Annual Report 2022

Reports of the
Federal Highway
Research Institute
A49

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Preface

Photo: BASt – Daniel Cameño, hat&cap

What does the mobility of the future look like? What do you read about it in the papers? What do you find out when researching this topic in scientific journals? Ask your friends or talk to members of your family. You will certainly notice that you will receive many different answers and encounter entirely different visions.

Let us look, for instance, at the discussion about expanding the transport infrastructure: some believe that the approval process and construction of infrastructure measures are not proceeding fast enough. They complain about shortcomings in availability, about delays or traffic jams. Others are strictly against any expansion – especially close to their homes. They are concerned about construction noise and an increase in traffic-related negative impact once the measures are completed.

Or let us consider the discussion about car-free inner cities: some think it is a good idea and they link this prospect to an increase in the quality of life. Others are worried about their businesses and assume that they will have fewer customers and lower earnings.

The list of diverging opinions is endlessly long when it comes to mobility, and as if this were not enough of a challenge, opinion leaders engage in what amounts to a "friend-or-foe" type of thinking, characterised by increasing aggression. This is often based on prejudices and leads to moral judgments about people with different opinions. These are no good preconditions for the mobility of the future, because such an extensive transformation towards an environmentally friendly transport sector cannot succeed without societal consensus.

As the president of BASt, I would like to contribute together with my team to a sustainable, ground-based mobility. For me, this means that we need to align our mobility system, mobility needs and behaviour with the global sustainable development goals, because this is what Germany's representatives promised to future generations at the United Nations summit meeting on 25 September 2015, together with 193 heads of state and government from all over the world. As a research institute of a federal ministry, our contribution consists of developing options for action for the political decision-makers so that this goal can be reached.

To this end, we focus on a wide range of topics, ranging from the use of digital approaches in the transport sector to promoting active mobility, automated driving and connected driving as well as sustainable construction and energy use to issues of predictive infrastructure management and proactive approaches in road safety.

I wish you an inspiring read.

Univ.-Prof. Dr-Ing. habil Markus Oeser
President of BASt

34

59

68

92

Table of contents

6.

7.

Highlights

New start for BASt's Scientific Advisory Board

On 22 November 2022, BASt's newly appointed Scientific Advisory Board convened for the first time for its constituent meeting. At this meeting, Professor Wolfram Ressel, Rector of the Stuttgart University, was elected chairperson and Professor Kerstin Lemke, Siegen University, his vice chair. The Federal Transport Ministry is represented at the Scientific Advisory Board by Gerhard Rühmkorf. The meeting discussed, inter alia, the thematic priorities of BASt, including approaches to secure skilled personnel in the transport sector.

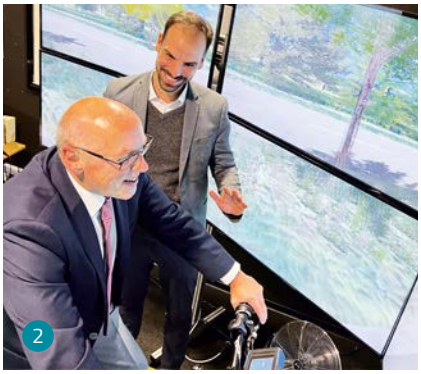
The future holds new challenges, tasks and subject areas for BASt. This is why in some cases new paths and structures as well as new approaches and instruments must be initiated in the near future. The target agreement between BMDV and BASt constitutes a first step in this direction. Against this backdrop, BASt's consultancy service has also been fundamentally restructured. This includes disbanding the advisory council and the two technical advisory councils in their prior forms. BASt is expecting valuable input and feedback from the newly founded scientific advisory board concerning strategic issues to further develop the federal institute.

Visitors at BASt

We are delighted that in 2022 we at BASt once again had an increased number of visitors. Their interest shows us that our research work is relevant and visible.

On the one hand, we were able to show political representatives what topics BASt is currently researching and how we are preparing ourselves for questions of future ground-based mobility. Important matters were addressed and ideas concerning different challenges were exchanged in intensive talks with BASt's leadership and specialists. Some of the research focuses in 2022 were active mobility, digitalisation/

New BASt Scientific Advisory Board.



1 German MP Jürgen Lenders visiting BASt. 2 Prof Kurt Bodewig, president of the German Road Accident Prevention Organisation tested, inter alia, BASt's bicycle simulator. 3 – 5 Guests from the BMDV included State Secretary Stefan Schnorr (left) and the Parliamentary State Secretary Oliver Luksic (centre) and the head of the "Central Services" department Dr Rudolf Gridl (right). 6 Students of the Mobility Innovations master programme at the Zeppelin University visiting the Automotive Engineering department.

automation, automated/connected driving, energy and infrastructure, sustainable construction, agile infrastructure management and the challenges of recruiting skilled personnel.

On the other hand, we were able to actively engage again in in-person technical exchanges on our premises. Besides visitors from partner institution and projects, we were also able to show young scientists how we work at BASt.

This included, for example, a group of 26 PhD students and postgraduates from the TU Dresden and RWTH Aachen, who are working on research topics associated with the digital twin road, and a group of students from the Zeppelin University, whose focus was on automotive engineering and traffic/mobility behaviour.

New CD

BASt has been featuring a new, fresh look since December 2022. The new corporate design comprises new colours, shapes and design elements. The aim was to create a look that is conducive to perceiving BASt as a modern research institution, both internally and externally. The relaunch also took practicability into account. It was intended to improve the font's legibility and also achieve a high recognition and identification factor.

BASt's new logo

With its straightforward typography, the CD reflects an institution responding to the challenges of the future with well-founded scientific work.

Noise barrier on the BASt premises

Since March 2022, BASt has had a 16-metre-long and 4-metre-high noise barrier. It is not intended, however, to serve as a protection from noise, but rather is a test object for a variety of modifications and measurements. For instance, noise dissipation above noise barriers equipped with crowns is evaluated. Thanks to the noise barrier, it is now possible to conduct measurements on prototypes on the BASt premises that are compliant with applicable standards.

