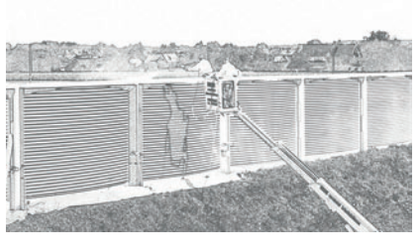
Annual Report 2015 / 2016



Reports of the Federal Highway Research Institute

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Federal Highway Research Institute

The Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) was founded in 1951. BASt began its work with research in the field of highway construction. In 1965 BASt was commissioned, beyond the scope of highway construction tasks, to work towards enhancing highway capacity and safety. In 1970 the Federal Parliament voted to establish a central agency for road traffic accident research which was set up at BASt.

Today BASt is a practice-oriented, technical and academic research institute of the Federal Government with a focus on the road sector. It covers diverse research subjects resulting from the relationship between road, people, and the environment. Its function consists of improving the safety, environmental compatibility, economic viability, and efficiency of roads.

BASt provides scientifically based decision support to the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI) in technical and transport policy issues. BASt is among the leading institutes in a network of centres of research excellence in the roads sector, and substantially involved in developing regulations and standards at the international level. Consultancy and expert opinions, reviewing and certifying are also among BASt‘s functions. Moreover, BASt is an assessment centre for driving licensing.

Its headquarters have been in Bergisch Gladbach since 1983 on premises covering about 20 hectares, including ten experimental halls and large-scale test facilities, some of them unique in the world.

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Bergisch Gladbach, August 2017

Introduction

Good transport policy making needs scientific advice. For a state system guided by the principles of precaution and safety, it is essential to have an understanding of the application and impact of modern technology, of road safety, mobility and traffic trends, of public health, the environment, energy and climate action, of changing working and living conditions as well as the challenges of a globalised economy. With the Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt), the Federal Republic of Germany has a modern research institution at its side, providing scientifically sound expertise. BASt thereby performs an important bridging function between politics on the one hand and science on the other.

BASt's strategic research planning is oriented towards transport-related long-term national, European and international programmes, while taking all social challenges that are relevant for road transport into account. These include the Roads in the 21st Century Programme, the Federal Government's road safety programmes and the European road safety programme.

Stefan Strick, President of the Federal Highway Research Institute

It is BASt's task as a departmental research institute to foster developments in the roads sector and to make scientifically sound decision support available to the Federal Government for upcoming transport policy issues and technical issues in the roads sector.

In its efforts, BASt is dedicated to improving and increasing the efficiency in building and maintaining road infrastructure, as well as enhancing the infrastructure's reliability, improving the performance of roads in the transport system and the efficiency of road safety, improving environmental compatibility in road construction and road transport, and enhancing the resilience of roads and technological progress in the roads sector.

BASt conducts its own research as well as external research that BASt designs, coordinates, scientifically supervises and evaluates. BASt takes up social, technological and economic questions and sees important challenges. The findings from its research activities serve as input for legislative processes as well as standards and other sets of regulations.

Innovative concepts, materials, technologies as well as methods and procedures need to be developed and researched to make the road system efficient and viable. It is important to generate more momentum in innovations and implementing them in building roads and bridges.

Innovative ideas need to be supported in order to accomplish both making the processes of new construction efficient and reliable and reducing the costs and efforts of necessary maintenance. The road of the future needs to be at the same time smarter, more economical, safer and environmentally compatible, while incurring lower sequential costs for users and operators.

BASt achieves its research objectives not only by its own research or external research but also by funding research. The „Innovation Programme for Roads" creates incentives for industry and

academia to intensify application-oriented research networking.

Staff

In the past two years, BASt's staff have conducted research in all areas of the roads sector at the high level of quality that BASt stands for. Over the past two years, the employees were active as lecturers at a variety of institutions in addition to their work at BASt. Another welcome piece of news is the fact that five scientists received their PhDs in 2015 and 2016, and that other employees were the recipients of awards and appointments.

We were able to recruit a number of new colleagues to BASt - many young ones among them – over the past two years. One of the facilitating factors was the BMVI Expert Network. This new research format was launched in January 2016. Seven departmental research institutions and executive agencies of the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI) were joined to form an innovative network, coordinated overall by BASt.

BASt has committed itself also to taking on trainees and offers apprenticeships for a number of professions. More than 20 young people have been trained over the course of the last two years.

Broader mandate

New challenges and topic areas necessitated structural adaptations at BASt.

The field of automotive engineering was restructured in mid2016. We set up the „Motor Vehicle Emissions" section in order to address this topic in an integrated approach and with the necessary external effects. This section covers exhaust emissions as well as noise emissions of vehicles and test procedures for tyres.

The automation of vehicles gives rise to new questions which are addressed by the new „Automated Driving" section.

The „Connected Mobility" section, also newly created, focuses on current challenges in the increasing connectivity of transport systems, vehicles and available traffic information.

The functions of the „Behaviour and Safety" department were also restructured and adapted to current requirements in 2015.

IT systems of various kinds are deployed in the field of research and have become indispensable. The „Coordination Office Research Management" was established in 2016 to build and operate a long-term high-performing and safe IT environment. The coordination office is in charge of gathering and assessing all relevant information on the development, implementation, operation and risk assessment of expert IT applications at an early stage. It thereby improves not only the economic viability of all projects involving IT but also security aspects as part of the research performance.

The construction of BASt's new premises for demonstrations, tests and referencing (duraBASt) in east Cologne began in June 2015. Newly developed construction materials, methods and procedures will be tested here in the future under realistic conditions. A reference track for the quality assurance and further development of fast-moving measurement systems is also located on the premises.

Articles

Our annual report focuses on representing selected insights and research findings from the past two years. 43 specialised articles will give you a good overview of the wide range of our activities.

Allow me to mention the field trial with longer trucks as an example. BASt was commissioned to conduct accompanying scientific studies from 2011 for the trial ending in December 2016. In summary, it was shown that no essential difficulties or shifting effects are to be expected from the use of longer trucks. From an economic perspective and the perspective of transport demand, the use of longer trucks is considered to make sense in certain fields for specific purposes. The insights gained in the field trial were used by the BMVI as a basis for its decision on a continued use of longer trucks.

While the number of deaths caused by road traffic in 2016 dropped to its lowest in more than 60 years at 3,200, the number of serious injuries has stagnated. However, there is little knowledge so far

about seriously injured victims of road accidents as there is no corresponding information available for all of Germany. BASt is participating in a study funded by the European Commission with data from the GIDAS (German In-Depth Accident Study) data base.

Climate change also has direct effects on the transport infrastructure. The RAINEX project defined the hazardous processes of extreme rainfall and identified their potential impact on the infrastructure.

The maintenance of engineering structures will play an ever more important role in the years to come due to the age and condition of the structures. Because the arms-length inspections which have been deployed so far are time-consuming and not without danger, BASt is studying innovative inspection methods for construction works. One project is the „condition survey in flight“ which studies the use of unmanned aerial systems.

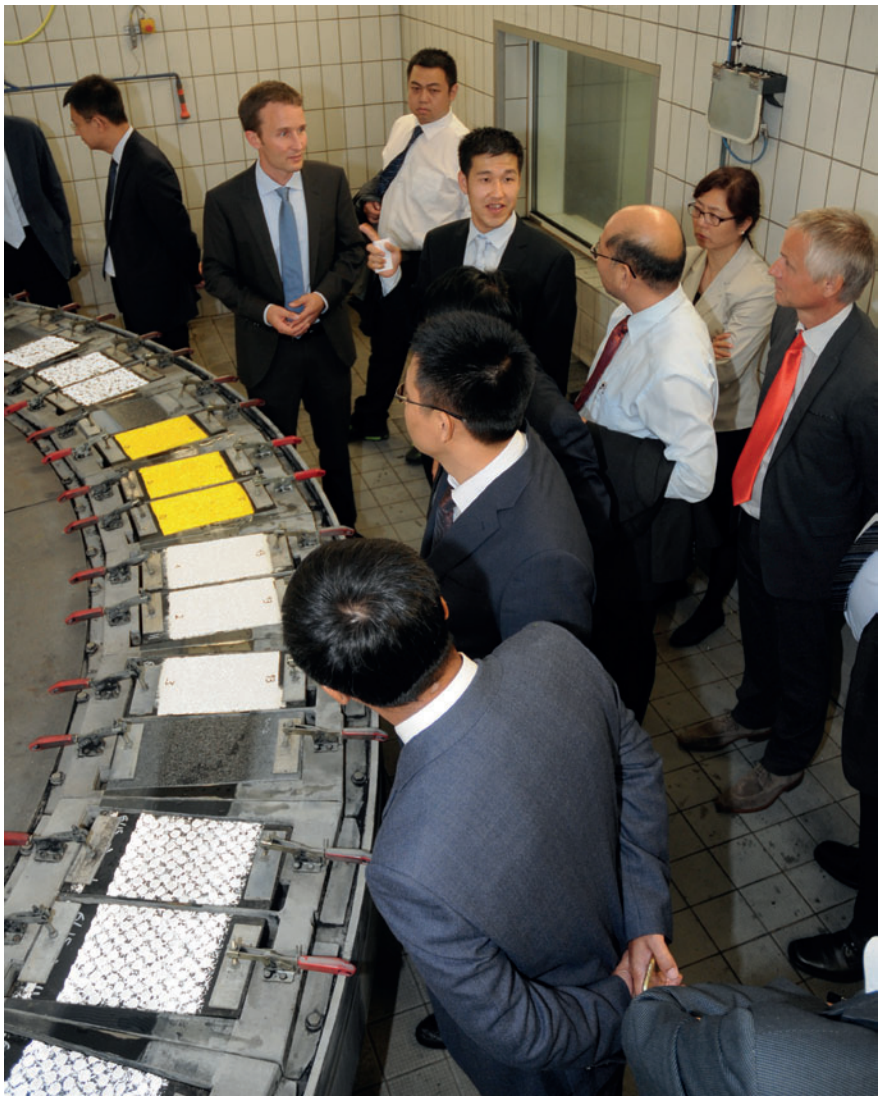
Contacts and guests

Internationally, BASt was active in more than 20 projects of the European Union and was represented by 80 scientists in 200 bodies of different organisations. BASt provides the President and Secretary General for FERSI (Forum of European Road Safety Research Institutes), Past President of FEHRL (Forum of European Highway Research Laboratories) and the chairman of the so-called Amsterdam Group.

BASt concludes cooperation agreements with foreign institutions to intensify international activities. In the past two years, new agreements were signed with Ukraine and China, and existing cooperations with the Netherlands and China were expanded.

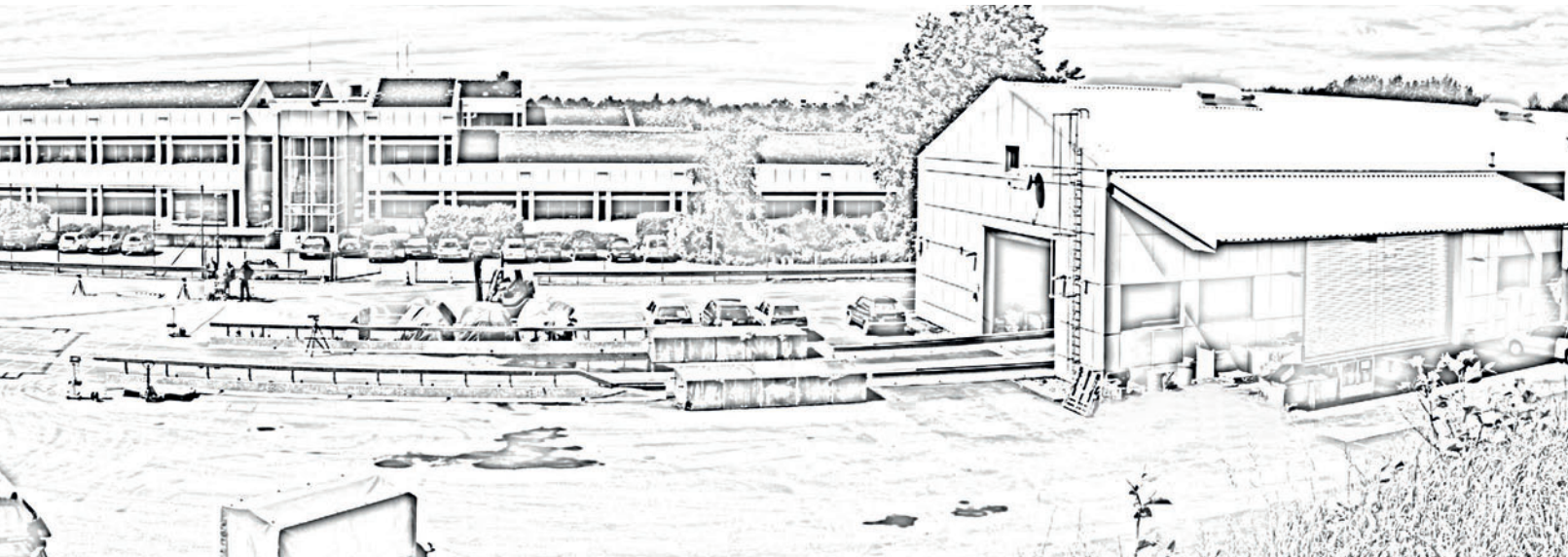
About 850 national and international visitors found their way to BASt in 2015 and 2016. 14 visiting scientists from abroad supported the work in our technical departments – sometimes over many months. We also welcomed guests from all over the world at numerous expert meetings at BASt. In June 2015, we opened our doors on Road Safety Day to give interested experts as well as our immediate neighbours insights into our work.

As the President of the Federal Highway Research Institute, I am delighted to have the honour of presenting the results of our research to you. I hope I was able to pique your interest in the present report and BASt‘s work.

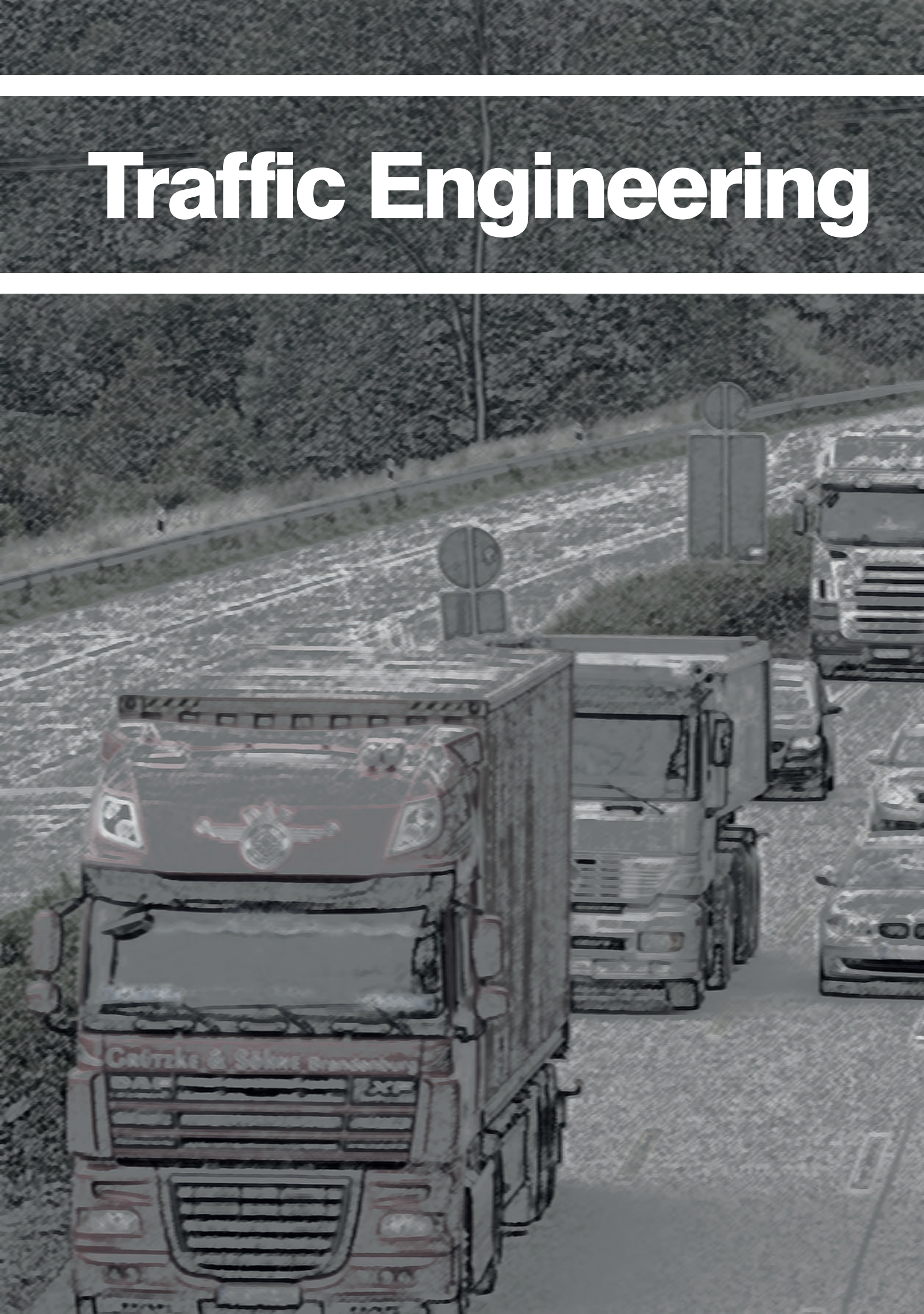


Many – also international – guests found their way to BASt

Content



Traffic Engineering

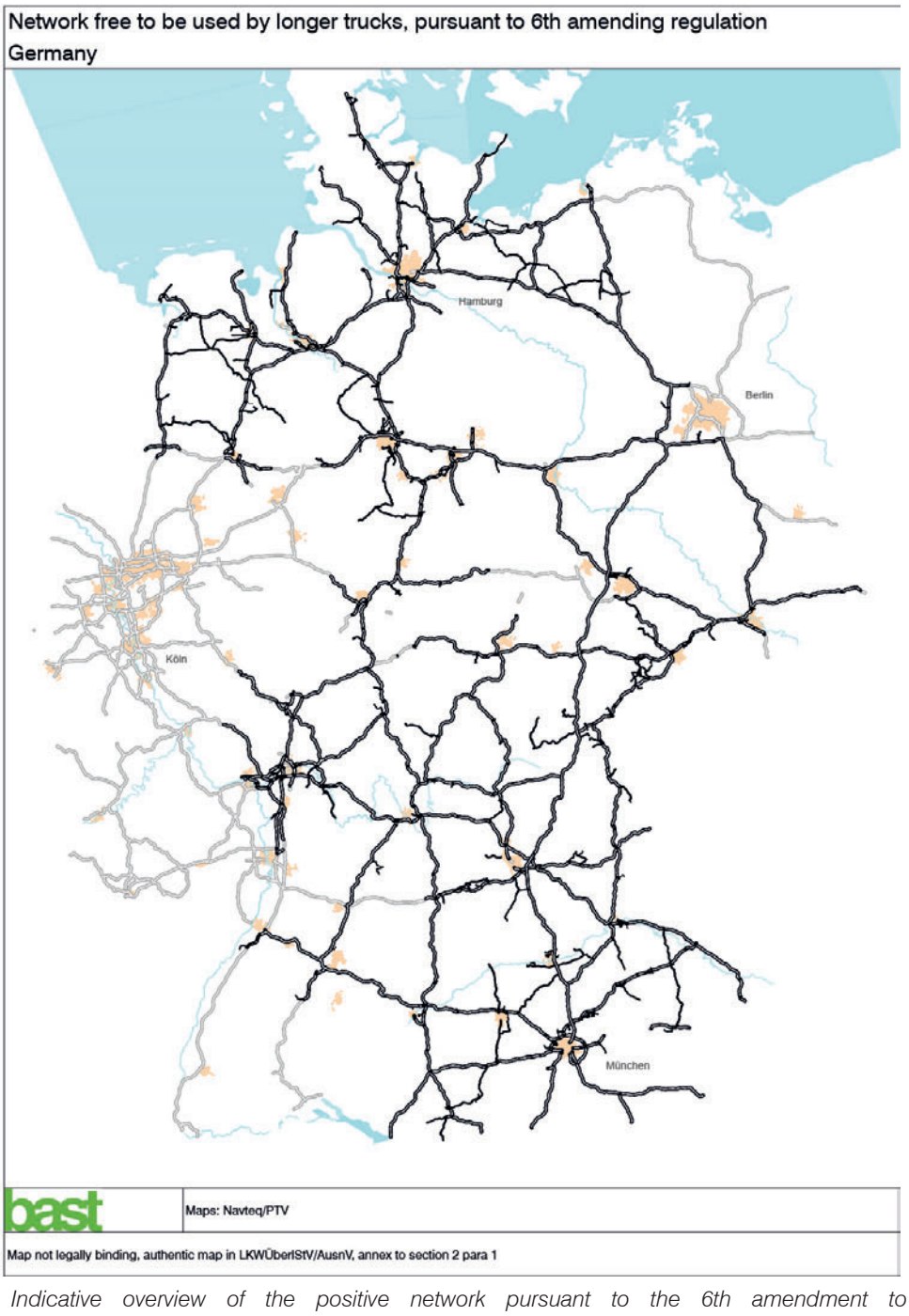


Field trial with longer trucks

The Federal Transport Ministry commissioned BASt in 2011 to conduct accompanying scientific studies to support the nation-wide field trial with longer trucks. Longer trucks can be up to 25.25 metres long and be longer by 6.5 metres than what is currently permissible in applicable legislation. However, in terms of weight they must not exceed the currently permissible weight of 40 tonnes, or 44 tonnes in combined vehicles including their front and rear units.

The trial started effective 1 January 2012 and was scheduled to continue for five years. It is a component of the Freight Transport and Logistics Action Plan (Aktionsplan Güterverkehr und Logistik) of the Federal Ministry of Transport and Digital Infrastructure.

The ordinance issued by the Federal Transport Ministry on exemptions from road traffic regulations for longer trucks and vehicle combinations (Verordnung über Ausnahmen von straßenverkehrsrechtlichen Vorschriften für Fahrzeuge und Fahrzeugkombinationen mit Überlänge, LKWÜberlStVAusnV), dating from 19 December 2011, and the relevant amendments form the legal basis for the trial. One of the requirements was that the use of longer trucks be restricted to a pre-tested route network, another that the field trial has to be accompanied by scientific support.



Indicative overview of the positive network pursuant to the 6th amendment to LKWÜberlStVAusnV dating 29 April 2016

Unbiased scientific supervision was intended to insert greater objectivity into the ‚longer trucks' issue, because, based on past discussions reasoning against longer and heavier trucks, concerns were expressed by advocacy groups of the German Railways and environmental organisations with regard to the field trial's exclusive focus on enlarging the vehicles.

The circumstance that the vehicles in question are longer but not heavier trucks did not fundamentally change the discussions.

Scientific support

The aim of the scientific supervision was to comprehensively address all hopes and concerns about the use of longer trucks. On the basis of a study of the international literature and taking the overall legal situation and public discussions into account,

Type 3 longer truck: rigid vehicle with dolly and semi-trailer, length = 25.25 metres

a list was compiled identifying the aspects that were mentioned by different sources as potential opportunities and risks involved in deploying longer trucks. At a colloquium in May 2011, experts discussed this list and developed it further.

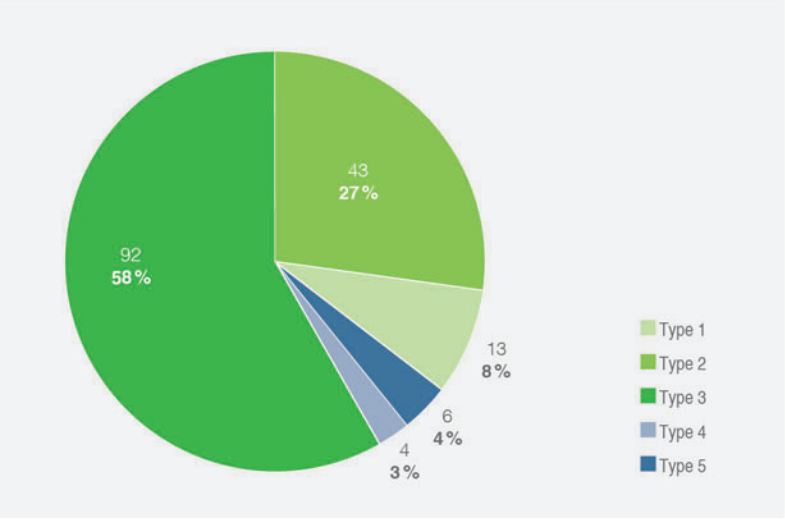
A number of research projects were initiated to answer the questions identified. Some were conducted by BASt itself over the past five years, but the majority were carried out by external research institutes.

BASt's final report presented at the end of the field trial in November 2016 includes – in addition to the legal bases necessary for the concept of the overall trial and findings from literature – summaries of the different research projects covering all stages of the scientific supervision. The reports on the field trial are available for download on the internet (www.bast.de/longer-trucks).

Results

The study results are intended as valuable support in the political decision-making process. In summary, it can be stated that no significant problems arose in the field trial. Compared to the multitude of research issues, the number of identified potential risks is low. Additionally, in view of the current number of longer trucks participating in the study, the risks identified can be categorised as acceptable or controllable, even assuming a significantly greater proportion of longer goods vehicles in freight transport volumes than projected in the scope of studies on their effects on transport demand.

Another finding is that the use of longer trucks has shown a positive effect on transport demand, as the mileage covered by longer goods vehicle was reduced, resulting in a reduction in the emission of climate gases and air pollutants will be possible in the future. So far, there have been very few and thus negligible effects on shifting freight transport away from rail or inland waterway transport. This was mainly due to the existing weight restrictions, but also caused by real restrictions or restrictions assumed in the model on possible transport routes.



Distribution of 159 longer trucks from 60 haulage companies registered with BASt in accordance with types defined by LKWÜberlStVAusnV (as of 30 September 2016)

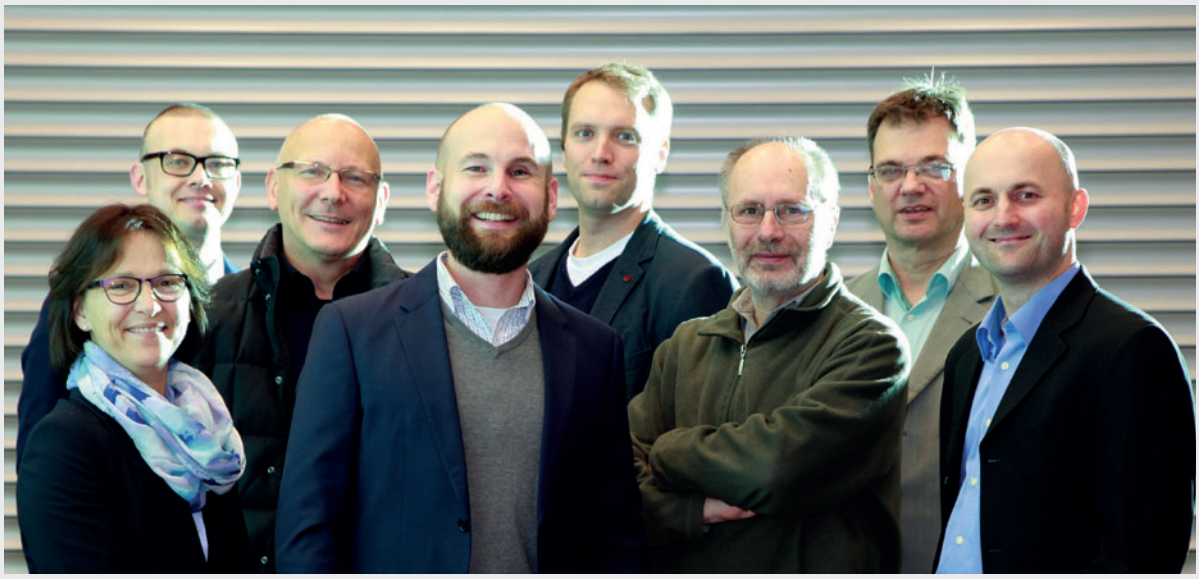
Though it has become clear that longer trucks are only a partial solution to containing the growth in freight transport and associated environmental impacts, their use in some fields makes sense from an economic perspective and the perspective of transport demand.

Longer trucks

Working group on longer trucks

Dr Wolfram Bartolomaeus, Physicist, "Environmental Protection" section

Dr Jan-André Bühne, Economist, "Accident Analysis, Safety Concepts, Road Safety Economics" section
Uwe Ellmers, Physicist, head of the "Motor Vehicle Emissions" section
Dr Jost Gail, Physicist, head of the "Active Vehicle Safety and Driver Assistance Systems" section
Dr Klaus-Peter Glaeser, at BASt until 2015 as the head of the "Vehicle/Pavement Interaction, Acoustics" section
Dr Hardy Holte, Psychologist, "Traffic Psychology, Traffic Education" section
Dr Marco Irzik, Civil engineer, deputy head of the "Highway Design, Traffic Flow, Traffic Control" section and head of the working group
Ilja Jungfeld, Civil engineer, "Highway Equipment" section
Rolf Kaschner, Mathematician, deputy head of the "Maintenance of Engineering Structures" section
Ingo Kaundinya, Civil engineer, head of the "Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section
Dr Thomas Kranz, Economist, "Research Controlling" office
Janine Kübler, Civil engineer, head of the "Highway Equipment" section
Sigrid Limbeck, Process engineer, "Motor Vehicle Emissions" section
Christof Sistenich, Mining engineer, deputy head of the Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section
Andreas Wolf, Civil engineer and tropics technologist, deputy head of the "Surface Characteristics, Evaluation and Maintenance of Roads" section for the "Maintenance of Roads" subsection



From left: Sigrid Limbeck, Dr Jan-André Bühne, Andreas Wolf, Ilja Jungfeld, Dr Thomas Kranz, Dr Hardy Holte, Dr Wolfram Bartolomaeus, Dr Marco Irzik; not in the picture: Dr Klaus-Peter Glaeser, Dr Jost Gail, Christof Sistenich, Ingo Kaundinya, Uwe Ellmers, Janine Kübler, Rolf Kaschner

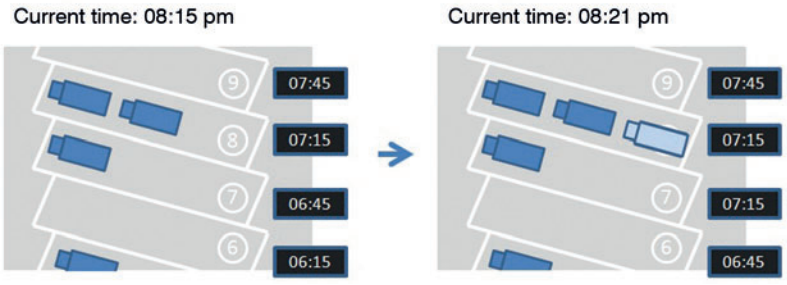
Compact parking for lorries: path towards practical implementation

Due to the dramatic increase in freight transport, there are at certain times bottlenecks and overcrowding at rest areas on Germany's federal trunk roads, despite the considerable number of existing parking spaces for lorries. In addition to extending, newly building and restructuring parking spaces, smart solutions for a more efficient use of existing parking capacities are being developed, tested and implemented as countermeasures to bottlenecks and vehicles parked where they pose a danger to road traffic. Using telematics, it is intended to better structure the demand for parking spaces along the route, thereby optimising the use of the existing parking spaces of rest areas. Telematics systems also enable improving the parking capacity of rest areas within the existing space: when sorted by departure time, several lorries can park directly behind each other in parking lanes. Middle aisles are no longer needed and their space can be used as additional regular parking spaces. These systems were summarised under the heading "special parking methods" (besondere Parkverfahren).

BASt developed the special "telematics-controlled compact parking" method – in short: compact parking – as a model for increasing the parking capacity of a rest area. Departure times are offered to the arriving vehicles depending on demand and using a dynamic display of departure times above the parking lanes. The arriving lorry drivers select a free parking lane with the departure time that fits their needs and park their vehicles closely behind each other. A detection system detects changes in lane occupancy - completely vacant, vacant, completely occupied – so that the offer of departure times is automatically adapted to the demand. As a result, the lorries park behind each other in a time-based order.

The image is a simplified depiction of how the system works for a section of four neighbouring parking lanes. At 8:21 pm, for instance, parking lane 8 is fully occupied and the departure time 7:15 am on the next day (duration of stay: 11 hours) is transferred to the neighbouring lane 7 and can immediately be offered.

The pilot project on compact parking was implemented on behalf of the Federal Ministry of Transport and Digital Infrastructure together with the Bavarian Highway Authority and BASt at the Jura West rest area on the A 3 motorway towards Regensburg and taken into service in early 2016. By re-designing traffic islands, the number of angle parking lanes for lorries and buses was increased from 66 to 70. By also re-marking what used to be the middle aisles, a total of 35 parking lanes over a length of about 70 metres were set up for compact parking. On the basis of counting three lorries per lane, this amounts to 105 parking possibilities.



Example of how compact parking works – occupancy-dependent offer

Compact parking is currently being tested in practice. The tests are intended in particular to provide information about user acceptance and the system's performance to show whether this method or similar telematics applications are suitable in the future as a supplement to conventional methods of extending and newly building parking spaces to increase parking capacity (www.kompaktparken.de).

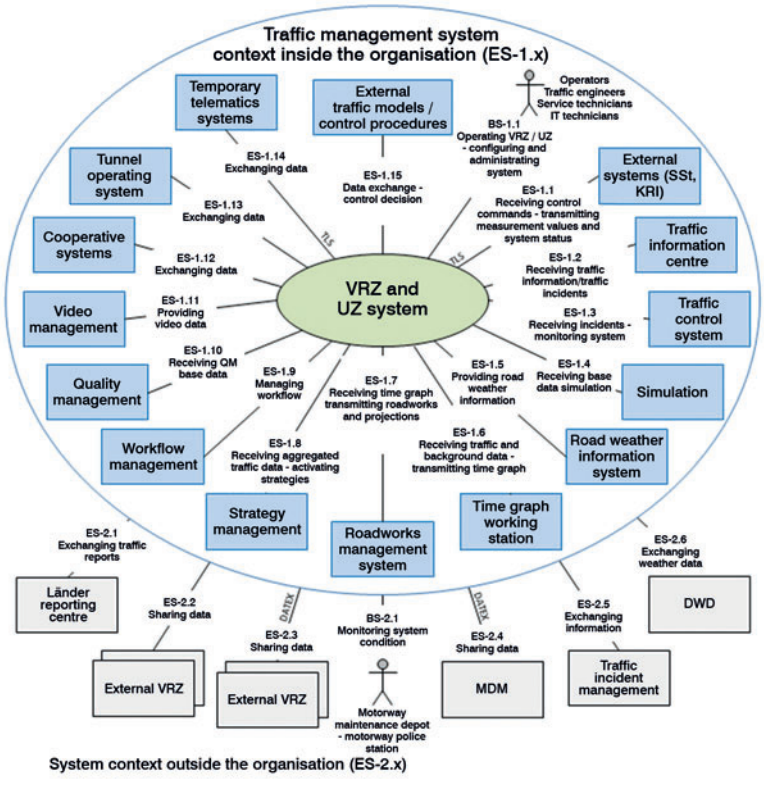
Compact parking

Rainer Lehmann
Electrical engineer
Head of the "Traffic Management and Road Maintenance Services" section

Jens Dierke
Civil engineer
"Traffic Management and Road Maintenance Services" section

MARZ: revised leaflet

New technologies and developments require the expansion and modernisation of traffic control centres (Verkehrsrechnerzentrale, VRZ) and secondary centres (Unterzentrale, UZ). They serve the purpose of steering, monitoring and coordinating adaptive traffic control systems. It needs to be ensured that all components of the adaptive traffic control system interact as optimally as possible. Besides technical aspects, economic aspects also play a role in this context. It needs to be possible to migrate subsystems and system components with little effort, independent of manufacturer. The existing hardware and software needs to be reviewed as to its re-usability. Furthermore, the systems must be designed in such a way that a future adaptation to new functions or linking with external systems will cause only little effort.



System context of the VRZ / UZ overall system

The leaflet for equipping traffic control centres and secondary centres (Merkblatt für die Ausstattung von Verkehrsrechnerzentralen und Unterzentralen, MARZ) developed in 1999 and introduced by the Federal Transport Ministry included requirements and fringe conditions for VRZ and UZ concepts. The leaflet was updated in an external research project to illustrate state-of-the-art technology and ensure the viability of traffic control centres [1].

The content and structure of the revised leaflet can be illustrated by means of the graphic that depicts the "VRZ / UZ system" in its system environment. In a first step, the functional requirements for the internal function areas (colour coded green) are described. These comprise data transfer, processing, maintenance and archiving, incident management, situation detection and evaluation, and a cross-check of measures. This is followed by functional requirements for external function areas within the same organisation that also operates the VRZ / UZ system (ES-1.1 to 1.15) and interfaces with external systems (ES-2.1 to 2.6). Additionally, non-functional requirements are defined such as system efficiency and performance, operational safety and resilience, software properties, computer security, and the overall system architecture, product contents and final acceptance process are described. New topics were identified during the update that are important for establishing and extending traffic control systems in an efficient, harmonised and sustainable manner. The topics determined in a parallel research project can be integrated into the new MARZ: requirements for a workflow management system, for services in the field of geoinformation (geo manager, map manager and object manager) as well as the definition of uniform framework conditions for the concept of the system architecture. The revised leaflet supports the harmonisation of the VRZ and the UZ system architectures in Germany.

Bibliography

[1] Revising and updating the leaflet for equipping traffic control centres and secondary centres, LISTL, G.; SCHWIETERING, C. et al.: „Überarbeitung und Aktualisierung des Merkblattes für die Ausstattung von Verkehrsrechner- und Unterzentralen (MARZ 1999)", 2016

Melanie Zorn
Industrial engineer
"Traffic Management and Road Maintenance Services" section

News about roadworks equipment

Congestion at construction sites - why are there so many traffic jams at roadworks?

Roadworks are a time-consuming nuisance for many road users. Though they are associated with inconveniences, roadworks are necessary: roads are subject to tear and wear, making it necessary, for instance, to retread the pavement after a few years (maintenance measures). Other measures include adding traffic lanes, erecting noise abatement walls, repairing crash barriers and concrete safety barriers after accidents or routine road maintenance. A functioning road network –¬ in particular a high-performance motorway – is an important building block for Germany's economic strength.

Traffic jams often occur at roadwork sites because fewer vehicles than usual can use the road per hour. Traffic jams can also be created 'out of nowhere' when vehicles decelerate as they approach the site. Roadwork sites are especially prone to create congestion when the number of available lanes on heavily frequented roads needs to be restricted during construction work. About 400 longer-term roadwork sites – defined as longer than a day – and about 100,000 shorter roadwork sites (one-day sites) are set up in Germany every year. Some of the one-day sites serve the purpose of preparing roadwork sites of a longer duration. Managing this great number of roadwork sites is a major challenge.

BASt is analysing roadwork sites in many ways to ensure that traffic is smoothly and safely routed through the site. How roadwork sites are equipped is an important factor in this.

Routing traffic through roadwork sites

The guidelines for safety at roadwork sites (Richtlinien für die Sicherung von Arbeitsstellen an Straßen, RSA) stipulate what a roadwork site looks like and how traffic is routed there. They define, for instance, the width of (auxiliary) lanes and determine how and where to install delineator posts, traffic cones or traffic signs. The RSA also establish speed limits for areas leading to roadwork sites and inside them. The maximum speed limit in the areas approaching the site decreases gradually every 200 metres by 20 km/h (traffic funneling) in order to prevent hard and abrupt deceleration. The usual maximum speed limit at roadwork sites in Germany – 80 km/h – is stipulated in the RSA. When the RSA are revised, BASt's research findings and experience from the past years will be integrated into the new regulation.

To date, the RSA determine only what the roadwork site looks like once its set-up has been completed by the entity responsible for traffic safety. The question of how this state can be achieved is the subject of one of BASt's current research projects. The project aims to establish a uniform order of consecutive work stages in setting up a roadwork site so as to reduce traffic interference to the greatest possible extent, prevent traffic congestion and ensure the safety of the road workers. Once the research project is completed, its findings will be transferred into the corresponding regulations.

