknesses. The aim is to develop innovative concepts of human-machine interaction in the railway sector.

Particular challenges are the continuous elaboration of legacy systems to incorporate new technological developments such as ETCS as well as the representation of large amounts of safety critical information in complex environments like the control centres for electronic interlocking systems (ESTW). DLR provides support to manufacturers as well as operators in the development and user-centred design of input and output media of existing and future operating systems in the railway domain. If usability is taken into account in an early stage of system development, the handling of resulting system will be more intuitive. The factor usability is also of economic relevance: a usability analysis at the outset adds little extra cost but helps to reduce training costs and expensive redesigns.

Besides usability and human centred design, automation plays an important role in our research. We are aware of the fact that automation in beneficial only up to a certain point. Tasks should only be simplified to a level where they provide adequate relief for a user. Too much automation leads to a monotonous working environment, which lowers attention and increases the risk of slips. A system must be designed in such a way as to provide optimum support to the user in difficult situations or when failures occur. User-centred system design directly contributes to a faster return to a normal operating state and reduces the occurrence of delays and connection problems.

Our research is based on three key issues:

• Understanding the user
• Evaluating existing systems
• Developing and testing new concepts

We research the relevant processes of human perception and decision-making to gain an understanding of the user. We rely on usability engineering methods to evaluate existing systems. We take into account particularly ergonomics and the methods of usability engineering and testing in developing intuitive designs for future systems.

A particular advantage: by using the RailSET® simulation environment for our tests, we can carry out controllable research under realistic conditions.

Our objective: with our human-centred approach, we aim to make a valuable contribution towards user-friendly, safe and smooth rail transport of tomorrow.

Safety and Approval Procedures

We optimise safety case processes. Reliably.

One major challenge in all areas of the rail system is to ensure a high level of safety with the minimum effort for manufacturers, operators and the approval authorities. Approval procedures for control and safety systems and for railway technology are very complex. The actors have to implement all the specifications defined in European regulations. The continuous improvement of approval procedures serves to maintain and optimise the high level of safety of the railway system and to lower the cost of these procedures.

The safety of the railway system depends on the reliability both of its technical components, and – particularly during non-routine operations – of the human operator. DIN EN 50126-1 in fact specifies that the importance of human factors should be taken into account when looking at reliability, availability, maintainability and safety (RAMS). However, it does not offer any detailed methodology. That is why the Institute of Transportation Technology at DLR is developing new methods for analysing human reliability in rail transport. These methods are based on cognitive psychological evidence on how errors occur and are yet designed to be easily applied in the railway sector.

In interdisciplinary teams, we develop innovative concepts and methods for efficient safety cases. Moreover, we develop models for the integration of the factor human reliability into the assessment of hazard rates. Using both proprietary and standard methods, we provide support to our clients, acting as verifiers, validators or consultants in projects concerning the development of level crossing protection systems, railway technology, and control and safety technology. Our portfolio comprises methods for a comprehensive safety assessment according to standards CENELEC EN 5012x and IEC 61508, as well as accident cause analyses, approval procedure support (including cross acceptance), and assistance in the implementation of CSM Regulation 352/2009.

Another focus of our activities, in addition to approval procedures and the development of efficient safety cases, is the design of safe technical systems. This refers first and foremost to innovative level crossing protection systems. In this area, we design concepts and technical solutions for a safer, better rail system.

Railway Simulation and Testing (RailSiTe®)

The laboratory.

is DLR's rail-specific simulation and testing laboratory. In 2012, the RailSiTe® has been accredited for the functional conformity testing of ETCS on-board units in accordance with DIN EN ISO/IEC 17025:2005. RailSiTe® permits accurate technical and operational simulations, and testing of railway control and safety systems. The complete functional chain of the rail system can be modelled in detail, ranging from trackside control and safety technology to interlocking stations, and from track infrastructure and the air gap between train and track to the on-board systems.

Thanks to its modular architecture, individual control and safety system components can be integrated into the simulation either as software modules or as hardware components, using real physical interfaces. RailSiTe® thus permits the testing of trackside components such as radio block centres, interlockings or field components as well as track infrastructures with regard to their technical-operational functions – either individually or in combination.

RailSiTe® is one of just three independent laboratories in Europe to carry out conformity and interoperability tests of components for the European Train Control System (ETCS). The Institute of Transportation Systems is a certified subcontractor for Eisenbahn Cert (EBC).