Reorganisation and new leadership members

The tasks of the "Traffic Engineering" department were restructured to strengthen the topics of climate action and sustainability.

The sections "Climate Protection, Sustainability, Traffic Statistics" headed by **Dirk Heuzeroth** and "Environmental Protection, Emissions" headed by Dr Anja Baum came into existence in February 2022.

In March 2022, BASt established 3 new offices: "Controlling, Quality Management, International Cooperation", which is headed by **Dr Karl-Josef Höhnscheid**, the "Academy of Sustainable Highway and Traffic Engineering" headed by **Karsten Strauch** and "Digitisation Road Sector" headed by Adrian Fazekas.

Photo: BASt – Daniel Carreño, hasb.cap

Dr Heinz Friedrich, former deputy head of the "Steel Structures, Corrosion Protection, Bridge Equipment" section, has been the head of section since January 2023. He is a civil engineer and has been with BASt since 1999.

The former deputy head of the "Concrete Structures" section, **Christoph Becker**, became the head of the "Road Monitoring and Assessment" section in November 2022. Christoph Becker is a civil engineer and has been with BASt since 2010.

Dr Anja Baum, former deputy head of the "Environmental Protection, Emissions" section became the head of section in November 2022. She is a geophysicist and has been active at BASt since 2003.

Oliver Ripke, former interim head of the "Road Maintenance Management" section, became the head of section on 13 September 2022. Oliver Ripke is a civil engineer and has been with BASt since 1997.

Dr Adrian Fazekas has headed the SD office "Digitization Road Sector" since 1 September 2022. Dr Frazekas is a technical computer scientist and previously worked as a research group leader at the RWTH Aachen's Institute of Highway Engineering.

Ayhan Toptas became the interim head of Z5 section "IT Administration" in September 2022. He is an IT administrator and has been with BASt since 2011.

Future-proof with new ways of working

Author:

Dr. Christine Kellermann-Kinner,
civil engineer, deputy head of the "Controlling, Quality Management, International cooperation" office

Agile work using OKR

The Controlling Office supports the technical sections in introducing and applying agile methods. One method particularly suited to combine strategic goals (top down) with operational aspects (bottom up) is the OKR method "Objectives and Key Results".

The agile framework helps all employees to be able to answer the questions: "What do we aim for with our strategic goals?" and "How does my work operatively contribute to this?". Everyone is working towards the same vision, setting objectives for themselves, measuring their success and is focused.

With the Objectives, the employees are expressing a qualitative target image for a limited period of time by asking: "What do we want to change, shape, achieve for our target group?" The Key Results renders the effects measurable and expresses a quantitative goal by asking: "How do we see whether we have changed something?"

We were able to involve the Digital Innovation Support Unit of the Federal Office of Administration in presenting the OKR method and agile work in the public sector.

A keynote presentation and in-depth workshop on this took place in late 2022. Since then, the Controlling Office team has been supporting the technical sections in drafting their annual goals and OKR sets.

Journal Club

The "Journal Club" was founded under the chairmanship of Prof. Dr Markus Oeser in early September 2022. This club aims to support employees with their scientific publications in international science journals in order to promote the scientific discourse.

In the long term, it is intended to develop the Journal Club into a nucleus for new publication ideas, in order to situate BASt's featured topics more prominently in the specialist community. Keynote speeches by scientists with publication expertise or editors of scientific journals are intended to serve as an impetus for this by providing tips and inspiration. These regular meetings also aim to connect individuals across departments by creating joint publications concerning BASt's featured topics.

Photo: maxi3r - stock.adobe.com

The Federal Highway Research Institute will make further advances in the fields of digitalisation and automation with the aim of strengthening its lead as a central location to store, analyse and provide data in the transport sector. The integration of digitalisation processes both within the research departments and across the organisation is being intensified systematically for this purpose.

Digitalisation is vital in research, innovation and modern administration. It is essential when it comes to automating processes and methods in the transport sector, electrification and supporting a sustainable development in the roads sector. The raw material enabling this is data. In order to efficiently evaluate and process data, using algorithms and introducing new and standardised data interfaces are of key significance. The ultimate goal is to generate new knowledge from the data collected and to develop it for political, scientific and economic purposes. The Federal Ministry for Digital and Transport (BMDV), for instance, offers a mobility library, called Mobilithek, as a platform to

1. Digital transport

enable access to open mobility data and a B2B exchange of data services. Its predecessor was a service provided by BASt, the Mobility Data Marketplace (MDM).

BASt is also making headway by establishing its new "Digitization Road Sector" office. Links with other data management organisations such as Autobahn GmbH are being established, and future access to private sector data by way of the "Mobility Data Space" platform will also lead to enormous benefits.

Planning, construction and operational processes are becoming increasingly complex, and new data repositories and data processing chains need to be created. The Building Information Modelling method is an important tool here. The increasing automation of road traffic generates a high demand for real-time connectivity and data processing technologies. The algorithmitising and introduction of new data interfaces that this entails will be tested and implemented in the future by using digital twins.

Manual road traffic census 2021 (SVZ) – pandemic, flooding and other framework conditions

Authors:

1 **Alexander Bloch,** mathematician

2 **Friedhelm Quast,** computer scientist, "Climate Protection, Sustainability, Traffic Statistics" section

A Germany-wide 2020 traffic census on federal trunk roads (SVZ) was scheduled for 2020. However, the restrictions due to the COVID-19 pandemic prevented the SVZ from being conducted as planned. It was thus only possible to do the road traffic census in 2021. In addition to the pandemic and flooding disaster, there were other disruptions in the process of conducting the SVZ, such as the bankruptcy of a subcontractor who had been commissioned to conduct the full survey in Schleswig-Holstein, the survey on the motorways of the northern branch of the Autobahn GmbH and in many of the regions of North Rhine-Westphalia and Hesse. New solutions were swiftly found for these areas, but the census had to be suspended for the most part in the first six months of the year. Nonetheless, traffic values were collected at nearly all of the roughly 12,500 count sites on federal trunk roads. Of these, 1,680 count sites are permanent count sites delivering reliable results and 3,530 are count sites for temporary measurements using lateral radar devices (TM) that have been deployed since 2016 on a rolling basis for the purposes of the road traffic census. Thanks to the constructive collaboration of all involved, the traffic data was published on time despite all the adverse circumstances. Besides BASt, the other parties involved were the Autobahn GmbH, the Federal Ministry for Digital and Transport and an office subcontracted for data processing.