Equipping the road with traffic installations

A range of different elements are used at roadwork sites to control traffic and to separate the traffic areas from the work areas. These include the delineator posts and traffic cones mentioned above, and temporary safety barriers and temporary (yellow) markings are also among them. These products may only be used if they comply with special requirements in addition to fulfilling general requirements as part of the German Road Traffic Regulations (Straßenverkehrs-Ordnung, StVO). In addition to structural requirements such as minimum weight, dimensions and stability and structural stability, these mostly also include visibility properties such as colour and brightness. These requirements are stipulated in the Technical

Roadwork site: four auxiliary lanes on one carriageway

Terms of Delivery (Technische Lieferbedingungen, TL) or the Additional Technical Terms of Contract (Zusätzliche Technische Vertragsbedingungen, ZTV).

BASt conducts the associated suitability tests and assesses the products in the scope of expert reviews. Ensuring "passive safety" plays an especially important role: no traffic installation may endanger the occupants of vehicles crashing into them. In order to prove the passive safety of delineators posts, for instance, BASt conducts crash tests at 80 km/h for manufacturers. Only delineator posts passing this crash test successfully fulfil passive safety requirements and may be used as traffic safety elements for roadwork sites. BASt is substantially involved in the preparation and review of TL, ZTV and other technical regulations and guidelines.

Marking roadwork sites

In Germany, yellow markings are a key element in the traffic safety of roadwork sites. When a roadwork site is up for a longer period of time, the markings show the road users the temporary changes in the routing of traffic. In accordance with StVO, yellow markings annul the existing white markings. To fulfil this function, they need to be perceivable by day and by night just as well as white markings. Minimum requirements for visibility are contained, for instance, in the Additional Technical Terms of Contract and Guidelines for Road Markings (Zusätzliche Technische Vertragsbedingungen und Richtlinien für Markierungen auf Straßen, ZTV M 13). To ensure that the yellow markings deployed in Germany comply with applicable requirements, BASt has been conducting suitability tests for 25 years now using its circular test track, which is unique in Germany. There are up to four million roll-overs over these markings on this large-scale test station, recording the traffic engineering properties of the markings. Only markings which sustainably fulfil ZTV M 13 minimum values will be issued a test certificate, the precondition for use at roadwork sites. The current list published by BASt includes a total of 65 yellow markings with positive test results, consisting for the most part of marking films manufactured in one piece in factories. The list also includes, however, yellow markings that are assembled at the roadwork site from individual components.

BASt's circular test track

Besides visibility, there are other, sometimes technically opposed, requirements that yellow markings need to fulfil. On the one hand, marking films that are used frequently need to be firmly attached to the road surface, but on the other they need to be easily and cleanly removable once the construction work is over, so that road users are not misrouted by residual traces of the markings and to prevent damages to the road surface. As it has frequently proved difficult in practice to remove yellow marking films cleanly, possibilities to assess the removability of markings in a laboratory test were studied in a research project. Using extensive stress and de-marking tests, it was possible to show that the removability depends on many different factors such as surface texture and structure, material properties and the age of the road surface. The findings were used as a basis to derive recommendations for future test settings to supplement suitability tests.

Protecting road users by means of temporary safety installations

It is often necessary to route all traffic along only one carriageway to make the other fully available for the construction work. At these times, the usual separation between the carriageways of a motorway by means of centre crash barriers or concrete safety barriers on the central reservation is lifted. To ensure that the road users remain protected nonetheless, so-called temporary safety barriers (temporäre Schutzeinrichtungen, TSE) specifically developed for this purpose are deployed. They are intended to prevent vehicles from accidentally moving into the opposite lane. This also applies to securing the roadwork sites themselves. Temporary safety barriers must fulfil the requirements of the European DIN EN 1317 standard and require a BASt test certificate to demonstrate their suitability. There were frequents incidents in the past where because of the rigid assembly of their individual

elements, light-weight temporary safety barriers fell to their side over a number of kilometres as a consequence of a crash.

To prevent temporary safety barriers from tipping over longer stretches after a crash, tests may be necessary under certain circumstances to determine their tipping length. It needs to be demonstrated that the total length of the falling elements (tipping length) is not more than 250 metres. If necessary, a so-called tipping length limiter needs to be deployed at least every 250 metres to prevent the TSE from tipping over long distances in case of a crash. The "Technical Terms of Delivery and Test Conditions for Temporary Safety Barriers" (Technische Liefer- und Prüfbedingungen für temporäre Schutzeinrichtungen) are currently being revised, incorporating the experience gained in past years in improving traffic safety at roadwork sites with temporary safety barriers.

Innovation

BASt develops, assesses and supports technical and organisational innovations on a regular basis. BASt already showed in tests some years ago that delineator posts in an arrow design are much better for routing road users through a roadwork site than posts with striped lines. Arrow posts have been introduced as standard delineator posts for the future in the revised RSA. BASt is currently supporting pilot tests for routing traffic at roadwork sites in reversible lane operation. Reversible lane operation means that, depending on traffic volume, a traffic lane can be enabled for traffic in either direction. Relieving commuter traffic is one possible application as commuters usually drive into the city in the morning and out in the evening. Reversible lane operation can bring about improvements in traffic flow, provided that the respective conditions on site enable doing so. This applies especially to cases where the number of the available traffic lanes needs to be reduced.

Stress test to determine tipping length

Rumble strips are installed on the lane to be closed or on the hard shoulder 100 metres before the mobile roadworks warning signs. Should an unobservant road user not have changed lanes in time, the mechanical impact of the rumble strip will call attention to the imminent lane closure, leaving enough time to change lanes or slow down. It is possible and permitted to drive over rumble strips. BASt is conducting suitability tests in accordance with the "Technical Terms of Contract and Test Conditions for Rumble Strips" (Technische Liefer- und Prüfbedingungen für Warnschwellen).

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Catalogue of traffic signs: revised and recast

The catalogue of traffic signs (Verkehrszeichenkatalog, VzKat) is an annex to the administrative regulation of the German Road Traffic Regulations (Verwaltungsvorschrift der Straßenverkehrsordnung, VwV-StVO). It includes every design and variant of official traffic signs valid in Germany as well as traffic installations such as markers, delineator posts and traffic cones valid here. It is thus a key instrument for the local road traffic authorities in charge of putting up traffic signs and traffic installations.

The catalogue of traffic signs was last revised in 1992. Since then, many amendments to the Road Traffic Regulations and its administrative regulation have resulted in modifications of the catalogue of traffic signs. A number of traffic signs were discontinued, new traffic signs were introduced and extensive restructuring followed the 2013 amendment of the Road Traffic Regulations that aimed for “fewer traffic signs - better signing”. All this made it necessary to urgently revise the 1992 version of the catalogue of traffic signs.

Variants of the 274 sign

BASt began the revision by first analysing all amendments and other official notices in individual Federal Ministry of Transport Gazettes on the Road Traffic Regulations and its administrative regulation made since 1992 for their relevance with regard to the catalogue of traffic signs. These were continuously cross-checked with the still valid 1992 version of the catalogue of traffic signs, and on this basis necessary changes were derived and included in the catalogue.

In the scope of the Federation-Länder expert committee on the Road Traffic Regulations, the number of supplementary signs in the catalogue of traffic signs has increased significantly in extensive coordination efforts with the highest road traffic authorities of the Länder. Supplementary signs supplement the contents of other traffic signs in black characters on white, and are installed together with them. The supplementary signs included in the catalogue of traffic signs are restricted, however, to those that are frequently requested such as distance and time specifications. The highest road traffic authorities of the Länder also have the possibility to introduce separate supplementary signs in their jurisdictions for specific applications.

In contrast to the version applicable until now, the new catalogue of traffic signs does no longer illustrate all variants graphically but only describes them in a verbal list. This applies, for instance, to the 274 StVO sign on “maximum speed limit”. This method has contributed to significantly reducing the size of the catalogue.

A revised version of the catalogue of traffic signs is now available after all the changes mentioned above were incorporated by BASt and implemented. It is intended to be officially introduced in the scope of the upcoming amendment of the administrative regulation of the Road Traffic Regulations, thus becoming officially valid. This amendment is going through the legislative process and, according to current plans, is scheduled to be promulgated in spring 2017.

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Overtaking model for single carriageways of dual-lane rural roads

The "Guidelines for the design of rural roads" (Richtlinien für die Anlage von Landstraßen, RAL 2012) were introduced in 2013 by what was then the Federal Ministry of Transport, Building and Urban Development (Bundesministerium für Verkehr, Bau und Stadtentwicklung). As accidents on rural roads tend to be especially severe, improving road safety was a priority in revising the guidelines.

One approach is to reduce the number of accidents in longitudinal traffic that can be traced back to mistakes in overtaking manoeuvres. In this approach, a separate overtaking principle is allocated to each of the four design categories for rural roads (Entwurfsklasse für Landstraßen, EKL). While overtaking on roads that are key connecting sections of the network is enabled on an additional passing lane over the entire section (EKL 1) or at intermittent stretches (EKL 2), overtaking manoeuvres on rural roads of regional significance (EKL 3) generally use the carriageway of the opposite direction.

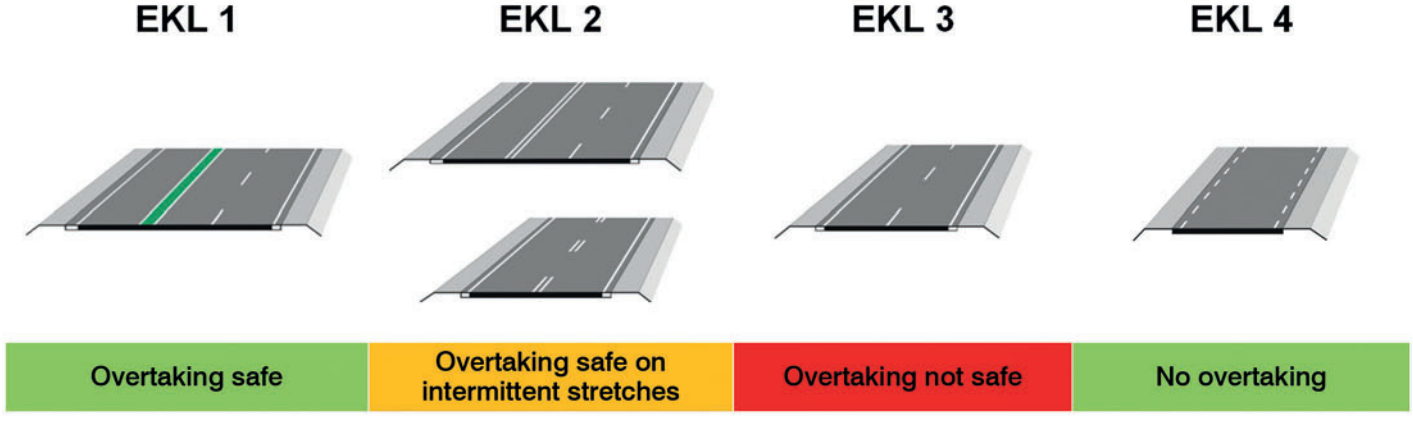
The passing sight distances recommended for overtaking manoeuvres are basically based on empirical studies from the 1980s that were later further adapted on the basis of theoretical considerations. That is why BASt recently completed its research project on "updating overtaking models for rural roads", during which current overtaking behaviour on rural roads was analysed in empirical studies on the basis of the current vehicle fleet.

Study method

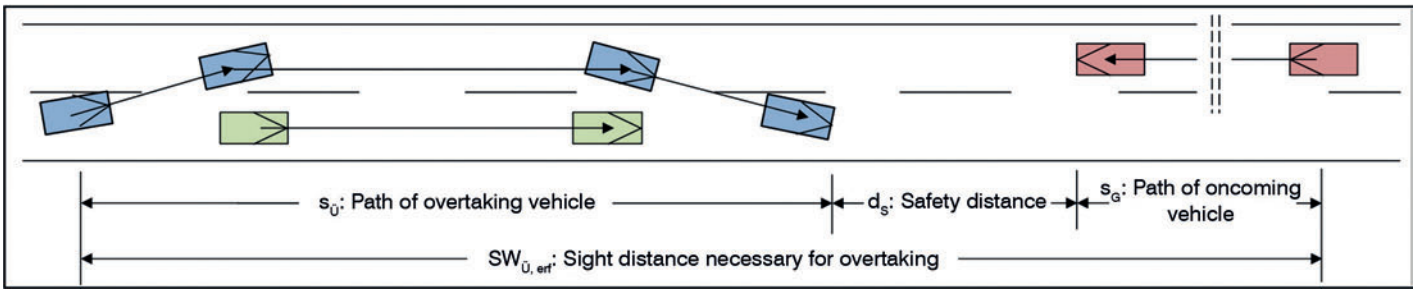
A method was used for this task which enables continuous detection of overtaking manoeuvres: sight distance, spatial distance, speed, acceleration, etc. A "Hovering Remote Controlled Ultralight Sensor Platform" (HORUS) drone technology was deployed with a high-definition camera system that requires only a clear aerial view of the individual study section in question. This survey method offers the great advantage that driving and overtaking behaviour is not influenced by the measurement setting itself. Flying at an altitude of 250 metres, the drone is practically invisible for road users. It automatically maintains its programmed position diagonally to the study section to be surveyed. Image stabilisers ensure steady pictures. Once the measurement data was processed, distance-time trajectories were available for each surveyed vehicle; these could then be superimposed over location maps and the sight distances of the individual sections. Sight distances were available for every point of the studied sections because the location and height of the sections had been measured in advance for use in evaluations at a later stage.

Results

The results were based on about 1,200 overtaking manoeuvres surveyed on eight study sections in daylight and on dry road surfaces. The survey was conducted in different Länder and comprised about 90 hours of flight time. The maximum speed limit was 100 km/h on all study sections.



Overtaking principles for rural roads pursuant to RAL 2012



Overtaking model for rural roads

More than 50 per cent of all overtaking manoeuvres are passenger cars behind lorries when the first vehicle behind the lorry accelerates to overtake it. The speed of the overtaking vehicle in this accelerated passenger car / lorry overtaking manoeuvre averaged over the entire manoeuvre was below the maximum speed limit, even though speeds usually exceeded the limit at the point of pulling back into the original lane. The lorries show a constant speed during the overtaking manoeuvre that is slightly lower than the average speed of all lorries on rural roads.

The decision to overtake also greatly depends on the visibility of oncoming traffic. If oncoming traffic can already be seen at the beginning of the overtaking manoeuvre, the overtaking vehicles use an average sight distance of 620 metres (median value). If the overtaking vehicle cannot see oncoming traffic at the beginning but only once the manoeuvre has started, significantly shorter sight distances are accepted for the overtaking manoeuvre (405 metres). This results in correspondingly shorter safety distances towards the oncoming traffic at the end of the overtaking manoeuvre. This type of overtaking involves comparatively higher speeds at the end of the overtaking manoeuvre.

"HORUS" drone with aerial image (images: Technical University Dresden and Airclip GmbH)

Recommendations

The findings of the empirical study were transferred into an overtaking model for rural roads, consisting of the overtaking vehicle's path, the oncoming vehicle's path and the safety distance between the two vehicles at the end of the overtaking manoeuvre. Based on observations during the survey, accelerated passenger car / lorry overtakings were selected as key overtaking types to determine necessary sight distances. Taking the maximum speed limit into account, a sight distance of about 600 metres is thus needed for a safe overtaking manoeuvre. These findings confirm the sight distance recommendations included in RAL (2012).

The observations have also shown that overtaking vehicles sometimes considerably underestimate the existing distances when oncoming traffic is not yet visible at the onset of overtaking and the overtaking vehicle is thus not immediately aware of the imminent danger. That is why the study also provides a starting point to determine distances to be included in traffic regulations to support and protect road users, as the danger of overtaking is not obvious enough due to perception psychology.

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Wildlife warning reflectors and preventing accidents involving wildlife

Optical wildlife warning reflectors (WWR) are often installed on road edges to reduce the number of accidents involving wildlife. These are intended to reflect the light from the headlights of passing vehicles onto the edges of the road. The light reflexes are to scare off wild animals and thus prevent accidents.

The photometric operating principle of optical wildlife warning reflectors was studied on behalf of BASt in the "operating principle of wildlife warning reflectors" research project. This project extensively analysed the geometrical relations between the headlights approaching the wildlife warning reflectors, the wildlife warning reflectors and potential positions of wild animals on the edge of roads, and simulated approach processes in photometric measurements. A total of nine different optical wildlife warning reflectors – commercially available standard products – were tested. The photometric measurements were conducted in three different laboratory settings: one setting enabled the simultaneous representation of the spatial reflexion on the entire area of the road's edge. A second setting was used to identify specific radiation values for two exemplary positions observed and a number of practical implementation scenarios: rural roads of various cross-sections with vehicles on all regularly used lanes in a straight, curved, slope, peak and sag design. A third setting served the purpose of measuring the retro-reflecting properties of WWR from the driver's perspective.

Results

A photometric characterisation of WWR from the animals' perspective showed that the light reflected by the wildlife warning reflectors in the intended direction does not radiate across a large area. Instead small-area mirror reflexions of only a few millimetres in dimension can be observed. Studies of all WWR showed that when looking at them from the road edge, more than 75 per cent of their surfaces did not show any reflexion, while 90 per cent of the surfaces of two thirds of the studied WWR remained dark. In 148 (92.5 per cent) of a total of 160 simulated approach scenarios on a straight road stretch, the light reflexes generated by the WWR were not visible at all.

Twelve situations showed at least sectional visibility in four different wildlife warning reflectors and they all involved the approaching vehicle using a driving beam. The photometric effect potential of the WWRs studied focuses on narrowly limited spatial areas. On average, the areas covered by the effect were identified to be less than five per cent.

The average percentage of the object's reflecting surface amounts to about 1.5 per cent across all WWRs studied from the perspective of animals on the road edge. This means that the intensity of the light reflected onto the area of the road edge is low to such an extent that the animals cannot see these reflexions against the road section illuminated by the lights from the headlamps. To put it in more graphical terms, the reflected light looks like a candle flame seen through two sets of sunglasses worn on top of each other. In view of the real conditions at rural roads with multiple spatial layouts, the varying terrain across wide spaces and thus intense variation of the viewing geometry caused also by the different eye level and positions of animals on the road edge, it can be concluded that the general approach of using optical wildlife warning reflectors is not suitable as an effective animal-based instrument for preventing accidents involving wildlife.

Outlook

Further research activities on equipment to enhance road safety at federal trunk roads are planned to comprehensively analyse other factors leading to accidents involving wildlife. These include the effectiveness and economic viability of wildlife fences, evaluation of hotspots of accidents on federal trunk roads involving wildlife, land use at federal trunk roads and how to influence road users when there is the risk of conflicts with wildlife.

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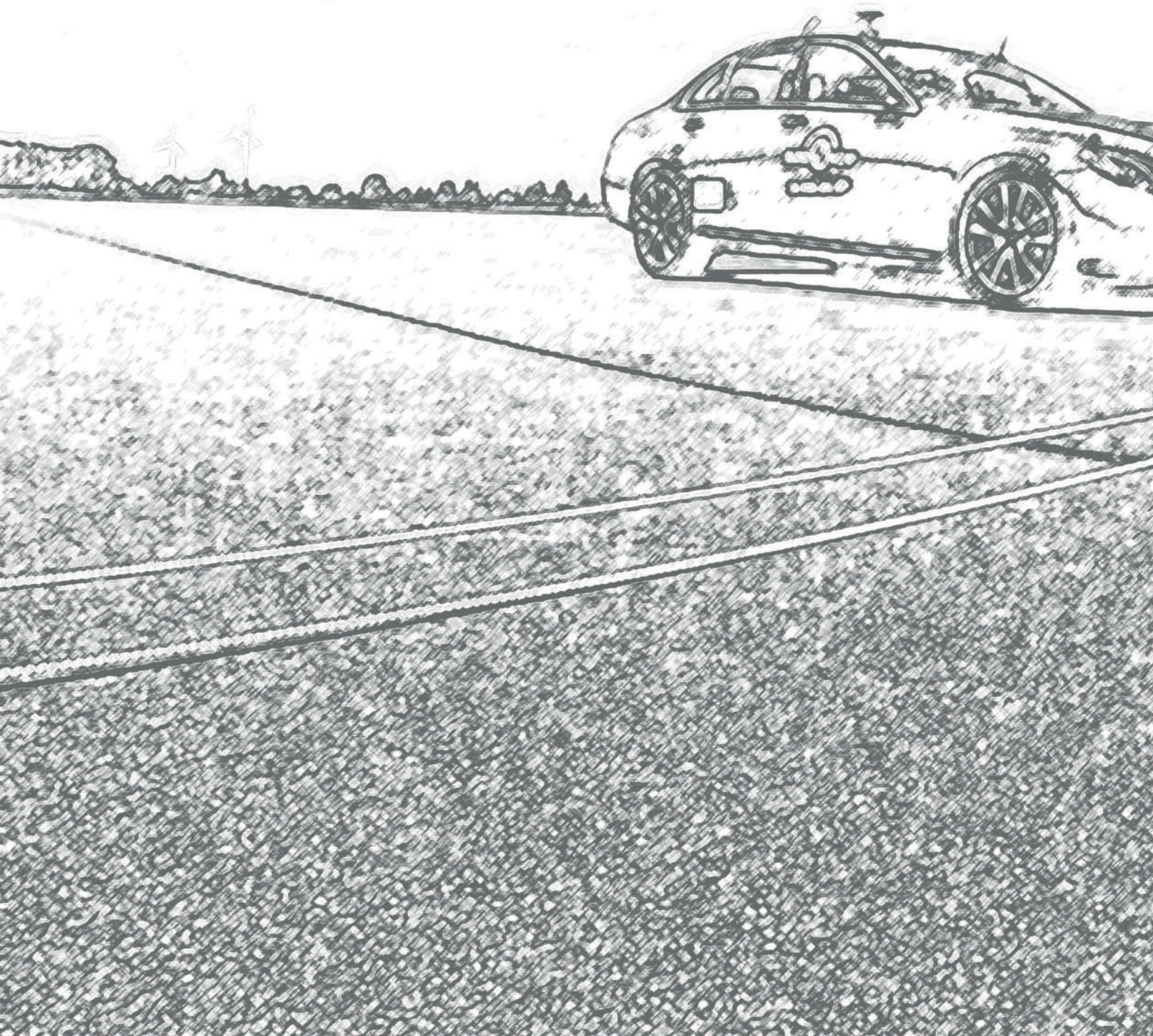
Automotive Engine



eering

Introducing cooperative systems and services in Europe

Researching, demonstrating, testing technology – preliminary work has been done

Vehicles and transport infrastructure that ‚talk' to each other, informing each other about road conditions and warning against hazards, have been the subject of numerous research activities and field tests in Germany and Europe for more than a decade - including field tests in the region of the rivers Rhine and Main in the scope of the simTD and DRIVE C2X projects. Previous BASt annual reports show a consistent image of this development and BASt's ongoing active participation in various phases of maturity of the technology. Now that the technology's operational maturity has been established and essential standards and fundamental system profiles are available, the implementation of cooperative intelligent transport systems – C-ITS in short – and of additional services that are based on them is on the horizon, especially as the technology is becoming increasingly affordable. A fertile area of implementation has been developing in Europe and in other developed economic regions, while supranational institutions have been busy creating the framework at the same time.

An initial implementation schedule

Representatives of infrastructure organisations in Europe started consultations with representatives of the automotive industry as early as 2011 to create a joint basis for an initial implementation of cooperative systems and services. CEDR (Conference of European Directors of Roads) was involved as the European advocacy group of national road authorities, as were ASECAP as the umbrella organisation of toll road operators, POLIS as the advocacy organisation of innovative transport solutions in cities and the Car2Car Communication Consortium as the representative of the automotive industry. Some of these services, for example warning against approaching rescue vehicles or spreading information on hazard braking ahead, target communication among vehicles. Other services, such as warnings about road works or information about traffic control signals (traffic light phases) turn infrastructure into a core partner for implementation. The strategic alliance between infrastructure organisations and the automotive industry is known under the name the Amsterdam Group. It prepared an initial rough schedule from the perspective of the implementation partners involved in 2013, and named the issues that needed to be resolved for a successful roll-out: these included specifications for initial applications, IT security, data privacy, conformity assessments, concept for hybrid communication, roles and responsibilities, international harmonisation.

Communication – the basis for cooperation

Communication in a network of vehicles and transport infrastructure – later including mobile devices – can be enabled via short-range communication based on the ETSI ITS G5 standard (a variance of the IEEE 802.11p WIFI standard which uses the frequency band at around 5.9 GHz), mobile communications systems (based on 3G – UMTS, 4G – LTE and future developments up to fifth generation 5G) as well as digital radio DAB+. Applications for road safety are of core interest. Safety-relevant information requires real-time communication. Because of latency period requirements, it would be advisable to spread warnings about hazardous locations in an ad hoc-hoc network directly via ETSI ITS G5. For less safety-critical applications, for example strategic information about traffic disruptions for road users on their travel routes, communication via mobile communications systems may be appropriate (back end of vehicle manufacturers, traffic control centres of road operators, national access point for transport data – MDM: mobility data market place). Generally speaking, in a dynamic technology-open approach, the type of communication should be deployed which is best suited to fulfil the requirements of the service to be offered. The mix of the communication types used may vary over time when the performance and operational maturity of communication technologies change, for example DAB+ or 5G communication. The same applies to add-on functions that become available for the same kind of communication technology.

Currently, the share of connected vehicles is reaching 20 per cent of the vehicle population. The vehicles are connected via mobile communications systems at this point in time („connected" services by vehicle manufacturers). According to the Car2Car Communication Consortium, it can be

expected that 15 vehicle manufacturers and more than 30 global suppliers will spread ETSI ITS G5 across their vehicle fleets starting in 2019.

Implementations initiated by transport infrastructure organisations

The three transport ministers of Germany and the neighbouring countries - the Netherlands and Austria - initiated the implementation of cooperative systems in 2013. The Cooperative ITS Corridor considers itself an initial step towards transitioning a new services generation into standard operation in the network of trunk roads. The two initial joint applications of the three countries consisted of services for warning about road works and improving traffic management on the basis of vehicle data. The schematic diagram of the services and the communication pathways used (ETSI ITS G5, mobile communications) are depicted in the image. It shows that the warning against road works is communicated directly to vehicles in the vicinity of the hazardous location. At the same time, the mobile road works warning sign communicates basic data via mobile communications to the cooperative traffic control centre, for example on position and placement of arrows. This data is made available by the MDM mobility service providers. On the other hand, the infrastructure receives traffic data from the vehicles so as to use it for improved traffic management. The specific introduction of C-ITS services is also being prepared in other EU Member States. Cases in point are SCOOP@F in France, BaSIC in the Czech Republic, and NordicWay in Finland, Sweden, Norway and Denmark. The bundling of services for initial applications can be summarised under the headlines „hazard warning“ and „transmitting traffic signs into vehicles“. The Amsterdam Group has done significant preliminary work towards harmonisation among the implementation partners, and it has now become consensus among all institutions involved.

A platform for implementing cooperative systems and services

Mobility in Europe crosses borders effortlessly. Drivers usually do not take any notice of who provides the street for road users. This is common practice for ‚hard‘ infrastructure elements; it is intended to work smoothly in the field of mobility services as well. A successful introduction of interoperable services across Europe constitutes a major challenge for all involved. For this reason, the European Commission (EU-COM) launched a platform for implementing cooperative systems and services in 2014: C-ITS Platform. As the EU-COM‘s expert group, it forms the basis for a dialogue among all the institutions participating in the implementation. After more than one year of intensive work, the final report on phase 1 of the C-ITS Platform was published in January 2016. It contains the results and recommendations of the expert group on a wide range of topics comprising technical, legal, organisational and financial issues. Some of the issues require that a European framework be set.

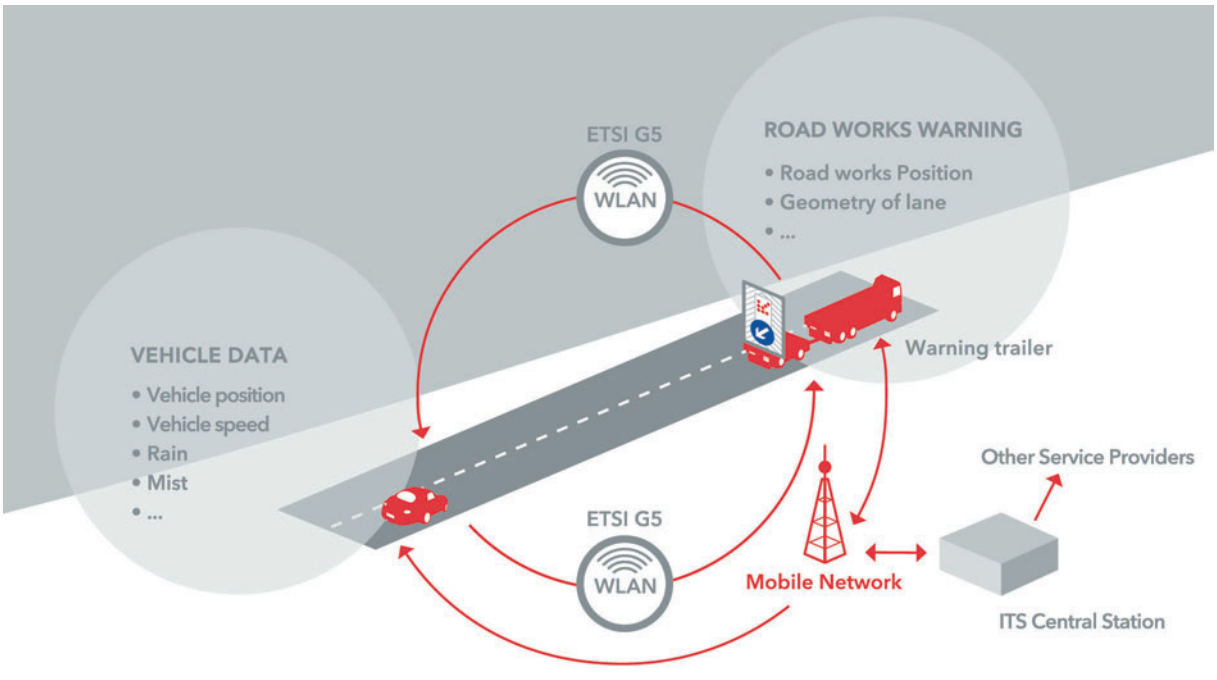
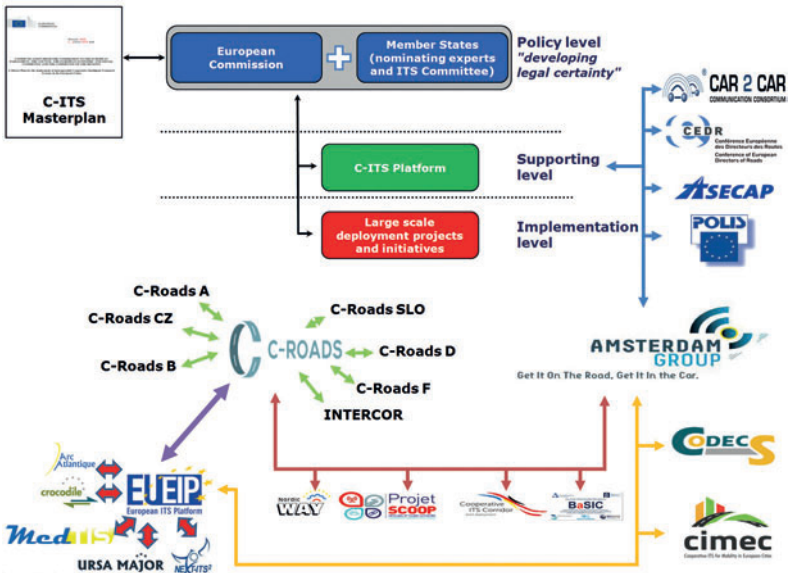


Diagram of initial application in the Cooperative ITS Corridor

These include uniform regulations for IT security, data privacy, conformity assessments, technical interoperability requirements and consistency of services (list of initial applications). On the basis of ITS Directive 2010/40/EU, these topics will be incorporated at the political level into a Delegated Regulation on cooperative systems and services which is currently being prepared. The EU-COM's C-ITS master plan addresses the topics in question and implementation-related responsibilities.

Towards a fruitful implementation landscape

Successful policies can also be measured by the success of the implementations. This is why the EU-COM, as well as the key partners for the launch, show great interest in fruitful and visible implementation. Since autumn 2016, additional C-ITS pilots and implementation initiatives have been in place, co-funded by the EU-COM by means of the Connecting Europe Facility (CEF). All in all, more than ten EU Member States have thus committed themselves to introducing C-ITS. All these implementation initiatives have committed to contributing to harmonisation and interoperability within the C-Roads Platform. This overarching activity which was also started in 2016 has a central role to play in knowledge management with respect to C-ITS implementation, similar to the role of the European ITS Platform (EU EIP) in implementing conventional ITS services. The Amsterdam Group continues to provide space for a strategic exchange between infrastructure organisations and the automotive industry.



Synopsis of the framework for introducing cooperative systems and services

BASt commitment in the scope of introducing cooperative systems and services

BASt is very active in this multi-faceted implementation landscape for the Federal Transport Ministry and is actively co-shaping the framework for introducing cooperative systems and services in Europe. This is accomplished at the implementation level in the C-ITS Corridor and C-Roads Germany. At the level of expert exchange, BASt is active as a coordinator in the Amsterdam Group. Furthermore, it is an active member of the C-ITS Platform and partner in a number of support activities such as EU EIP and CODECS. BASt's active participation in standardisation bodies is also of great relevance. The publication of a standard on the organisational architecture of cooperative systems and services and associated roles and responsibilities (ISO TS 17427) is a visible outcome.

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Amsterdam Gruppe

Cooperative ITS Corridor

C-ITS Platform

C-Roads Platform

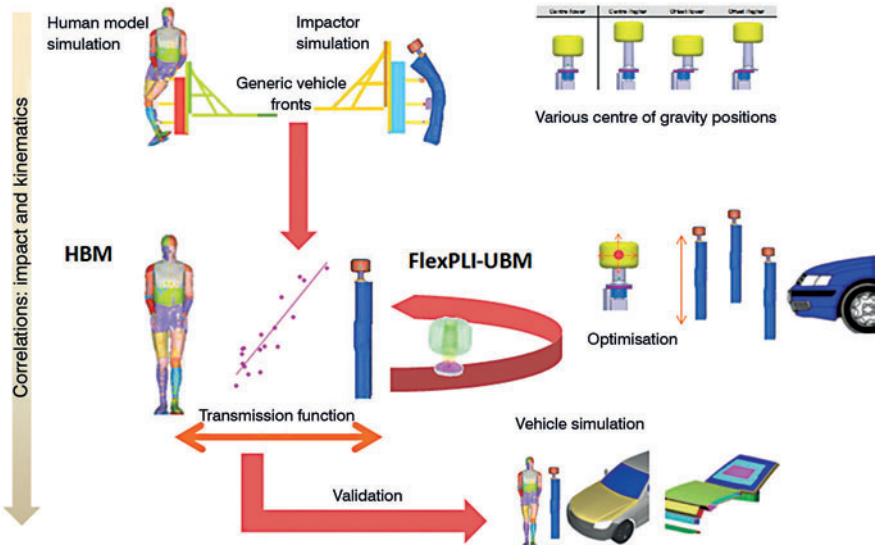
SENIORS: further developing test procedures for pedestrian protection

The most recent analyses of various European databases on traffic accidents show that there has been a shift in accident patterns involving pedestrians and cyclists in collisions with passenger cars. Accidents with cars type-approved in accordance with regulations on pedestrian protection show a higher proportion of severe rib cage injuries while the relevance of head injuries and injuries of the lower extremities has remained the same. This effect has been observed to be aggravated for senior road users (65 and older). Rib cage injuries are not, however, taken into account in the current test procedures.

The European "Safety-Enhanced Innovations for Older Road UserS" (SENIORS) projects rebalances this trend by newly developing or further developing test procedures and impactors for passive pedestrian and cyclist protection. The head and leg impactors currently deployed in legislation and consumer protection representing these body regions will be supplemented by lacking body masses such as a pedestrian torso, and thus optimised in their bio fidelity (human-like properties). This is especially useful for kinematics and biomechanics of injuries.

One tool for predicting rib cage injuries is being implemented for the first time in an impactor test procedure. Virtual human models and impactors are used in computer simulations to study impact collisions with the front of a vehicle. The transmission functions to be developed on this basis translate human injury risk into impactor limit values. These limit values provide indicators of the protection potential vehicle front ends offer during a real accident. The next step consists of optimisation, and finally the new impactor models are validated in simulations using virtual vehicle models. Developing impactor prototypes and drafting corresponding test and evaluation procedures will result in an estimation of their effectiveness once they are introduced into legislation and consumer protection.

The ultimate aim is to substitute for the current test procedures and impactors tests using the newly created flexible leg test specimen with upper body mass (FlexPLI-UBM), the head-neck impactor (HNI) and the thorax injury prediction tool (TIPT) to better address the constellations and injury patterns of pedestrians and cyclists as they currently occur in accidents, and to contribute to further reducing the number of fatalities and severe injuries in public road traffic.



Flow chart for developing a new test procedure using the example of developing a leg test specimen with upper body mass specimen

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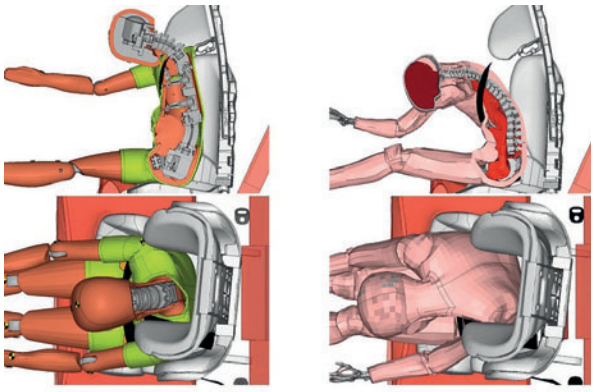
The impact of security belts on children

Tests using dummies and human models

In Germany, children up to the age of twelve who are shorter than 150 centimetres need to use a suitable child safety system (Kinderschutzsystem, KSS). Systems for older children, so-called boosters (raised seats), with or without backrest, are intended to position the vehicle's adult safety belt systems in such a way that it can also fulfil its protection potential for a child.

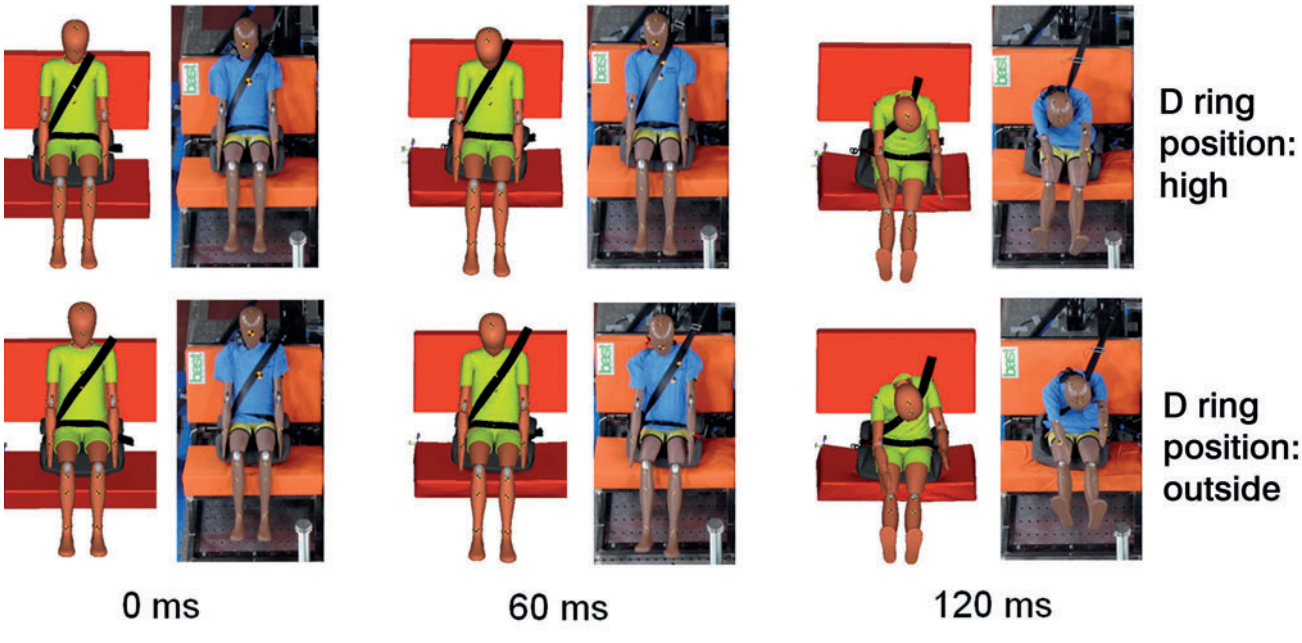


Q10 and THUMS 10YO during a simulation: comparing the forward shift

The safety potential is assessed using child dummies of the Q dummy series. It is important to know how realistic and true to biofidelity the mutual influence is between safety belt and dummy to be able to realistically rank the findings of varying test procedures. In the scope of a parameter study, the interaction between safety belt and child was studied in the belt/shoulder and belt/abdomen areas using a Q10 dummy. The Q10 dummy represents a child that is ten and a half years old. During the test and the simulation, the dummy was compared to a ten-year old human model, the THUMS 10YO.