At its current level of development, RailSiTe® permits the following:

- Validation and functional testing for conformity and interoperability of ETCS units at the component level
- Validation and functional testing of the interaction between on-board and trackside components of the whole ETCS system
- Assessment of the operational suitability of ETCS lines

Realistic modeling of track-side infrastructure

Railway Simulation Environment for Train Drivers and Operators (RailSET®)

The laboratory.

As part of their functions as train drivers, control centre operators or rail traffic managers , humans in the railway system interact with several technical interfaces – both on board the train and in the control centres. The effectiveness, efficiency and satisfaction with which employees perform their tasks affect the safety and efficiency of the railway system and are in turn affected by various factors related to the interactions between human, machine and environment.

Optimum interaction between humans and systems requires appropriate consideration of users' capabilities and skills during system development. This also applies to the railway sector. User requirements regarding function, design and operation of the respective interfaces must therefore be analysed and reviewed by interim results. The RailSET® – Railway Simulation Environment for Train Drivers and Operators – laboratory makes a substantial contribution to all levels of such a human-centred development process. This rail-specific simulation environment enables a realistic representation of the context of use found in the workplaces of train drivers and control centre operators. Hereby, influencing factors can be modified as required and their subsequent effects on humans examined.

Original control desk at the RailSET® train driver workplace

The train driver workplace for study participants is equipped with an original control desk from a railcar which is integrated into a closed cab. Subjects in the driver's seat experience a fully simulated route. Trackside elements (such as signals and level crossings) are visualised along the track. Simulation according to the underlying control command signalling and safety technology can depict both regular and failure modes, enabling to study different operational scenarios without affecting real rail traffic or creating hazards. These scenarios allow for evaluations of new or existing information and assistance systems or design options for interactive systems at the train driver's workplace, as well as influences wielded by different protection systems.

Experimental facilities are complemented by a simulated workplace for control centre operators.

Railway Driving and Validation Environment (RailDriVE®)

A testing vehicle for road and rail.

The Institute of Transportation Systems has developed the RailDriVE® testing and measurement vehicle for the testing and development of continuous on-board positioning systems. This road-rail vehicle operates on the road for the preparation of tests and is then deployed directly to the test track as a railcar.

RailDriVE® offers a broad range of applications. It can be used to test new positioning components in order to assess interferences or to assist approval procedures under realistic conditions. For clients, DLR will itself develop suitable algorithms for fusing the various positioning sensor data, or assist them in such development work.

We can also test and evaluate different sensor combinations in order to find the combination that is best suited to a client's requirements. Moreover, RailDriVE® is available to clients as a platform for the development of applications based on Galileo, the future European satellite navigation system.

RailDriVE®: Testing and measuring vehicle for road and rail

In addition to its application in the testing and implementation of positioning systems, RailDriVE® is also used for track geometry measurement. From these measurements, digital route maps can be generated.

The option of combining vehicle-based positioning systems with wireless communications systems permits the development and testing of infrastructure-independent collision avoidance systems. These can provide additional protection, to improve the safety of shunting or driving in work site areas and on tracks where no technical safety system is in place yet.

RailDriVE®'s portfolio also includes the logging of failures in the track superstructure.

RailDriVE® provides a flexible, adaptable platform for positioning tests and status logging of the rail track superstructure. The road-rail vehicle is equipped with a range of positioning and communications components. Thanks to its modular architecture, the basic configuration can be expanded at short notice if required.

The basic configuration comprises a GNSS (Global Navigation Satellite System) antenna and receiver including a GSM (Global System for Mobile Communications) and radio modem, to receive correction signals and thus determine the absolute position, the speed and the time. Doppler radars by various manufacturers, a distance pulse generator, and an optical sensor are installed to measure distance and speed, as is an eddy current sensor, which will also detect points. An inertial measurement unit provides information about the vehicle's yaw rate and acceleration. A balise antenna, an RFID antenna system and a laser scanner for monitoring the environment complete the range of on-board positioning sensors. The basic configuration comprises moreover an independent power supply and two computer workstations with an integrated time server for the synchronous logging of all sensor data.

DLR at a glance

DLR is Germany's national research centre for aeronautics and space. Its extensive research and development work in Aeronautics, Space, Energy, Transport and Security is integrated into national and international cooperative ventures. As Germany's space agency, DLR has been given responsibility for the forward planning and the implementation of the German space programme by the German federal government as well as for the international representation of German interests. Furthermore, Germany's largest project management agency is also part of DLR.

Approximately 7000 people are employed at 16 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen and Weilheim. DLR also operates offices in Brussels, Paris, and Washington D.C.

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