The traffic loads surveyed for the year 2021 (average daily traffic values Monday-Sunday) on federal trunk roads decreased by an average of about 8 per cent compared to the SVZ 2015. At the local level, the results of the SVZ 2021 show significant changes in the traffic volumes of motorised private transport

Allgemeine Angaben				
Straße	**Land**	**TK / Zst.-Nr.**		
	zust. Stelle		Region	Zählart
E-Str.		Zählabschnittsanfang		
		Zählabschnittsende		TZ
			Zabl. km	
	Anz. FS	FS / OD	ges. / FS	DZ
A 61	5 NW	**5106 2102**		MZ
	1		05 061 05	
		AS Türnich (21)		
		AS Gymnich (22)		
	FS = 4	FS	4,0 / 4,0	
A 61	5 NW	**5106 2103**		MZ
	1		05 061 05	
		AS Gymnich (22)		
		AD Erfttal (A 1)		
	FS = 4	FS	2,3 / 2,3	

Results of the manual road traffic census 2021

and heavy goods traffic compared to the values of previous surveys and current traffic loads. These changes can be attributed to a variety of possible influencing factors. Measures and effects associated with the COVID-19 pandemic in the survey year 2021, such as working from home and closed borders, are a crucial factor. But changes in leisure-time and vacationing habits can also have an impact on the results. Additionally, the flooding incidents in July 2021 played a significant role in large parts of North Rhine-Westphalia and Rhineland-Palatinate. In general, the influence of specific local conditions can never be fully excluded. Despite comprehensive planning for carrying out the manual and temporary surveys, such events have an influence on road traffic as a dynamic system that cannot be eliminated. They lead to deviations that can be minor or major from previous surveys or current traffic loads. The results of the road traffic census thus present a snapshot of the situation in 2021. Because of a suspected mix-up of data, the data from 226 count sites at federal trunk roads were included only at a later stage and after a renewed review. After the evaluation was concluded, it was possible to calculate and publish annual mileages, average daily traffic values and the parameters for the 2020 E-Road Census of the United Nations Economic Commission for Europe (UNECE).

Manual road traffic census 2025

The manual census for the upcoming road traffic census (SVZ) 2025 may potentially start already in 2024. The temporary measurements for SVZ 2025 using lateral radar devices are already being conducted. The intention here is to reduce the time pressure and unbundle the tight time frame and to render the results independent from external influences. This is why all the preparations for the SVZ need to be made in a timely manner. In this context, a workshop of the working group on the road traffic census (AK SVZ) has already been planned for spring 2023. The agenda includes items such as adapting and supplementing individual aspects and chapters of the guidelines and directives. Another item is the drafting of a guidance document for plausibility checks. The aim is to establish comparable, standardised processes on this basis as a next step. These processes should ensure a high data quality and better estimates for how much time will be needed for the census.

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Verkehrsbelastung					GL-Faktor	MSV	Zähldaten					RLS19			
DTV	**DTV**	**LV**	**SV**	**Di-Do NZB**			**Kfz_{Ri1}**	**SV-Ant.**	**Kfz_{Ri2}**	**SV-Ant.**	**Anz. Tage**	**M**	**P_1**	**P_2**	**P_{Krad}**
2015				**Kfz**	fer	MSV Ri1	NoW_{15-18}				NoW	T	Tag 6 – 22 Uhr		
SV	W		Bus			$b_{SV,Ri1}$	Fr_{15-18}				Fr	D	Day 6 – 18 Uhr		
2010	U	Krad	LoA	LV	b_{So}	MSV Ri2	FeW_{15-18}				FeW	E	Evening 18 – 22 Uhr		
SV	S	LVm	LZ	SV	b_{Fr}	$b_{SV,Ri2}$	So_{16-19}				So	N	Night 22 – 6 Uhr		
[Kfz/24h]	[Kfz/24h]			[Kfz/24h]		[Kfz/h]	[Kfz/h]	[%]	[Kfz/h]	[%]		[Kfz/h]	[%]	[%]	[%]
45.966	**32.722**	**24.649**	**8.073**	**40.967**	0,84	2.687	1.973	23,1	1.249	19,8	2	1.849	4,5	18,3	0,3
9.485	36.466		100			17,4 %	2.029	17,3	1.160	17,9	2	2.068	4,8	18,3	0,3
40.910	30.587	104	1.431	29.773	0,52	1894	2.005	23,7	1.306	17,6	2	1.191	2,7	18,6	0,3
9.308	21.390	24.545	6.543	11.194	0,91	17,7 %	1.055	5,0	897	3,2	2	392	6,4	35,6	0,1
	Flutkatastrophe – verringerter Verkehr														
43.587	**26.847**	**19.666**	**7.180**	**32.895**	0,84	2.642	1.883	24,7	872	23,4	2	1.514	4,7	20,1	0,4
9.383	29.688		72			17,4 %	1.995	17,3	782	21,0	2	1.694	5,0	20,1	0,4
41.258	24.935	91	1.235	22.694	0,56	1.113	1.895	25,6	910	20,7	2	974	2,8	20,4	0,3
8.110	18.608	19.575	5.874	10.201	0,95	17,7 %	1.189	4,8	672	3,6	2	328	6,6	38,2	0,1
	Flutkatastrophe – verringerter Verkehr														

mentioning the flooding disaster and resulting reduction in traffic.