The study aimed to analyse the differences in the interaction between safety belt and passenger for the dummy as opposed to the human model, and to identify possible causes for the differences. The findings were then to be used to develop proposals for how to address these deviations by improving the dummies.

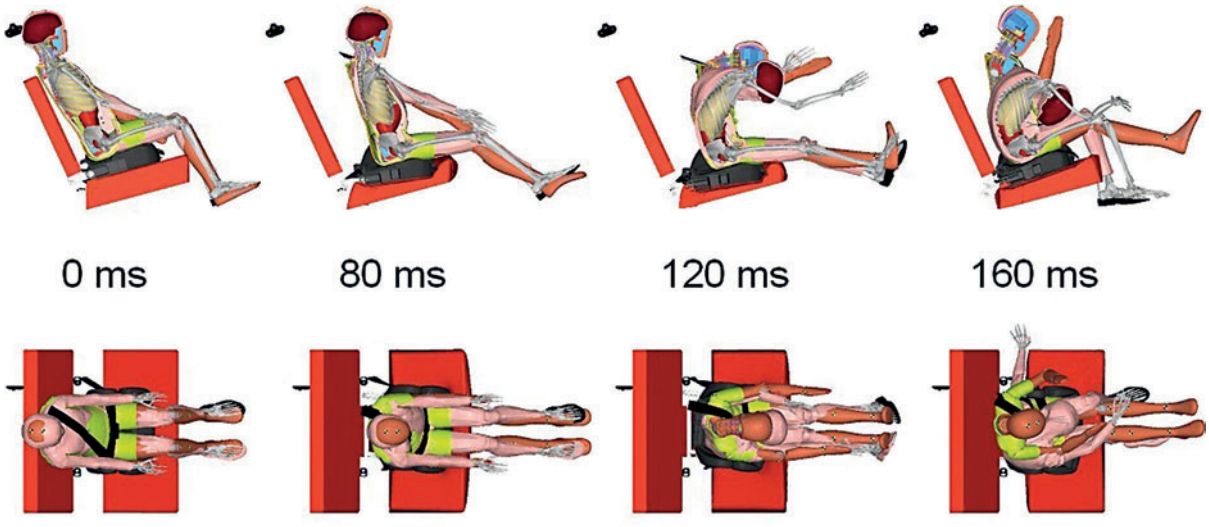
The test set-up enabled a number of variations so that it was possible to study the influence of the KSS backrest and the effect of belt tensioners and belt force limiters, a rotation of the vehicle, and the influence of the position of the upper anchorage points of the seat belt (D ring). The image below shows an example of a good alignment of the belt movement during the test and the simulation with the Q10 dummy.



Comparing Q10 dummy during the test and the simulation

The image below shows the comparison between a Q10 dummy and a THUMS 10 YO during a simulation. In this configuration using a booster without backrest, a belt tensioner and a 3.5 kilo Newton belt force limiter, the THUMS human model shows an increased rotation around the vertical axis in the shoulder area. Differences can also be found in the head/neck forward shift caused by a heavier rotation around the horizontal axis in the thoracic spine area. Independently of the configuration, the simulations using the THUMS show a more pronounced shift of head and chest, though in most cases with the same tendency. Comparing the maximum values of the analysed values measured across all configurations, the Q10 and THUMS show similar tendencies for most of the values.

As a result, it can be stated that the Q10 is suitable in principle to show the impact of safety belts on children. The most significant differences are caused by the more flexible spine of the human model and its more flexible ribs, making bending and rotating possible. It is especially relevant to accurately imitate human movement when the safety belt appears not to be positioned optimally. Additional studies are necessary in this context to develop possible improvements in the dummies.



Comparing Q10 dummy and THUMS 10 YO in the simulation

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Man-machine interaction in automated driving

The current development towards continuously automated driving can be seen in a range of degrees of automation, ranging from conventional driving – without automation – to assistance systems, partially automated systems, highly automated systems, all the way to fully automated driving functions. The automotive industry has announced the roll-out of highly automated driving functions at the end of this decade, while driver information and driver assistance systems have been used in road traffic for some time now, and the first partially automated systems are now available on the market. However, the impact of automated driving on road traffic cannot yet be fully estimated.

Research subjects

As the tasks of human drivers will change significantly, BASt is focusing its research on man-machine interaction (MMI) issues. With an increase in the degree of automation, the proportion of driving that automated functions will be able to take over will also increase. At least in the mid-term, however, there will be tasks and situations that automation will not be capable of handling. In these cases, human drivers continue to play the central role. After brief notice, the driver will need to take over the steering of the vehicle again when the system asks for it.

The following aspects are at the focus of research based on the changing requirements in the cooperation between man and machine:

- Currently available automation of continuous driving and the associated shift in the driver's tasks towards monitoring tasks can already now lead to changes in attention and alertness. Knowledge about the driver's availability and willingness to take over is of great significance in view of transferring the task of driving back to the driver.
- The design of the man-machine interface is also important for successfully shaping the task of driving. In this context, system transparency and suitable information and operating strategies are essential in order to avoid mix-ups in operating modi, or due to incorrect use and abuse.
- With regard to preventing collisions in mixed traffic, the question arises of how to communicate the intentions of the automated vehicle and those of the surrounding non-automated road users.
- It is intended to give the driver the possibility to take up non-driving related activities during highly automated driving. The question needs to be studied what other activities are suitable for this and may even have a positive effect on the driver's willingness to take over driving if needed.
- Existing methods for assessing MMI need to be reviewed and adapted. New test methods need to be developed for specific aspects of automated driving.

Simulation instruments

Experimental studies are one basis of research when evaluating the effects on driver behaviour that originate from assisted systems to automated driving functions. In these studies, real trial participants (drivers, passengers) 'experience' the system functions and their operation in the context of the primary driving task. Simulations are often used in these experiments. With the help of model constructions which reproduce real systems in abstract form, elements of the human driver's driving, road infrastructure, operating tasks of electronic on-board systems as well as automated driving functions can be integrated into the test setting, generating trial conditions that are relevant for the study.

BASt uses various test settings depending on the research subject to be studied: MMI laboratory, driving simulator, BASt test vehicle on non-public test tracks and in real road traffic. BASt's test vehicle, for example, enables the simulation of varying degrees of automated driving to investigate automation effects, and can thus be used in a versatile way to study the interaction between automated driving and the human driver.

Example projects

Influence of ambient situations on take-over performance

As highly automated driving functions rely on returning the task of driving to the human driver with short notice, the question arises whether and how the driver can perform taking over the driving task in different traffic situations. BASt is conducting a

study on this question in real road traffic using its test vehicle. Besides the test driver, the test manager is also in the vehicle during the experiment. The study aims to identify potential influences of different traffic situations on performance when taking over the driving task, and to estimate the criticality of ambient parameters.

Studies on driver alertness during automated driving

With the increase in automation, the driver's task is shifting towards a monitoring task. There is concern that the driver will find it difficult to stay alert when automated driving is combined with monotonous traffic situations. In this context, BASt is studying how driver alertness changes by comparing conventional, partially automated and fully automated driving. In an on-going study on driver fatigue, driving tests are conducted in BASt's test vehicle on a test site. The aim is to collect data on changes in the driver's condition in a low-stimulus environment. It is particularly interested in finding out whether the driver's availability and performance skill are adversely affected after having to monitor automated driving over a lengthy period of time.

Influence of hands-free driving on taking back control over the vehicle

A project on partial automation jointly supported by BASt and the Automotive Engineering Research Institute (Forschungsvereinigung Automobiltechnik, FAT) studied how hands-free driving and other driving situation factors influence a driver's performance when taking back control over the vehicle. Several experiments were conducted in a driving simulator, and a validation study was carried out using a real vehicle on a test track. The resulting take-over times after hands-free partially automated driving were longer compared to non-hands-free partially automated driving.

Comparing partially automated driving to conventional driving showed higher values with regard to steering wheel angle, lateral acceleration and standard deviation from yaw angle error which, however, proved in the majority of cases not to be critical for performance in take-over situations. However, not all trial participants were capable of handling take-over situations successfully at high vehicle speeds.

Compensatory driver strategies in the context of automated driving functions

People have behavioural strategies to handle driving tasks. The question arises to what extent drivers can fall back on these strategies when they quickly need to take over driving in a critical situation and at the same time ensure safe driving. To answer this research question, a study was conducted in a driving simulator on behalf of BASt. During this study, driving a highly automated vehicle was simulated in congested traffic on a two-lane motorway. The drivers were able to turn away from the driving task and do tasks that had nothing to do with driving. The findings show that drivers are capable of reducing their non-driving related activity upon a take-over request, and thus of adapting to the requirements of conventional driving.

Developing methods to assess alertness effects

BASt participated in further developing and standardising a new method to measure effects of driver alertness on the basis of the driver's cognitive stress level. Significant cognitive stress can occur, for example, when information and communication systems are used in the car or during monitoring tasks in connection with automated driving. This new method can be deployed in a number of test settings: laboratory, driving simulator, test track. It was tested for applicability in the scope of a coordinated international series of tests in BASt's MMI laboratory. A continuous tracking task on the

BASt's test vehicle for researching automation effects

computer was used to simulate the driving task. The trial participants had to complete additional tasks on the computer in parallel which were used in the experiment to simulate the cognitive stress from non-driving related activities. The International Standardisation Organisation (ISO) has used the test results for further standardisation work.

Conclusion and outlook

The methods mentioned above serve the purpose of identifying the requirements for automated driving and evaluating solutions. The great number of different questions about man-machine interaction during automated driving requires a broad range of methods and test settings which are interlinked and complement each other. Simulations contribute to conducting studies that are highly safe and repeatable, and reduce technical and scientific test efforts.

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From left: Alexander Frey, Tom M. Gasser, Dr Heike Hoffmann, Rico Auerswald, Nadine Moritz-Kokot, Torsten Marx, Roland Schindhelm (not in the picture: Anne Klamroth)

Camera monitor systems to replace wing mirrors

The wing mirrors of vehicles are traditionally used for indirect vision towards the back, especially for watching traffic behind the vehicle. The field of vision that needs to be covered and additional requirements are defined in UN/ECE R 46 (United Nations Economic Commission for Europe Regulation Number 46). With the entry into force of the current version of UN/ECE R 46, camera monitor systems can now be used as an alternative to mirrors. Camera monitor devices for indirect vision always consist of a combination of a camera and a monitor.

Technical and ergonomic studies as a basis

In an initial BASt study, camera monitor systems and conventional wing mirrors were compared and evaluated both from a technical perspective and from an ergonomics perspective in the man-machine interaction. Their deployment in passenger cars and lorries was analysed in test drives and laboratory tests. The results were the basis for deriving quality criteria that need to be fulfilled for passenger cars and lorries to use camera monitor systems to replace mirrors for indirect vision.

Camera monitor systems showed additional benefits such as being capable of showing more information than a mirror system, in order to, for example, reduce blind spots. Generally speaking, drivers adapted quickly to using camera monitor systems and no safety-relevant situations arose during the familiarisation phase.

New international regulations in automotive engineering

The findings of the study described above were utilised by the UN/ECE “Informal Group on Camera Monitor Systems (IGCMS-II)” to expand and adapt Regulation Number 46. The current version, which entered into force in June 2016, describes the requirements for devices for indirect vision and now enables camera monitor systems on passenger cars and lorries to replace mirror systems. The regulation also refers to ISO standard 16505 “Road vehicles – Ergonomic and performance aspects of Camera Monitor systems – Requirements and test procedures”. This standard describes test procedures for camera monitor systems in connection with technical performance indicators and ergonomic requirements.

Outlook

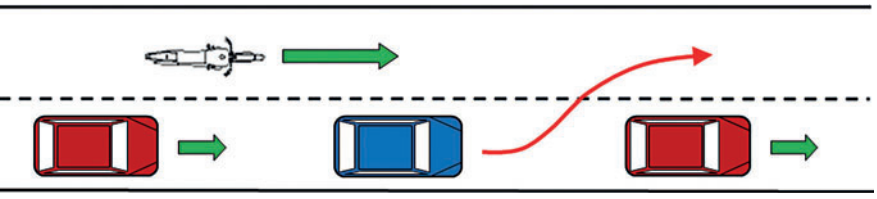
BASt will explore special aspects of camera monitor systems in detail in further studies. On the one hand, the man-machine interface is intended to be analysed in detail, including various monitor positions, perception speeds and discrimination capacity when using camera monitor systems. These results can also become the basis of requirements for future systems. On the other hand, the question of how typical and special weather conditions and light situations as they can occur in real traffic are to be taken into account will be studied as regards type approval for these systems.

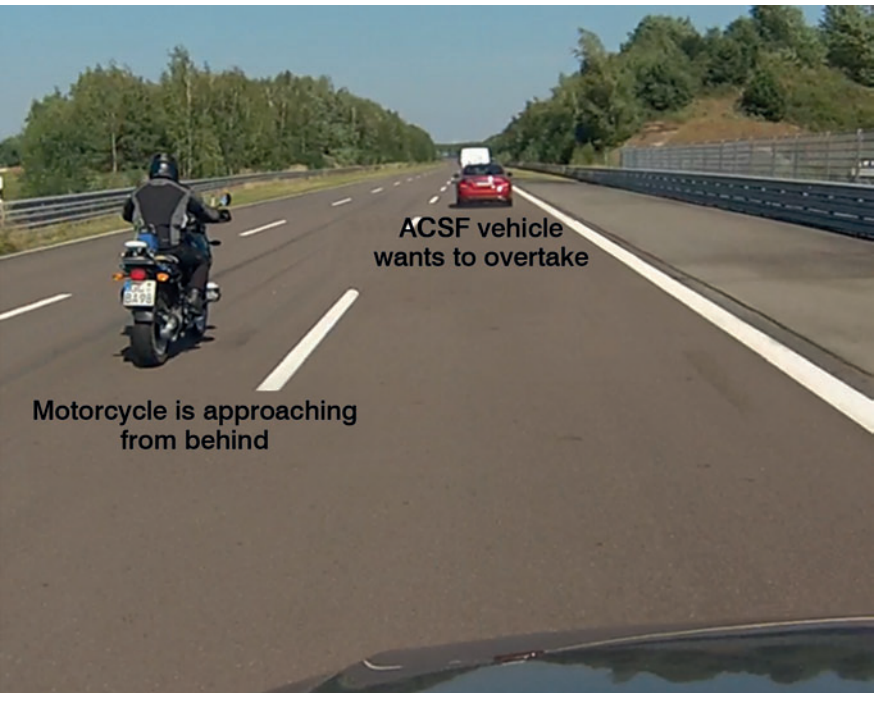
Camera mounted on the original spot of a wing mirror

Maxim Bierbach
Mechanical engineer
“Active Vehicle Safety and Driver Assistance Systems” section

Requirements for automatic steering

According to UN Regulation Number 79 on uniform provisions concerning the approval of vehicles with regard to steering equipment, automatic steering functions are only permissible for speeds of up to 10 km/h, with the exception of discontinuous, corrective steering functions. As the technology for driver assistance systems and automated driving has developed further, however, it is technically possible to deploy automatic steering functions even at higher speeds.





Example of a functional test for an ACSF vehicle during an automated overtaking manoeuvre: the red vehicle's automated lane-switching mode (overtaking manoeuvre) must be switched off when the motorcycle has already come too close

Oliver Bartels
Physicist
"Active Vehicle Safety and Driver Assistance Systems" section

In addition to enhancing comfortable driving, these systems are expected to contribute to improving road safety by preventing accidents. This road safety potential can only be tapped, however, if automatic steering systems are designed to be safe enough and show a minimum of performance. It is intended not to allow potential risks specifically caused by automatic steering to arise or to minimise them.

For the reasons above, an informal working group at the United Nations Economic Commission for Europe (UNECE) is working to revise Regulation Number 79 with regard to "Automatically Commanded Steering Functions" (ACSF).

The aim is to be able under certain conditions to approve them also for higher speeds. Technical requirements for automatic steering and test procedures as required for automotive engineering regulations are being developed. Structural safety systems are of special significance when activating automatic steering, depending on whether the driver has his or her hands on the steering wheel or not. The brake also plays an important role, though the focus here is on developing regulations for steering systems: on the one hand, brakes are important when longitudinal control is to be continuous as well, for example, when not only a lane keeping assistance system is in place but also cruise control and adaptive cruise control systems. Braking is also important when a critical situation arises suddenly during automated driving and it is no longer possible to transfer back to the driver because of the limited time available or because of the driver's improper behaviour, for example a lack of alertness.

In these cases, emergency braking systems need to be capable of handling the situation independently. There is, however, a qualitative difference to the emergency braking systems that are currently available where braking is usually preceded by a warning phase and which must include a potential driver reaction such as steering to avoid collisions.

Assessing emergency braking systems in field tests

The European New Car Assessment Programme, better known as Euro NCAP, has dedicated itself to assessing the safety of new vehicles in a differentiated manner.

Euro NCAP awards zero to five stars per vehicle. This rating is based on tests in four different categories (passenger safety, children's safety, pedestrian safety, safety based on assistance functions). Since 2014, emergency braking tests have been included in addition to the crash tests which now contribute to the star rating. BASt conducts all tests on its own.

Euro NCAP tests series production vehicles straight from the factory. Once a car is selected from the factory and transported to BASt, in this case for example a Mercedes E220d, it will be equipped with measuring technology and driving robots that are capable of steering the vehicle automatically with an accuracy of five centimetres. The tests are conducted at the test site of the RWTH Aachen university in Aldenhoven near Düren.

A vehicle which succeeds in automatically avoiding a collision with other passenger cars, protects not only its own passengers but also other road users. This is tested by driving onto a target object made of a soft material that for radar sensors, however, looks like a car. In addition to being used as a stationary object, it can also be moved with the help of a special trailer to simulate a slow-moving vehicle ahead or a vehicle that is suddenly decelerating.

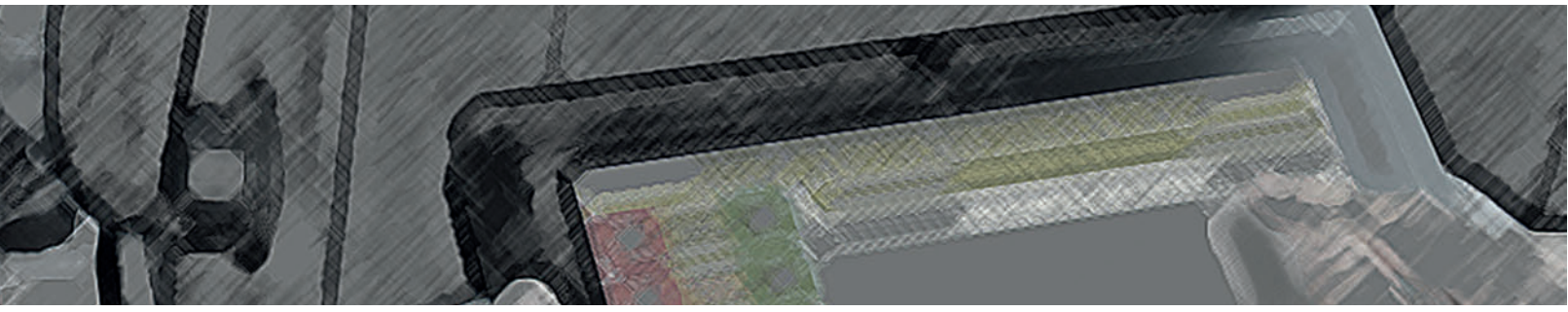
Preventing accidents involving pedestrians is of particular significance for road safety. The test object for these cases consists of a dummy with moving legs which is drawn across the road in order to realistically simulate four different collision situations: varying running speeds, adult or child, setting off early or late.

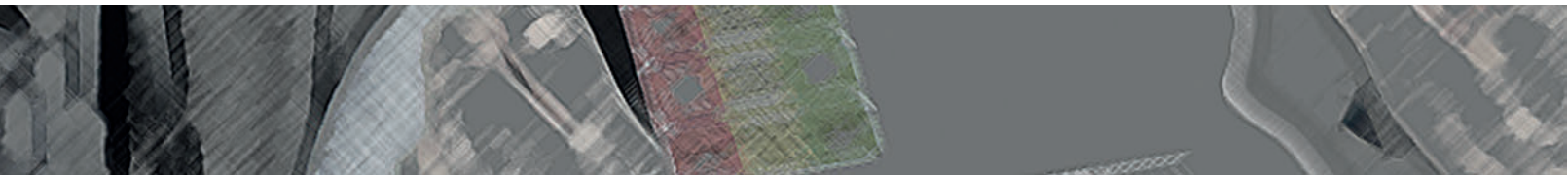
The vehicle BASt tested here avoided nearly all collisions with a stationary car, a slow-moving car ahead and a braking car. In a total of 33 test situations, there were only three collisions, which suffices to reach the full score for the "emergency braking - city" criterion and almost the full score (2.94 of 3) for the "emergency braking -outside cities" criterion. Accidents involving pedestrians are in general much more difficult for technology to avoid as there is hardly any possibility to brake in time at high vehicle speeds. The rating system, however, takes this into account and thus what is currently the second-best score of all vehicles tested was achieved in this category: 4.2 of 6 points. A summary of all tests BASt conducted can be found on Euro NCAP's YouTube channel.

Euro NCAP's YouTube channel

Dr Patrick Seiniger
Mechanical engineer
Deputy head of "Active Vehicle Safety and Driver Assistance Systems" section

Road Safety





Optimising practical driving tests

Driving tests are a central measure in the system of preparing novice drivers. On the one hand, their purpose is to only permit novice drivers with sufficient driving competence to take part in motorised road traffic (selection function), on the other these tests provide standards for road safety preparations, especially in driver training (control function).

Extensive research and development projects have been conducted over the past few years to improve both parts of the test – theory and practice. At the outset, the efforts to optimise the tests focused on the theory part of the tests. Test content and methodology were adapted in a number of steps to align them with current scientific standards.

The introduction of theory tests on a computer created the basis for the tests to include components of driving competence that previously could not be tested sufficiently – especially with regard to traffic perception and averting danger – using computer-generated dynamic scenarios in road traffic.

Practical driving tests were also optimised in a multi-stage approach. A number of studies were conducted and additional input provided by TÜV|DEKRA arge tp 21, in addition to projects commissioned by BASt.

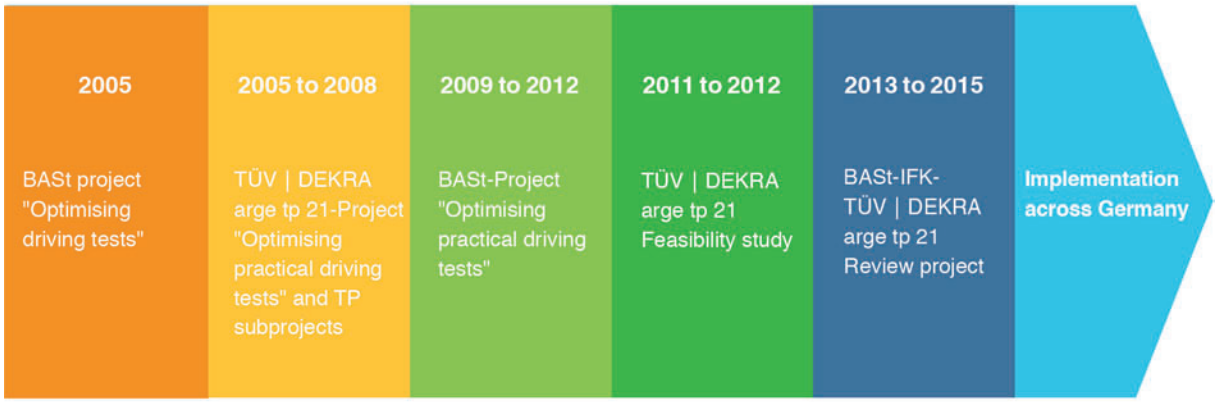
Scientific basis

The science-based model of an optimised practical driving test that was developed on behalf of BASt by the Institute for Applied Research for Family, Children and Youth (Institut für angewandte Familien-, Kindheits- und Jugendforschung, IFK) at the University of Potsdam [1] was an essential element in this development process. As a first step, selected driving competence models from traffic psychology were analysed together with the contents of training and testing documents. Based on these findings, possibilities to model and measure driving competence were discussed, and a competence model was outlined to theoretically determine the content of tests. This constituted the basis for defining requirement standards for an optimised practical driving test and minimum standards for the performance of candidates for a driving licence.

List of driving tasks and electronic test protocol

An expert body was established in the course of the project to develop a list of driving tasks based on these preliminary analyses. This body included representatives of examining organisations and the association of driving instructors, as well as scientists. The list of driving tasks developed defines requirement standards for driving tests in the form of situation-specific driving tasks and observation categories independent of a specific situation. It also contains criteria for result-oriented performance evaluation, an overall evaluation of competence as well as criteria for decision-making as such.

A content and method-based concept was developed for an electronic test protocol, an „e-test protocol“, to implement the updated requirement, evaluation and documentation standards. This concept also comprises the design of the e-test protocol based on hardware and software



Stages in the optimisation process of practical driving tests (image: author's representation in analogy to [2])

ergonomics. The computer-aided documentation of test performance is intended to support driving examiners in planning the testing procedure and evaluating the driving conduct of candidates for the driving licence. Furthermore, an optimised performance feedback for the candidates and improved possibilities for scientifically evaluating the optimised practical driving test are expected.

Manual on the driving test system (practice)

In the scope of the project, recommendations were developed on the content and methods of an (operational) concept for a continuous management, quality assurance and further development of the practical driving test. The „manual on the driving test system (practice)“ (Handbuch zum Fahrerlaubnisprüfungssystem (Praxis)) describes institutional structures of optimised testing systems and test methods and processes, including the requirement, evaluation and documentation standards necessary.

Review

BASt commissioned additional studies on instrumental evaluation and field tests concerning optimised testing methods [2]. Experts tested the implementation, requirement and evaluation standards using the e-test protocol during a total of about 9,000 real driving tests. The results confirmed the theoretical and methodological concept of the optimised tests. The content and the structure of the list of driving tasks and the definition of competence areas and evaluation criteria have proved to be viable.

Overall, the results of objectivity, reliability and validity studies provide proof that the quality of the method is satisfactory and that the optimised tests are ready for use. The tested model procedure for practical driving tests is recommended from a scientific point of view. The decision to implement them across Germany is pending.

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Electronic test protocol in use (image: TÜV|DEKRA arge tp 21)

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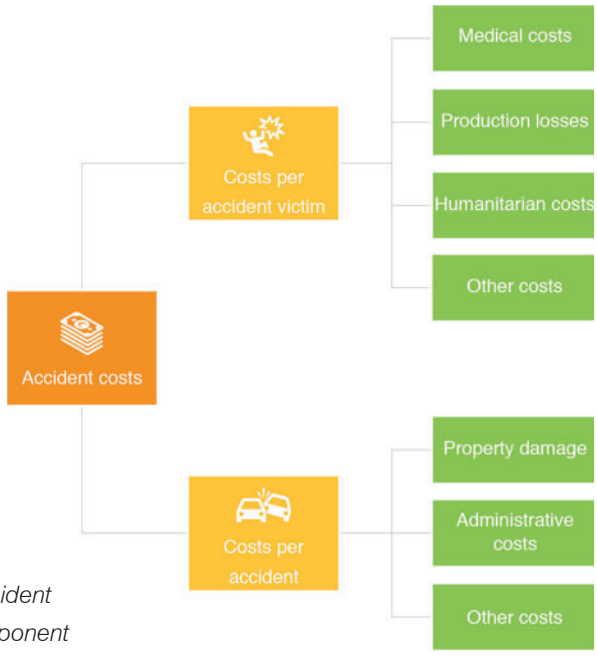
Improved road safety for vulnerable road users

Developing holistic methods for analysis and evaluation

When does insecure conduct in road traffic lead to accidents? What factors play a role and what are the causalities? Appropriate analytical methods and perhaps even new methods are necessary to answer these questions. In the scope of the HORIZON 2020 European Research Framework Programme, BASt is participating in a research project focusing primarily on improving and further developing methods to analyse the road safety of vulnerable road users and evaluating the costs of accidents involving these road users: "In-depth Understanding of Accident Causation for Vulnerable Road Users" (InDeV) (www.indev-project.eu).

The project primarily aims to give recommendations on how and what methods to deploy in order to better understand the relationship of cause and effect leading to accidents in road traffic. A particular focus was placed on further developing technical approaches to use video monitoring for road user behaviour and critical situations that may subsequently lead to accidents. As such situations occur much more frequently, analysing them can lead to new significant results faster. The project especially includes methods for holistically evaluating the costs of accidents which are intended to be used as the basis for a reliable cost-benefit analysis of road safety measures. The first step of this project consisted of critically examining the accident cost calculation methods of European countries. The project was able to determine that neither the methods nor the underlying data or definitions are uniform. What is more, almost no country takes the special issues of vulnerable road users into account.

In a published project report [1], BASt shows how accident costs could ideally be calculated. By the end of the project in 2018, BASt will also develop approaches for better including the issues of vulnerable road users also in evaluations on the basis of accident costs.



Break-down of accident costs by cost component

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InDeV Homepage

HORIZON 2020

Serious injuries in road traffic

In 2015, 67,706 people were seriously injured in road accidents [1]. According to official accident statistics, victims of accidents are considered seriously injured if they are treated in a hospital for a minimum of 24 hours. The physical consequences of accidents among those injured individuals vary greatly, especially as regards the severity of the injuries.

Road accident casualties with especially severe injuries are of great significance for road safety activities, as they generally cause high macro-economic costs, and the humanitarian costs – suffering and mourning – are also high among this group.

What is more, there are indicators that the positive reduction rates observed in the number of fatalities in road traffic over past decades, do not apply to the number of seriously injured casualties. Instead, their number has probably stagnated [2].

So far, there is only limited knowledge about seriously injured casualties, because no nation-wide data is available in Germany to supplement information on the severity of injuries beyond the 24-hour criterion recorded by the police.

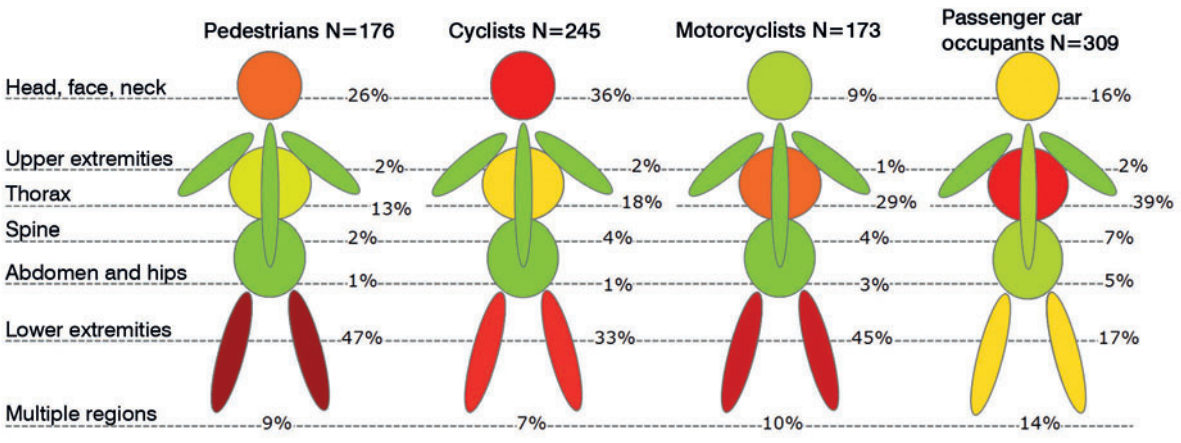
European Commission sets the course

The European Commission strives to harmonise the recording of seriously injured casualties of road accidents in Member States and for this purpose has defined the severity of injuries for this purpose. The Member States have agreed on a Maximum Abbreviated Injury Scale (MAIS) as a measurement tool for the severity of injuries; it is a scale of survival probability.

The scale differentiates among six stages of severity (1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, 6 = maximal). A threshold value of MAIS3+ was determined for recording "serious injuries".

A study [3] funded by the European Commission aims to shed light on the circumstances under which serious injuries occur. On the basis of a number of European accident data bases, data was compiled and analysed for about 78,300 seriously injured casualties (10,300 pedestrians, 37,200 cyclists, 9,200 motor cyclists and 21,600 passenger car occupants) from nine European countries. The graphic shows the results for Germany based on data from the German In-Depth Accident Study (GIDAS) for the 2005 to 2015 period. For accident victims with multiple injuries the graphic deploys the body region which was injured the most seriously. In cases of two or more body regions being affected equally severely, "multiple regions" was used in the code.

A further analysis of typical accident scenarios revealed, for instance, that thorax injuries in motorcyclists occurred primarily in single-vehicle accidents and in collisions with a solid object. By contrast, injuries of the lower extremities frequently occurred in collisions with passenger cars. Knowledge of the specific circumstances of accidents is useful when specific preventive measures are to be developed in the future.



Percentages of the most seriously injured body regions (MAIS3+) for pedestrians, cyclists, motor cyclists, and passenger car occupants (GIDAS, accident years 2005 to 2015)

Such comprehensive and detailed analyses of accident situations for Europe as a whole cannot be accomplished at the moment. The countries' data collection methods vary too much from one another. The introduction of a Europe-wide uniform definition of "serious injuries" may be considered one important initial step towards homogenising accident data recorded in Europe.

The European Commission asked all Member States in 2015 for the first time to provide data on the number of serious injuries in 2014. At the moment, data is being compiled for the reporting year 2015.

A Europe-wide survey conducted by the Forum of European Road Safety Research Institutes (FERSI) [4] analysed whether the Member States collect the necessary data and if so, what methods they are using to collect or determine the data. The result showed a very heterogeneous image. Currently, only a limited number of Member States is capable of providing information on the number of serious injuries as defined by MAIS3+. The individual countries use different methods, making it difficult to compare the data across countries. Additionally, the countries are confronted with differing challenges that they will need to meet in the years to come.

In Germany, a working group was set up at BASt to identify the number of serious injuries in road traffic. Its members include representatives of TraumaRegister® of the German Society for Trauma Surgery (Deutsche Gesellschaft für Unfallchirurgie, DGU), the German In-depth Accident Study (GIDAS), the German Insurers Accident Research (Unfallforschung der Versicherer, UDV) and experts in official accident statistics. The working group aims to develop methods to extrapolate the number of serious injuries as defined by MAIS3+ for all of Germany on the basis of existing data sources, and to evaluate the newly gained information as a starting point for developing future road safety measures. The main data sources were GIDAS and TraumaRegister DGU®.

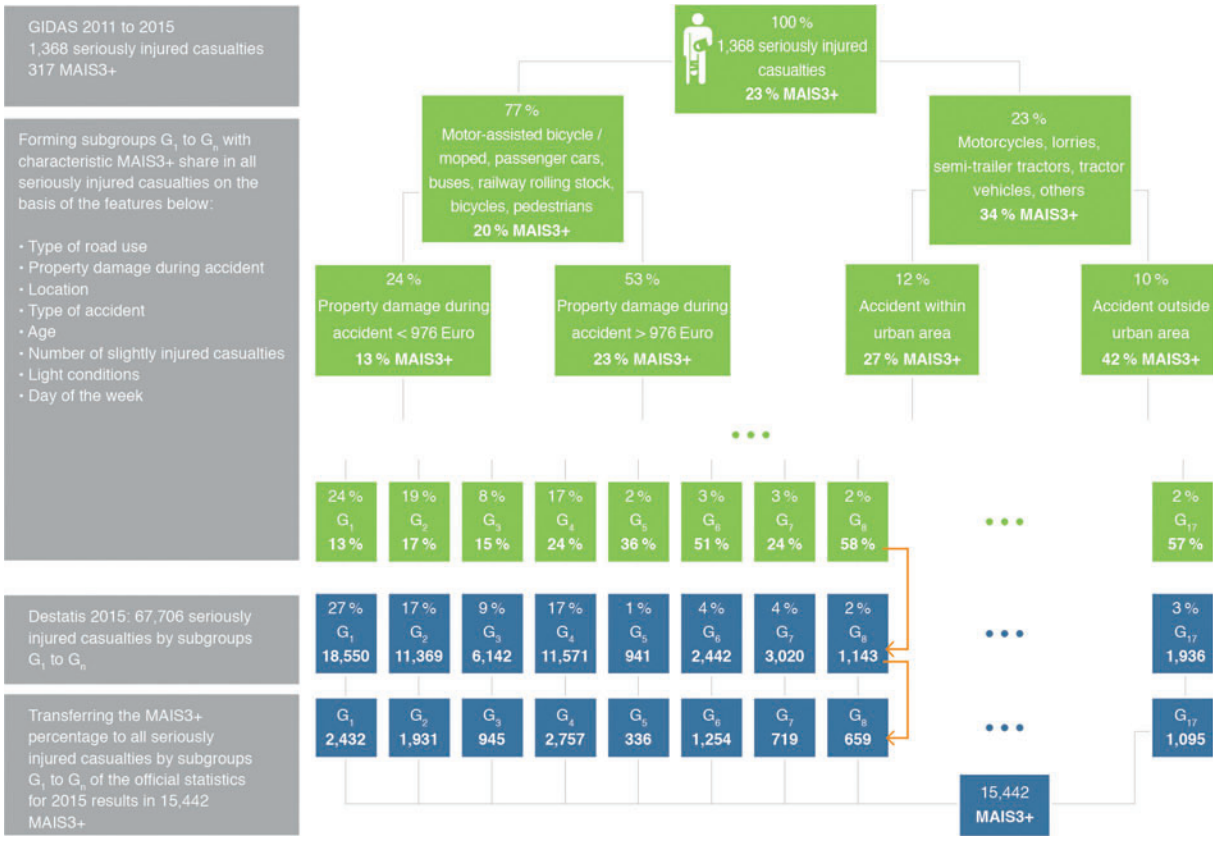
Projecting the number of serious injuries in Germany

In the scope of the GIDAS project, the documentation of road traffic accidents involving casualties focuses on in-depth surveys in two German regions (Hannover region and Dresden region). Technical as well as medical accident data are collected. As GIDAS data collection comprises a very detailed representative sampling of police records of road accidents, and because the surveyed regions are considered to have exemplary character for Germany to the greatest possible extent, this data is appropriate as a basis to extrapolate the number of serious injuries for all of Germany. The absolute number of serious injuries can be determined as well as the proportion of serious injuries according to the European scale (MAIS3+) compared to all serious injuries (24-hour criterion). The data can also provide more detailed information – such as type of road use, location of accident – that is relevant for identifying high-risk groups. This in turn is relevant for developing target group-specific road safety measures.

A decision tree procedure was selected for projecting the number of serious injuries. This method aims to differentiate subgroups according to the severity of their injuries on the basis of risk factors, such as type of road use, location, time of day. The risk factors are restricted exclusively to attributes that are deployed by both national statistics and GIDAS. The initial sample constitutes all serious injuries recorded by GIDAS (inpatient treatment for more than 24 hours) with known MAIS and risk factors documented for the 2011 to 2015 period. The percentage of serious MAIS3+ injuries of all serious injuries was determined for each subgroup. A total of 17 subgroups (G1 to G17) were differentiated that exhibit characteristic MAIS3+ proportions.