Parking space detection systems with area-wide data collection – functional requirements, test and final acceptance

Authors:

1 **Jens Dierke,**
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2 **Rainer Lehmann,**
electrical engineer, head of section,
"Traffic Management and
Road Maintenance Services" section

The Federal Ministry for Digital and Transport (BMDV) sees potential to improve the parking situation for heavy goods vehicles by using telematics-based parking guidance systems at rest stops (see also the BMDV's five-point plan to improve the overnight parking situation for heavy goods vehicles). Parking information for truck drivers is intended to help them find a parking space especially in the evening hours when rest stops become increasingly full.

BASt was commissioned to develop a concept for a nationally uniform parking guidance system (PLS) for trucks on motorways.

The development is conducted together with the truck PLS working group, founded for this purpose, in which besides the Federal Ministry for Digital and Transport, also the Autobahn GmbH and individual highway authorities of Germany's Länder are represented.

As a first step, to make parking information available, the current occupancy status of rest stops needs to be identified reliably. To this end, parking detection systems, for example, with appropriate, certified sensors and evaluation are used. The detection of individual traffic areas enables a spatially differentiated evaluation. During concept development, functional criteria for "parking detection systems with area-wide data collection" were drafted together with the truck PLS working group and compiled in a report by BASt. They are intended to serve as a uniform basis for future tenders in the field of federal trunk roads.

PLS are intended to help truck drivers find parking spaces.

Furthermore, under the lead of the Central Office for Traffic Management (ZVM) at the Bavarian State Building Administration, and together with the truck PLS working group chaired by BASt, a testing regulation for functional and suitability testing of parking detection systems with area-wide data collection was drafted and coordinated. An engineering office supported the content-related work. The functional and suitability tests are performed by experts audited and approved by BASt. These experts need to be commissioned directly by the specific manufacturer of the system to be tested. Pursuant to the testing regulation, the test result needs to be confirmed by BASt with regard to the testing process. In general, the functional and suitability tests can be performed at the PWC Gelbelsee-West rest stop (federal motorway A9 near Ingolstadt).

Interested companies can also use the proving ground set up there by the Autobahn GmbH, a federal agency, for practical tests in the scope of product developments.

A third component is recommendations for action offering guidance for contracting entities aiming at a uniform process from tendering to final acceptance of such parking detection systems at rest stops.

The BMDV has announced the 3 documents on “parking detection systems with area-wide data collection” in a circular letter.

These and further information can be accessed on the BASt website (www.bast.de/PLS).

Digital connectivity to increase process safety in the construction of concrete roads

Author:

Barbara Jungen,
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"Concrete Structures" section

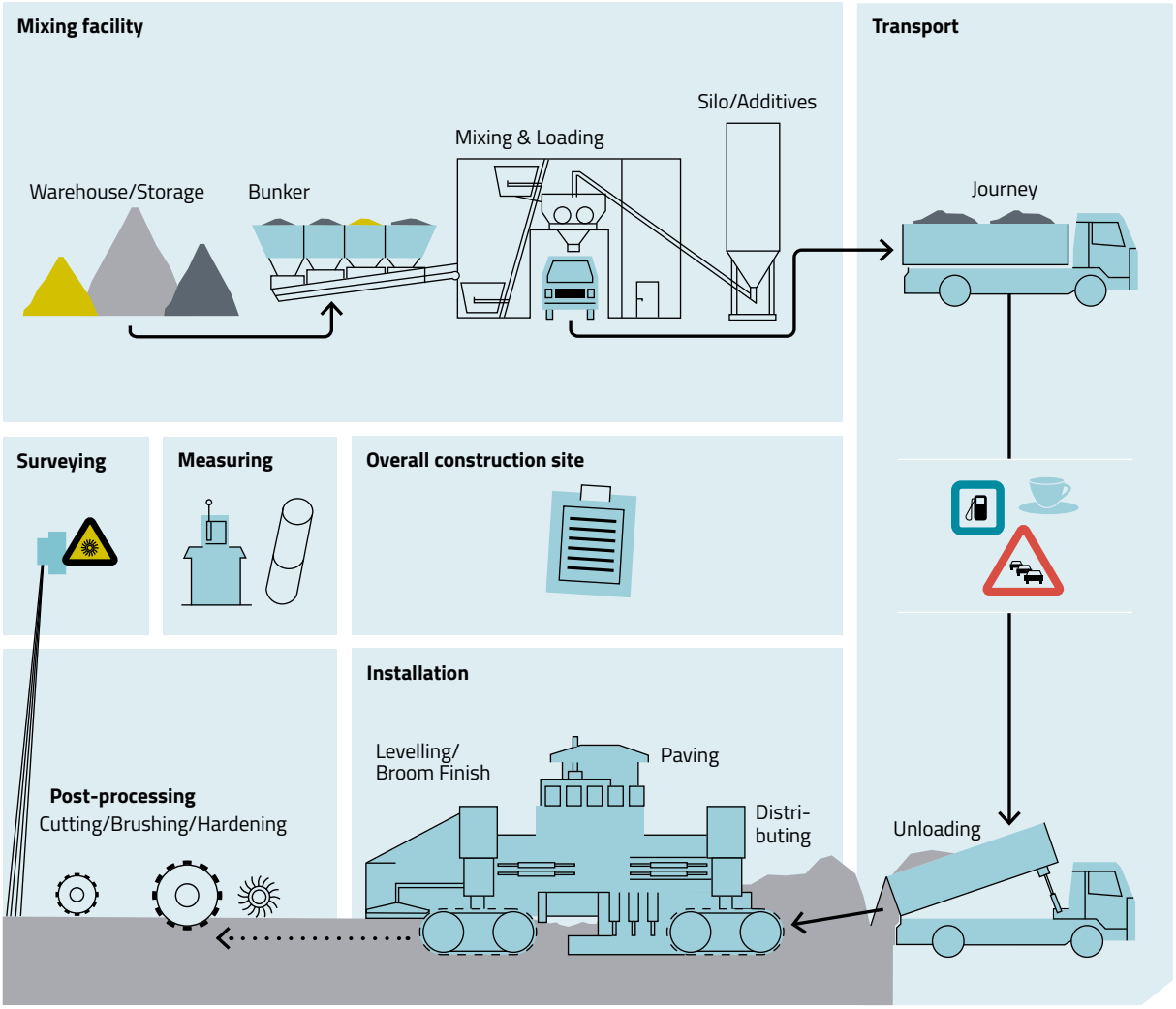
The "Digital Planning and Construction" road map of the Federal Ministry for Digital and Transport constitutes the strategic basis to introduce modern IT-based processes and technologies in the building sector. To date, the focus here has been on planning, operating and dismantling structures. In contrast, during the construction phase digital data collection, the exchange and the analysis of relevant information are currently often carried out using insular solutions. In the scope of the Concrete Pavement 4.0 interdisciplinary project funded by the Innovation Programme, the entire process chain from manufacturing concrete to finishing the road surface was analysed, digitised across processes and mapped deploying a central process information system.

Concrete pavements are constructed in a conventional linear roadworks project; they depend heavily on the interactions of various companies and people contracted to carry out specific sub-processes (mixing, transport, installation, post-processing etc.). Communication at the construction sites and interfaces is mainly handled in an analogue and de-centralised manner.

The current state of the art in process chains was first determined with visits to the construction sites and measuring campaigns. All the data collected was documented, and the machines at the construction site were equipped with additional sensor systems.

The scope and level of detail of the available information were then analysed using this data base, and possible correlations among the process steps were identified. As a next step, the entire process chain was modelled in a discrete event simulation. This included processing geo-referenced data, such as the positions of transport vehicles, the concrete paver and post-processing machines.

All information, including subsystems to integrate the machine data, was put together in an information model which formed the basis for the BF4.0 WebApp's data base.



Simplified process chain in the construction of concrete roads.

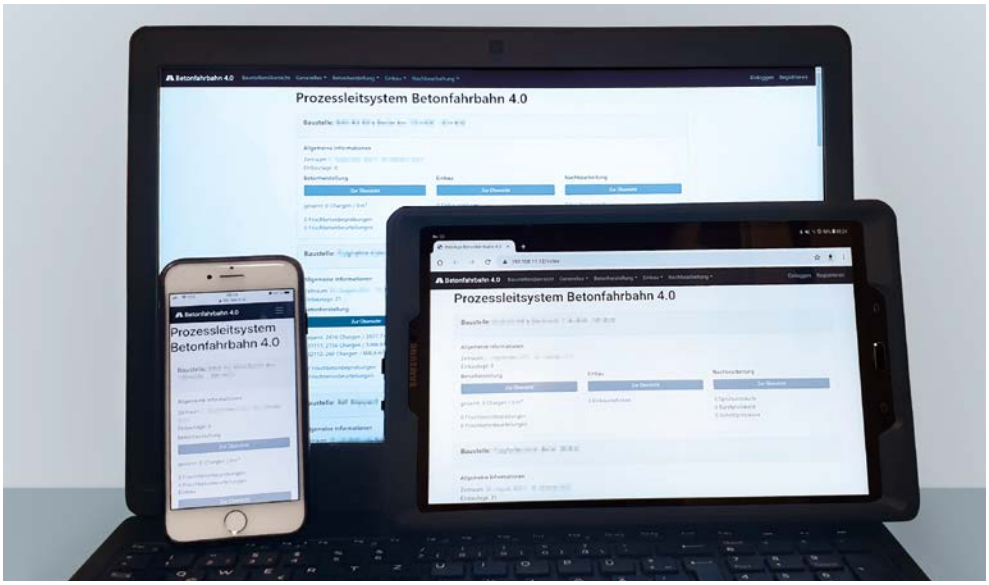
Source: Institute for System Dynamics (ISYS) - University of Stuttgart

The BF4.0 WebApp was also used to configure the interfaces to all machines at the construction site. The BF4.0 WebApp, which was developed as the front end of the process information system, was used to collect analogue data (f.ex. building material test results) in templates and then prepared in expert and overview charts.

In this manner, it was possible to exchange information in real time among the different process steps while work was ongoing at the linear roadworks site to identify necessary changes to the process flow on time and to intervene with suitable adaptations as corrective actions. Transporting the mixing facility to the location of the installation, for instance, is a time-critical factor with an impact on the concrete which is needed just in time for both the mixing facility and the slipform paver.

The BF4.0 WebApp was used to its full extent at a demonstrator construction site. This enabled collecting all relevant information digitally and live and making it available to the construction site staff in a processed form.

Especially the real-time overview charts mapping the actual condition at the construction site in detail increase process



Front end of BF4.0 WebApp on various end devices.

reliability by enabling immediate corrective action in the overall system.

The BF4.0 WebApp as a prototype was able to show that digital process monitoring and mapping is possible even in traditional sectors such as road construction. However, it has also become clear that some challenges still need to be overcome for future use. Besides problems such as completing network coverage along the entire length of the linear construction site even in rural areas, there are challenges on the implementation side that can only be solved jointly by all parties involved.

The integration of the machines presents a particular problem as no standard exists yet as to data format and data scope or the technology to be used. It is, however, essential to determine defined interfaces in the development of standardised overall systems. Beyond digitally connecting the individual parties during the construction phase, digital documentation is also an important component in developing BIM models and/or digital twins.

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Our principles

"We are all responsible for the success and reputation of the Federal Highway Research Institute and are using our skills to serve the common good."

Univ.-Prof. Dr-Ing. habil. Markus Oeser, civil engineer, president of BASt

"Our work is practice-oriented, unbiased and independent of individual interests; we make our findings available to the general public and appreciate the knowledge community's feedback."