For the projection itself, the MAIS3+ numbers of the serious injuries across subgroup G1 to G17 were extrapolated in accordance with the official accident 2015 statistics. In this way, the number of serious injuries can be identified per individual subgroup and also in total. For Germany, the total number amounts to 15,442 serious injuries in 2015. This corresponds to a percentage of 22.8 per cent of a total of all 67,706 victims of accidents receiving inpatient treatment. In 2014, the figure was slightly lower at 15,392 serious injuries according to the MAIS3+ scale (22.7 per cent of all serious injuries).

A second extrapolation algorithm was developed on the basis of the TraumaRegister DGU® data. The TraumaRegister DGU® includes all patients in the hospitals participating in the register who are admitted through the trauma room and subsequently



Decision-making process and extrapolation

receive intensive care, as well as patients arriving at the hospital showing some vital signs but dying before they could be admitted to the intensive care unit. The register has become established all across Germany and enables a relatively complete coverage of all road casualties. The specific challenge in extrapolating the number of serious injuries is in how to determine the proportion of patients whose injuries fulfil the MAIS3+ criteria but not the criteria for inclusion into the TraumaRegister DGU®, for example when the patients do not need to be treated in an intensive care unit of a hospital. It is also important to filter victims of road traffic accidents out from the total number of accident victims – for example sports-related accidents – and to adjust for lost data, for example the number of patients treated in hospitals not taking part in TraumaRegister DGU®. Taking these deviations into account as correction factors, the number of serious injuries in the current 2015 reporting period totals 15,838, while in 2014 the number was 16,694.

The "true" number of serious injuries is assumed to be within the range set by the values identified by GIDAS and TraumaRegister DGU®.

What other steps need to be taken?

Initial steps towards harmonising the recording of serious injuries have been taken at the European level. In terms of implementation, there are numerous challenges to be overcome in the Member States in the years to come before reliable results can be reported that can be compared across Europe.

In Germany, the efforts to optimise and validate the two extrapolation algorithms need to be continued. Filtering out high-risk groups from the total number of seriously injured casualties is an additional objective. GIDAS data is expected to provide differentiations by type of road use, location of the accident, and the victims' age and gender. Serious injuries can be differentiated by the type of road use on the basis of the TraumaRegister DGU®, but it is also possible to correlate the cases with medical parameters, such as injury pattern, length of treatment and after-effects of injuries. These are crucial to gain a comprehensive understanding of the situation of seriously injured people and of certain high-risk groups. The new information gained in this manner can be instrumental in supporting the development of innovative and target group-specific road safety measures, thereby contributing to reducing the

number of serious injuries and the severity of the injuries.

All in all, an important step has been taken to develop new ways for successful road safety activities on the basis of the European Commission's initiative and the specific implementation in Germany to identify the number of serious injuries. Continued cooperation and a consensus among experts at the national and the international level will continue to play a decisive role in the future.

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Routine road maintenance: workload and age structure

While routine road maintenance activities are an unavoidable disruption for road users which usually need to be accepted for only a short period of time, this type of work is a significantly higher and longer-lasting burden for the road maintenance workers themselves. Road maintenance work is considered the activity with the highest risk of accidents, a fact mostly unknown to the general public. The work is physically strenuous and dangerous. This can have adverse effects on workers' health, safety and well-being.

This is why BASt has awarded contracts for a series of studies over the past few years to research the physical work aspect of routine road maintenance. Three supplementary studies have now also been conducted focusing specifically on the psychological effects of routine road maintenance work.

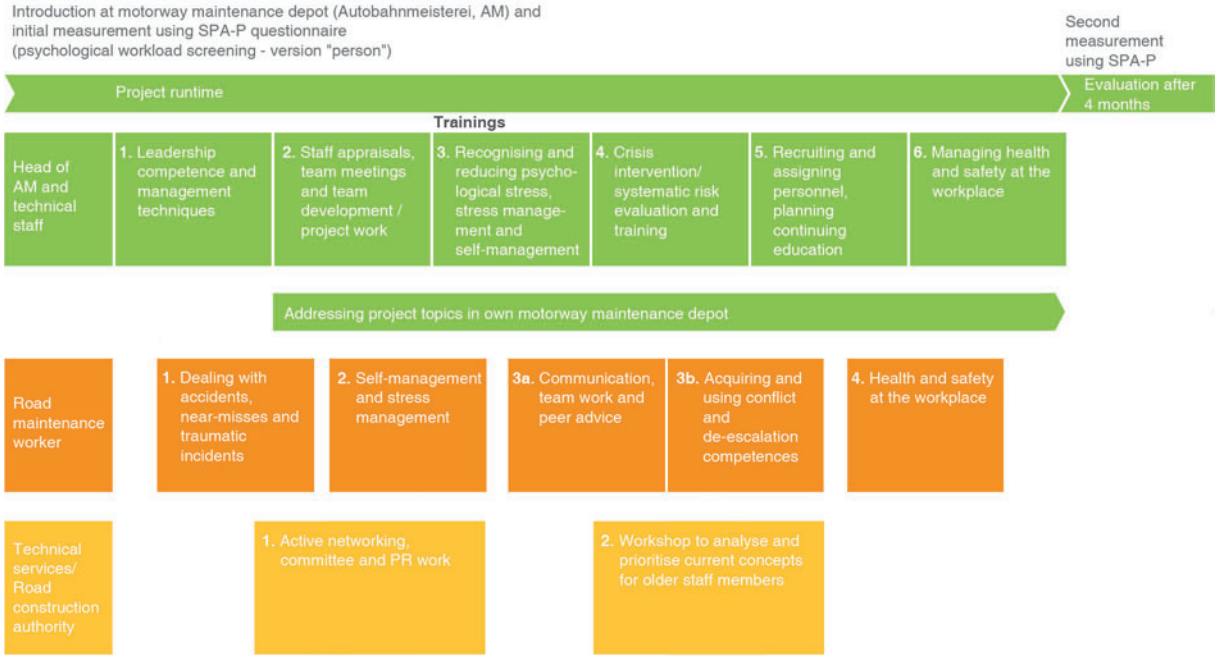
Workload

After a study identified and described the most important areas of psychological strain [1], a pilot study tested the proposed measures for reducing the psychological strain [2]. 143 road maintenance workers and eight heads and deputy heads of four maintenance depots participated in the study, together with representatives of road construction authorities.

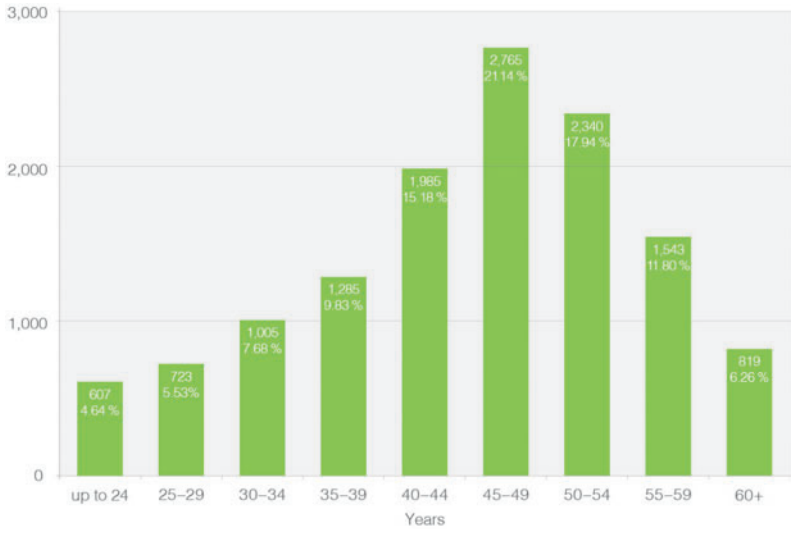
Using a standardised procedure, the road maintenance workers' strain and stress levels were identified before and after training sessions. The findings showed that the training sessions for the road maintenance staff primarily led to reduced stress levels. It also became apparent that so-called 'soft' factors, such as inadequate information flow, lack of support from superiors and low appreciation of their work by the general public, were perceived by the road maintenance workers as a particular strain. The pilot study resulted in determining areas for action for widespread use. However, any measure needs to be embedded into a comprehensive health management programme, and the overall organisation needs to show its clear intent to integrate the thematic area and support it by taking appropriate resource decisions.

Age structure

An additional project [3] studied the impacts of the demographic shift on routine road maintenance. The study shows the current situation across Germany in the individual Länder and provides projections for the future development of the work force.



Project workflow (image: author's own representation in analogy to [3])



Age structure of road maintenance staff in the Federal Republic of Germany, updated 2013 (image: author's own representation in analogy to [3])

According to the study, in ten years' time routine road maintenance will need to be accomplished by workers older than 50 years of age. It became clear that the strenuous workload over many years can be expected to result in significant adverse physical and psychological effects making it difficult for the staff to carry out the heavy work routine road maintenance entails. In the scope of interviews among road maintenance staff conducted in all German Länder, the road maintenance workers stated that all in all they were content in their work but that they were worried about the end of their productive years due to the intense psychological and physical strain.

Areas for action were derived to maintain the performance level of routine road maintenance in view of the effects of the demographic shift. In this context, the focus is on maintaining and promoting employees' health in the scope of health management programmes, accompanied by age-critical work organisation and design as well as measures for human resources marketing.

Outlook

There is no information on whether the recommended measures – based on the results and insights gained in the three studies described here – have been implemented. It would therefore make sense to evaluate the workload again in the near future.

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Behaviour in tunnels: automatic firefighting systems

Equipping road tunnels with stationary firefighting systems as an additional safety element is increasingly being considered as an option all across Europe. One good reason to do so can be found in the results of a number of studies showing the effectiveness of these systems in containing a fire in a tunnel and keeping it at a low level until the rescue services arrive. In this context, it is important that the systems are activated at an early stage. There were no studies available so far, however, on how the onset of these systems influences the behaviour of tunnel users in rescuing themselves. This is why BASt conducted a series of studies to investigate the influence of an activated system on human behaviour. The key parameters of the studies were reaction and escape speed.

As real-life experiments can rarely be conducted because the tunnels need to remain available for road transport and because only few tunnels are equipped with automatic firefighting systems so far, the influence of an activated system on tunnel users was initially tested in virtual reality (VR) tests. Each trial participant experiences the scenario in a virtual tunnel as the driver of a passenger car, coming to a halt inside the tunnel behind a lorry on fire generating heavy smoke, and hearing an announcement to vacate the tunnel. In order to research differences in behaviour, one participant experiences the scenario with an activated firefighting system while another experiences it without any. Though the activation involves significantly restricted visibility for the individual trial participants both inside and outside their cars, in the VR activation of the firefighting system had only little influence on the time period before the participants left their cars or the rest of their escape-related behaviour.

The VR study provided important initial insights into how tunnel users experience the activation of a firefighting system and how they behave, and it represented the visual and auditory effects of such a scenario in a realistic manner. Supplementary real-life tests were conducted to include haptic effects such as wet and cold conditions. These took place in a comparable test setting in a road tunnel with an installed automatic firefighting system using compressed air foam (CAF) and a water mist system (WM), respectively. The real-life tests confirmed the results of the VR tests in terms of visibility. The announcement to vacate the tunnel was not clearly audible when the firefighting system was activated. There was a tendency to wait longer before reacting and leaving the vehicle in the flight behaviour of trial participants confronted with an activated system, but they were then faster in escaping from the tunnel. The tests also showed that not all trial participants followed the request to escape and that some tried to make an emergency call, although the announcement to vacate the tunnel could have been seen as an indication that rescue services had already been alerted.

All in all, the results indicate that though the activation of a firefighting system leads to significantly restricted visibility in a road tunnel, it has no significant adverse effect on the flight behaviour of tunnel users, provided that parts of the infrastructure of the tunnel are coordinated with the activation of such a system. It is particularly important to ensure a clearly audible announcement, which where appropriate should include information about the activation of a firefighting system, so that even people within direct reach of the firefighting system understand the announcement and leave their vehicles. The findings of the study have been collated in Volume B 135 of BASt's reports.

Firefighting system of the water mist type at the time of activation

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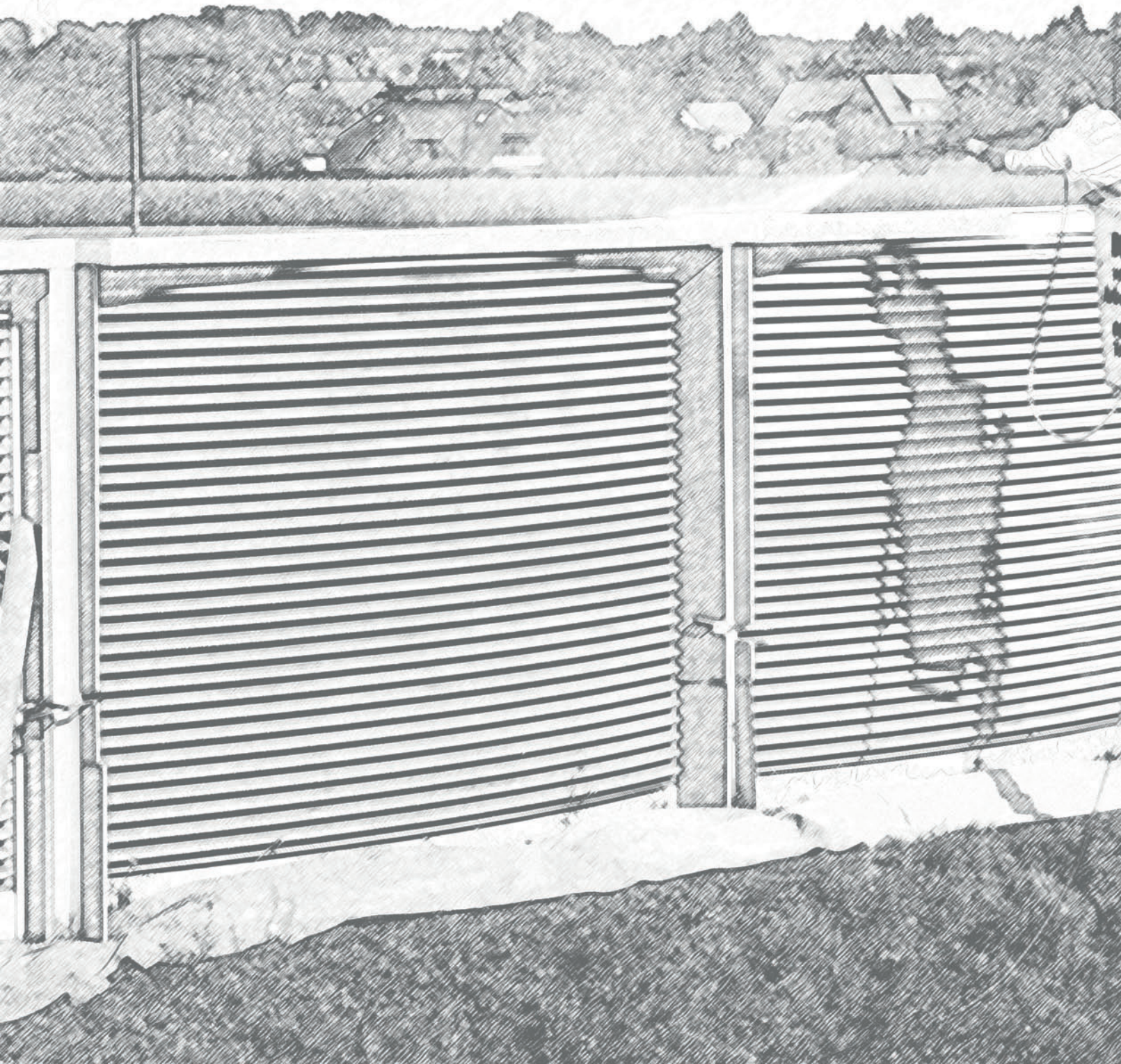
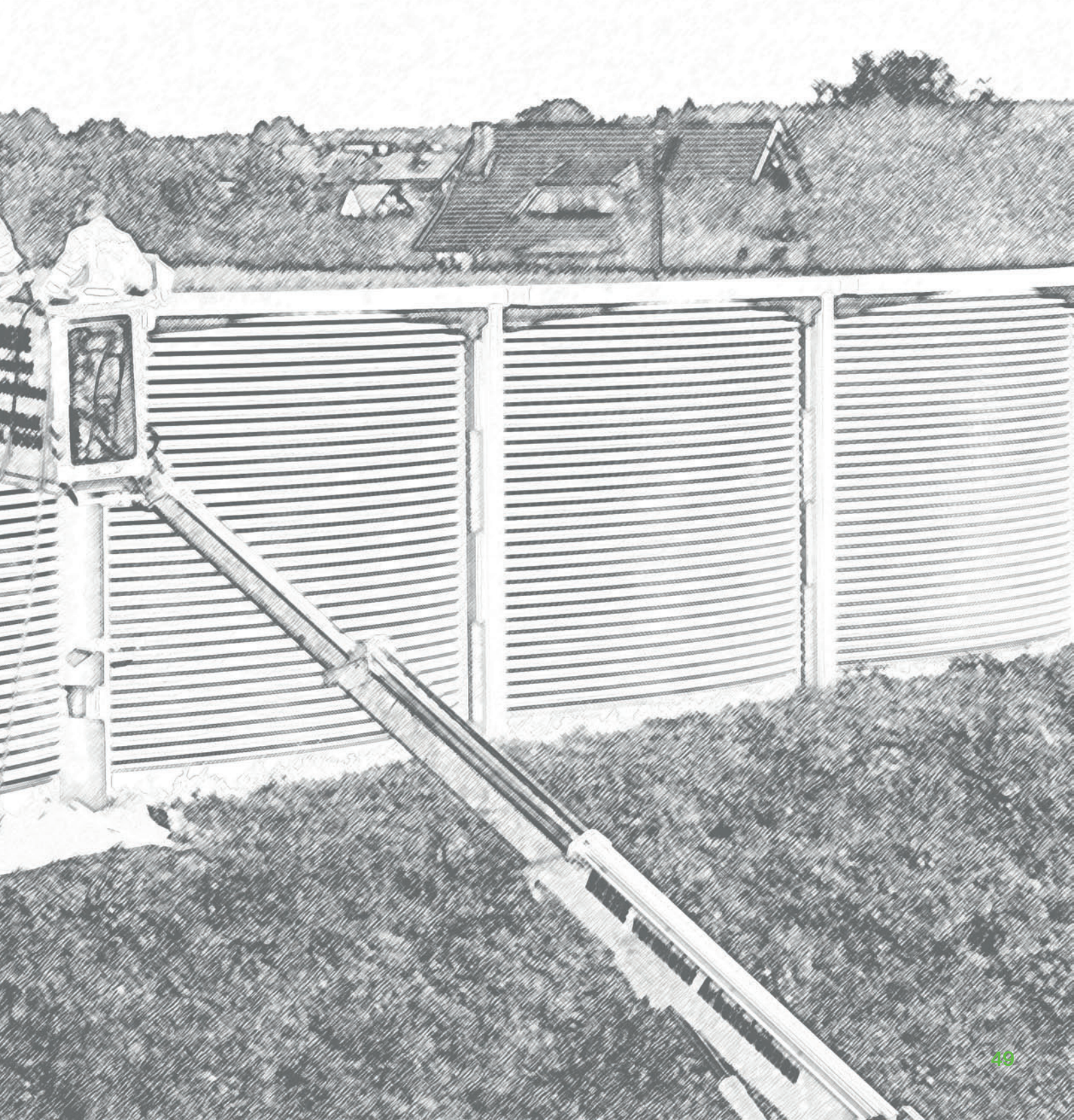
Environment





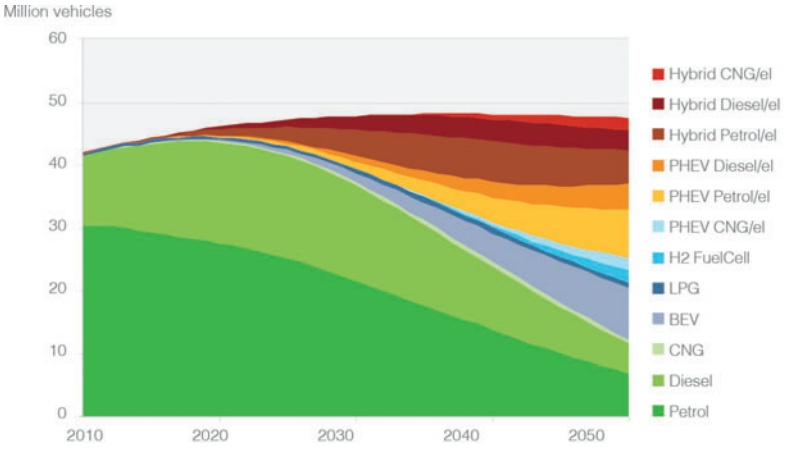
Mobility 2050 in Germany

Trend scenarios on the development of road transport emissions and vehicle population

The mobility sector has been subjected to continuously progressing technological changes as a consequence of the further development of national and international legislation on reducing of the emissions of pollutants and greenhouse gases, especially in urban areas. Besides modern drive systems and concepts in automotive engineering that are being newly developed, it is also the progress achieved in digitising the road transport sector that increasingly characterises mobility. The incremental market penetration of alternative drive technologies and energy sources in combination with innovative transport strategies will result in a significant reduction in road transport emissions and energy consumption by 2050. BASt uses the TREMOD (Transport Emission Model) to calculate emissions and to answer emission-relevant questions as well as to prepare political measures. The model has been expanded to include data sets on alternative drive technologies and energy sources in order to enable the calculation of trend scenarios for the development of road transport emissions, mileage and vehicle population of passenger cars by the year 2050.

TREMOD

Motorised transport in Germany covering the different modes of transport – road, air, rail, inland waterways – is mapped in the TREMOD emission calculation model. It accounts for transport services, mileage as well as energy and fuel consumption and associated emissions of air pollutants and greenhouse gas emissions for the period ranging from 1960 to 2050. TREMOD's results are based on real emission and mileage data of registered vehicles, and in the trend scenarios they are based on assumptions about future developments in automotive engineering, updated emission-related legislation and forecasts for implementing political goals and funding initiatives. Motorised road transport is covered in particular detail because of its essential significance. About one third of pollutant emissions and about one fifth of greenhouse gas emissions can be attributed to this sector.



Composition of passenger car fleet 2010 to 2050 (CNG: Compressed Natural Gas, PHEV: Plug-In Hybrid Electric Vehicle, LPG: Liquefied Petroleum Gas, BEV: Battery Electric Vehicle)

Trend scenario 2050

In some cases, the results of the calculations for the 2050 scenario show significant changes with regard to CO_2 emissions, mileage and fleet composition compared to the baseline year 2010. According to the forecasts, the total number of passenger cars registered for use in transport will remain almost stable at about 45 to 48 million vehicles by 2050. A trend towards alternative drive systems becomes apparent as of 2020. The percentage of vehicles with conventional drive systems (diesel and petrol) will decrease continuously as of 2020, while the market penetration of alternative drive systems will increasingly gain significance from that point onwards. The scenario shows that various types of hybrid systems will be the first to enter the passenger car market, while vehicles powered solely by electricity are estimated to only start having a relevant share in the market starting in 2030. According to TREMOD, the percentage of conventionally powered vehicles in the German fleet of passenger cars will drop to about 20 per cent by 2050.

The mileage of vehicles equipped with alternative drive systems will develop more or less similarly to the development in the composition of the vehicle fleet. The trend scenario indicates that an increase in total vehicle mileage by about ten per cent to 660 billion kilometres can be expected by 2030 compared to the baseline scenario of 2010. In this time period, the percentage of mileage by vehicles with alternative drive systems is estimated to rise to about 25 per cent. By 2050, the share of vehicles with

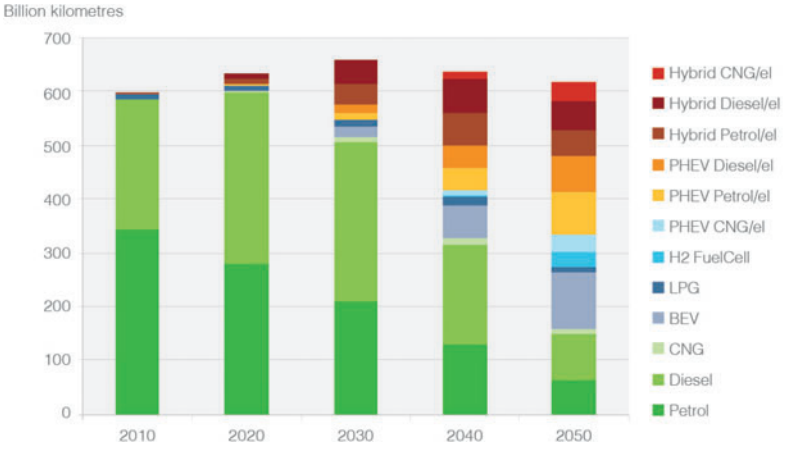
such drive systems in the total mileage will amount to about 75 per cent. In a parallel development, the total mileage of passenger cars will decrease between 2030 and 2050 as a result of demographic developments among other factors. It will gravitate back to the value of about 600 billion kilometres per year in the baseline year 2010. According to the projections, vehicles powered by hydrogen fuel cells will only contribute visibly to the total mileage on German roads with about five per cent in 2050.

On the basis of a changing composition in the vehicle population and the developments in mileage, the trend for road transport CO_2 emissions caused by passenger cars is as follows: an increasing market penetration of vehicles with alternative drive systems will lead to reduced CO_2 emissions per vehicle and thus for the entire vehicle fleet. A reduction of almost 20 per cent in the CO_2 emissions to about 81,000 kilo tonnes per year can be expected by 2050, despite slightly increasing mileage compared to the baseline scenario of 2010.

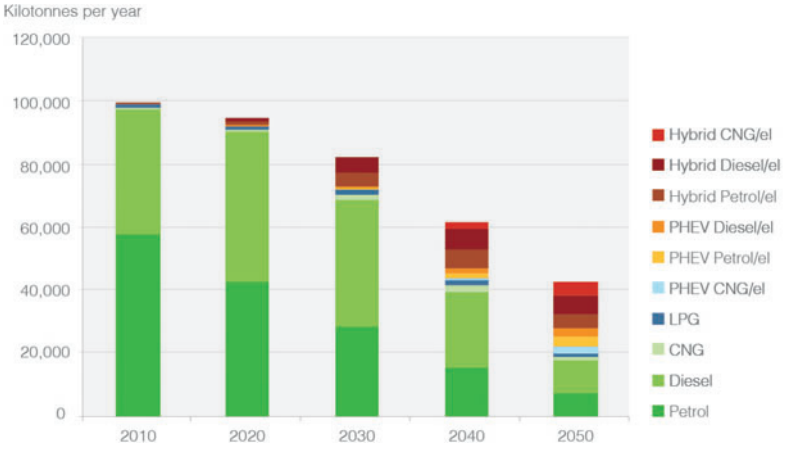
This trend will manifest itself more strongly as of 2030 because of the onset of decreasing annual mileage. In combination with an increasing market penetration of alternative drive systems, this will lead to a reduction by half of CO_2 emissions by passenger cars by 2050 compared to 2030, about 40,000 kilo tonnes per year.

Outlook

Adding data sets on emissions, mileage and vehicle population of vehicles with alternative drive technologies to the TREMOD software enables the projection of transport scenarios up to 2050. The calculations are based on current vehicle population data as well as assumptions on developments in mileage and market penetration of modern drive systems. Political decisions are also taken into account. The quality of the results always depends on how recent and differentiated the input data base is; the model must be continuously further developed and maintained.



Passenger car mileage by drive system 2010 to 2050



Passenger car CO_2 emissions 2010 to 2050

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Photocatalytic surfaces of noise abatement walls

Solving the nitrogen oxide problem on heavily used transport routes?

Air pollutant measurements all across Germany have shown that nitrogen dioxide levels far exceed the annual average limit value for the protection of human health, especially at sites close to road traffic. Though nitrogen dioxides within vehicles were reduced significantly several years ago by means of inner-engine measures and after-treatment of exhaust gases, nitrogen dioxide immissions have not decreased or not decreased to the expected extent.

Short-term and mid-term measures are being discussed which could reduce pollutants beyond the scope of automotive engineering. They include using titanium oxide (TiO_2) which can be applied to surfaces as a suspension or added directly to cement during the manufacturing of concrete. The influence of UV(A) radiation activates TiO_2 and reduces pollutants such as nitrogen dioxide. Titanium dioxide is a photo catalyst which is not consumed during the chemical reaction, so that the oxidation process can be repeated as often as desired. During full reaction, nitrogen dioxide is turned into water-soluble nitrates and organic pollutants into carbon dioxide and water. A high potential to reduce nitrogen dioxides has been shown under laboratory conditions. In-situ experiments are rare, however, and they have arrived at highly differing conclusions and effectiveness levels in their findings.

Pilot programme

In the scope of a pilot programme spanning a number of projects, the potential of titanium dioxide to reduce nitrogen dioxide is being tested under real conditions at different engineering structures of highly frequented transport routes. There have been studies at three locations on different structures: on a noise abatement wall on the A1 motorway near Osnabrück, on a road surface on the B433 in Hamburg and in a tunnel on the A113 in Berlin.

Different configurations of photocatalytically active surfaces are used in the three projects. A TiO_2 suspension was applied on the noise abatement wall. The street was paved with a surface made of open porous asphalt with TiO_2-rich cement sludge added into its top few centimetres. It is planned to install boxes in the tunnel, closed to the tunnel environment; in their interior, the tunnel air pumped into the boxes and containing pollutants will be transported to the surfaces containing TiO_2. UV (A) lamps included in the boxes ensure the photocatalytic process. After the photocatalytic reaction, the air is returned to the tunnel environment.

Coating the noise abatement wall on the A1

A series of preliminary tests had to be concluded before the photocatalytic materials could be used. These included skid resistance tests when using the materials in road pavements and tests on the open porous materials of noise abatement walls. Model calculations were carried out for all three projects.

During the projects' runtime, a number of accompanying tests were also conducted, such as soil analyses, testing weather effects on test specimens and measuring the nitrate content in the drainage water from the noise abatement wall. In the case of the tunnel project, intensive laboratory tests have been conducted to develop suitable materials.

The preliminary tests were used to adapt the materials in such a way as to prevent adverse effects on the engineering structures, including for example an adaptation of the suspension's viscosity in order to be able to exclude that the absorption properties of the noise abatement wall would deteriorate.

The accompanying tests showed, inter alia, that nitrogen oxide was transformed into nitrate under direct solar radiation by analysing the nitrate loads in the discharge water of the noise abatement wall. However, the tests also established that the nitrate volumes are low enough to be well within the limit values of ordinances on drinking water and surface waters.

Results

The noise abatement wall studies took place on the A1 motorway between the Osnabrück-Nord und Osnabrück-Hafen junctions. The total test area comprised a length of about two kilometres. The six-lane motorway is enclosed by noise abatement walls on both sides in this section. At a length of one kilometre, a suspension containing TiO_2 was applied on both sides of the walls in September 2011 using an Airless spray. The coated area is about 20,000 to 30,000 square metres. A partial section of the wall about one kilometre in length served as a reference area for the tests.

The pollutant concentration was determined at four locations along the side of the noise abatement wall facing traffic; two measuring sites were on the coated wall section and two on the wall section without any coating. Furthermore, 22 passive NO_2 samplers of the Baden-Württemberg Regional Office for the Environment, Measurements and Nature Protection (Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg, LUBW) were erected at varying distances from the wall on both sides, facing traffic and facing away from traffic.

The evaluation of data on air pollutants showed that NO_2 was reduced at a single-digit rate. The highest reduction rates were found on the eastern side of the motorway, where presumably the pollutants were able to stay on the photoactive wall for longer periods of time compared to the western side due to the prevailing side wind. This observation is supported by model calculations conducted in parallel.

Combining the developments in the reduction rates with weather-effect tests covering years of data collection would seem to indicate that the photocatalytic suspensions may sometimes need several months to burn themselves free and to release the active TiO_2 particles onto the surface. In close vicinity to the road, pollution on the photoactive surfaces caused by traffic is certainly counter-productive. This phenomenon is not expected to occur when TiO_2 particles are used contained in construction concrete.

Furthermore, the results of the passive sampling measurements showed that the noise abatement wall in and of itself is responsible for a significant

Racks containing specimens for weather-effect tests on the A1 (image: KRONOS)

Measurement container and passive sampler at one of the four sites of continuous measurements on the A1

Funnel construction to collect sufficient amounts of run-off rain water (image: UIT GmbH Dresden)

reduction in the NO_2 concentration in its direct surroundings. In this case, however, this is not due to a decomposition or transformation of NO_2 – as in a photo catalysis – but only because pollutants are dispersed into higher atmospheric layers.

At the Hamburg site (B433), comparative vertical profiles were measured and skid resistance tests and materials tests conducted to determine the durability of the road surface installed in addition to measuring the reduction of NO_2. The evaluated data from air quality measurements did not show, however, that the photocatalytic surface had a nitrogen oxide reducing effect.

The tests in the Rudower Höhe tunnel in Berlin (A113) are scheduled to be continued with a study on the durability of the box systems once laboratory tests and model calculation have been successfully completed.

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RAINEX: protecting transport infrastructure

Recent incidents of flooding and the resulting adverse effects on important transport infrastructures such as bridges, underpasses and dams show how necessary it is to adapt existing safety aspects as regards the availability and performance of the transport infrastructure. In this context, the impact of climate change on extreme rainfall – frequency, intensity, spatial and temporal occurrence – needs to be taken into account.

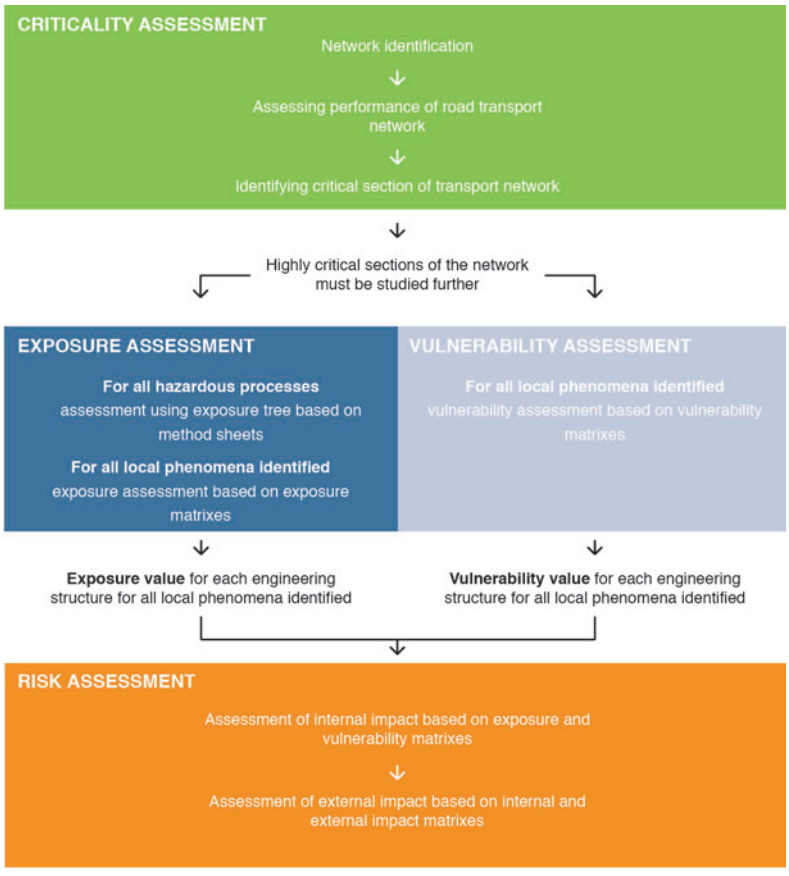
In the scope of a research project headed by BASt and funded by the EU on "a risk-based approach for the protection of inland transport infrastructure against impacts of extreme rainfall" (Risikobasierter Ansatz zum Schutz der Landverkehrsinfrastruktur vor den Auswirkungen extremer Regenfälle, RAINEX), certain hazardous processes were defined and their potential impact on transport infrastructure identified. A simplified identification process is illustrated in the graphic (www.rainex-project.eu).

The primary objective of the RAINEX project was to ensure or enhance the availability of inland transport infrastructure. The risk-based semi-quantitative assessment method which was developed for this purpose enables owners and operators to identify and evaluate their transport infrastructures with regard to criticality, exposure and vulnerability to risks caused by extreme rainfall.

Assessment methodology

The RAINEX methodology is a risk-based assessment method which can be divided into four main steps. In a first step, the criticality of the road network in question is determined, identifying sections which, if damaged, would have the strongest impact on the availability and performance of the entire transport network (network level). In subsequent steps, exposure and vulnerability are evaluated for each engineering structure (object level) in the sections of the transport network previously identified as critical.

The user will have a quantified estimation as a result on the basis of which the individual engineering structures can be categorised. The final step is collating the results of the findings from the exposure and vulnerability assessments in a risk assessment procedure. When users deploy this method, they can evaluate potentially at-risk transport sections and then set priorities accordingly.



RAINEX assessment methodology

The RAINEX project was successfully completed at the end of August 2016. The most important result of the research project was the development of a manual to support owners and operators of inland transport infrastructures in identifying and assessing exposed, vulnerable and critical transport infrastructure affected by rain-related hazards.

RAINEX

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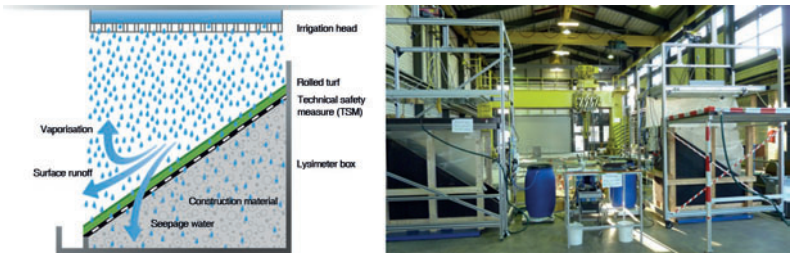
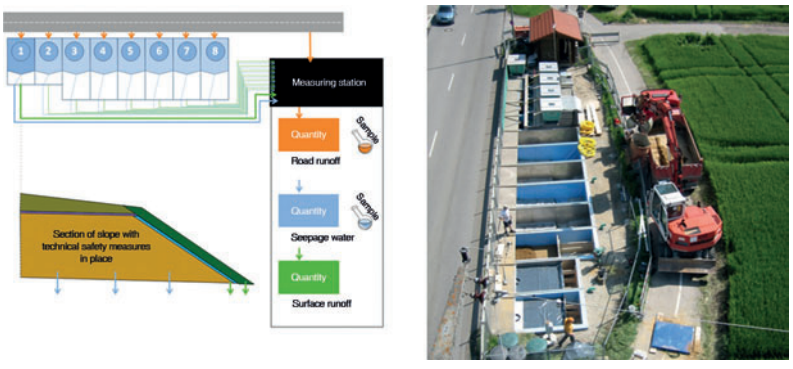
Leakage at road slopes

Recycled construction materials, industrial by-products and soil materials containing ecologically relevant substances are subject to environmental requirements in addition to structural requirements. These construction materials can contain ecologically relevant ingredients that could be discharged into soil and groundwater together with seepage water. This is why some of the construction materials can only be used when technical safety measures have reduced the discharge of these ingredients.



Lysimeter under laboratory conditions: diagram and test facility



Lysimeter in field tests: diagram and test facility

The regulations on technical safety measures vary across Germany. The Working Group of the German Länder on Waste Issues (Länderarbeitsgemeinschaft Abfall, LAGA) calls for elaborate sealing systems as technical safety measures, analogously, to those of landfills; they are intended to completely prevent leakages. BASt is studying technical safety measures as alternatives to these sealing systems in a number of projects. These projects aim to develop instruments for road construction with which to prove the effectiveness of structural design including technical safety measures for soil and groundwater protection when the materials referred to above are deployed. For this purpose, reliable data on leakages at road slopes needs to be generated. These were gained in large-scale experiments in lysimeters under laboratory conditions and in the field.

In the field lysimeter test, two different soil materials were deployed in parts of the road slope: cohesive soil with weak water permeability and gravelly soil with good water permeability. The “zero lysimeter” without technical safety measures can be compared well with the sections including layers with good water permeability, drainage mats, or injected with bitumen emulsion.

In the laboratory, recycled construction materials and selected industrial by-products were installed in lysimeter boxes with the soils described above, sometimes in combination with different technical safety measures, and subjected to artificial rain. The amount of seepage water and surface runoff were measured and the leachate was tested for ecologically relevant substances.