Christopher Gerhard, M. Sc. (Donau University Krems) PR and Integrated Communication, deputy head of the "Press and Communication" office

"We respect ethical principles in research and in economic life."

Jennifer Bednorz, architectural draughtswoman and M. Eng in civil engineering in the "Bridges and Structural Technology" department

As forms of active mobility, cycling and walking are sustainable and promote physical and mental health. 40 per cent of all trips made by car are under 5 kilometres. Such short trips offer great potential to be covered by foot or by bicycle in an environmentally friendly manner.

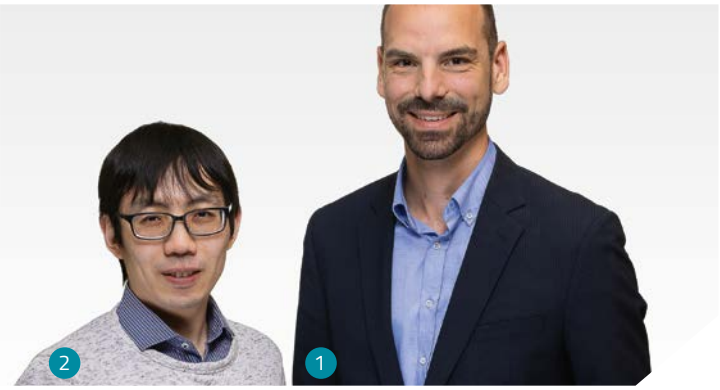
Therefore, it is an important task of the Federal Highway Research Institute (BASt) to promote cycling and walking by creating and transferring knowledge. This applies to active mobility in both urban and rural areas, and includes developing and testing cycling- and walking-friendly infrastructure solutions in practice, such as new forms of road traffic installations, road markings or direction signage.

2. Active mobility

Research is also being conducted on how door-to-door journeys that combine various modes of transport can be shaped in a more attractive and safer way in order to avoid congestion in urban areas and to better connect rural areas. Furthermore, BASt is analysing how active mobility can be fostered in all stakeholders' mindsets: road users on their way to going shopping as well as urban planners when redesigning a road section. Measures are being developed to shape (mobility) habits at an early stage or to change them towards more active mobility. To achieve this, for example, the possible use of novel teaching materials and concepts is being reviewed.

BASt's activities in the field of active mobility is intended as a contribution to increasing cycling and walking to make our mobility more sustainable, more inclusive and healthier.

Pedestrian behaviour – potential use of VR goggles in experimental road safety and mobility research



Authors:

1 **Fabian Surges,**
psychologist,
deputy head of section

2 **Hong Ma,**
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"Road User Behaviour and Mobility" section

Walking regularly has a positive impact on physical health, helps to increase well-being and is a sustainable form of movement, as it emits neither pollutants nor noise. Despite these positive effects, there has been a noticeable decline in distances covered on foot in the past few years. To counteract this trend, BASt is researching how to further increase the safety and attractiveness of walking.

One focus is on researching how pedestrians experience different traffic situations and conduct themselves in them. BASt intends to make increasing use of studies in virtual reality (VR) for this purpose. During virtual reality studies, test participants move in a simulated environment while their behaviour and that of other (virtual) road users around them is recorded. VR-based research is very safe and enables controlling disrupting influences such as weather conditions or intensity of traffic. One method to research pedestrian behaviour in virtual reality is the use of so-called VR goggles that completely isolate test participants from the outside world to enable immersion into a particularly intensive 360-degree virtual experience. There are currently many different VR goggles available, which to a certain extent vary greatly in their technical performance and effectiveness. This is why BASt had an external research project conducted to answer questions about the possibilities of using VR goggles in scientific research.

Training environment developed by BASt to analyse pedestrian traffic.

VR goggles in pedestrian traffic research

Commissioned by BASt, the HFC Human-Factors-Consult GmbH investigated the question of how a VR system needs to be designed to fulfil the high standards of scientific research. Besides VR goggles themselves, the accessories and software that may be necessary were also analysed. Depending on the use case, these include joysticks, special shoes or treadmills, as well as sensors and detectors that are necessary to record and evaluate the movements of the test participants in the virtual reality space. As a first step in the project, the requirements for VR systems (VR goggles plus accessories) to be used in scientific studies were identified. These requirements were summarised in a catalogue of criteria with which it is now possible to assess for the first time the suitability of (new) VR systems in a partially standardised way. Based on the hardware currently available, the research also examined how a VR system needs to be composed to best capture and analyse the behaviour of pedestrians in varying situations. One essential result of the projects is that overall, three VR systems can be considered suitable for this use case, albeit each with specific advantages and disadvantages:

- a low cost "self-sufficient VR system" that can be deployed flexibly and enables the test participants to walk naturally but offers lower performance.
- a "laboratory-bound VR system" that offers high performance but is dependent on an artificial movement technology (for example, the use of sensor shoes) in almost all analysis scenarios, increasing the risk of cyber sickness[1].
- a "high-fidelity system" which combines high performance with the possibility to move through space naturally. These benefits come with high costs for the hardware to be purchased and require a large space (for example a large hall).

1 Cyber sickness can occur when using VR goggles, and is similar to the phenomenon of motion sickness.

BASt's VR laboratory.

BASt's VR laboratory

On the basis of the findings from the project, BASt expanded its recently established VR laboratory. A "laboratory-bound VR system" was set up to perform studies in behavioural science. Besides high-performance VR goggles, this system currently consists of sensor shoes for moving around in the virtual reality space, two controllers, a heavy-duty computer and two tracking stations to enable recording the movements of the test participants with great accuracy. The Unity software used in the VR laboratory originally comes from the field of gaming and makes it possible to set up a wide variety of traffic scenarios and situations. As a first step, an environment was developed to perform standardised training aiming to familiarise the test participants with a virtual environment and also with the artificial movement technology. In 2023, BASt is planning to conduct its first feasibility study with the "laboratory-bound VR system".

Besides aspects of research practice, such as the duration and tolerance of a VR study, the feasibility study is intended to analyse technical aspects, for instance, the impact of automated and autonomously-driving vehicles on a pedestrian's experience and behaviour.

Prospects for VR-based pedestrian research

BASt's VR laboratory will be further developed and optimised in the future. Additionally, a review will analyse to what extent a high-fidelity system can be implemented on the BASt premises. Possible research focuses in VR pedestrian research could include, for instance, analysing interactions and conflicts between pedestrians and other groups of road users, analysing and testing new infrastructure elements or analysing the effect of the quality of experience in a traffic environment.

Seeing and being seen

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"Safety Concepts, Safety Communication" section

The intensity of bicycle use depends significantly on the cyclists' subjective assessment of how safe they feel. Cyclists' visibility is severely restricted in the dark and in twilight conditions. An accident analysis in 4 cities has shown a high number of serious accidents during turning involving pedestrians and cyclists. The potential root causes for these accidents include, for example, varying lighting conditions along road sections. The reason for this is in particular that stationary street lights do not offer sufficient visibility of cyclists at every spot in illuminated traffic areas in mixed traffic.

Against this backdrop, BASt commissioned the Technical University of Berlin to develop and test a comprehensive system of innovative lighting and design parameters, such as key performance indicators, light intensity distribution and installation geometry for future stationary LED street lighting systems. The aim is to use the findings that are to be concluded by 2024 for recommendations to revise the DIN EN 13201 "Road lighting" standard, and particularly as a basis for a new guidance document. This document is intended to provide specific recommendations of action for rural and urban authorities in designing cyclist-safe street lighting.

Selected data from the GIDAS (German In-Depth Accident Study) accident database with cyclist involvement will be evaluated based on the available literature. This will be used to derive the specific situations and conditions during darkness that most often lead to accidents. As a next step, parameters will be developed to make cycling traffic more visible. Developing innovative street lighting concepts using LED technology will not only improve the visibility of cyclists, but the cyclists themselves will be able to see the traffic areas better.

The parameters to be developed are being tested by researchers in a lighting laboratory and will then be validated on a real test street, the so-called "LED runway".

The project will be implemented as part of BASt's safety research programme, which focuses on research activities for safe cycling in a jointly used road environment.

Technical innovations for safe cycling

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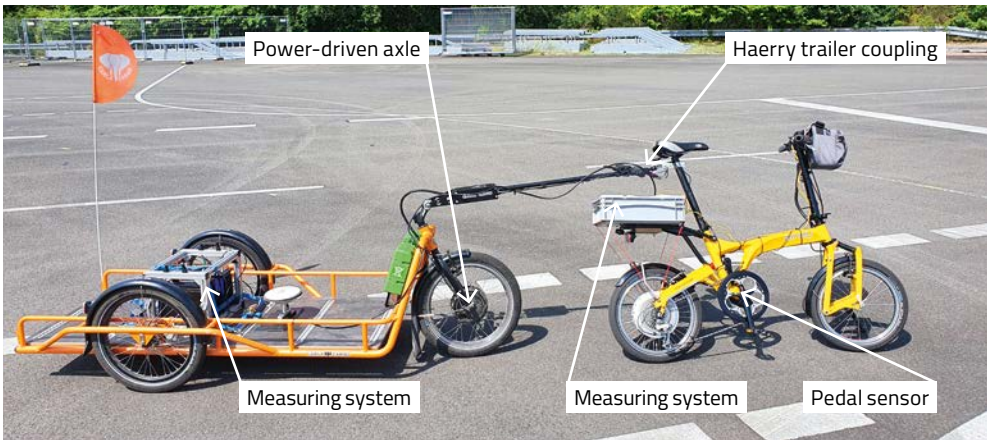
Bicycles are a sustainable and environmentally-friendly means of transport, but, as shown by the current development in traffic accident rates, cycling needs to become safer. While the overall number of accidents resulting in severe personal injuries is steadily declining, this trend cannot be observed in accidents involving bicycles. Various ongoing projects are therefore analysing how cycling can be designed to be safer and more comfortable by using innovations in vehicle engineering. Cases in point are improvements in lights and brakes, more stringent requirements for seats and restraint systems and the possibility of road user connectivity. In 2022, specific findings were gained from the following studies.

Improving vision and visibility through the use of bending lights

In Germany, bicycles need to comply with defined technical equipment regulations to be authorised for road traffic. This also includes their lighting equipment. BASt was instrumental in adapting and expanding the "Technical Requirements" (TA) for these to meet the latest technological standards. Bending lights for bicycles are one crucial innovation.

When driving along a curve, systems such as these regulate the horizontal alignment of the cut-off line of the bicycle's headlight by using, for example, a mechanism. Furthermore, they gently rotate the light towards the inside of the curve which in turn improves the illumination of the curve and at the same time reduces glare for oncoming traffic. The new TA number 25 "System to automatically align bicycle headlights" defines specific requirements

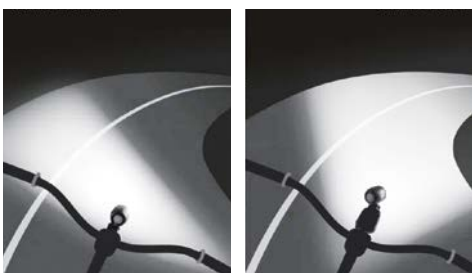
Measurement bicycle with prototype light during test operation.



Power-driven trailer in a test operation using a measurement bicycle.

that bending light systems need to fulfil. These requirements are intended to ensure that only effective systems are installed and that cycling at night will be safer in the future. Particularly the precision requirements for the integrated angle measurement need to be defined here to prevent wrongly adjusted headlights from blinding oncoming traffic.