The tests confirmed that the amount of seepage water essentially depends on the type of soil and construction material used. The amount of seepage water can be significantly reduced by applying a layer onto the slope that has good water permeability. By retaining the seepage water, the amount of discharged substances of ecological relevance will also be reduced. The bitumen emulsion which was intended as a water repellent layer did not lead to any changes in the amount of seepage water.

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Safe solution: octanoic acid methyl ester

Asphalt is a construction material that consists of a mix of aggregates and bitumen. This mix is very adaptable in its application and can be flexibly deployed in all pavements for traffic spaces. Asphalt can make roads skid resistant to the desired extent, low-noise, water-permeable or waterproof, and optimise roads for the most intense types of use. The asphalt's composition will have a different mix of aggregates and bitumen depending on what the optimisation efforts are intended to achieve.

Asphalt is manufactured in large-scale asphalt mixing plants. The volumes to be produced for road construction are very large, as about 9,500 tonnes of asphalt are needed to build one kilometre of a two-lane motorway including hard shoulders. 380 trailer loads are required to transport this amount to the construction site.

Asphalt quality control

The process of asphalt manufacturing and refining is subject to regular quality control. Quality control aims to ensure durable asphalt layers which are used to build roads that require little maintenance, thus ensuring uninterrupted traffic flow over a long period of time.

One aspect of this quality control is to verify the composition of the asphalt mix. Does the delivery correspond to what was ordered? Is the asphalt mix in line with the formula that was determined beforehand on the basis of sophisticated tests? Does the manufacturing process need to be changed? The answers to these questions are of great significance for everyone involved in road construction measures. Samples taken at various stages of the manufacturing and refining processes are broken down into their component parts to check the composition of the asphalt. In an extraction process, the bitumen is washed out of the asphalt mix and separated from the aggregates. The bitumen is then separated from the washing solution and recovered. Subsequently, both the aggregates and the bitumen can be evaluated for quantity, type and texture. As the bitumen in asphalt is very stable vis-à-vis other substances, suitable solvents need to be deployed. The solvent of choice in Germany has conventionally been trichloroethylene.

The conventional solution: trichloroethylene

Trichloroethylene is a hydrocarbon and offers a number of benefits for extracting bitumen from asphalt. It has a high solvency, it is not flammable and it has a low boiling point so that bitumen can be separated with little effort from the washing solution. Bitumen is extracted from the asphalt in automatic devices that work with high precision.

Besides the purely technical benefits of trichloroethylene, there are also serious drawbacks in handling the solvent. According to an evaluation by the European Chemicals Agency (ECHA), trichloroethylene is a substance of very high concern. Trichloroethylene is classified as a carcinogenic, mutagenic and reprotoxic substance. The consequence has been that the use of trichloroethylene has been banned since 2016 or continues to possible only with the approval of the ECHA upon request for a limited time in the future. Such a request for continued use of trichloroethylene was submitted in a cooperation between the German Asphalt Association (Deutscher Asphaltverband) and DOW Chemical Company, the world's largest manufacturer of trichlorethylene. Such an application needs to outline how the consumption of the substance of concern will be gradually phased out and ultimately be fully substituted with some other solvent. Individual steps and entire processes were further developed in asphalt laboratories over the past ten years so as to bring about a significant reduction in the consumption of trichloroethylene. Possible alternatives for trichloroethylene as a solvent were also searched for intensively. The efforts already undertaken to reduce the consumption and searching for an alternative were documented in the application submitted. A decision by ECHA on how long the solvent trichloroethylene may be used in the future is still pending.

The alternative solution: octanoic acid methyl ester

Other chlorinated hydrocarbons such as dichloromethane or tetrachloroethylene that are used for extractions from asphalt in other countries have deliberately not been pursued, as

in the medium term similar ECHA evaluations are expected with comparable results.

A research project [1] demonstrated initial successful approaches in the search for a suitable alternative solvent. In the scope of the project, 15 different vegetable oil esters, various bio diesel types and other alternative solvents and detergents were tested for their bitumen solvency. Esters from vegetable oils have the advantages of being easily biodegradable, not requiring any labelling in accordance with the Hazardous Substance Ordinance (Gefahrstoff-Verordnung) or the Chemicals Act (Chemikaliengesetz), and being practically non-toxic. The project also showed that the process to recover the bitumen needs to be adapted to the individual solvent, which turned out to be an additional challenge in searching for a 'safe solution'. After it was established that octanoic acid methyl ester was a good solvent, further tests were conducted. These included distilling the solvent to recover bitumen after it was extracted, and other simple tests involving the recovered bitumen. Octanoic acid methyl ester was found to be an essential alternative to the conventionally used trichloroethylene.

In an additional research project for which BASt was responsible [2], the octanoic methyl ester solvent was studied further. This project used different types of asphalt of differing compositions.

The research project findings show that automated extraction processes in the asphalt analyser can in principle be conducted with the octanoic acid methyl ester. However, the asphalt analysers operated by the octanoic methyl ester solvent were failure-prone and required further development. By now, the problems in the process reliability of asphalt analysers are considered solved.

With regard to process reliability for the automated devices used in extracting bitumen from the asphalt, the manufacturer of these devices has carried out modifications so that the automated devices can be expected to be operated reliably in the future.

According to findings so far, the use of the octanoic acid methyl ester solvent in the extraction processes on the basis of an automated asphalt analyser is considered non-critical in terms of health and safety at the workplace. However, the process of extracting bitumen using solvent takes twice as much time as the extraction with the trichloroethylene solvent.

The determination of the recovered bitumen's properties indicates that a full separation of the bitumen-solvent mixture (washing solution) does not succeed when deploying vacuum distillation in a rotary evaporator. Residues of the solvent remain in the bitumen so that it is not possible to conclusively evaluate the recovered bitumen. The findings from comparative extraction tests in five different automated devices show that bitumen can be extracted from asphalt mixes, and that the composition of the mix can be determined with a precision similar to processes using the solvent trichloroethylene.

Outlook

Two problems remain to be solved on the path towards a safe solution: on the one hand, process runtime needs to be shortened for the alternative octanoic methyl ester solvent. At the same time, the procedure to recover the bitumen needs to be improved. Results need to be made available swiftly and the bitumen's properties need to be definitely identified.

The project on optimising the process of asphalt extraction using octanoic methyl ester commissioned by BASt is intended to clarify these two open questions so that a safe solution will be available for quality assurance of asphalt in 2018. This solution needs to be then incorporated into road construction regulations to provide a framework for a safe transition from the conventional solvent trichloroethyle to the alternative solvent octanoic methyl ester. It is intended to create all the preconditions for secure investment decisions and a rapid market penetration of this new safe solution.

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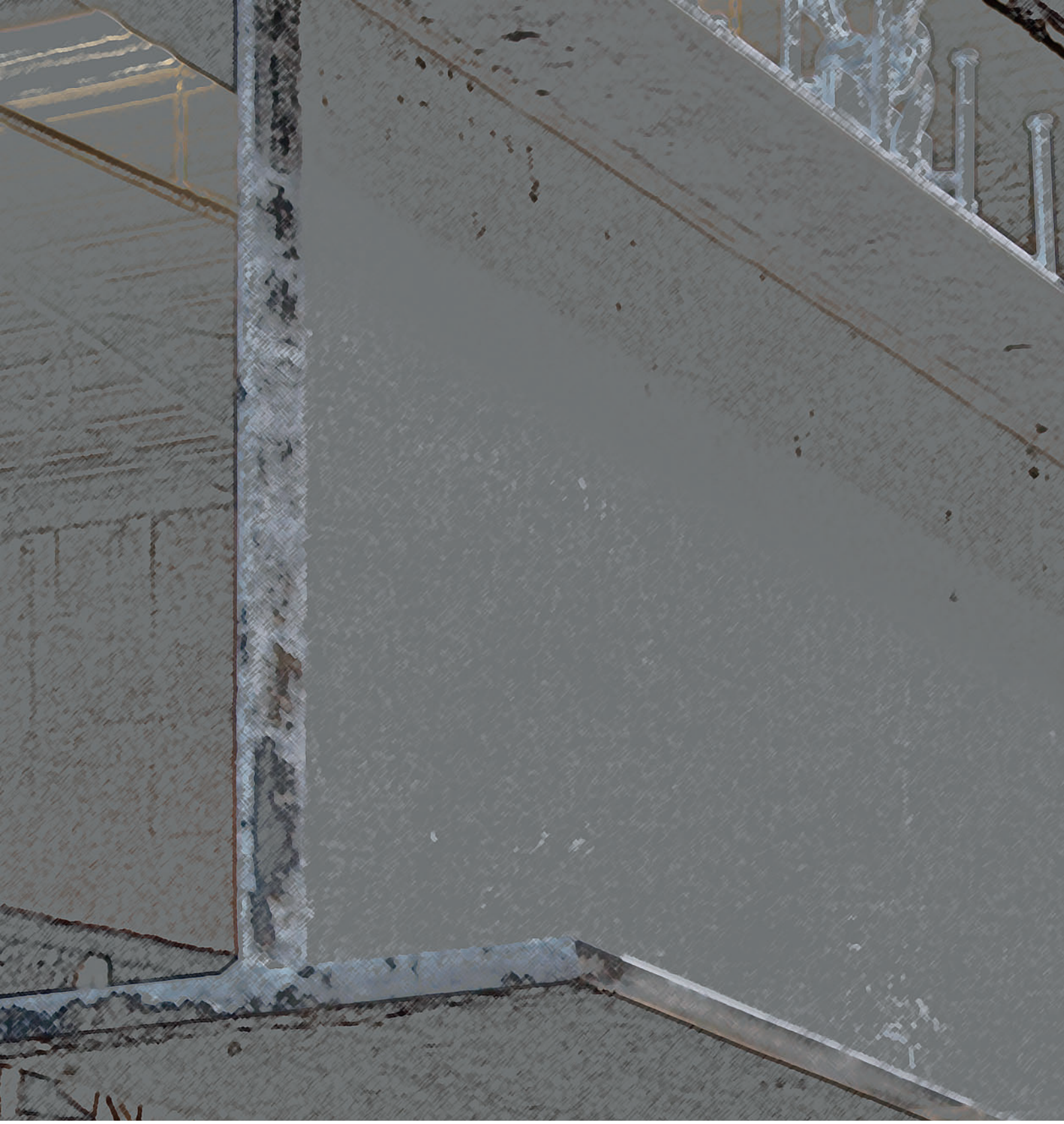
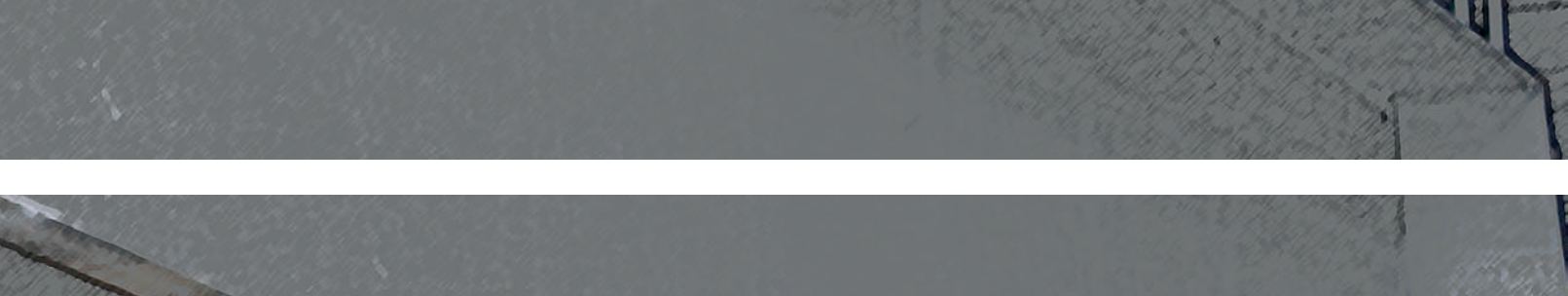
“Asphalt Pavements” section



Infrastructure



Condition survey in flight

How can unmanned aerial systems support inspecting engineering structures?

The age and condition of engineering structures along federal trunk roads make it necessary to invest significantly more effort in their maintenance in the future. This is why the corresponding financial means have been increased considerably. This is also reflected in the draft Federal Transport Infrastructure Plan.

It is necessary to survey the condition of the structures at an early stage and as comprehensively as possible in order to use these funds in a targeted manner and with as little interference as possible in the safety and ease of traffic flow.

For many years, there has been the tried and tested procedure of arms-length inspection of engineering structures in accordance with DIN 1076. This entails inspecting and evaluating all components of the structure every six years to check them for damages and deficiencies. This procedure is very time-consuming and resource-intensive and requires working in or near the traffic space, which in turn constitutes a hazard for the inspecting personnel and an interference in road users' road safety.

This is why BASt is researching innovative inspection procedures – specifically how they perform with regard to supporting the inspection of engineering structures. The potential as well as the limits of the procedures themselves are being tested and evaluated, as is their economic viability compared to the usual process.

Deployed aerial system (image: TÜV Rheinland)

Innovative procedures

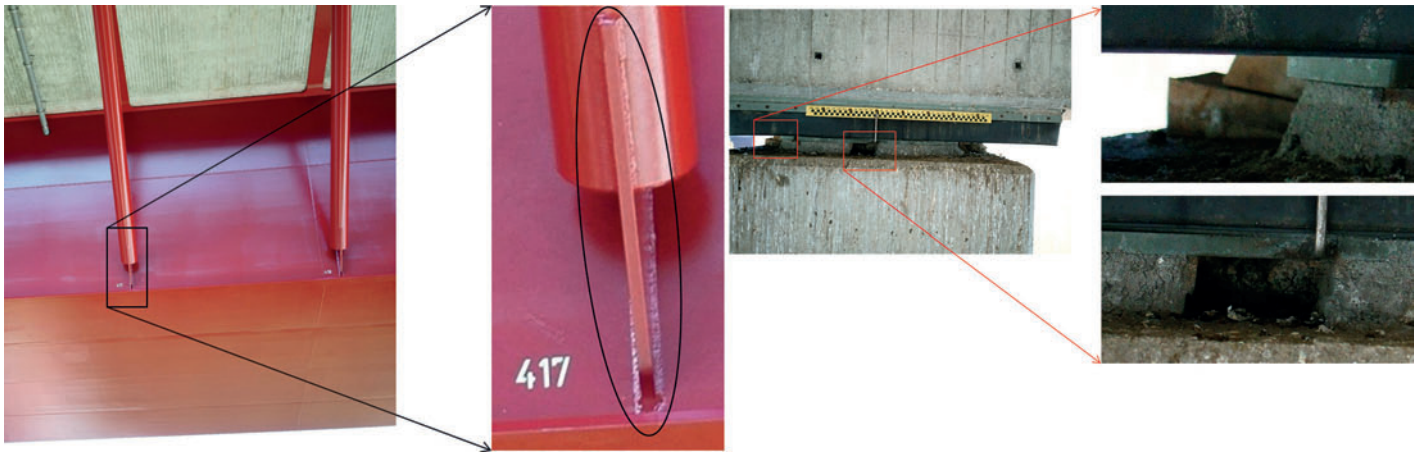
Unmanned Aerial Systems (UAS) have been used in many fields in recent years and continuously further developed in the process. It made sense to find out what potential these devices offer in combination with appropriate recording technology to survey and describe the changes in engineering structures. This is why BASt initiated a research project in 2014

- to research typical damages which may be detectable by unmanned aerial systems,
- to prepare a concept for surveying, evaluating and describing typical damages using UAS and
- to implement the concept and test it on a real bridge.

Results

The project confirmed that fundamentally UAS are suitable for supporting inspections of engineering structures. It also revealed that - as expected - not all relevant damages can be detected by UAS. Other damages that at the outset of the project were considered undetectable or hard to detect proved to be detectable after all. The aerial technology and the recording technologies are quite mature. However, in order to detect minute damages – for example cracks starting at 0.1 millimetres – it is necessary to be very close to the components of the structure in question. This requires automated positioning and distance control so as to be able to react very quickly to changes in overall conditions during the inspection, such as wind gusts. There is room for development as relates to the manufacture of automated distance control and stabilisation devices.

In addition to technical issues, legal issues proved to have a significant influence on the preparation period and the surveying flights themselves and thus on the economic viability of deploying UAS. One solution is to prepare inspection plans and plans for the surveying flights as they are already



Connection between cantilever bracing and bearing (images: TÜV Rheinland)

available for the approval procedures necessary, shortening the latter considerably.

The images of the different components are of good quality throughout. Using overlapping images, it is also possible to create 3D images that are of use for applications and inspections at a later stage. This constitutes another benefit of this procedure. Once the components and the damages and deficiencies are digitised, a good basis will be available for an automated comparison of images taken during different inspection cycles – usually every six years – which will make evaluating changes in the damages easier.

In summary, unmanned aerial systems are well suited to provide good quality images of the condition in areas that are difficult to access or of large areas in a short period of time, for example pillars of valley bridges. The surveying flight times of twelve to fifteen minutes are still restricted these days, but a significant increase in operating periods can be expected in the future. A (partially) automated detection and dimensioning of damages using different algorithms is already being deployed successfully in other fields. In other projects, the transferability of their use to bridges and other engineering structures connected to roads will be studied. This will make an additional technology available for inspections of engineering structures in the future to optimise condition surveys and evaluation for the purposes of systematic maintenance planning.

3D presentation (pillar) (image: TÜV Rheinland)

Ralph Holst
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"Maintenance of Engineering Structures" section

Hot-dip galvanised composite bridges

Steel and steel composite bridges are important components of the transport infrastructure. The benefits of using steel as a material in bridge construction become evident especially when special challenges need to be met such as wide spans, low headroom or short construction periods. Current research findings indicate that steel can be used as a material even for short and medium-sized spans to build sustainable and cost-efficient – as seen from the perspective of their entire lifecycle – bridges. However, steel components need to be protected against corrosion to ensure a sufficient service life. Organic coatings and hot-dip galvanisation have proved particularly useful measures in this regard.

The use of hot-dip galvanised steel components in building bridges and engineering structures in connection with federal trunk roads has until now been restricted to traffic sign gantries and bridge elements, for example railings. Based on state-of-the-art science and technology, it will soon be possible to deploy hot-dip steel girders also in bridge construction. The scientific basis to prove that hot-dip galvanising is fatigue-resistant was provided by conducting extensive studies on the influence of hot-dip galvanisation on fatigue strength. On the technical side, a great number of large-scale galvanising plants have expanded their facilities and now include dip tanks and lifting gear for hot-dip galvanising steel components in the dimensions required for bridges.

Hot-dip galvanised composite bridge at the Waldkappel-Hoheneiche junction

An 8.5 metre-long main girder is lifted out of a zink dip tank

The first composite bridge using hot-dip galvanised steel constructions on the federal trunk roads was built during the new construction of motorway A44 between Kassel and Herleshausen. It is an integral single suspended bridge with a 40-metre span that serves as an overpass over an access road. BASt has been instrumental in implementing this pilot project:

- Membership in the group of mentors of the "hot-dip galvanising in the construction of steel brides and composite bridges" research project conducted by the Research Association for Steel Application (FOSTA) (between November 2010 and May 2014).
- Providing an expert opinion on the application for one-time approval in the scope of the pilot project on hot-dip galvanised steel components of a steel composite bridge (June 2013).
- Initiating and supporting BASt's "sustainability calculations for hot-dip galvanised steel bridges" project; BASt report B 112 (between July 2013 and June 2014).
- Expert technical support in implementing the pilot project crossing the A 44 motorway (from March 2015 to March 2017).

Heinz Friedrich
Civil engineer
Deputy head of the "Steel Structures, Corrosion Protection, Bridge Equipment" section

Strengthening concrete bridges

Eliminating deficits in concrete bridges as concerns their load-bearing capacity and serviceability by strengthening them is increasingly gaining significance in order to maintain a viable network of federal trunk roads. Since 2011, deficits have been identified on the basis of recalculation guidelines. BASt was commissioned by the Federal Transport Ministry to develop decision support aids and regulations to support effectively planning and implementing of strengthening measures on bridges.

Decision support aids for strengthening concrete bridges

In the scope of a research project, the current state of knowledge on strengthening methods was compiled as a first step. Subsequently, representative application cases, provided by highway authorities and engineering firms, were described, systematically evaluated and ranked on the basis of the criteria: applicability, performance and economic efficiency. The following strengthening methods have proved their worth as "standard strengthening methods" in bridge construction:

- additional external prestressing,
- strengthening with bar tendons or bonded plates,
- top concrete layer with dowels,
- additional reinforcement in grooves,
- bonded CFRP strips,
- CFRP strips pasted into slits,
- cross-section expansion with concrete.

The results were summarised in the "strengthening older concrete and prestressed concrete bridges, collection of case studies" documentation. It is available for download on BASt's website (www.bast.de/regelwerke-ingenieurbauten).

Rules for strengthening concrete bridges

The research project's second step was to identify provisions necessary for a safe application of strengthening methods in bridge construction. These are supplements to general provisions that exist on strengthening methods, such as general licensing regulation for construction supervision, which often do not take issues of concrete bridge construction into account in their entirety. Provisions affecting the planning of strengthening measures have been added to the "Guidelines for Drafting and Building Engineering Structures, Part 2 Bridges, Section 2 Constructive Principles (Richtlinien für den Entwurf und die Ausbildung von Ingenieurbauwerken (RE-ING), Teil 2 Brücken, Abschnitt 2 Konstruktive Grundsätze). Provisions on carrying out strengthening measures have been consolidated in the "Additional Technical Terms of Contract and Guidelines for Civil Engineering Works, Part 3 Massive Structures, Section 7 Strengthening Concrete Components (Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauwerke (ZTV-ING), Teil 3 Massivbau, Abschnitt 7 Verstärken von Betonbauteilen).

Upon completing the last formal steps, the two sets of regulations will be made public by the Federal Transport Ministry in a General Circular in 2017 and will then be available for download on BASt's website.

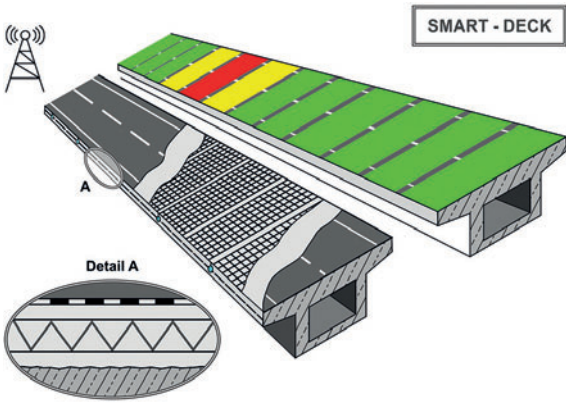
Conclusions

The collection of case studies helped create a basic overview of technologies suitable for strengthening concrete bridges. This document serves as a decision-support aid to effectively and economically plan strengthening measures. Furthermore, provisions to ensure quality controlled planning and implementation of strengthening measures in concrete bridge construction were prepared to be included in RE-ING and ZTV-ING.

Dieter von Weschpfennig
Civil engineer
"Concrete Structures" section

SMART-DECK: intelligent strengthening and protection system

The durability of road bridges is especially jeopardised by compromised sealing, damaged joints and transition profiles caused by chlorides penetrating the concrete structure. Corrosion damages in a bridge's reinforcements usually only become visible on its top side once considerable damage has already occurred. Furthermore, structural deficits due to increased traffic can be observed on some existing bridges in their transverse shear strength and flexural strength. SMART-DECK – a multifunctional, intelligent strengthening and protection system – aims with its modular functions to prevent the deficiencies mentioned above. The system monitors the humidity content of the entire deck panel using preventive cathodic corrosion protection and strengthens it in terms of transverse shear strength and flexural strength without significantly increasing the deck panel's own weight. A reduction of the structure's lifecycle costs and fewer traffic disruptions can be expected when SMART-DECK is deployed.



Functional SMART-DECK design (image: ibac)

How it functions

SMART-DECK consists of a thin layer of a humidity-sensitive mortar which is reinforced by two carbon fibre mats that are fixed with spacers and fully impregnated with epoxy resin. The cross-section is expanded directly in the structural concrete on the surface of the bridge's deck panel. Subsequently, the superstructure can be sealed and a typical surface course can be applied. To locate the damage area in case of leakages, textile reinforcements are divided into fields that are up to twelve square metres in size. Each field represents a sensor which for measuring purposes is accessed separately via a bus system. Suitable calibration curves are deployed to identify the mortar's humidity content on the basis of electrical resistance measured between the carbon layers. A drop in resistance is an indicator of leakages in the sealing as low resistances result from a high water saturation of the mortar. A status display enables the operator to monitor the bridge in real time by means of mobile communications technology or the internet. If in case of damages it is not possible to repair the bridge promptly, preventive cathodic corrosion protection can be activated to postpone repair to a more favourable time period. When preventive cathodic corrosion protection is activated, an electrical field is generated between the textile reinforcement and the steel reinforcement, which counteracts the diffusion of chlorides, thereby preventing a depassivation of the steel reinforcement.

Analyses and outlook

With EUROVIA company's structural repair branch as the head of the consortium, the project partners – RWTH Aachen (ibac, IMB), StoCretec, FTA in cooperation with solidian GmbH, Massenberg, instakorr and BASt – compiled a set of requirements and developed a mortar system, textile reinforcement and a measuring system. In April 2016, a small-scale demonstrator was completed on BASt premises to evaluate and optimise the overall system beyond the laboratory scale that had been studied up to that date. The demonstrator is used to test the monitoring function by measuring humidity, temperature and resistance, and to test the functions of the preventive cathodic corrosion protection system. Furthermore, larger segments of the structural component have been sawn out to test their tensile strength in the laboratory. After a final step of optimising individual parts, the SMART-DECK system will be implemented on an existing bridge to validate the concept under real roadworks conditions.

Sarah Dabringhaus
Mechanical engineer
"Concrete Structures" section

New engineering models: recalculations of box girder bridges

A large portion of concrete bridges in the network of federal trunk roads is already 40 to 60 years old. During the service life of these structures, freight transport has increased disproportionately and led to a change in use of older bridges which were originally not designed for this type of impact. The arithmetic evaluation of the load-bearing capacity that has been conducted since 2011 on the basis of the recalculation guidelines for the structures that are most affected, which are the structures recalculated as a priority, has repeatedly indicated that there was not sufficient evidence for a shear-resistant connection between the bottom plates and the side panels of box girder bridges. An evaluation of arithmetically calculated deficits in load-bearing capacity indicates that increased impact from current traffic volumes is not solely responsible for the findings. Instead, the detection format to identify shear strength in the revised version, as a result of updated technical provisions in Germany which apply as detection formats for shear-resistant connections between bottom plate and side panel without any noteworthy modifications, lead to very conservative results with regard to the measurement task described here. This can be considered another significant reason for the current situation in recalculation practice.

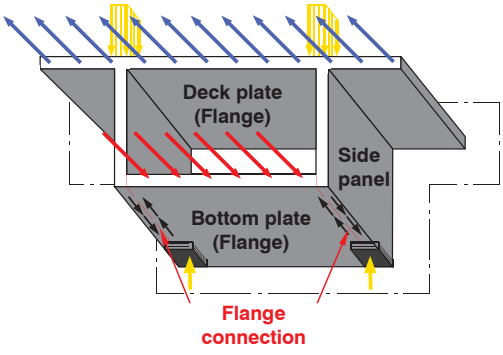
Development base for new measuring models

A research project conducted by BASt compared assumptions for calculation purposes and fringe conditions of the measuring model currently introduced by law in Germany with the load-bearing behaviour observed in tests and identified in analytical and arithmetic model calculations. The project was able to show that essential correlations, which have a key influence on the load-bearing behaviour of flange connections, are taken into account only inadequately or not at all.

In contrast to side panels, the individual loads on flange connections are corresponding parameters, consisting in essence of longitudinal loads and shear loads at the disk level. This context is ignored in the newly introduced detection procedure to measure shear-resistant connections. This means, on the one hand, that the measured or calculated results are on the safe side, but on the other that they may be very conservative under certain circumstances. Such a conservative approach in measuring indeed makes sense when planning new constructions since it will result in a robust interpretation of load-bearing capacity and at the same time will lower additional costs for reinforcements identified in this way. Nonetheless, more detailed procedures are necessary for evaluating existing structures because reinforcements in this field ex post are cost-intensive and frequently technically questionable.

Simple manual calculation methods were derived on the basis of recalculations of experimental tests and additional simulated calculations of components using dimensions that are relevant for bridge construction. These make it possible to identify the load-bearing resistance of flanges in bending compression areas in a more realistic manner.

Diagram of a hollow box cross-section



Outlook

A specific proposed text is currently being prepared to be incorporated into the planned further development of the recalculation guidelines. This will ensure that new research findings are available for practitioners in a timely manner.

Dr Matthias Müller
Civil engineer “Concrete Structures” section

Transition joints made of polyurea and polyurethane

Flexible, stable and low-noise

Joints need to be placed between a bridge engineering structure and adjacent road surfaces because of the bridge's temperature-related movements as well as the creep and shrinkage of concrete. Various expansion joints can be used to bridge over and seal these joints. The type of expansion joint selected depends on the type and extent of the movements to be absorbed, the direct and indirect impact of traffic and the bridge's structural conditions.

While only steel expansion joints are deployed on bridges with wide spans, asphalt expansion joints have also been used since the 80s for bridges with an expansion length of up to about 50 metres. This has been regulated since 1998 in the "Additional Technical Terms of Contract and Guidelines for Civil Engineering Works" (Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauwerke, ZTV-ING) Part 8 Section 2. In addition to lower costs, this type of system offers the following benefits: quick installation, the possibility to renew the joints traffic lane after traffic lane, as well as low sound generation and the ease with which vehicles can drive over them. The limited stability of the system is a disadvantage; that is why these expansion joints have limits in their suitability for traffic lanes used by heavy duty vehicles on highly frequented routes.

To compensate for this disadvantage, expansion joints have been developed in the same design made of polyurea or polyurethane (polymer expansion joints).

Polymer expansion joints are elastic joints for road surfaces which in their functions correspond for the most part to the expansion joints described in ZTV-ING Part 8 Section 2. Elastic polymers based on polyurea and polyurethane are used, however, instead of bituminous masses. In this way, the material is stable while highly elastic and – in contrast to expansion joints made of asphalt – and it is largely independent of temperature.

The system requires perforated sheet metal angles to be installed parallel to the channel edges of the existing asphalt layer; these are then embedded into the system when the joint sealant is added.

Expansion joints in difficult geometric conditions

This for the most part reduces the adjusting effort of the polymer expansion joint edges towards the adjacent surface course, where the joints expand widely due to low bridge temperatures, thus minimising the risk of the edges disbonding.

Depending on design and installation width, the expansion joints made of polyurea and polyurethane that are currently being deployed are suited for nominal expansion movements between 15 and 135 millimetres.

As Germany does not yet have regulations for the use of polymer expansion joints, this system is currently only applied when approval is granted on a case-by-case basis. The following engineering structures were among those inspected by BASt for the collection of case studies on “expansion joints made of polyurethane”:

- Bridge A70 near Kulmbach: installed 2013-14, per section and with support ribs. Asphalt chunking out around joint, therefore replaced by support braces made of polymer concrete.
- Bridge A45 over the Dill valley in Hesse: installed in 2012 across three lanes without support ribs or braces. Damages consisted of chunking out between expansion joint and old surface course and on the area around the edges of the road surface. Repairs completed.
- Bridge A5 in Hesse: installed in three days per construction section while traffic flow was maintained. No 2-week complete closure necessary.
- Hattenbach motorway junction A7/A5: some joints shaped with acute angles, and a great number of branch-offs. Pulled vertically at safety kerbs and guide sections. Sometimes pores on the surface.
- Tram overpass Rudolf Diesel Straße in Schwerin: installed in 2014.
- Wildlife overpass Hamburg. Installed in 2013: polymer expansion joints, sometimes with support ribs in the surface course.
- Moor bridge Waren-Müritz B192: One of four polymer expansion joints shows chunking out where polymer expansion joints meet the old surface course. Presumably existing surface not sufficiently stable.
- Bridge over the Suhl valley B27 Baden-Württemberg: steel expansion joint broke three times in few years. Repair necessary in tight time frame, therefore polymer expansion joint.
- Friedrich Engels ring road Neubrandenburg 2015: ring road around historical old town, therefore five low-noise polymer expansion joints installed.

Chunking out at joint edges

The benefits of polymer expansion joints compared to conventional steel expansion joints are in the lower costs they incur and significantly shorter time they require for installation. Depending on size and overall conditions, the polymer expansion joint can be installed over a weekend with short preparation time. The possibility to install polymer expansion joints one traffic lane at a time constitutes another advantage, as traffic can be maintained during the installation. The joints are connected after preparing dovetail jointing at the future connection point or by activating the connection point. The polymer expansion joint can even be deployed in geometries that are unusual.

Machine installation of channel filling

Creating an even height in the joint channel by applying polymer concrete

The experience gained with polyurea and polyurethane as materials for this and other purposes has shown that these materials can react sensitively to the installation conditions on bridge sites that may be less than ideal. This is why, the installation conditions need to be ensured with special diligence when construction work is carried out, especially with regard to temperature and air humidity. In any case, moisture is to be avoided on the base course, including moisture caused by temperatures below the dew point and moisture impact during the installation. It is also important to ensure that the channel edges and the base course are clean.

The transition between the surface course and adjacent asphalt surface has proved to be a fundamentally critical point in polymer expansion joints. Polymer expansion joints should therefore only be deployed in combination with a new surface consisting of mastic asphalt.

If there are no plans to renew the surface on the road section or bridge in question, a strip of the existing surface at a minimum width of one metre should be replaced with mastic asphalt. It can make sense to install support ribs in the adjacent surface areas in order to avoid rutting.

In Germany, there are no regulations as yet on using elastic expansion joints on road surfaces on the basis of polyurea or polyurethane. The "expansion joints made of asphalt" working group 7.7.4 of the Road and Transport Research Association (Forschungsgesellschaft für Straßen- und Verkehrswesen, FGSV) is, however, preparing an initial draft for guidelines: "information on using expansion joints made of polyurea and polyurethane for engineering structures". If the experience gathered has positive results, these guidelines are scheduled to be introduced in 2017.

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"Steel Structures, Corrosion Protection, Bridge Equipment" section

Michael Staeck
Technician
"Steel Structures, Corrosion Protection, Bridge Equipment" section

Structural fire safety in German trunk road tunnels

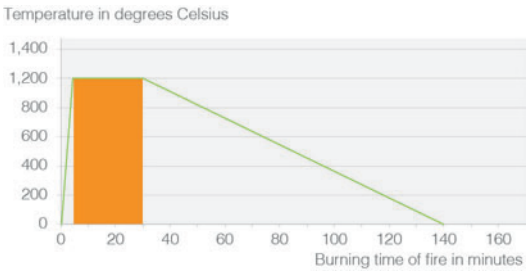
Particle fibres made of polypropylene (PP fibres) have been studied as an additive in the concrete of tunnel inner linings to improve structural fire safety in German trunk road tunnels. In case of a fire, the PP fibres, which are evenly distributed in the concrete mixture, will melt. This creates a net of connection channels which in turn enables water vapour resulting from the fire in the concrete to diffuse, thereby preventing concrete from bursting across large surface areas.

The study focused in particular on how much fibre needs to be added to prevent concrete from bursting across large surface areas and to maintain the temperature below 300 degrees Celsius as required for reinforcements pursuant to the provisions of the "Additional Technical Terms of Contract and Guidelines for Civil Engineering Works" (Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauwerke, ZTV-ING). Another point to be clarified was whether and how such concrete could be accurately produced with regard to consistency, hardening and bleeding (water discharge on the concrete's surface) properties in line with the provisions of the ZTV-ING and the processing requirements of the specific construction site. Furthermore, the question needed to be studied how the special requirements of this type of PP-enforced concrete could be taken into account in legal provisions.

By means of fire tests using large-scale specimens, it was possible to confirm the effectiveness of PP fibres that were six millimetres long, had a cross-section between 0.016 and 0.020 millimetres and were added at the quantity of two kilogrammes per cubic metre.

Pilot projects

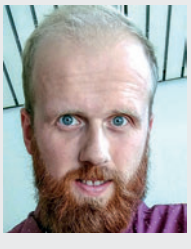
Pilot projects were conducted with BASt's scientific support at the Bautzen tunnel for open tunnel systems and at the Bühl tunnel in Siegen and the Hirschhagen tunnel for closed tunnel systems. The experience from the pilot projects was used to compile the necessary contractual basic requirements for a satisfactory version of PP fibre concrete in an annex of ZTV-ING Part 5. This means that binding requirements have been established for future new tunnel construction projects on federal trunk roads to improve the static-structural safety of a tunnel in case of fire. It can be assumed that according to the temperature-time course described in ZTV-ING, in case of a fire, the thermal reinforcement will not be heated to more than 300 degrees Celsius and thus not permanently damaged.



Temperature-time course caused by fire pursuant to ZTV-ING

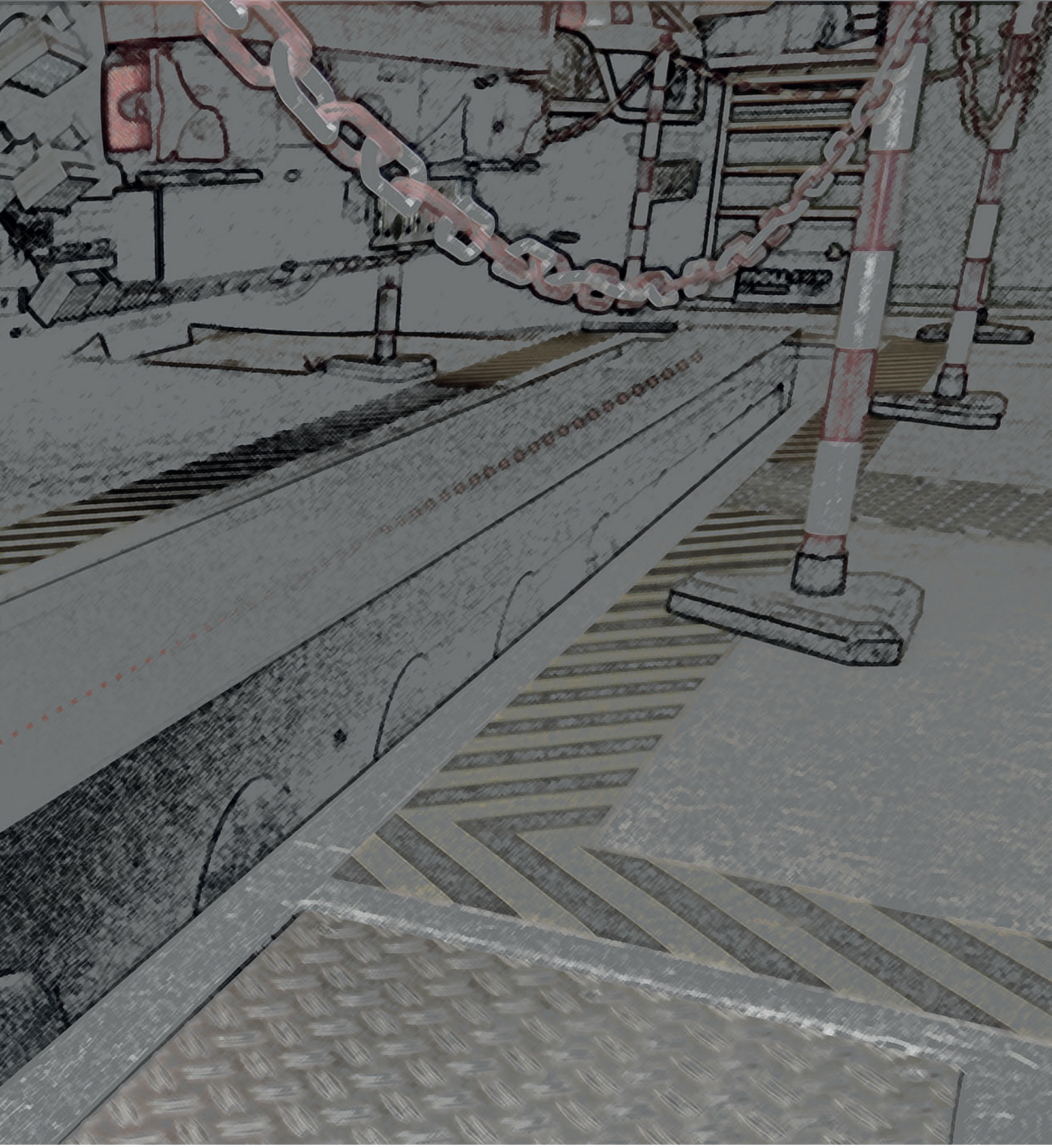
Studies are currently being conducted on behalf of BASt to focus on more detailed questions, for example gaining more knowledge about the influences of the mixing method on the fibre's properties and distribution. Additionally, a method is to be developed to draw conclusions about fire resistance on the basis of pore structure and transport mechanisms across the concrete, for example gas permeability. It is also important to study the long-term stability of PP fibres in the concrete's alkaline environment. In view of a service life of 100 and more years assumed for tunnels, sufficient fire safety through the use of PP fibre concrete needs to be ensured over the entire period. Possible requirements for repair methods are being researched as well, in order to be able to repair damaged tunnels with an inner lining of PP fibre concrete in the future, as well to improve the fire safety of existing tunnels that do not contain PP fibre concrete.

These in-depth research activities are intended to contribute to ensuring the quality of PP fibre concrete as a construction material, thereby ensuring the tunnel's enhanced safety in case of a fire. This applies to the tunnel users affected by a fire breaking out, as well as the tunnel's stability and lower repair needs after the fire.



Daniel Eickmeier
Civil engineer
"Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section

Highway Const



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duraBASt: BASt's new test track

BASt's new premises for demonstrations, tests and referencing – duraBASt stands for Demonstrations-Untersuchungs- und Referenzareal der BASt – can be found on the outskirts of eastern Cologne. This facility is located between the A3 and A4 motorways on a previously unused property at the Cologne-East motorway interchange. The test track cost about seven million euros and was built in cooperation with the North Rhine-Westphalian Highway Authority (Landesbetrieb Straßenbau Nordrhein-Westfalen) and the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur). An initial service life of 30 years has been envisaged for the track, which is about one kilometre long.

The test track contains typical elements of road infrastructure, including sections built in a variety of asphalt and concrete designs as well as bridges, a tunnel-like situation below a bridge, noise abatement and screen walls and carriageway drainage systems. duraBASt is subdivided by function into three units: reference track, testing area, and demonstration area (see image below).

Reference track

The structural condition of federal trunk roads is surveyed in Germany in regular intervals using fast-moving measurement vehicles. The reference track of duraBASt is used to test and ensure the quality of measurement vehicles owned by BASt and third parties. This track is also used to further develop these measurement systems.

The reference track is composed of sections to survey surface properties such as skid resistance, texture, material features, as well as longitudinal and transverse evenness. The road surfaces are produced in such a way as to test the limits of the measuring systems. A rapid change in the surface's gradient is intended, for instance, to ‚rattle' the measurement technology on a rolling track. As the duraBASt premises are apart from public road traffic, the measurement vehicles can operate at low speeds and without disturbing anyone. The reference tracks also enable a direct comparison of different surveying techniques and various measurement systems.

Testing and demonstration areas

Currently, the cycle for developing innovations in road construction often comprises a period of more than 20 years. This is due, inter alia, to long service lives and the great need for safety. With its research programme „roads in the 21st century", BASt is reacting to the continuously increasing requirements for roads, based for example on an increase in freight transport and progress in technological and demographic changes. It is important to also conduct realistic pilot applications

Aerial view of the duraBASt sections for referencing (green), testing (yellow) and demonstrating (red) – the test track is located at the Cologne-East motorway interchange

On 3 June 2015, the construction site was launched by symbolically breaking the ground. From left: Winfried Pudenz, Straßen.NRW Managing Director; Stefan Strick, BASt President; Michael Groschek, NRW Transport Minister; Rainer Bomba, BMVI State Secretary; Gerhard Rühmkorf, BMVI Directorr; Dr Hermann Tebroke, District Commissioner of RBK

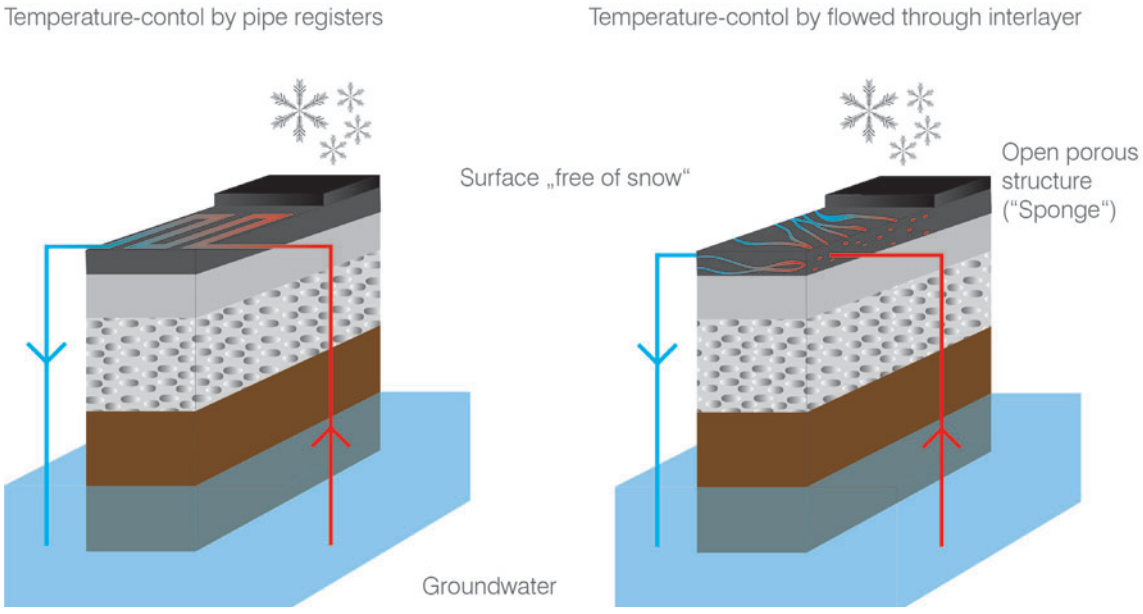
in addition to small-scale and large-scale laboratory tests in order to swiftly and successfully introduce research results and innovations into construction practice. Newly developed construction materials, methods and procedures are tested under real conditions in an accelerated manner. The duraBASt premises include six test areas of a length of 100 metres each as well as a „smart bridge“.

In the „smart bridge“ area, various sensors monitoring the condition of bridges in real time are tested. Using these sensors, it is intended that bridges be capable in the future of transmitting data about their condition at an early stage. Some of the sensors were already installed in the „smart bridge“ in 2015 so that initial results are already available.

The demonstration areas are primarily used to present new developments. One of the pilot projects planned to be implemented is the „temperature-controlled road“ pilot installation. The road surface will be ‚heated‘ during frost using geothermal energy. Preventing black ice enhances the safety of road users. By contrast, in summer the road can be cooled down by diverting the surface heat, preventing rutting.

The test areas are used to test whether new developments are fit for use. Modern construction

Installing sensors on the “smart bridge”



Principle of the “temperature-controlled road”: a heat medium is circulating by means of piping or channels in asphalt layers; energy in the form of geothermal heat can be extracted from the subsoil

materials and innovative designs are mechanically constructed at a 1:1 scale and tested under real weather conditions on these areas. BASt‘s own Mobile Load Simulator (MLS30) applies traffic loads to test surfaces in an accelerated manner, see also the article on the next page. Using a variety of sensors, the changes in the road pavement are documented by measuring expansion, tension, humidity and temperature. This enables a swift evaluation of the structural condition and durability of the newly developed construction materials or designs.

Examples for pending tests on these areas include a porous top course consisting of a polyurethane compound that was developed by a research consortium headed by the RWTH Aachen university in the scope of the „InnoBond“ project, and a road construction that transforms heat into electricity. This futuristic road surface is being developed by the Technical University of Dresden in cooperation with partners from the industrial sector and research for the „SEDA“ project.

The test areas of duraBASt are available for interested parties from the industrial sector, administration and research.

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duraBASt

Smart Bridge

Mobile Load Simulator MLS30: past and future projects

BASt conducts accelerated load tests at a 1:1 scale using the Mobile Load Simulator MLS30, formerly known as MLS10. These accelerated tests can be used to gain experience for transferring laboratory test results to real road pavements, and also to test and evaluate new methods to evaluate the structural condition of road surfaces.

Since 2013, BASt has been using a realistic load device which uses four load wheels (standard truck tyres) to test the load-bearing capacity of road surface structures. Besides setting up the necessary infrastructure, the MLS30 was also used to investigate the specific characteristics of load-related tests. For the long-term goal of being able to more clearly classify the mechanical processes within a road's surface structure when subjected to loads, MLS30 continues to be used on defined road pavements. The use of non-destructive methods of measurement plays a decisive role in detecting changes during the application of loads. This approach is to be applied in the future and is currently being applied in testing innovative materials and construction designs. Many studies have been conducted on the asphalt model street in the air-conditioned test hall which was built in 2003. In the future, the open-air testing grounds of BASt's demonstration, testing and referencing premises (duraBASt) will also be used - see previous article. In this setting, the road structure is planned to be subjected to real weather conditions which cannot be influenced; real installation technologies will also be deployed.

Temperature tests: practical application of MLS30

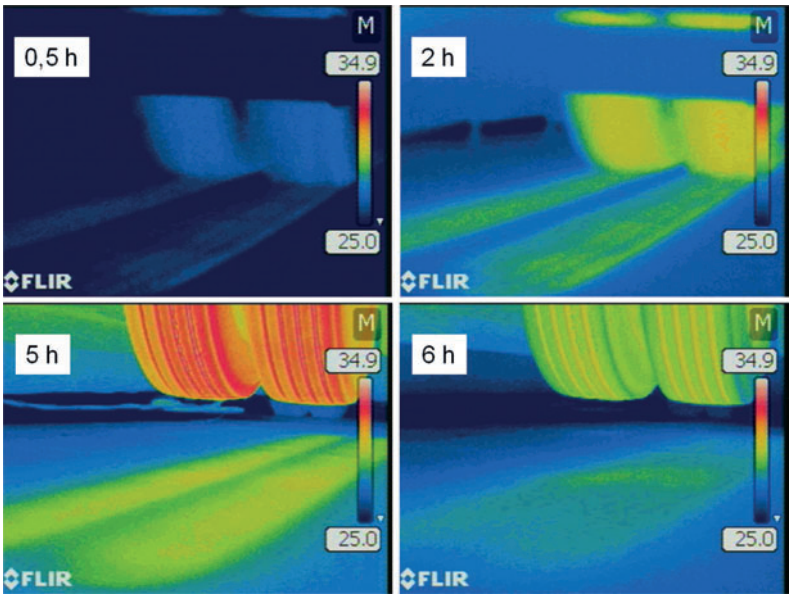
BASt conducted extensive temperature measurements to better understand the MLS30 device. Temperature sensors were installed in different places and an infra-red camera was used to visualise the temperature developments inside the device and on the road surface. It was possible to detect key heat sources in these studies. The studies also helped to determine that the optimum point in time to conduct comparable non-destructive measurements of load-bearing capacity is after loading. This and other results are taken into account in developing and evaluating new load programmes.

InnoBond: testing innovative construction materials

Loads were applied on a pavement including polyurethane compounds for a large-scale test of this innovative construction. A series of tests enabled the collection of data for further material-related developments. Additionally, on the basis of MLS30 tests, valuable information was gained about installation requirements during the construction of the road pavement, though this was not the focus of the loading programme.

Loading tests: non-destructive evaluation of road pavements

Loads were applied on a total of two fields of the model street in the scope of the eighth call of BASt's innovation programme. At defined time periods, two research teams deployed non-destructive methods of measurement. BASt itself not only ensured the operation of the MLS30 (three million roll-overs in 85 days, in other words 300,000 roll-overs in eight days) but also conducted its own measurements using established methods. In another test, outside the scope of the funded call, BASt applied loads onto another field of the model street, significantly exceeding the sizing-relevant scale. The experts involved were able to derive a wide range of insights in the course of the project. The next step will consist of blending all the findings in order to then derive innovative methods for structural condition evaluations. Established laboratory methods



Infrared images during loading tests using the MLS30

Installing new test fields in BASt's test hall

Drill core for material testing in the scope of the innovation programme

will also be included for validation purposes to determine material parameters.

MLS30 will continue to be used to investigate methods of structural condition evaluation in subsequent projects.

Outlook and other objectives of loading tests

The MLS30 is intended to be used on a number of road structures on BASt's new duraBASt testing grounds. These are projects in which BASt is either involved as a partner, conducts its own research, or sub-contracts research activities to external research institutes.

In the scope of the HEALROAD EU project in which BASt collaborates as a partner (www.healroad.eu), an innovative method is being tested for non-invasive maintenance of asphalt roads. In these tests, the newly developed asphalt mix will be installed at a 1:1 scale, and in 2017 loads will be applied by the MLS30 until a certain level of damaging occurs. Subsequently, the magnetic particles that are part of the asphalt will be heated by electro-magnetic induction. The previously created damage is intended to be closed or healed by the bitumen in the mix.

Preliminary tests by BASt are intended to identify suitable road structures for the HEALROAD project, as well as for other purposes, for example tests on the duraBASt testing grounds. In September 2016, the existing pavement of the model road was partially demolished and work began on installing a new pavement.

Dr Dirk Jansen
Civil engineer, head of the "Design and Structure of Pavements" section
Bastian Wacker
Civil engineer, "Design and Structure of Pavements" section

Dr Dirk Jansen (left) and Bastian Wacker

HEALROAD

Looking into the street: non-destructive methods for structural condition surveys

A regular survey of the current condition of roads is of vital importance for planning and initiating road maintenance measures in good time. For some time now, these surveys have been conducted using fast-moving non-destructive methods of measurement. As this procedure provides a comprehensive evaluation of only the road surface, additional methods were sought with which to survey the pavement's stabilisation elements and their condition.

Georadar constitutes one of these alternative methods. Radar waves are transmitted by an antenna into the subsoil, partially reflected there and then detected again by the antenna. Reflexions can be observed when electro-magnetic properties of the material change, similar to a sound echo in the air bouncing back from a wall. The entire road structure can be analysed and mapped in this manner, because of the various construction materials used in the different layers of the road's pavement. The inventory of the road network and the formation of homogenous sections can thus be accomplished in fast-moving processes. They can also detect larger inhomogeneities. Further non-destructive measurements can be conducted to evaluate the current load-bearing capacity of the road pavement. In these cases, the load-bearing capacity is evaluated on the basis of a road's deformation behaviour when loads are applied, either by dropping a stationary weight or using a rolling truck wheel. Using suitable methods, parameters can be determined on this basis for planning maintenance measures.

New possibilities offered by 3D georadar

In contrast to conventional georadar systems which can record one profile line in each measurement, a 3D radar uses up to 25 channels, i.e., 25 profile lines are recorded in parallel at the same time. The integrated stepped frequency technology enables faster but nonetheless highly precise signal detection as compared to the impulse radar systems that have mostly been used to date. A single radar sweep enables very fast measurements while still delivering high resolution images, but the multiple channel technology also enables surveying the entire width of the road in one process. On this basis, in addition to line-based evaluation, the subsoil structures can be spatially represented, similar to an aerial picture. It becomes easier to identify hollow spaces, pipes and expanded structures at their location lower in the ground.

Research activities

On-going research activities aim to investigate the possibilities and limitations of non-destructive methods of measurement for structural conditions surveys and evaluation, and to use the findings for deriving systematic applications. Internal and also external research projects are being analysed for this purpose. Furthermore, a fast-moving measurement system will be purchased for structural condition surveys at the network level with which to measure in particular load-bearing capacities, also enabling fast-moving georadar measurements. Special approaches are pursued for in-depth structural condition surveys at object and network levels that are based on both non-destructive and invasive testing.

3D georadar system in use – the antenna is mounted onto a mobile supporting frame

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Geophysicist, "Design and Structure of Pavements" section

Concrete pavement structures: practice-oriented research

"Mobility is a central precondition for economic growth, employment and the individual's participation in society" (guiding principle of the Federal Ministry of Transport and Digital Infrastructure). Road infrastructure plays a key role in this context. Investment run-up periods, existing deficits in the federal trunk road network, the privatisations of subsections and discussions about an infrastructure company governed by private law all clearly show that a high priority needs to be placed on maintaining the structural integrity of the road network. Needs-oriented and practice-oriented research is indispensable to ensure the necessary quality today and in the future. In the field of concrete pavements, the focus is on road construction under controlled process conditions, targeted regulations, further and newly developed innovative technologies and construction materials, structural maintenance and environmental aspects. Examples of research activities with enhanced practice relevance are reported below.

Noise-related properties of concrete road surfaces – status quo

Currently, a washed concrete texture is the standard texture for concrete road surfaces to reduce tyre/carriageway noise. A noise reduction of -2 db(A) in road surface correction value (DStrO) is assigned to this type of texture. As noise control requirements in road construction become stricter, it is important to make road surfaces available that have improved auditory and noise-reducing properties. Road surfaces with a dense concrete texture are currently being studied, with respect not only to further improving the washed concrete texture but also with respect to the acoustic effects of longitudinal textures (grinding). Comparable textures have been deployed for more than 15 years as a measure to improve skid resistance. Furthermore, there are intense research activities on open porous concrete in materials development.

Grinding describes the production of defined longitudinal textures that are incorporated into the surface of a hardened concrete pavement using a diamond grinding method. In theory, this can achieve noise reductions of about -5 dB(A). Practical applications have also shown that such textures exhibit high skid resistance, and can be produced at high quality and a high level of homogeneity. Grinding can reliably produce textures that are weather-independent. When this method is used, the evenness of road surfaces can at the same time be significantly increased compared to conventional requirements in road construction. It can be deployed in structural maintenance measures as well as in new pavements. Concrete surfaces with a texture produced by grinding processes can also offer economic benefits as it may be possible to substitute less cost-intensive aggregates for the high-quality chippings required in washed concrete.

Fundamentally, grinding textures are studied that can be differentiated into two categories depending on their acoustic properties: grinding a standard texture (type S) as an alternative to washed concrete, and a texture with enhanced acoustic properties (type A). Since 2013, this has been implemented

Grinding texture A14 (10/2016)

on existing sections as well as new pavements. The results of special noise measurements (nearfield method) indicate that noise reductions of up to –5 dB(A) can be expected. It was also possible to comply with an increased evenness requirement of ≤ 2 mm/4 m by using a combination of evenness and texture grinding. The durability of all necessary surface properties is currently being tested for type S textures with the aim to transfer them into applicable regulations. Scientific proof for the durability of type A textures is still pending, as are additional studies on optimisation.

Open porous concrete is a multi-component system with interconnected voids that are accessible up to the surface. Such systems that are rich in voids are deployed in road construction for surfaces, such as open porous asphalt (OPA), to exploit their physical property of sound absorption among other reasons. In theory, this could result in noise reductions of much more than -5 dB(A). For this reason, BASt has been conducting studies since 2012 on utilising open-porous concrete on federal motorways. The primary aim was to develop a formula with which to comply with general road construction requirements for wet and hardened concrete. Based on numerous laboratory tests, open-porous concrete was first tested in a large-scale BASt testing facility. The project was about testing the practical implementation of this installation technology and gaining an initial understanding of the material's durability. Subsequently, a test track was built in 2016 in an auxiliary facility near the A6 motorway (northern Bavaria) using an advanced concrete formula. It is intended to study the durability of open-porous concrete under real-life conditions in a systematic monitoring scheme.

New applications for prefabricated systems in the construction of concrete roads

Disruptions in the traffic flow need to be reduced to a minimum to ensure the availability of road infrastructure, especially during structural maintenance measures on motorways. The time frame for repairs can be significantly reduced by deploying modular rapid-repair systems using prefabricated concrete components. Additionally, the benefits of serial production in factories can be translated to the field of constructing concrete roads so that high-quality concretes with defined surface textures can be produced reliably within the targeted parameters.

Constructing an end piece using prefabricated components (A14)

BASt has been studying the utilisation of prefabricated concrete components since 2012. In an initial step, single-piece prefabricated components were developed to repair singular damages. These were tested in laboratory experiments and practical applications. Based on these results, the prefabricated components were further developed to be adapted for further types of application. As the replacement of individual concrete slabs (individual field replacement) is common in practice, a multi-component prefabricated system was developed for this and other purposes. It has been tested on the motorways A7 and A352 (Lower Saxony) since 2015. To date, more than 35 applications have been implemented in repair and maintenance measures in the network of German motorways, scientifically supervised by BASt.

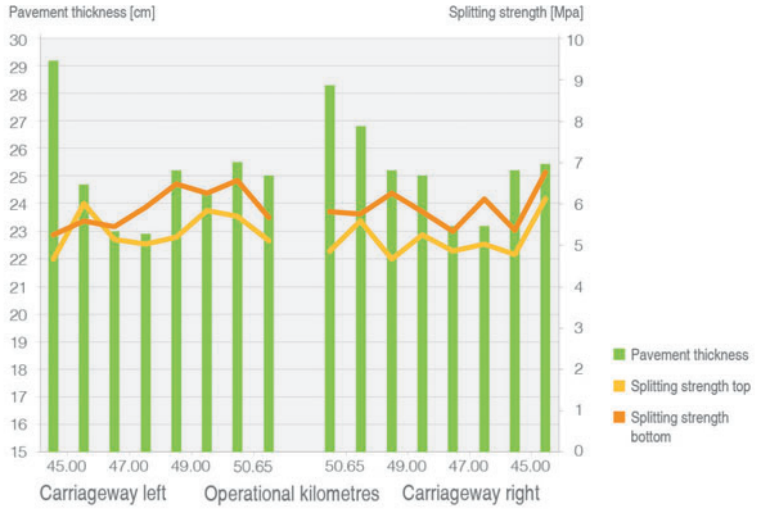
The findings thus far indicate that the new repair procedure "single-piece prefabricated system" can soon be expected to be incorporated into road construction regulations. Besides road construction applications, a system was developed to be used for repairing operation areas of airports, potentially including inset lights (lighting for runways and taxiways). In November 2016, these prefabricated components were installed at the Munich airport for the first time.

The transition to neighbouring road surfaces is an important detail in concrete road pavements. In a research project, a structural solution was developed for building so-called end pieces in new road pavements. The durability of the construction is to be increased compared to conventional methods of building end pieces. This system was used for the first time on the A14 motorway in Saxony-Anhalt in 2016.

In a collaborative project funded by the Federal Ministry of Education and Research, BASt has been investigating a hybrid strengthening system for road maintenance (hybrides Ertüchtigungssystem für die Straßenerhaltung, HESTER) in cities and municipalities. It will be applied in heavily used traffic areas, such as bus lanes, roundabouts and intersections. The scientific challenge consists of developing a complex prefabricated system for which issues related to material, construction and installation methods need to be solved in an integrated manner.

Systematic survey of concrete road surfaces in the motorway network

A structural condition survey and assessment of road surfaces on all German motorways is conducted at regular four-year intervals, in order to have an objective overall impression of the network condition. The data collected also forms the basis for maintenance management and for identifying the fitness for use, as well as their structural value. As the surveys focus specifically and exclusively on road surfaces, this value is only contingently reliable. It would be advisable to include additional parameters addressing the structural substance beyond the surface to devise preventive and economical action. On-site and laboratory tests are conducted, for instance, to completely clarify the causes for damages at the object level; these are time-consuming and costly. For network-related considerations, however, it is important to know about early stages of structural damaging in order to be able to take them into account early on when planning maintenance measures. The hypothesis needs to be investigated whether and how the reliability of structural values for the motorway network based on present conditions and forecast values can be significantly improved by including additional parameters. This is strongly linked to the topics of computational structural design and residual condition assessments of road pavements.



Depiction of selected parameters from studies in the motorway network (anonymised representation of the road section data)

For some time, BASt has been conducting intensive studies on concrete pavements in the motorway networks of Bavaria, Rhineland-Palatinate and Saxony-Anhalt in order to survey section-related material parameters for describing and assessing structural conditions from an engineering perspective. In 2015, 2,000 core samples were taken out on a stretch of about 600 kilometres in Saxony-Anhalt alone. Subsequently, typical material parameters for road construction were identified in about 6,000 individual tests, for example compressive and splitting strengths, static and dynamic e-modules, specific thermal expansion coefficient. As expected, the results showed that it was possible to distinguish the structural conditions of concrete pavements with no features relevant to substance displayed on their surface by their material parameters, for example splitting strength. Based on the principle of computational structural design, the hypothesis referred to above can be supported in so far as taking relevant mechanical parameters into account in structural condition analysis leads to improved quality in the value for the current condition the analysis produces. As maintenance planning is especially based on forecasts of future condition values, the quality of the value for the present condition is also of fundamental significance in this context.

These findings were the basis for a pilot application in the networks of the Länder mentioned above, in which material parameters were deployed for

systematic maintenance planning. A new method was deployed that enables both a static and mechanically sound assessment of the current condition of concrete pavements, as well as forecasts for the future. Survival analyses were conducted to calculate failure rates describing the percentage of concrete pavement failures over time. The “failure rate” parameter can be validated with the help of surface images, taken, for example, from the regular structural condition survey and assessment. As a result, recommendations were made available to the Länder on short-, medium- and long-term measures for structural maintenance, reference being made to the individual sections studied.

It is important to identify more precisely data that may be lacking in current test procedures in subsequent studies to be able in particular to analyse in detail the range of variations of real material parameters occurring in the network. Furthermore, BASt is planning to develop a test procedure for a standardised determination of the thermal expansion coefficient of concrete pavements. In view of continuous technical advances, the question of how the accuracy of structural condition assessments can be further improved also needs to be clarified. One of the questions to be answered is, for example, to what extent conventionally used parameters need to be supplemented or replaced by others depending on the research issue.

Measuring the position of dowels in the scope of section-based analyses in the motorway network of southern Bavaria

“Concrete pavements” section

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Christiane Fischer, Civil engineer
Barbara Jungen, Civil engineer
Alexandra Spilker, Civil engineer
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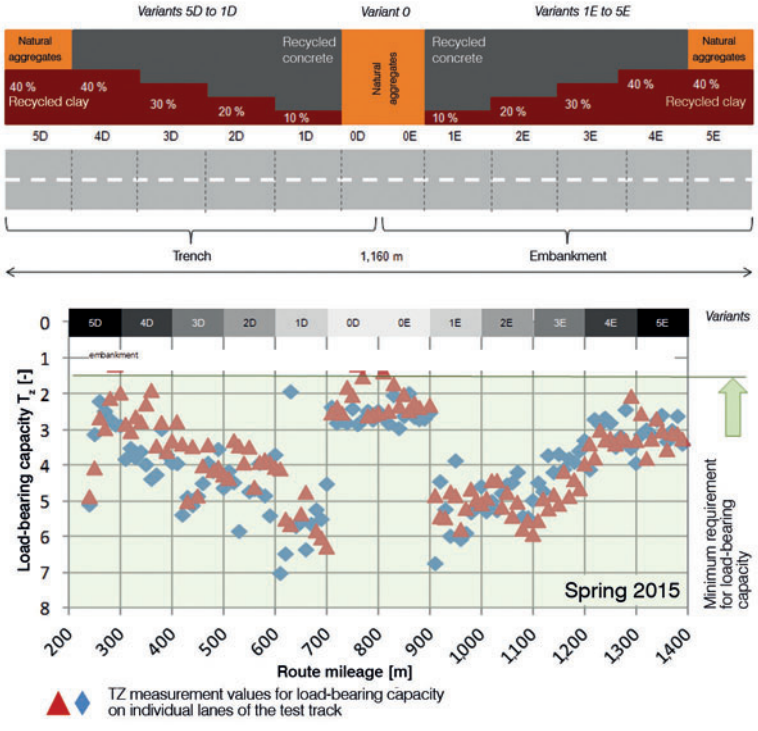
From left: Christiane Fischer, Christoph Becker, Barbara Jungen, Alexandra Spilker, Dr. Marko Wieland

Base courses made of recycled concrete rich in clay

A test track was built on the initiative of the Brandenburg Highway Authority to investigate the permissible clay content in layers without binders under real traffic and weather conditions.

Different test fields were produced on the test track using recycled concrete with varying clay contents. The percentages varied from ten to 40 per cent (variants 1 to 5) and the clay content was compared to a road pavement made of conventional materials (0 variant with greywacke). One half of the test track had an embankment design, the other a trench design.

Comprehensive and regular tests were conducted along the test track during the period of observation between 2007 and 2015. The load-bearing capacity, for example, was measured twice a year using a falling weight deflectometer, and frost surveys were conducted in winter after frost occurrences. Hourly updates of temperature and humidity data of the different layers of the road structure were used as input data for the evaluation.



Representation of the test track with division into test fields and results of the load-bearing capacity measurements

The test track is in good condition after what has now been eight years of use. The load-bearing requirements were sometimes significantly surpassed, especially in the variants with a high percentage of recycled concrete. Trends in differences in load-bearing capacity in relation to the composition of the layers without binders were clearly distinguishable. The higher the clay content in the layers without binders that are made of recycled concrete, the lower the load-bearing capacity. The most flexible variants in the comparison are the variants with natural aggregates. Evaluated load-bearing capacity parameters showed, however, that there was sufficient load-bearing capacity in all variants in accordance with the load classes selected for each variant and the loads applied from traffic to date. Furthermore, the trench design show a tendency towards higher load-bearing capacities than the embankment design. Spring measurements show more flexible structures with lower load-bearing capacities than autumn measurements.

The evaluation of temperature and frost heaving data do not show any systematic correlations between temperature penetration and the few frost heavings that were observed or the composition of the layers without binders. No abnormalities were seen which would indicate structural damaging caused by the composition of the layers without binders.

On the basis of the studies so far, the increase in clay content in recycled concrete implemented in pertinent regulations can be classified as non-critical. The subsequent formation of conglomerates in the test variants with high content of recycled concrete can be considered critical. These test variants showed transverse cracks which may have been caused by parts of the recycled concrete layer solidifying at a later stage. This aspect needs to be reviewed.

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Deputy head of the “Earthworks, Mineral Aggregates” section

Quality assurance in structural condition surveys

The road surfaces of federal trunk roads are surveyed at regular intervals with regard to their transverse evenness. This is accomplished in the scope of a structural condition survey and assessment, during which in essence the rut depth and crossfall of road surfaces are determined. The measurement systems deployed are inspected annually by BASt during fixed-term approval procedures (Zeitbefristete Betriebszulassung), ensuring their quality. It became necessary to develop a high-precision calibration facility in order to accommodate current and future requirements for testing and equipment technologies. BASt's measurement systems can now be more precisely calibrated using a purpose-built test bench for transverse evenness (Querebenheitsprüfstand, QEP). It also enables quality assurance for the measurement systems of third parties to be applied in the scope of regular structural condition surveys and assessments and construction contracts in accordance with these requirements.

Putting the test bench for transverse evenness into service

The QEP is let into the floor of the testing hall and can be covered by a roll cover to prevent damages to the sensitive measuring surface. The QEP's individual components consist of a carrying and lifting unit, a sensor bar, temperature-controlled ventilation, measuring sensors and steering unit. The sensor bar is wrapped in reversible film on its upper side in order to provide an optically homogeneous, non-reflecting surface as the measurement surface.

It consists of gabbro granite (Impala), is 4.6 metres long, 0.3 metres deep, 0.5 metres high and weighs about 1.2 tonnes. The carrying and lifting unit is of a similar weight. The sensor bar is always kept in balance and can be moved vertically by +/- 150 millimetres. The evenness deviations of the sensor bar's surface amount to only about 17 micrometres. By comparison, an average human hair is three times thicker, at about 50 micrometres.

The measuring devices for determining the vertical position work with a precision of about 1.5 micrometres. The systems to measure the sensor bar's longitudinal as well as transverse inclination have an accuracy of five micrometres per metre. This means that an absolute height difference significantly lower than 100 micrometres is achieved over the entire length of the sensor bar. The repositioning precision of the sensor bar is one micrometre, showing the high standard achievable in steering the ball spindle for vertical movements.

When idle, the sensor bar is set at minus 150 millimetres and the roll cover is closed. When it is to be used, the roll cover is taken off and the sensor bar is lifted vertically to zero millimetres. This corresponds to the hall floor level. This is the starting point for systematically setting different height levels and comparing the measured values with regard to deviations from the reference values.

Test bench for testing transverse evenness with roll cover, sensor bar, measuring system

A higher quality in transverse evenness data is achieved for structural condition survey and assessment processes and for construction contracts when these measurements are combined with dynamic testing on the duraBASt testing grounds, see article on page 74. This method also considerably improves BASt's in-house quality assurance. The two testing facilities QEP and duraBAst are envisioned to create the basis for future test procedures to detect three-dimensional evenness.

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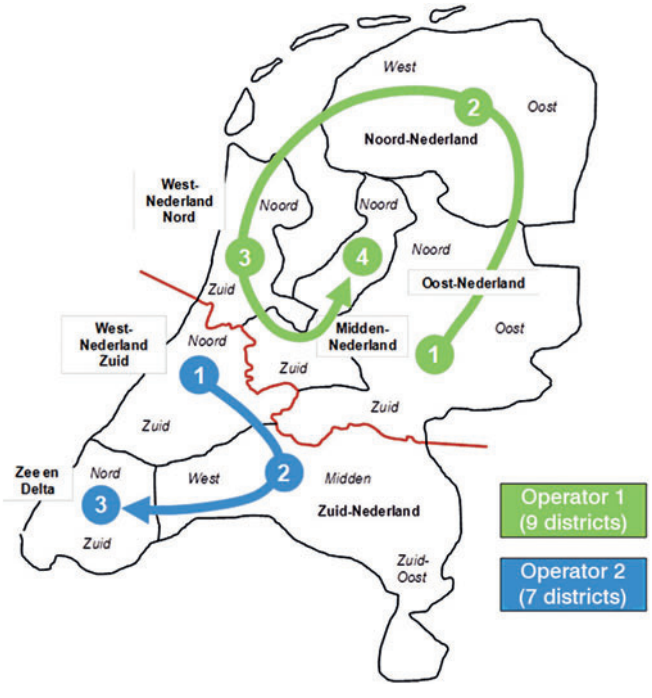
"Surface Characteristics, Evaluation and Maintenance of Roads" section

Skid resistance measurements using the Side Way Force method

Cooperation between Rijkswaterstaat (RWS) and BASt

Since the mid1990s, the skid resistance of truck lanes has been measured systematically in the Netherlands, initially in two-year intervals and on an annual basis since 2009. The measurement method deployed so far was RAW 72. With this measurement trailer, longitudinal skid resistance is measured based on the principle of stopping the measurement wheel to a defined degree by braking (slip ratio of 86 per cent) and using a non-profiled PIARC tyre.

Against the backdrop of European harmonisation and standardisation efforts, the Netherlands decided in 2013 to convert to measuring skid resistance using the Side Way Force (SWF) method as of 2016. In this context, BASt agreed to take over the task of quality assurance, i.e., the approval and external monitoring of the Dutch measurement vehicles, as well as conducting verification checks. BASt will also accompany the entire process of transition and implementation with its technical expertise until the end of 2020 and will participate in research activities, especially with regard to collecting case-studies on open porous road surfaces.



Dividing the Dutch motorway network into two subsections to be surveyed with a total of 16 districts (7 regions) and diagram of the rough time frame of the measurement workflow

The cooperation between Rjikswaterstaat (RWS) and BASt was outlined in a Memorandum of Agreement in late 2015.

Characteristics of the Dutch motorway network

The Dutch motorway network administered by RWS comprises a route length of about 3,000 kilometres, amounting to about 5,800 kilometres in lane-based length according to surveys.

Two special features needed to be taken into account for planning and conducting control measurements. On the one hand, about 90 per cent of the top courses consist of open porous asphalt (OPA) for which temperature corrections have not yet been secured. Accordingly, the measurements also serve the important purpose of collecting important experiences with this type of road structure. On the other hand, the lanes are not numbered from left to right as in Germany but in reverse order. This can lead to a situation in which a main carriageway changes its number when lanes are added or subtracted. This had to be taken into account particularly to clearly identify pre-selected sections.

The route network was divided by RWS into a total of 16 districts; these in turn were comprised in two subsections for the survey (north and south), each measured by one operator.

Online notification system

BASt needs to be able to trace the survey's progress down to individual days in order to plan and coordinate verification checks. This is why an online notification system was developed and implemented as a software programme. It needed to meet the specific needs of the Dutch network – including lane numbering and using the hard shoulder as a traffic lane – but at the same time it had to be easy and as comfortable to use as possible to enable the operators to have an intuitive access to it.

In addition to being displayed in tables, the surveyed and measured sections can also be illustrated graphically in a map.

It was also possible to use the portal to inform about unscheduled downtimes in the measurements to

enable checks that had already been planned to be rescheduled in a timely manner, minimising the time gaps with the operators' measurements.

By allocating individual read and write access rights to RWS, BASt and the two operators, the tool could be used efficiently and in a targeted manner by all parties.

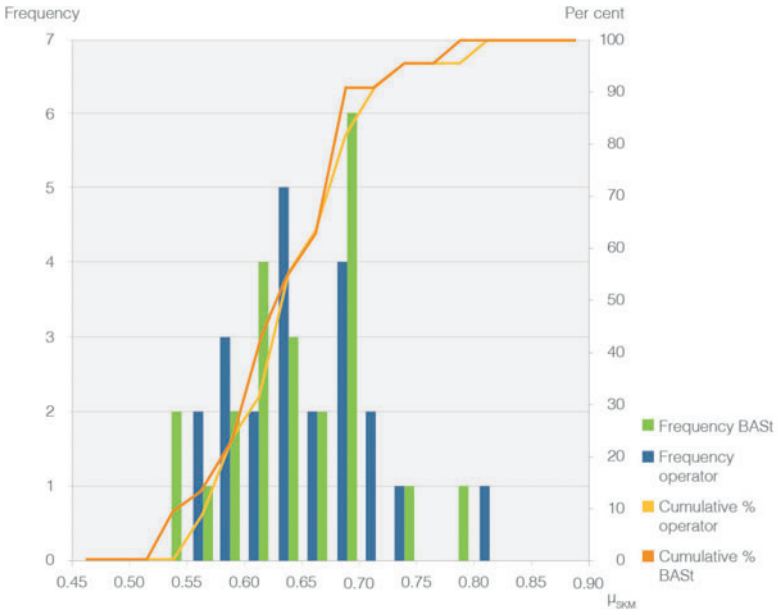
Insights from the verification checks

The SWF measurements were cross-checked in accordance with the German technical test regulations concerning the measurement of grip in road construction Part: Skid Resistance Test (Technische Prüfvorschriften für Griffigkeitsmessungen im Straßenbau, TP Griff-StB) 2007 in the form of duplicate measurements at a speed of 80 km/h. A total of 22 surveyed sections, each two kilometres long, were reviewed in four measurement campaigns between midMay and midAugust 2016. Additionally, two selected OPA sections (project sections), which are also regularly used by the operators for self-monitoring purposes, were measured to be included in the collection of case studies.

The image on the right illustrates the distribution of the skid resistance levels for the control sections reviewed, separated into BASt measurements and measurements by the operators. Though it is not possible to provide statistical data on the basis of this limited data volume, two insights can be derived from the illustration:

- Skid resistance values are all at a relatively high level. If compared to the values for the final acceptance of new road constructions in Germany (μ_{SKM} = 0.46), the measured values are all above this limit value.
- Skid resistance values range from 0.53 μ_{SKM} to almost 0.80 μ_{SKM}, so that the selected set of sections can be considered meaningful and representative for the entire network.

In cases of larger differences between BASt's measurement results and those of the operators, they were usually found to be caused by deviations in the measurement line (wheel path). It can be expected that these deficits will decrease over the coming few years due to the learning curve among the drivers of the SWF measurement vehicles.



Distribution of skid resistance μ_{SKM} on the basis of 22 control measurements

An illustration of the influence of the time of measurement on skid resistance can be seen on the next page, using the example of one of the project sections. Duplicate measurements were also conducted in this context. The skid resistance level was at 0.531 μ_{SKM} during the first measurement in midMay 2016; it dropped significantly to 0.481 μ_{SKM}, i.e., by 0.050 within the ca. three-month period. Besides traffic-related influences due to the polishing effects of tyres, seasonal fluctuations can be seen as a reason for this. These effects are very complex and difficult to be illustrated in models but they will be observed and analysed further in the course of the cooperation.

Conclusion

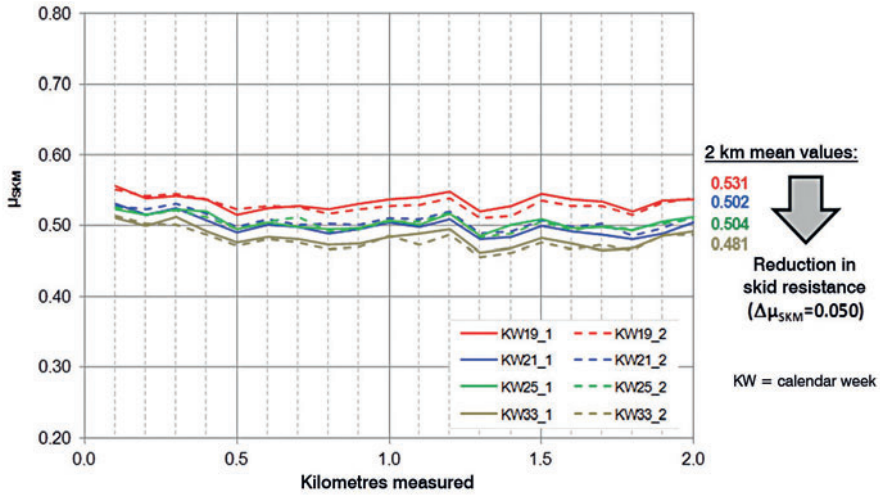
On 14 October 2016, after the transitional phase was completed, it was reviewed and evaluated during a review meeting of RWS, BASt and the two Dutch operators of the SWF measurement vehicles. The conclusion is as follows:

- A high technical standard was attested to the Dutch measurement vehicles in the scope of the quality assurance process.
- The quality of the measurement results was confirmed objectively, using evaluation diagrams in the scope of the verification checks. Differences between the measurements of BASt and those of the operators were analysed, and the operators were informed about presumed error sources, especially deficits in keeping to the wheel path.

- The test phase has fully served its intended purpose, and binding measurements can be tackled with confidence as of 2017.

Currently, RWS is evaluating all the measurement data with the aim of ensuring that the values from the previous method are re-calculated to the new SWF method in a statistically sound manner so that requirements based on the RAW 72 method can be maintained.

It is planned that BASt will also use this data, especially in order to verify the applicability of the temperature corrections for open porous asphalt and to adapt them if necessary.



Changes in the skid resistance level on one of the project sections (preselected sections) over three months (May to August 2016)

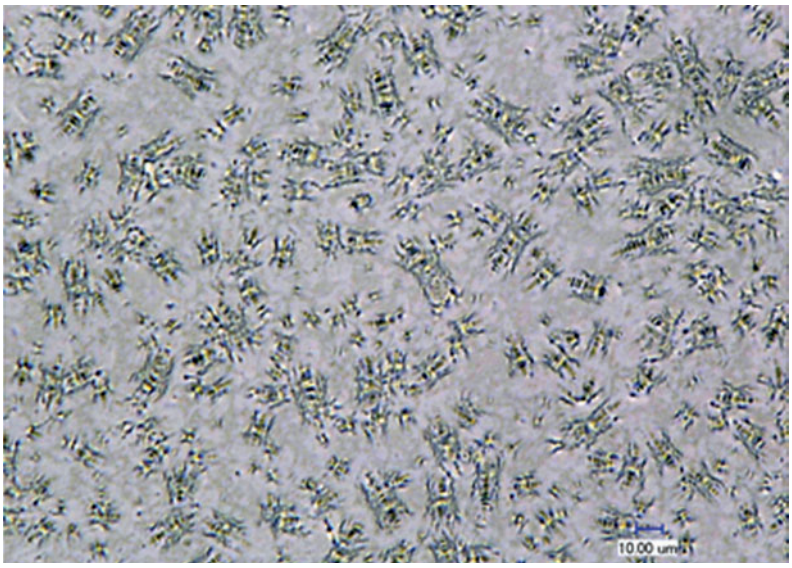
"Surface Characteristics, Evaluation and Maintenance of Roads" section

Tanja Altemeier, Geographer
Jürgen Cadera, Technician
André Meyer, Civil engineer
Hans-Joachim Olesch, Electrical engineer
Daniel Schüller, Computer scientist
Kevin Storz, Technician
Dr Ulrike Stöckert, Civil engineer, head of section
Karen Scharnigg, Civil engineer, "Traffic Management and Road Maintenance Services" section

From left: Jürgen Cadera, André Meyer, Kevin Storz, Tanja Altemeier, Karen Scharnigg, Dr Ulrike Stöckert, Hans-Joachim Olesch and Daniel Schüller

How do the bees get into bitumen?

At first glance, the following studies may appear to be lacking in practical relevance and of purely 'academic' interest. The complex chemical composition of bitumen manifests itself in forming the structures observed. If it is confirmed that the structures not only emerge on the surface but form a three-dimensional network, this will have significant consequences on the current modelling of bitumen structures. Even small changes in the chemical and structural composition of bitumen have an effect on the rheological and thermoplastic properties of the material. Though bitumen only has a small mass-content of asphalt, minute changes of its molecular distribution and the micro-mechanical structure have a significant influence on the performance of asphalt mixes. Therefore, a better understanding of the micro-mechanical and chemical properties of bitumen is an essential requirement to improve future modelling of the performance of asphalt mixes and their development over time.



Bee structure (light microscopy image)

Studies

For a number of years, the term "bee structure" has been appearing in connection with bitumen. What does it refer to? LOEBER et al. were the first authors to write about peculiar structures detected on bitumen surfaces by atomic force microscopy (AFM). These are striped patterns resembling bees directly surrounded by another distinctive phase. The patterns themselves were arbitrarily distributed in a largely homogeneous matrix. In the scope of studies at BASt, types of bitumen were identified that displayed structures so large that it even made sense to deploy light microscopy.

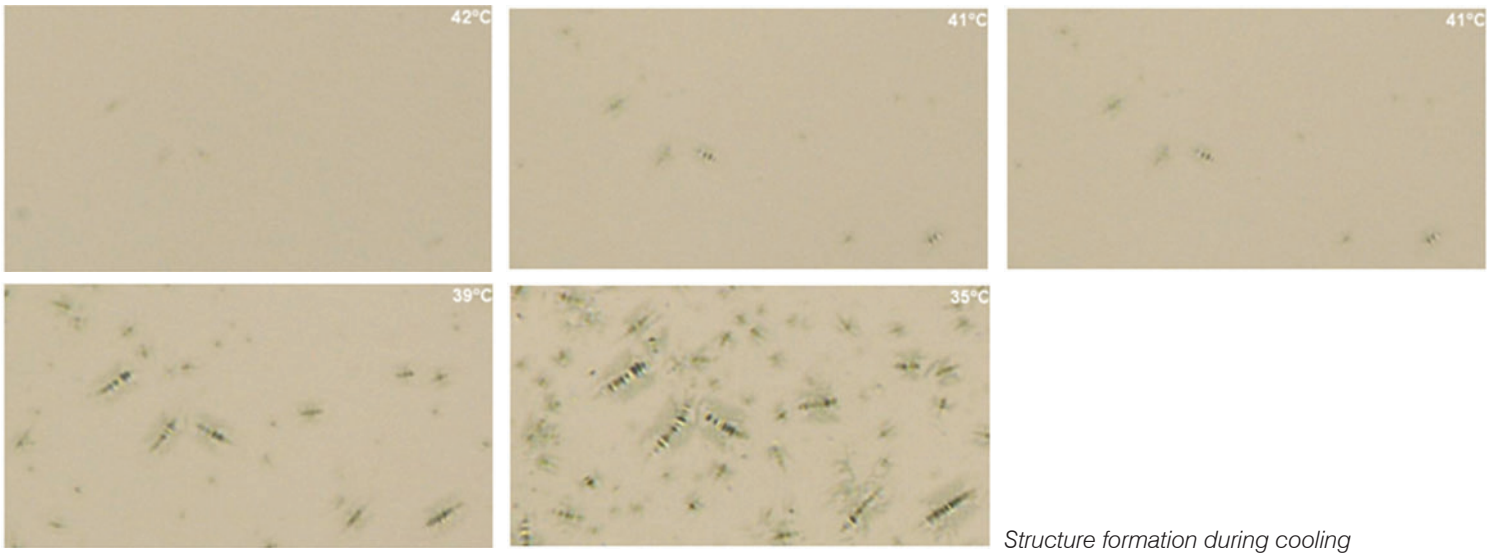
The image in the upper right corner depicts a striped bee structure for which the term "catana phase" has become standard. The neighbouring phase is called the peri or para phase, while the indifferent basic structure constitutes the perpetua or sal phase. There has not yet been a detailed explanation for the emergence of this phenomenon. All the findings indicate, however, that the formation of these structures is a consequence of molecular self-aggregation. This is defined as the spontaneous association of molecules accompanied by the formation of stable, regular structures based on weak interactions. The stability of the structures is a result of a complex combination of attractions and repulsions in a number of interactions, for example Van der Waals interactions, π-π interactions and hydrogen bonding.

The thermodynamic processes in multi-substance systems such as bitumen are generally not conducive to creating regular structures because this involves a local reduction in entropy (measure of the irreversibility of a system). The fact that there is nonetheless structure formation in bitumen can probably be attributed to a decrease in the free enthalpy ΔG of the molecular system and an increase in the entropy of the overall system. Clarifying the mechanisms that lead to structure formation is a major challenge because of the complexity of the system and the interactions involved.

Structure formation depends on the specific type of bitumen and occurs when the bitumen is cooled to temperatures within a narrow range. The series of images on the following page shows that the process starts at a temperature of 42 degrees Celsius and already reaches its final shape at 35 degrees Celsius.

Quick cooling leads to the formation of small structures (one to two micrometres) while slow cooling enables larger structures to be formed (20 to 35 micrometres).

When the sample is reheated, the catana phase is the first to disappear at temperatures between

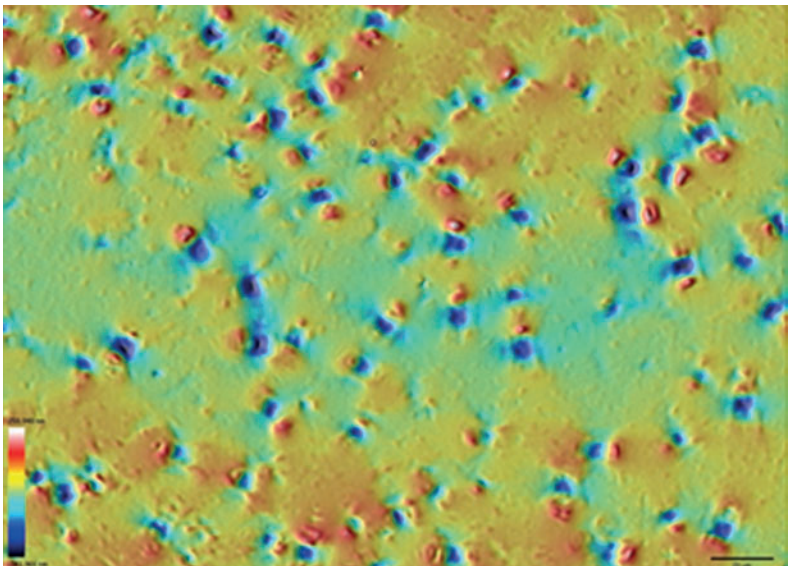


Structure formation during cooling

40 and 50 degrees Celsius. At the same time, the perpetua phase grows larger at the expense of the peri phase. The perpetua phase appears to be mobile, continuous and seems to have a mediator effect at almost any temperature. When the sample is cooled again, the original microstructure reappears. The process is thus completely reversible.

With the support of the Institute for Physical Chemistry at the Justus Liebig University in Gießen, significant height differences were identified on the seemingly smooth bitumen surface using confocal laser scanning microscopy.

Bee structures also display a profile of regular height differences as JÄGER et al. were able to prove with the help of AFM technology. The bee structure appears as a symmetrical sequence of elevations and depressions.



Height differences on the bitumen surface (confocal laser scanning microscopy)

The pulsed force mode of an atomic force microscope provides the possibility to gain an understanding of the mechanical properties of the different bitumen phases.

The catana phase shows an alternation between very hard and very soft properties that corresponds with the elevations and depressions. The surrounding peri phase is very stiff or hard; the third perpetua phase, by contrast, shows low viscosity and is quasi-liquid.

Generally speaking, surface areas that are very stiff have reduced adhesive properties. This applies in particular to the peri phase.

A generally accepted explanation for the chemical composition of the different phases has not yet been found. The conventional bitumen model is only of limited usability in this case. According to this model, the micelles (molecular aggregates) consist of high-molecular aromatic structures (asphaltenes) wrapped in lighter components with fewer aromatic properties. The greater its distance, the chemical composition of the ‘shell’ continuously transitions to the composition of the inter-micellear phase. This is why no clear delineation of the different areas can be observed.

Two extreme shapes can be formed: the “sol bitumen” with asphalt micelles that have fully dispersed and do not interact, and the “gel bitumen”

with interacting asphalt micelles. Most bitumen in road construction correspond to a state between the extremes.

There is a multitude of explanations of the bee structure, and they are in some respects contradictory. Some authors assume that the catana phase consists of crystalline paraffins and that as a pure surface effect it does not reflect an underlying structure.

FISCHER, DILLINGH and HERMSE interpret bitumen as a heterogenous liquid that includes a share of crystallised fractions consisting of two phases. Asphaltenes function as 'crystallisation seeds' which precipitate because of their affinity to parrafin waxes. This could lead to the formation of not easily soluble asphaltene flakes.

AGUIAR-MOYA et al. found indications that the bee structures are not linked to asphaltenes. They suspect instead a correlation with naphtene aromates. The crystallisation of parrafin waxes and the oxidisation of bitumen are not seen as relevant for structure formation.

Conversely, JÄGER et al. assume that the hard and soft areas of the bee structures are formed alternately by high-polar molecules such as asphaltene and resins and polyaromates/aromates.

Experiments conducted at BASt support the hypothesis that asphaltenes are necessary for the formation of the catana structure. It is known that asphaltenes consist of changing proportions of planar structures which can build larger aggregates piled on top of each other.

Asphaltenes alone do not suffice, however, to explain the bee structure. Asphaltenes have a stiffening effect on bitumen whereas the series of polar compounds, polyaromates, aromates and aliphates show decreasing viscosity. One possible explanation for the significant change in the physical properties of the alternating stripes in the bee structure can be found in the formation of a 'sandwich structure'. This is formed from 'stiff' aggregated asphaltenes and intermittent low-viscose components, primarily consisting of aliphates. In general, such structures could indicate a distribution that is likely to correspond to the nature of a "gel bitumen".

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Insights, Facts an

nd Data

Traffic census 2015

Image: Staatliches Bauamt Traunstein

Information on the type and volume of motor traffic constitutes a vital basis for transport infrastructure planning and transport policy decisions. In 2015, another regular traffic census, which also included all 12,000 sections of the federal trunk roads network, was conducted across Germany to provide the statistical basis.

Data collection methods

No separate counting was necessary at every eighth section (12 per cent) as data is obtained automatically and continuously from permanent count sites. Two thirds of all sections (65 per cent) were surveyed manually, as was also done in the past, by people standing with tally sheets at the roadside. They counted the number of vehicles for three hours in the afternoon on six to eight selected days between April and October. There were additional counts on two days from seven to nine in the morning on heavily used routes.

The use of invisible side radar technology that is integrated into delineators is a new feature to collect traffic census data. This technology was approved for use in the traffic census (Straßenverkehrszählung, SVZ) 2015 for the first time and was deployed at one quarter of the sections (24 per cent). It enables a reliable survey of the vehicles (including bicycles) in neighbouring lanes. The counted data is accessed daily by mobile communication and entered into an online database by BASt using an automated system.

The three data collection methods are juxtaposed in the table.

Count type	Manual traffic census	Temporary measurements	Automatic permanent count sites
Beginning	1952/53	2014	1975
Time frame	Sampling (five-year cycle)	Sampling	Exhaustive sampling
Spatial reference	Exhaustive sampling	Suitability of location	Sampling
Projection	Motor vehicle traffic per year	Motor vehicle traffic per year	Motor vehicle traffic in federal trunk road network
2015 survey	Motor traffic on open-area sections of supra-regional roads		
Number of count sites	12,650	6,050	1,635
Federal motorways	1,840	-	765
Federal highways	5,960	2,875	640
Regional and district roads	4,850	3,175	230
Count time per count unit	3pm to 6pm on 8 days*	non-stop for 3 weeks**	non-stop for 365 days
Identification of vehicle type	5 motor vehicle groups + bicycles	5 motor vehicle groups + bicycles	2 to 8 motor vehicle groups ***

** 2 ordinary weekdays 7am- 9am and 3pm- 6pm, 2 weekdays during holidays 3pm-6pm, 2 Fridays 3pm-6pm, 2 Sundays 4pm-7pm*

*** 1 ordinary week during the first half of the year, 1 week during summer holidays, 1 ordinary week in the second half of the year*

**** up to eight motor vehicle types can be identified depending on device used*

Traffic counting in Germany

Temporary measurements using side radar technology will be continued in subsequent years to reduce the counting efforts for the next cyclical census (2020). It is likely that this new technology will also be used to survey the network of regional and district roads more intensely.

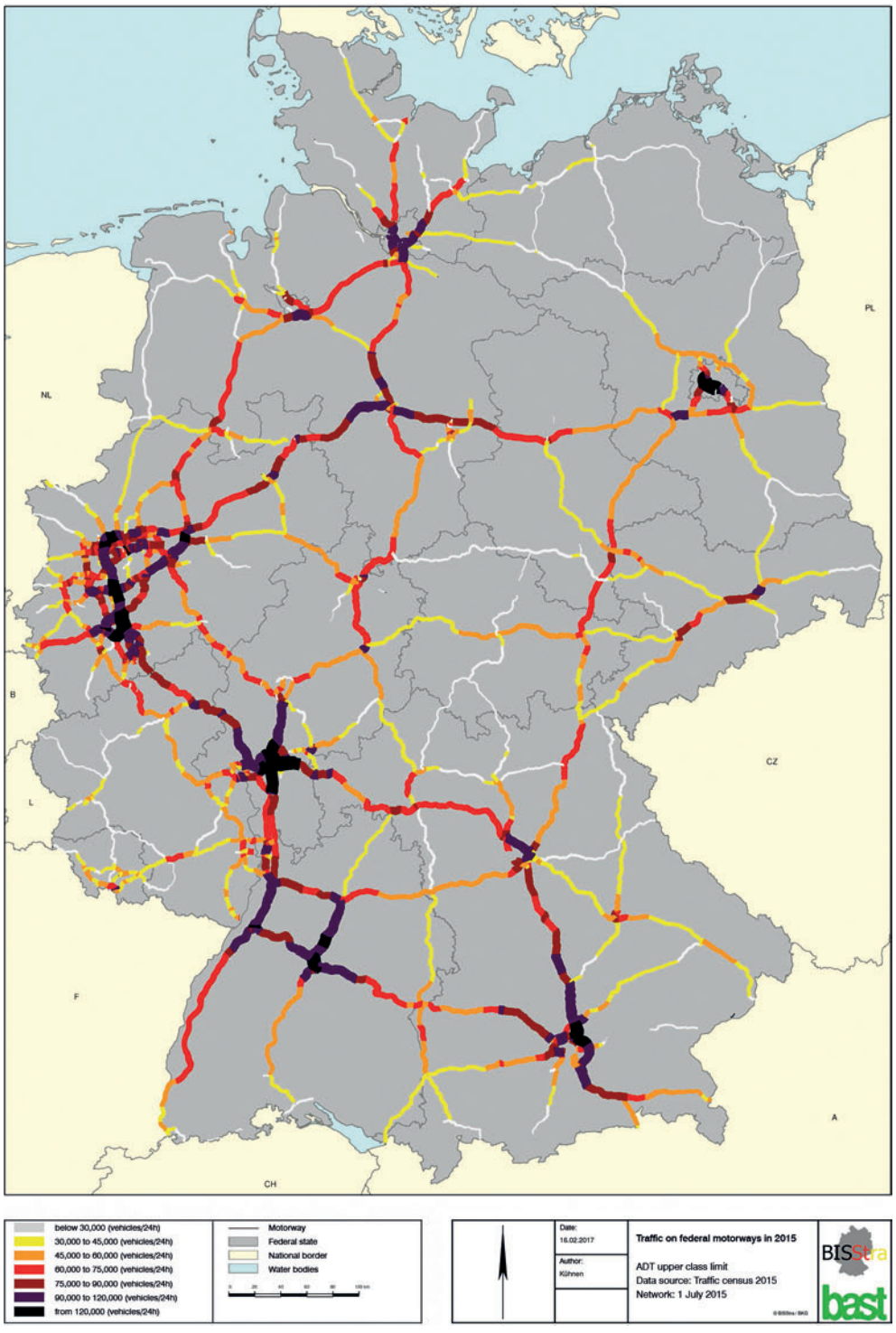
Results

The traffic census provides data for each section of the federal trunk roads network. The results are available on the BASt website - together with maps of federal motorways indicating the total traffic volume as well as the traffic volume of heavy goods vehicle traffic.

Also in 2015, the sections of the A3 motorway in Cologne and the A100 motorway in Berlin turned out to be the most heavily used sections of the federal motorways network. The average traffic volumes reached a mean value of more than 165,000 vehicles per day. Traffic volumes were generally the highest in conurbations.

Peak values for heavy goods vehicle traffic amounted to 20,000 vehicles per day. In this context, the A2 motorway was significantly prominent not only with peak volumes in individual sections but also as the main route of heavy goods traffic from east to west. Additional peak volumes were again counted at the sections of the A3 motorway around Cologne.

All the results are discussed in detail in the traffic census report 2015 as part of BASt's publication series. The report is supplemented by a large-scale map of Germany indicating the traffic volumes in the entire network of federal highways.



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Economist
"Traffic Statistics, BISStra" section

Mileage survey 2014

The total distance travelled by vehicles on Germany's road network is a key parameter to describe motorised road transport. Fieldwork to determine this parameter requires a lot of time and money and is thus conducted only at relatively large intervals. The targeted data can only be retrieved in the scope of a survey and projection procedure that consists of two – complementary – components. For the first time since 2002, a survey has been conducted for 2014 on both the mileage of vehicles registered in Germany (mileage by nationals) and the mileage of German and foreign vehicles on Germany's road network (national mileage).

The mileage by nationals was compiled by the Federal Motor Transport Authority (Kraftfahrt-Bundesamt) on behalf of BASt by conducting a survey among car owners. The national mileage was surveyed in a traffic census in 2014 as planned. In the meantime, plausibility checks have been conducted, the collected data evaluated and the results conclusively analysed.

Vehicle type	Mileage (billion kilometres)	Percentage of foreign vehicles
Motorcycles	17.5	9.1
Passenger cars	586.2	3.5
Passenger cars with trailers	14.8	7.5
Buses	4.6	5.4
Lorries	51.8	5.7
Lorries without trailers	22.4	9.1
Lorries with trailers	16.6	27.1
Tractor-trailers	26.2	31.7
Other	3.8	6.7
Total	743.8	5.6

National mileage 2014 by vehicle type

Road type	Mileage (billion kilometres)	Percentage of foreign vehicles
Federal motorways	228.3	12.4
Federal highways	168.9	3.1
Regional roads	137.3	2.0
District roads	72.0	2.1
Other	137.3	2.9
Total	743.8	5.6

National mileage 2014 by location

Nationality of vehicle	Mileage (billion kilometres)	Percentage
German	702.0	94.4
Other	41.8	5.6
Total	743.8	100.0

National mileage 2014 by nationality of vehicle

The results will be published in two separate reports "Mileage Report 2014 - national mileage and risk of accidents" (Fahrleistungserhebung 2014 - Inlandfahrleistung und Unfallrisiko) and "Mileage Report 2014 - mileage by German nationals" (Fahrleistungserhebung 2014 - Inländerfahrleistung), inlcuding a comprehensive annex of tables. The data set comprising the mileage by German nationals will also be made available to the Clearing Centre of the German Aerospace Centre (Deutsches Institut für Luft- und Raumfahrt, DLR) for further scientific analyses.

Results of the national mileage survey

The total mileage for 2014 on German roads amounts to 743.8 billion vehicle kilometres. Roughly 31 per cent took place on motorways. About 5.6 per cent of the total mileage are distances travelled by foreign vehicles; on motorways this figure is even 12.4 per cent. The mileage figures can be used, for example, to calculate accident involvement rates (number of vehicles involved in an accident per one billion kilometres driven) and thus to quantify the risk of accidents in motor vehicle traffic.

When interpreting the results, it is important to take into account that the results have been derived from extrapolating the sample counts at census spots onto the entire road network. It is not possible to indicate the mileage of individual road sections or regions or make statements on the number of vehicles responsible for the mileage compiled.

Vehicle type	Accidents causing deaths	Accidents causing severe injuries	Accident causing light injuries	Total
	Vehicles involved in accidents per one billion vehicle kilometres			
Motorcycles	41	781	1,851	2,673
Passenger cars	5	99	526	630
Delivery vans	4	53	249	306
Passenger cars with trailers	3	38	151	193
Buses	13	199	1,014	1,226
Lorries without trailers	9	58	209	276
Lorries with trailers	7	48	124	179
Tractor-trailers	13	71	179	263
Other	32	389	1,327	1,748

Vehicles involved in accidents per billion vehicle kilometres 2014 by vehicle type and accident category

Vehicle group	Mileage by German nationals 2014 (billion kilometres)	Mean number of registered motor vehicles 2014 (1,000 vehicles)	Mileage per motor vehicle and year (kilometres)
Motorcycles	12.4	4,148	2,982
Passenger cars – private owners	489.1	39,657	12,334
Passenger cars – commercial owners	109.6	4,469	24,519
Buses and coaches	4.0	77	51,309
Lorries – private owners	17.4	921	18,949
Lorries – commercial owners	46.4	1,753	26,486
Semi-trailer towing vehicles	19.3	194	99,692
Other towing vehicles	0.6	133	4,209
Other motor vehicles	3.6	304	11,921
Motor vehicles with insurance indicators	4.6	1,824	2,532
Total	707.0	53,480	13,220

Mileage by German nationals 2014 by vehicle type

Results of the mileage by nationals survey

The survey of vehicle owners revealed a total mileage of German vehicles of 707 billion vehicle kilometres in 2014. Distances travelled abroad account for about three per cent of this mileage. The annual mileage per vehicle amounts to more than 13,000 kilometres as a mean value for all vehicle types combined. Peak mileages per vehicle were attributed to tractor-trailers.

Using the knowledge gained about vehicle types and vehicle owner characteristics, mileage parameters can be broken down to detailed information such as mileage by vehicles of specific drive systems and emission categories.

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Deputy head of the "Accidents Analysis, Safety Concepts, Road Safety Economics" section

Economic impact assessment for regulatory proposals

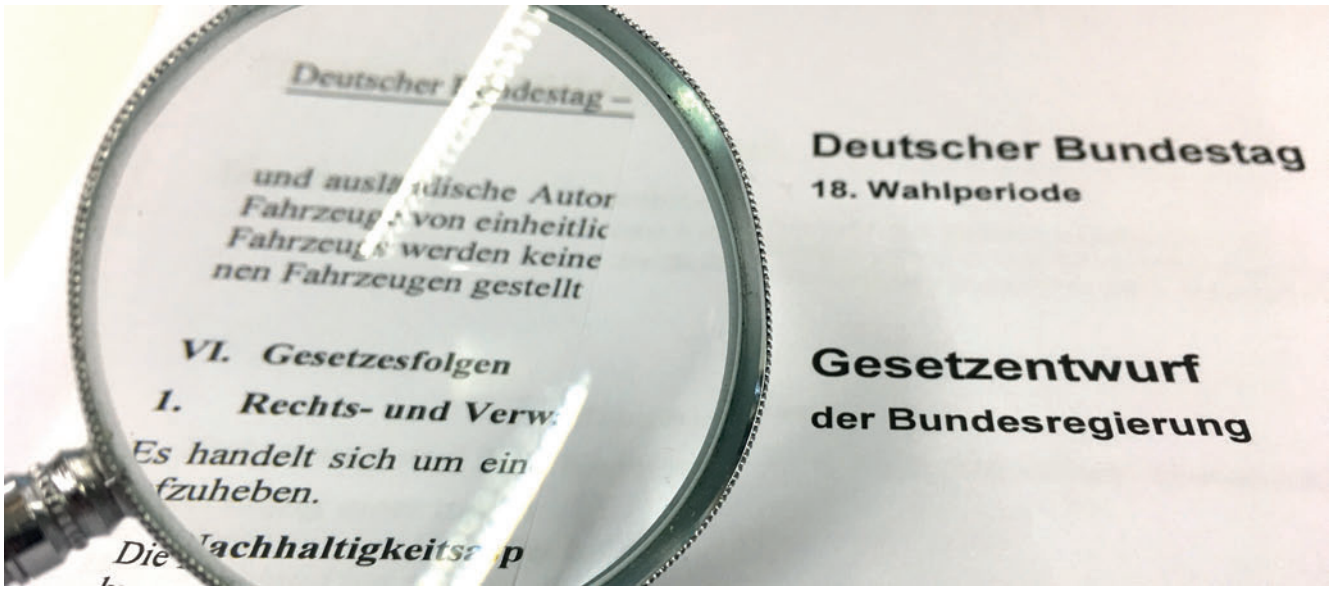
As of 2001, every regulatory proposal of the German government has to be accompanied by an impact assessment that indicates the increase or decrease in the financial and administrative burden the legislation will cause, as well as sustainability aspects and generally every significant intended impact and unintended side effect. Impact assessments aim to shape government action more effectively and efficiently, to restrict state intervention to a necessary minimum and to include possible alternatives.

The Joint Rules of Procedure of the Federal Ministries (Gemeinsame Geschäftsordnung) describe the process for bills drafted by the federal ministries. Lead ministries need to comply with a host of requirements in the legislative process. Their number has increased significantly since the Regulatory Control Council (Normenkontrollrat) was established in 2006. The Council is the political steering body that monitors compliance with the principles of standardised bureaucracy cost measurement. One key component is determining the total measurable expenditure - compliance expenditure – for the addressees of the legislation in question, citizens, the economy and the administrative sector.

Since 2011, BASt has been measuring the compliance expenditure for selected regulatory proposals of the Federal Transport Ministry in the field of road transport on the basis of the guidelines for determining and describing compliance expenditure in regulatory proposals of the federal government (Leitfaden zur Ermittlung und Darstellung des Erfüllungsaufwands in Regelungsvorhaben der Bundesregierung). This includes already when preparing the draft law or ordinance, reviewing the increase or decrease in the time and money required, including bureaucracy costs that result from a law or an ordinance. A distinction is made between one-off transition costs and annual consequential costs.

BASt systematically includes Länder and municipalities in a survey of selected authorities to determine compliance expenditure.

Authorities at the municipal level are usually named by the regional ministries and can then be contacted by BASt directly. BASt uses a questionnaire it developed itself which enables a structural collection of the individual compliance expenditure data of each authority interviewed. The aim is to describe the compliance expenditure at the Länder and municipal levels in a practice-oriented manner and to take them into account when drafting or revising pieces of federal legislation. This means that the time or costs required are described for each case and, if possible, an estimate is made for the total number of cases in Germany, so that ultimately the impact for all of Germany can be determined. The calculations for annual and one-time compliance costs for each addressee of the legal norm are published in both the covering note and the preamble of the draft law.

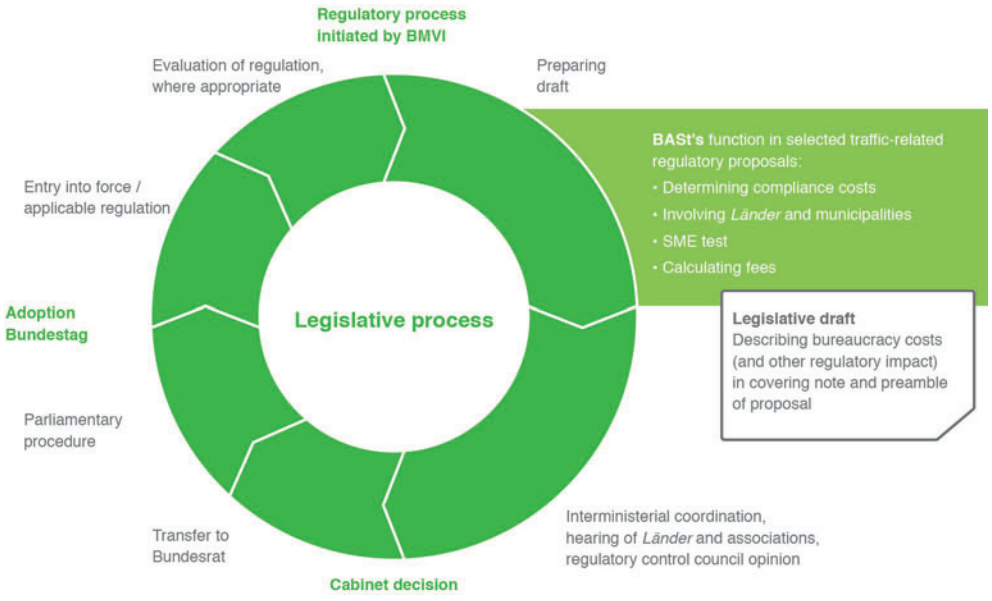


Should small and medium-sized enterprises (SMEs) be especially affected by high compliance costs, BASt will in certain cases also conduct SME tests. This will ensure that the interests of SMEs are taken into account at an early stage when preparing a new federal law. Furthermore, regulatory proposals may make it necessary to re-calculate the fees for administrative acts; this is also done by BASt. Since early in 2016, assessing the compliance costs of regulatory proposals has not been restricted only to national legislation. For regulatory proposals of the EU Commission with compliance costs (consequential costs) amounting to more than 35 million euros per year, the national legislative is obliged to evaluate the EU Commission's impact assessment and to conduct its own estimate of the compliance costs for Germany.

In the past ten years, a comprehensive system has been created which makes the administrative burden and the costs of the Federal Government's regulatory proposals transparent to the administration, citizens and enterprises in Germany to an unprecedented degree. Clear points of reference can thus be provided to the government, parliamentary decision-makers and the interested public.

Examples

BASt's activities have contributed significantly in this time period to implementing essential regulatory proposals in the field of road transport. With its studies on compliance costs, BASt has contributed to the necessary transparency for subjects ranging from reforms in the penalty points system for traffic offenders and the law concerning driving instructors to promoting e-mobility and car sharing. BASt's findings have enabled the relevant decision-makers to turn important projects on road safety and sustainability into laws, while taking economic consequential costs into account.



BASt's functions within the legislative process

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Felix Heinl
Economist, "Accident Analysis, Safety Concepts, Road Safety Economics" section

Felix Heinl (left) und Dr Jan-André Bühne

BMVI Network of Experts Knowledge – Ability – Action

Since January 2016, the BMVI Network of Expert Knowledge – Ability – Action has been working on research issues on the safe and sustainable development of Germany's transport systems. BASt and six other executive agencies of the Federal Transport Ministry constitute part of this collaborative research association: the Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG), the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH), the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau, BAW), the German Meteorological Service (Deutscher Wetterdienst, DWD), the Federal Office for Goods Transport (Bundesamt für Güterverkehr, BAG) and the Federal Railway Authority (Eisenbahn-Bundesamt, EBA). Together, they are designing a new format for departmental research.

BASt experts contribute scientifically and technically to research and development across all modes of transport in the various subject areas the network covers. BASt is responsible for the overall coordination of the expert network; it is in the hands of a scientific task force providing technical and organisational support for research activities and the transfer of knowledge and technology (bmvi-expertennetzwerk.de).

Subject area 1: Adapting transport and infrastructure to climate change and extreme weather conditions

Subject area 1 is dedicated to shaping the transport infrastructure of the Federation to be resilient against extreme weather events and climate change. For this purpose, climate scenarios and risk analysis procedures are developed and applied in focal regions.

BASt scientists are in charge of the key topics "risk analysis", "earth slides" and "focal area inland" and collaborate on subsections of the key topics "flood risk" and "adaptation options". With this content orientation, subject area 1 contributes to the German Strategy for Adaptation to Climate Change (Deutsche Anpassungsstrategie an den Klimawandel, DAS).

Under "risk analysis", a tool is being developed to analyse climate risks. It is based on a Geographic Information System (GIS) and links geo information with infrastructure data and spatially visualises it. The risk analysis draws upon an indicator model, using integrated evaluation methods to create a system of potential damage scenarios. It uses chains of cause and effect to create a risk impact model. Data products are developed to provide information about the risk potential and vulnerabilities for both the near and the distant future.

Flooded area (image: © mb67 - Fotolia)

Another key topic, "earth slides", consists of the development of risk information maps and the installation of a data base on earth slides. In the scope of GIS-based studies, disposition factors are analysed statistically, weighted on the basis of expert systems and turned into spatial models.

Digital terrain and landscape models and data from geological engineering and climate research are an essential basis for work in this field. Risk information maps for the rail and road transport systems will make it possible to identify potential hazard areas at the network level and preselect them for analyses on site.

Local case studies in risk areas with high traffic volumes are conducted under “focal area inland”. Selection criteria such as risk factor and criticality as well as data and model availability are used to select suitable research sites. In addition to the main axes of the Trans-European Network for Transport (TEN-T) in Germany, significant transport hubs and hinterland connections are analysed. “Focal area inland” focuses on spatial aspects in order to analyse risk potential on site, using refined methods.

Subject area 2: Green design for transport and infrastructure

Transport ensures the mobility of a country’s population and contributes to no small extent to a country’s economic growth. Designing transport and infrastructure in an environmentally sound manner is an essential precondition for sustainable development.

The increase in traffic volumes, however, is always accompanied by an increase in environmental stress. These include sealed soil surfaces, use of raw materials for energy purposes, interventions in sensitive biotopes and subsequently damages to fauna and flora, climate-harming carbon dioxide emissions as well as air and noise pollution.

All modes of transport pursue the same protection goals with respect to adverse impact on the environment. Subject area 2 “Green design for transport and infrastructure” therefore aims to integrate the competences of the partners with each other and to make use of synergies in the three fields below.

Wildlife overpass in Brandenburg (image: © Mario Hagen - Fotolia)

Preserving and promoting biological and structural diversity

Transport separates and connects habitats. Furthermore, it impedes and sometimes even supports the propagation of organisms. This focus deals with two key aspects of biological diversity and its interactions with mobility:

- Preservation or restoration of habitats at a minimum size required for biodiversity to develop.
- Introduction and propagation of alien species (neo biota) to which all modes of transport contribute.

Evaluating and minimising material and non-material-based impact

Material and non-material-based pollution caused by transport has an adverse effect on human health and the environment. This key topic focuses on qualitative disruptions to the natural living spaces of people, animals and plants:

- Transport is a source of pollutants emitted especially into ambient air which may, however, also have adverse effects on soils and water bodies.
- When transport routes are built and in fact when transport structures are operated, pollutants can be introduced particularly into soils and water bodies, sometimes also into ambient air.
- The use of any mode of transport results in noise pollution for humans and the environment.

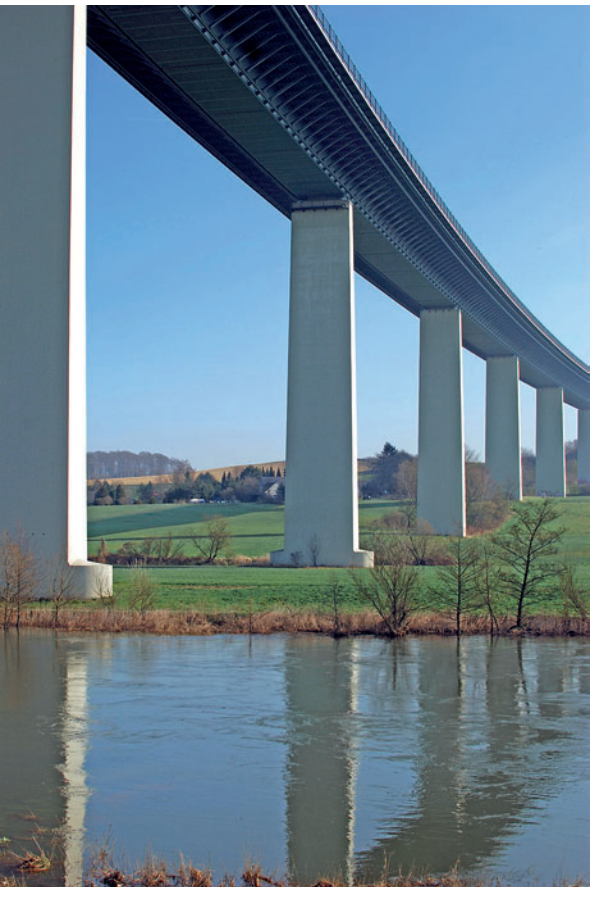
Sustainability assessment

This focus plays a role across all projects of the overall subject area. General requirements for sustainable action and green development, such as lowering energy consumption, reducing greenhouse gas and pollutants emissions, reducing transport noise, restricting land consumption and preserving unfragmented habitats, are taken up and translated into practical guidelines for decisions on sustainability assessment.

The collaboration across all modes of transport will result in viable solutions for the future which will safeguard our mobility in the long run, are economically feasible and socially balanced and at the same time will have a low impact on the environment.

Subject area 3: Enhancing reliability of transport infrastructure

The transport infrastructure of the transport systems: rail, road, waterway is aging. This is particularly true for bridges and other engineering structures such as tunnels, locks, weirs and retaining walls. It is important to ensure that the transport infrastructure is reliable.



Mintard bridge over the Ruhr valley (image: © travelpeter - Fotolia)

Maintenance strategies and concepts need to be reviewed to see how they can be improved so that Germany's transport system can be further developed in a resilient and sustainable manner.

This is why the activities under subject area 3 have been subdivided into four fields:

- taking stock and evaluating the current situation,
- reliability analyses,
- vulnerability analyses,
- construction while in service.

Processes to identify and evaluate the current state form the basis of every activity. In this context, new procedures and technologies are to be tested for suitability and further developed. At the same time, tried and tested procedures will be evaluated as to the quality of their findings and their cost-benefit ratio.

Besides providing information on the current situation, it is crucial to be able to make qualified projections about the future behaviour of transport structures. It is intended to supplement the procedures in place, for the most part deterministic in nature, in the future with reliability- and risk-based approaches; in the long run they will be substituted.

In addition to routine stress that is in line with the infrastructure's intended use, it increasingly needs to withstand extraordinary events such as floods and accidents. The corresponding procedures and methods need to be adapted or newly developed for these cases.

Finally, (construction) measures need to be carried out. These face the special challenge that they need to be completed at the quality level necessary quality while being used, causing as little traffic disruptions as possible. For this, existing procedures and methods need to be adapted and new ones developed.

BMVI-Network of Experts

Dr Anja Baum
Geophysicist
Deputy head of the "Environmental Protection" section

Ralph Holst
Civil engineer
"Maintenance of Engineering Structures" section

Dr Martin Klose
Geographer
"Smart Road Construction, Renewable Energy, Climate Change" section

Research management at BASt

BASt conducts its own research and awards contracts to third parties to answer technical and transport policy-related questions. The research is financed by BASt's own budget and by funds from the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI). When designing their research, BASt works closely with the BMVI and other institutions, such as the Road and Transport Research Association (Forschungsgesellschaft für Straßen- und Verkehrswesen, FGSV). BASt is in charge of 350 external research projects per year with a total volume of approximately 70 million euros, focusing on:

- the "Road Sector Research Programme" (Forschungsprogramm Straßenwesen) from the BMVI budget with approximately ten million euros per year,
- its own "Research Programme on Road Safety" (Forschungsprogramm Straßenverkehrssicherheit) from its own budget of approximately three million euros per year,

- its own "Innovation Programme for Roads" (Innovationsprogramm Straße) from its own budget of approximately one million euros per year
- the "Research Programme on Urban Transport" (Forschungsprogramm Stadtverkehr) from the BMVI budget, amounting to approximately three million euros per year.

The "Innovation Programme for Roads" (Innovationsprogramm Straße) should be emphasised here, which has been covering research financed by BASt grants since 2009. The aim of the programme is to promote innovative concepts and technologies for the construction and maintenance of roads. The research programmes listed above are part of the BMVI's overall research programme.

EU research

Between 2015 and 2016, BASt was involved in 21 projects of the seventh and eighth Framework Research Programmes of the European Union. In this reporting period, BASt has been active in international cooperation, specifically in the fields of road construction (ROSANNE, ECOLABEL, HEALROAD projects), resilience (RAIN-EX, RESILENS projects) and automation and connectivity (ECo-AT, European ITS Platform, AdaptIVe, CODECS projects). BASt is the lead agency of the consortium in the SENIORS (Safety ENhanced Innovations for Older Road userS) project which was launched in 2015.

Other projects for the eighth framework research programme (HORIZON 2020) are in the application phase or in the contract negotiation phase.

Dr Ingo Koßmann
Sociologist
Head of the "Research Coordination, Library and Documentation Centre" section

Dr Karl-Josef Höhnscheid
Economist
Head of the "Research Controlling" office

Intermodal approach for European research planning

The Forum of European National Highway Research Laboratories (FEHRL) is the umbrella organisation of national transport research institutes at the European level. Between 2014 and 2016, BASt's President Stefan Strick was also the President of FEHRL. During this time, essential steps were taken to kick off the new "Strategic European Road and Cross-modal Research Programme (SERRP)" with the "Forever Open Road, Rail, Runway and River across all modes" FORx4 initiative. Using an intermodal approach, knowledge transfer by and among all modes of transport is taken into account in the new SERRP. Additionally, new materials and technologies are to be swiftly implemented since the targeted added value can only be achieved in this way (www.fehrl.org).

The European Commission has been focusing on enhancing the intermodal character of the transport sector in recent years with the aim to create a Trans-European intermodal transport network [1]. The "Horizon 2020" European Framework Research Programme therefore includes a number of different activities to promote intermodal research. A case in point is the development of joint research approaches that can be supported by "Coordination and Support Actions" (CSAs). CSAs are intended to support the European Commission in implementing the work programme in evaluating and monitoring European research projects.

This has been specifically implemented, for example, in three projects: "Forever Open Infrastructure across (x) all modes" (FOX), "Users, safety, security and energy in transport infrastructure" (USE-iT) and "Rethinking future infrastructure networks" (REFINET), which are receiving EU funding from 2015 to 2017. Partners from all four modes of transport have been involved, representing the differing interests of research, the industrial sector and administration and controlling sectors (www.useitandfoxprojects.eu).

REFINET aims to express a joint European vision of how the sustainable and multimodal infrastructure network of the future should be planned, built and maintained. Within the project, the REFINET consortium, consisting of various stakeholders with a high proportion of business representatives, has committed to this challenge (www.refinet.eu).

By contrast, the two projects FOX and USE-iT focus on identifying tried and tested technologies, promising approaches and the research needs for multimodal future development. FEHRL administers the projects and heads the work package in charge of disseminating project findings between the two connected projects. FOX and USE-iT are thus FEHRL's new flagship projects, implementing the strategic approach of the new SERRP VI and turning it into reality.

USE-iT aims to enhance the understanding of what the future common challenges are that all modes of transport have in the fields of safety, security and energy. Traffic engineering issues are its main focus. FOX focuses instead on further developing the intermodal transport infrastructure. A variety of stakeholders will be brought together in the scope of the two projects in order to evaluate and draft potential joint research goals based on their experiences. At the same time, joint workshops provide the foundation for an intensive intermodal dialogue in the future.

BASt is especially involved in the FOX project, which aims to identify joint, innovative measures and processes as well as joint needs for research about all processes of the transport infrastructure's life cycle. Four technical work packages have been established:

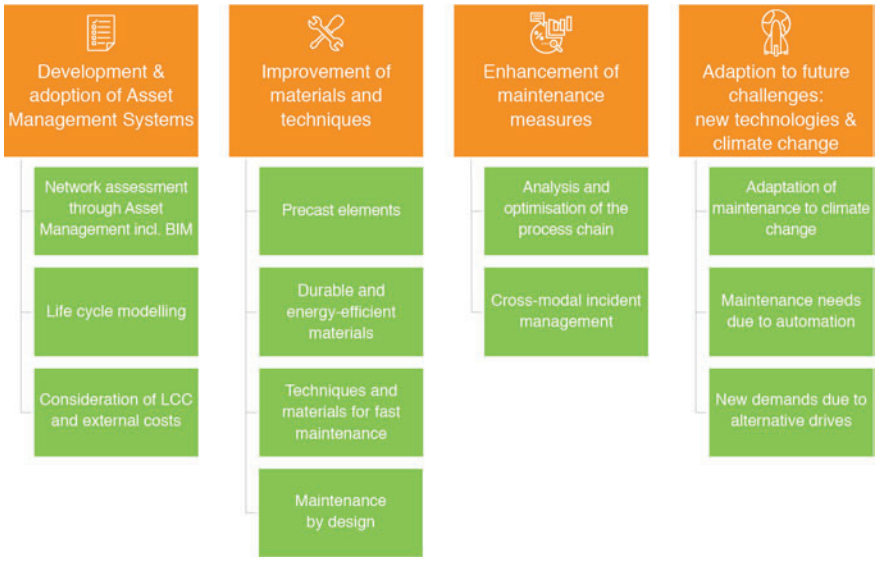
- Construction (WP 2; chaired by: Ifsttar/France),
- Maintenance (WP3; chaired by: BASt),
- Inspection (WP4; chaired by: ZAG/Slovenia) and
- Recycling and reuse (WP5; chaired by: TNO/Netherlands).

Besides these institutes, the following additional project partners are directly or indirectly (i.e. through the FEHRL umbrella) involved: transport research institutes from Israel (NETIVEI), Austria (AIT), Poland (IBDiM), Portugal (LNEC), Czech Republic (CDV), Ukraine (DNDI), and EURNEX (European umbrella rail institution) and STAC (French technical centre for civil aviation). The active participation of these organisations reflects the interests of all modes of transport. BASt experts support the work package chairs with their knowledge, thus ensuring the transfer of German expertise.

FOX as well as USE-iT have a great number of additional stakeholders involved to take the different perspectives of all institutions into account (policy makers, public and private infrastructure operators, research institutions, universities) when defining and developing future research goals. Everyone involved is requested to express their opinion by attending workshops and participating in surveys and interviews. The two projects collaborate closely in their methods in order to achieve this.

After extensive research, two joint FOX and USE-iT stakeholder workshops have so far been held in Brussels, and a major questionnaire campaign and target-oriented interviews with key individuals have been conducted. In addition, there was the opportunity to meet other experts during presentations at national, European and international events as well as in the scope of web seminars, and to take their assessments and proposals into consideration.

The findings so far encompass a list of best practices and optimal approaches for the fields covered by the individual work packages. A joint assessment methodology was developed by the FOX and USE-iT consortium to enable the experts involved to assess the potential of intermodal further development. Its result was used as a basis to define research areas which were allocated to future challenges. One example of such an interim result for "maintenance management" is shown in the table. The two projects' final step is to develop road maps, i.e., strategic schedules. The road maps propose a time frame for the practical implementation of short- and medium-term research for the most promising technological and methodological approaches. These road maps serve as guidelines for decisions by the European Commission when strategically determining the future agenda of intermodal research in the field of "transport infrastructure".



Challenges and areas of research identified for FOX WP3

Another important result is establishing a new culture of exchange among the various modes of transport. The many shared points of contact the modes of transport have while working on the project are an important step in this direction; the intention is to maintain the contact even after the project is concluded. Social media networks such as LinkedIn and Twitter, among others, are to be used for sharing information and for continuing to work together in the future.

Enhanced intermodal cooperation among the individual modes of transport is necessary and required. The project's results so far have made it clear that targeted support for monomodal research will be indispensable in the future because of the differences between the individual modes of transport.

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FEHRL

USE-iT und FOX

REFINET

Ursula Blume
Geologist
"International Road Construction Research Tasks" section

International cooperation

BASt's research activities usually do not stop at national borders. This means that international cooperation is an essential component of the work of BASt's scientists, providing the opportunity not only to exchange experiences but also to form strategic alliances.

Committees and organisations

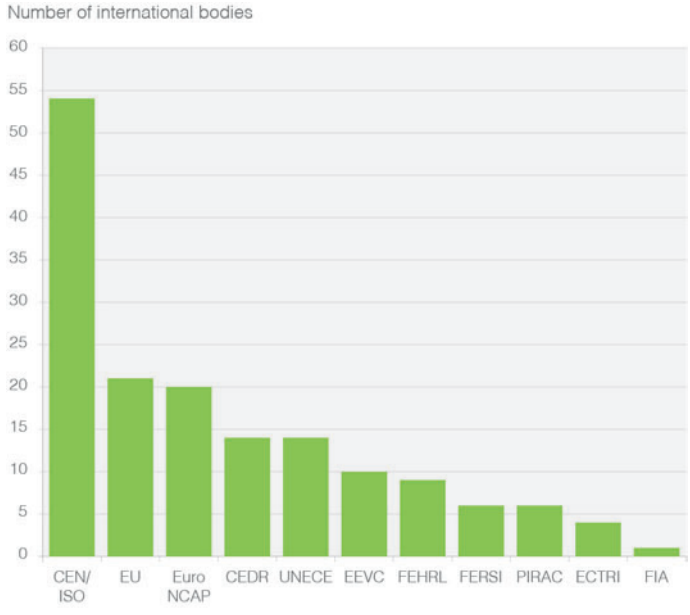
Over the past two years, more than 80 of its staff members have represented BASt in 200 committees at more than 30 organisations. The majority of the bodies with the highest number of BASt representatives work on developing standards. More than 50 per cent of the committee members are active in this field, for example in the international working group on "Man-Machine Interface". BASt participated in further developing and standardising a new method which measures the effects on a driver's attention depending on the driver's cognitive stress levels (Tactile Detection Response Task, TDRT). Corresponding trials were also conducted at BASt's MMI Laboratory. The test results were incorporated into the ISO standard 17488 published in 2016. In view of the planned introduction of automated driving functions, terminology is being defined at the moment that can be used as a basis for further developing metrics to measure human availability and performance in self-driving vehicles. The findings of this harmonisation work will contribute to ISO Technical Report 21959.

Additionally, bilateral and multilateral cooperation at every level and in various networks is significant. BASt, for example, was active in the scope of German-French cooperation at annual conferences and meetings of experts and senior management. BASt participated in numerous technical working groups and headed about ten percent of the committees. BASt's President Stefan Strick chaired FEHRL (Forum of European Highway Research Laboratories) until 2016. Dr Horst Schulze, head of the "Behaviour and Road Safety" department was re-confirmed as the President of FERSI (Forum of European Road Safety Research Institutes) in October 2015, as was Raschid Urmeew as Secretary-General.

In September 2015, BASt scientist Dr Torsten Geißler took over chairmanship of the Amsterdam Group. The implementation of cooperative systems and services (C-ITS) is one of the high-profile topics in the field of smart transport systems on roads. Germany and its neighbouring countries - the Netherlands and Austria - are jointly testing pilot applications in this context. At the European level, the infrastructure organisations CEDR, ASECAP and POLIS are working within the Amsterdam Group in a dialogue with the automotive industry on creating the framework conditions for coherent C-ITS implementation.

Projects and awards

Dr Horst Schulze as the project coordinator received the Widmark Award in October 2016 for the



BASt's participation in selected organisations

CEDR	*Conference of European Directors of Roads*
CEN	*Comité Européen de Normalisation*
ECTRI	European Conference of Transport Research Institutes
EEVC	*European Enhanced Vehicle-Safety Committee*
Euro NCAP	*European New Car Assessment Programme*
FEHRL	*Forum of European National Highway Research Laboratories*
FERSI	*Forum of European Road Safety Research*
FIA	*Fédération Internationale de l'Automobile*
ISO	*International Organization for Standardization*
EU	*Europäische Union*
PIARC	*World Road Association*
UN ECE	*United Nations Economic Commission for Europe*

DRUID has been the largest European research project to date in its field with the participation of 37 research institutions from 17 EU Member States and Norway and a budget of 23.5 million euros.

European DRUID (Driving Under Influence of Drugs, Alcohol and Medicines) project. This award is given to outstanding, internationally visible achievements in researching alcohol and other drugs and their impact on road safety. DRUID is a project funded by the European Union and coordinated by BASt. Its aim was to create a scientific basis for decisions on road safety within the EU, and to propose efficient measures against driving under the influence of alcohol, recreational and prescription drugs.

In September 2016, BASt organised and chaired a workshop at the European Commission at which European policy makers, scientists and practitioners developed recommendations for driver training and driving tests as a basis for the next EU directive on driving licences.

At the transnational level, BASt has been instrumental in continuously developing instruments and processes for cross-border cooperation in what are currently nine transnational tendering processes after the start of ERA-NET ROAD in 2008 and its continuation until 2016 through the CEDR Transnational Research Programme. Roughly 70 projects were funded with a total budget of almost 25 million euros. The projects were carried out by more than 100 research organisations from more than 20 countries. In the German-speaking region, it is also advisable to pool existing resources in joint research projects to enable more comprehensive research.

An initial pilot project on "further developing concrete technology in road construction", for example, was jointly designed by Austria and Germany with a budget of more than two million euros. The tendering process was successfully initiated in spring 2016. Based on this positive experience, it is intended to conduct a similar tendering process in 2017 on asphalt technology with the additional participation of Switzerland.

Cooperations

Since January 2015, BASt's accident experts have advised Ukrainian experts from the Ukrainian Infrastructure Ministry on setting up a team for technical reviews of severe traffic accidents involving commercial vehicles (lorries and buses). In the scope of this EU twinning project, BASt staff have been asked to provide not only technical details but to support Ukraine in drafting bills and to show how past experience can be used to improve road safety. An existing cooperation agreement with RIOH (Research Institute of Highway) in Beijing was consolidated in two meetings of scientific experts in Germany and China.

In 2016, the German-Dutch expert meeting took place at BASt with a focus on road construction. For the first time, the Dutch Organisation for Applied Research in Natural Sciences (TNO) was part of the Dutch delegation, headed by Theo van de Gazelle, the Deputy Director General of Rijkswaterstaat.

In December 2016, Andre Seeck, head of BASt's "Automotive Engineering" department signed a cooperation agreement with Xiaobo Wu, the Vice-President of the China National Institute of Standardization (CNIS). The agreement focuses on reviewing and analysing traffic accidents on site. The concept is modelled on GIDAS (German In-Depth Accident Study), the largest project for a detailed analysis of accidents in Germany.

Petra Peter-Antonin
Engineer for safety technology
Head of the "Press and Public Relations" office

Press and public relations

One activity at the Road Safety Day was the presentation of a rear-end collision with simulated fire brigade operation

Road Safety Day was celebrated for the eleventh time in a row on 20 June 2015. On this occassion, BASt too opened its laboratories and test halls, and together with 23 partners offered a great number of activities for visitors to join in, as well as information about road safety-related aspects.

Furthermore, it has already become an annual tradition for BASt to present itself with its own booth at the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI) during the Open House of the Federal Government every August: in 2015 BAST focused on electric mini-cars, in 2016 on information about children's safety in cars.

Events

A great number of expert events and workshops attended by national and international experts were carried out in 2015 and 2016, sometimes in cooperation with other organisations. Some of them are listed below:

The BMVI was the patron of the conference "Road structures, environmental protection, circular economy: how can they be made compatible?" (Straßenbauwerk, Umweltschutz, Kreislaufwirtschaft (StrUK): Wie sind sie miteinander vereinbar?) which was opened by State Secretary Rainer Bomba and took place at BASt on 22 and 23 June 2015. About 100 experts convened to find solutions to this question at the conference hosted by BASt together with the Road and Transport Research Association (Forschungsgesellschaft für Straßen- und Verkehrswesen, FGSV).

The fifth German-Chinese Road Safety Symposium took place at BASt on 3 September 2015. The high-level delegation of Chinese scientists was primarily interested in improving road safety by means of traffic engineering and organisational measures.

Experts from all over Germany met on 8 and 9 October 2015 at the invitation of the ZNS Hannelore Kohl Foundation and BASt in Bergisch Gladbach to develop new care options for the approximately 70,000 victims of traffic accidents suffering from head injuries, and to develop measures to reduce the number of accidents. Parliamentary State Secretary Norbert Barthle conveyed a welcome message from the Federal Transport Minister at the outset of the conference.

"Smart bridge - how to turn it into reality" (Intelligente Brücke - Der Weg in die Praxis) was the title of a symposium on 30 November 2015 attended by 200 experts who came to BASt for information on state-of-the-art technology and on implementing recent findings into practice.

For the first time, BASt was a co-host in spirit at the STUVA Congress of the Research Association for Underground Transportation Facilities (Studiengesellschaft für unterirdische Verkehrsanlagen). Approximately 1,800 tunnel experts gathered in Dortmund in early December 2015 and were able to see a segment of the model tunnel in the accompanying exhibition. This model will be used at BASt in future to research flow-optimised ventilation systems.

The eighth German-Russian Road Safety Conference, which was hosted by BASt, the German Road Safety Council (Deutscher Verkehrssicherheitsrat, DVR) and the Moscow Technical University for Automotive and Road Engineering (MADI), took place at the Federal Transport Ministry in Berlin on 9 and 10 June 2016. Norbert Barthle, Parliamentary State Secretary at the BMVI, gave the welcome address.

The International Symposium on Enhancing Highway Performance (ISEHP) under the patronage of Transport Minister Alexander Dobrindt joined for the first time the 7th International Symposium on Highway Capacity and Quality of Service with the 3rd International Symposium on Freeway and Tollway Operations of the US Transportation Research Boards (TRB). BASt coordinated the event which took place in Berlin from 13 to 17 June 2016. It was organised by FGSV and the TRB Committees on Highway Capacity and Quality of Service (AHB40) and Freeway Operations (AHB20). About 200 participants from more than 20 countries learnt about current projects in traffic engineering, innovations, and technical regulations.

BASt organised the fourth KOTSA-BASt Symposium under the headline "Road Safety in Korea and Germany: Status, Targets and Measures" on BMVI premises on 25 and 26 August 2016. The Korean delegation, headed by YoungTae Oh, the President of the Korean Transportation Safety Authority (KOTSA), met with representatives of BMVI and BASt to talk about European and national road safety issues.

Not one but two events in autumn 2016 were dedicated to vulnerable road users: under the patronage of Federal Transport Minister Alexander Dobrindt, the joint symposium of BASt and the German Insurers Accident Research (Unfallforschung der Versicherer, UDV) took place in Berlin on 21 September titled "More cycling - yes, but safely" (Mehr Radverkehr - aber sicher!) in which more than 200 experts participated. National and international experts presented findings on topics such as e-bikes in traffic, distracted cyclists and fast cycling lanes, and discussed cycle helmets during their concluding panel discussion during the ninth ADAC/BASt Symposium "Driving safely in Europe" (Sicher Fahren in Europa) on 11 October.

Exhibitions

BASt presented itself together with the Federal Transport Ministry at the World Road Congress in Seoul in November 2015, at the Transport Research Arena in Warsaw in April 2016 and at the German Road and Transport Congress in Bremen in September 2016.

Visitors

More than 850 international and national visitors, including high-ranking officials, visited BASt in 2015 and 2016. Representatives from ministries, administrative bodies, the industrial sector and academia came to BASt for information on up-to-date findings, ongoing research and new projects. Project workshops or meetings of international organisations and European institutions were held on a daily basis.

Over the past two years, 14 visiting scholars from eight different countries spent several weeks, sometimes even months studying at BASt. Four members of staff from the Ukrainian Ministry for Infrastructure spent two days observing the day-to-day work at BASt in late 2016.

Passed away

Former Professor Dr-Ing. Dr-Ing. Josef Kunz passed away in March 2015 at the age of 62. He was President of BASt between 2002 and 2008 and subsequently became Director General at the Federal Transport Ministry.

Publications

Selected research findings are published by BASt in the "Reports of the Federal Highway Research Institute" (Berichte der Bundesanstalt für Straßenwesen) series. A total number of 109 reports were published in 2015 and 2016. All reports are available as free downloads from BASt's electronic archive (ELBA): bast.opus.hbz-nrw.de. 54 of these reports are also available as print editions. Ten reports were published in the past two years in the BMVI's "Research on Road Construction and Traffic Engineering" (Forschung Straßenbau und Straßenverkehrstechnik) series, for which BASt is also responsible.

BMVI State Secretary Rainer Bomba (second from left) visited BASt in July 2016 for an expert information briefing

Special interest reports are summarised in "Research compact" (Forschung kompakt): a total of 50 issues were released in 2015 and 2016.

In addition to the German-language information service "BASt aktuell" which is released four times a year, there is also an English version "BASt topics". Both publications are free of charge and available online for download on BASt's website, as are many other BASt publications (www.bast.de).

Brochures

A new short profile of BASt has been available since autumn 2016. The "Five years of research at the Federal Highway Research Institute 2011 to 2015 " (Fünf Jahre Forschung 2011 bis 2015 der Bundesanstalt für Straßenwesen) brochure contains selected findings from BASt research.

Two brochures were particularly well received by the general public: "Children's safety in cars" (Kindersicherheit im Auto) and "Information on medical and psychological examination" (Informationen zur MPU, Medizinisch Psychologische Untersuchung). A total of more than 50,000 copies were ordered free of charge.

Press

The issue of medical and psychological examination was also of interest to the media. Their enquiries were mainly about current figures and the new brochure.

The media also showed a special interest in the field trial with longer trucks that was accompanied scientifically by BASt and concluded in late 2016 (see p. 10) and duraBASt for which construction started in 2015 (see p. 74). The temperature-controlled road project attracted the most attention.

The results of the traffic census (see p. 94) and the mileage survey (see p. 96) have been and continue to be a frequent subject of enquiries.

Over the past two years, BASt issued a total of 48 press releases on research findings and general interest events and answered about 1,600 press enquiries.

Intranet

In early 2015, BASt joined the Federal Transport Ministry's inet. This provides cross-departmental content for everyone, as well as a separate closed area for each agency that makes up part of the network. This concept offers an added value to staff members and at the same time reduces maintenance effort for the individual agencies.

"Press and Public Relations" office

Petra Bierl, Documentalist
Petra Fischer, International trade specialist
Christopher Gerhard, PR and integrated communication
Petra Peter-Antonin, Engineer for safety technology, head of the "Press and Public Relations" office
Guido Rosemann, Photo designer
Iris Schneidermann, Civil engineer, deputy head of the "Press and Public relations" office
Tanja Steg, Economist

From left: Petra Peter-Antonin, Petra Bierl, Christopher Gerhard, Petra Fischer, Iris Schneidermann, Guido Rosemann, Tanja Steg

BASt *ELBA*

BASt's scientific support

The Scientific Advisory Board provided advice and support for BASt also in 2015 and 2016. The focus was on evaluating results of BASt's research between 2011 and 2015, and consulting on the new medium-term research planning for 2016 - 2020. The Advisory Board convened four times during the reporting period, with additional support from Professor Martin Radenberg, Chair for Transport-Related Construction, Ruhr University Bochum. As the representative from the Federal Ministry of Transport and Digital Infrastructure, Director Gerhard Rühmkorf, "Road Investment Policies, Maintenance, Financing", followed his predecessor in office Dr Stefan Krause, who in turn was appointed Director-General for Road Construction. After eight years supporting BASt, the Scientific Advisory Board was disbanded at the end of 2016. It will resume its work seamlessly in the following year in a new set-up as an Advisory Board with two affiliated technical consultative committees on transport infrastructure and road safety. The new structure is intended inter alia to give greater scope to technical expertise for specific focal areas of BASt's activities.

Professor Martin Radenberg (left) und Gerhard Rühmkorf

Dr Karl-Josef Höhnscheid
Economist
Head of the "Research Controlling" office

Focus on quality

Quality is at the heart of everything BASt does. The continuously rising expectations of BASt's clients (the ministry and society) are always taken into account in this context. Staff cuts are a major challenge, as is the increasing scarcity of resources while the number of tasks is increasing. Dealing with the demographic shift, preserving knowledge and harmonising the requirements on the basis of EU Regulations increasingly influence BASt's activities.

BASt's testing and calibrating activities have had to and will continue to need to fulfil special requirements. The quality management commissioner coordinates the in-house implementation of relevant regulations in the individual sections that conduct conformity assessments. The "Passive Vehicle Safety, Biomechanics" section, for example, has been appointed by the Federal Motor Transport Authority as "Category A Technical Service" and has been notified as such at the EU Commission and the UN ECE Secretariat. The calibrating laboratory for sensors in the same field which was accredited for the acceleration parameter by the German Accreditation Agency (DAkkS) was again given a successful review by DAkkS in 2016.

The Certification Body for Highway Equipment (BASt-Zert) which was accredited by DAkkS in 2014, ensures the international recognition of its certificates on the basis of (successfully completing) regular audits by DAkkS, most recently in 2016. The accredited "testing laboratory for highway equipment" (Prüfstelle Straßenausstattung) undergoes regular reviews by DAkkS, most recently successfully in 2015.

Guidelines on ensuring good scientific practice and good scientific policy consultation have been developed to ensure quality in the fields of research and policy consultation.

The quality of the research projects is ensured by project controlling on the basis of standardised reporting (cost and performance accounting using SAP). The data is processed, analysed, and evaluated. Procedures and processes are reviewed and analysed by means of internal audits and, where necessary, improved. The quality management commissioner has been in charge of a team since 2015 to improve the quality of BASt products. She trains staff and collaborates in the project on introducing e-files. All these activities are intended to result in safe, error-free, reliable and standardised processes, projects and procedures with which to expand and further develop a target-oriented quality management system.

Sabine Lilgert
Mineralogist
BASt's quality management commissioner
Deputy head of the "Research Controlling, Road Infrastructure Assets" office

Budget and finances

Budget estimates (in thousands of euros)	2015	2016
BASt budget	44,609	48,690
Personnel expenditure	22,438	22,638
Non-personnel expenditure	18,734	19,335
Allocations/grants	1,770	1,400
Other investments	1,667	5,317

There were hardly any changes in BASt's 2015 budget compared to the previous year. For the fiscal year 2016, BASt included two budget-increasing measures in its budget estimates for which special funds were granted: purchasing a Traffic Speed Deflectometer (3.5 million euros) and necessary investments in the BISStra (Federal Information System Road) system aiming to update and further develop the process (0.4 million euros). Implementation of the two measures was initiated in 2016 but the measures remained cash-neutral. This led to the situation that funds from investment-related budget items were to a great extent not spent. The same applied to allocations and grants, albeit for different reasons. By contrast. the budget estimates for personnel and non-personnel expenditure were mostly spent.

Hildegard Behr-Greinert
Administrative official
Head of the "Financial Management, Cost Accounting" section

As of 2015, BASt's budget has been legally and technically modified. The modification consists of the ability to apply the flexibilisation provisions under Section 5 of each annual budget laws to other budget items. There are now only few budget items exempt from flexibilisation. In the meantime, after two years, the expected positive consequences have taken effect, for example through extended options for budget planning and management.

As of the fiscal year 2016, Individual Plan 12 of the Federal Transport Ministry was extensively restructured. The Individual Plan's chapter structure was changed completely; almost every chapter was given a new allocation. The most significant change resulted from the newly developed, separate chapter 1211 on "centrally estimated administrative revenue and expenditure" (Zentral veranschlagte Verwaltungseinnahmen und -ausgaben). For this purpose, certain budget items were removed from the chapters of individual agencies and combined in one central chapter for the entire portfolio. Budgetary responsibility for this chapter lies in the hands of the Federal Transport MInistry. The individual agencies shall receive their budgets from individual budget items, provided they already administered them previously.

Personnel

Personnel structure

BASt employs roughly 400 people, not including trainees, interns and student assistants.

The majority of BASt's staff has a background in natural sciences and engineering, but social scientists, legal experts and economists as well as traditional administrative personnel are also represented at BASt. About 50 per cent of the staff are employed as scientists in higher service. 43 per cent of the employees are female and one in five senior posts is occupied by a woman.

Due to the cutbacks in personnel over the past decades, BASt has significantly fewer posts and permanent posts than just 15 years ago. In some fields, BASt has been successful in increasing the number of revenue-financed posts because of continuous revenues. Overall, BASt still has more than 300 posts/ permanent posts for unlimited contract-based and civil service employment.

Approximately 20 per cent of BASt's staff have fixed-term contracts. In contrast to previous years, the number of employees with temporary contracts has increased only slightly, not least due to the elimination of legally prescribed staff cuts.

Fixed-term employment contracts are found for the most part in the scientific field. The majority of those

with fixed-term contracts (80 per cent) are scientists in higher service. Temporary contracts in non-scientific fields play a minor role at BASt. The latter are mainly for former trainees who are given a temporary contract to gain initial work experience once they have completed their training.

The law on fixed-term contracts for scientists offers the possibility of longer fixed terms under certain conditions, so that temporary contracts for scientists are usually concluded for a minimum of four years. The framework conditions were laid down in the "guidelines for temporary employment of scientific staff at BASt" (Leitlinien für befristete Beschäftigungsverhältnisse mit wissenschaftlichem Personal in der BASt) in 2016.

Qualification and continuous training

Continuous training and qualification play an important role at BASt. The overall conditions for BASt's comprehensive continuous training programme were collated in September 2015 in a continuous training concept.

"Guidelines for qualifying BASt's scientific staff" (Leitlinien zur Qualifizierung des wissenschaftlichen Personals der BASt) were compiled for scientists, also in view of the requirements stipulated by the law on fixed-term contracts for scientists. Five BASt employees successfully completed their PhDs as a special qualification project in 2015 and 2016.

Promoting a future generation of scientists is also a priority at BASt. Eight scientists lectured at universities in 2016 in addition to their full-time employment at BASt.

Vocational training

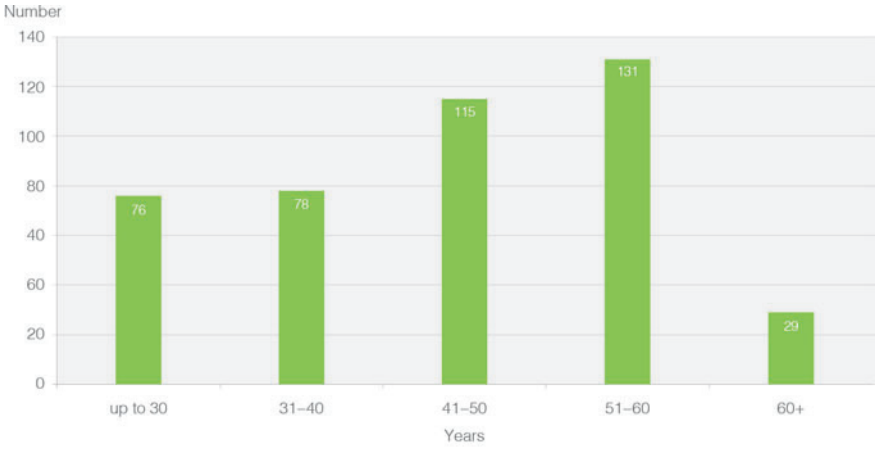
BASt offers a wide range of training professions such as building materials testers, physics laboratory technicians, chemical laboratory technicians, architectural draughtspersons, metal workers, specialists in media and information services as well as administrative specialists. In 2016, BASt employed 21 young people as trainees. BASt usually offers at least temporary employment contracts to trainees who have successfully completed their training. In some cases, it is possible to offer former trainees permanent contracts.

Age structure and health promotion

70 per cent of BASt's staff (not including trainees, interns, and student assistants) are older than 40, and 30 per cent are older than 50. BASt has intensified its health promotion measures, also against the backdrop that the average age of its permanent staff will increase over the next few years. Specifically, the following activities were carried out in 2015 and 2016:

- "Walking 3,000 more steps every day – exercising more in everyday life" by distributing pedometers,
- taking part in Cologne's corporate run,
- lunch break exercise,
- opening a fitness room,
- Health Day with a focus on nutrition.

The health promotion measures have been well-received by staff.

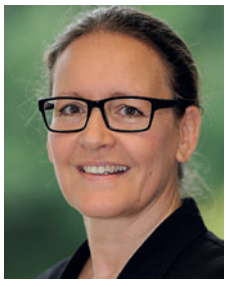


Staff age structure (as of 1 October 2016)

Dr Kirstine Lamers
Lawyer
Head of the "Human Resources, Legal Services, Procurement and Award" section

Awards/Appointments/PhDs/Teaching assignments

A number of awards, appointments and PhDs received by BASt staff and selected teaching assignments at a variety of universities and faculties listed below show how successful BASt employees were in 2015 and 2016.



Dr Martina Albrecht has headed the "Fitness to Drive, Driver Training and Improvement" section since November 2015.

Dr Anja Baum has worked as a volunteer member of the editing advisory council of the "Immissionsschutz" magazine since early 2016.

Dr Sandra Breunig received her PhD in Natural Sciences at the University of Cologne in early 2015.

Dr Jan-André Bühne was a guest lecturer in macroeconomics at the Fresenius University of Applied Sciences in Cologne in 2015.

Uwe Ellmers has headed the new "Motor Vehicle Emissions" section since July 2016.

Dr Martin Friese received his PhD in Engineering at the Technical University of Berlin in early 2015.

Dr Torsten Geißler was a guest lecturer in macroeconomics at the Fresenius University of Applied Sciences in Cologne and the Düsseldorf Public Administration and Business Management Academy until 2015.

Roderich Hillmann received the badge of honour of the Road and Transport Research Association (Forschungsgesellschaft für Straßen- und Verkehrswesen) in February 2015.

Ralph Holst became the coordinator of the subject area "reliable infrastructure" of the BMVI Expert Network in July 2015.

Dr Dirk Jansen has headed the "Design and Structure of Pavements" section since April 2016.

Dr Thomas Jährig received the “Best Paper Award” together with Anne Vetters (TU Dresden) at the TRB International Symposium on Highway Geometric Design in June 2015.

Sabine Lilgert has been a member of the “Building/Transport/Materials Engineering/Materials Testing” expert advisory council 1 of the German Accreditation Agency (Deutsche Akkreditierungsstelle, DAkkS) since September 2016.

Dr Simone Klipp is a guest lecturer in traffic psychology at the Heinrich Heine University in Düsseldorf and the Döpfer University of Applied Sciences in Cologne.

Dr Sebastian Lipke was employed at BASt until January 2016. He is a guest lecturer in road construction and transport at the University of Duisburg-Essen.

Bernhard Kollmus held six lectures each in 2015 and 2016 in a joint series of lectures at TU Dresden and the Bauhaus University in Weimar.

Dr Matthias Müller received his PhD in Engineering at the University of Dortmund in May 2016.

Beata Krieger became the general coordinator of the BMVI Expert Network in July 2015.

Jan Ork received the KEMNA prize for his master thesis on the influence of heat treatment for test specimens in cyclical tensile-fatigue tests on the input variables of computational structural design in January 2016.

Dr Jürgen Krieger has chaired the “Adaption Strategies/Resilience” technical committee of the World Road Association (PIARC) since summer 2016.

Dr Tobias Paffrath received his PhD in Engineering at the Bergische University in Wuppertal in March 2016.

Janine Kübler has headed the “Highway Equipment” section since September 2016.

Dr Eiad Ramadan received his PhD in Engineering at the Bergische University in Wuppertal in spring 2016.

Dr Horst Schulze was re-elected in October 2015 as the president of the Forum of European Road Safety Research Institutes (FERSI) for three more years.

Andre Seeck is a lecturer at the “Vehicle Safety and Traffic Accident Research” Master programme at Dresden International University and at the “Traffic Accident Research” Master programme at the Technical University in Graz.

Stefan Strick, President of BASt, was appointed a member of the advisory council to the Regional Accident Prevention Organisation of North-Rhine Westphalia in April 2015 and is Past President of the Forum of European Highway Research Laboratories (FEHRL).

Tobias Teichner is a guest lecturer in traffic lights control at the Bergische University in Wuppertal.

Dr Marko Wieland is a lecturer at the Bavarian Bau-Akademie Feuchtwangen, the ABZ Mellendorf and the BFW Bau Sachsen in Dresden in the scope of concrete technology programmes.

Professor Dr Ulf Zander has headed the “Highway Construction Technology” department since September 2015.

Dr Dirk Jansen, Bastian Wacker and Dr Lutz Pinkofsky (from left) received the Best Paper Award during the first international congress on road transport TRC in China in June 2016.

Dr Sandra Jacobi and Janine Kübler have headed the “Accredited Testing Laboratory for Highway Equipment” since August 2016.

The three trainees Jennifer Sammet, Carina Prechel and Adrian Rink (front row, from left) as well as the trainers Manfred Eilers and Silke Sielaff (back row) were recognised for outstanding training achievements in federal traffic and transport administration at the Federal Ministry of Transport and Digital Infrastructure in November 2016.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