Prototype lights mounted on a test bicycle for measurements were deployed in drafting the technical requirements. By now, the first mass-produced products have become commercially available – initially for Pedelecs because of the mechanism's energy consumption.



Without and with system for aligning the cut-off line.

Power-driven bicycle trailers

Bicycles are increasingly being used to transport loads, for which, besides cargo bikes, trailers can be used. Power-driven bicycle trailers are particularly convenient for this purpose, but to date they have not been taken into account in regulations. It has not yet been clear under what conditions power-driven trailers may or may not adversely affect the stability of bicycles when riding.

In the scope of the project, the behaviour of bicycles with an attached power-driven trailer was thus analysed in terms of vehicle dynamics. This analysis covered trailers with a maximum drive power of 0.25 kilowatts and support of up to a maximum of 25 kilometres per hour. Initial results have shown that such trailers do not adversely affect the vehicle dynamics, provided that the power drive only supports and does not push the bicycle.

Cycling in mixed traffic on main roads

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Cycling is in fashion more than ever. This can be seen particularly in big cities when looking at the distribution in the volume of transport in the transport statistics of different modes or means of transport (modal split) and the increase in the distances covered by bicycle over the past years.

At the same time, the general promotion of cycling as an environmentally-friendly and sustainable means of transport is often faced with limited resources in day-to-day practice: creating corresponding cycling facilities necessitates in many cases significant financial effort on the one hand, but on the other the narrow width of roads does not always leave enough room for separate cycling paths.

This is why a research project commissioned by BASt intends to determine how and under what general conditions cycling can be a safe and cost-efficient option in mixed traffic with motor vehicles. Besides objective safety aspects, the aim is to identify at the same time what general conditions in the situations described will promote cyclists' acceptance of driving in mixed traffic.

An analysis of the accidents registered by the police which occurred at a representative selection of road sections showed that accidents involving cyclists# in mixed traffic without advisory cycle lanes happen most frequently in connection with parallel parking spaces in stationary motor traffic. Collisions with suddenly opening car doors ("dooring accidents") were frequent accidents. Tracks in the road surface are another risk factor for road safety. It was also possible to establish a clear correlation between the intensity of motor vehicle or cycling traffic and accidents involving cyclists. At junctions where roads of a lesser order meet major arterial roads, restricted visual axes also have an adverse effect on cycling safety. This is why compliance with the required lines of sight needs to be ensured in these areas. In many cases, this can be done by reducing the number of parking spaces, which, where applicable, can effectively be implemented together with traffic engineering measures.

An analysis of the areas used by cyclists showed a sharply fluctuating acceptance of driving in mixed traffic in the road environments under review. Depending on the specific case studied, between 0 to 90 per cent of the cyclists preferred the footpath rather than the street itself. An average of about 20 per cent of cyclists drove on the footpath. "The street is too unsafe" was the most frequent (subjective) reason given by the interviewees for why they used the

Dooring accidents can lead to severe injuries.

footpath. In the scope of further multi-criteria-based analysis, it became clear that a higher intensity of cycling traffic, lower intensity of car traffic, lower share of heavy goods traffic and a robust speed limit of under 50 kilometres per hour were conducive to the acceptance of using a bicycle in mixed traffic. With regard to the number of accidents, it was possible to verify the latter correlation to some extent at junctions of minor and major roads, but not at road sections along major arterial roads.

The core significance of "dooring accidents" has led, for the use cases of mandatory and advisory cycle lanes, to an inclusion in the Administrative Regulations of the German Road Traffic Regulations (StVO): In the meantime, the regulation calls for an additional safety area from stationary traffic. The Guidelines for Road Markings that will be introduced soon also require the same for cycle-only lanes. Drafts of other regulations currently being updated such as the "Recommendations for cycling facilities" (ERA) generally call for a safety dividing strip of 75 centimetres in built-up areas.

This not only applies to the distance between parallel parking spaces and cycling facilities, but also to routing cycling traffic on road surfaces in mixed traffic (f.ex. cycle-only lanes). However, the impact of a safety dividing strip on "dooring accidents" in general has not yet been systematically examined. It is planned for this to be part of a BASt research project in the near future. The narrow dividing line which is currently the recommended form of marking a safety dividing strip for routing cycling in mixed traffic bears the risk of being confused with an (obviously too narrow) advisory cycle lane. A point to be analysed in this context is to what extent the form and surface quality of the safety dividing strip also have an influence on the distance cyclists maintain towards parked cars. One research issue that arises is whether a different type of marking (crosses, for instance) or a very uneven surface (cobbled, for instance) can, depending on the use case, make the safety dividing strip effective in its function.

Communicative and educational measures to promote cycling safety in adolescence

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Teenagers as a target group for prevention messages

Promoting cycling goes hand in hand with needing to make a greater commitment to the safety of cyclists. Teenagers should be made a focus here. In their identity forming phase, teenagers challenge the mobility-related behaviour their parents were instrumental in forming, and shape their own safety-relevant attitudes. This process is influenced by their peers and role models. Peer group values they perceive also have an influence, for example, on whether teenagers wear a helmet when cycling or not. In recent years, the proportion of teenagers and young adults wearing helmets has always been significantly lower than that of children.

To differentiate themselves from grown-ups and their parents, in particular, teenagers develop their own communication practices. They negotiate standards and values not only explicitly but also implicitly, for instance, through images in social media. In this phase, they often resist attempts by persons of authority to influence them. This is why it is particularly important to align the strategy and content of road safety measures to the characteristics of this target group. BASt is therefore analysing how prevention messages can incorporate teenagers' prevailing communication practices and generate acceptance.

Social media as a channel for bicycle helmet campaigns

Many young people follow influencers in social networks. These people – who have an extensive reach and are popular in their community – are seen by teenagers as role models and sources of inspiration. This means they are instrumental in creating trends and can motivate their followers to try out something new.

As there are findings suggesting that many young women in particular are not wearing bicycle helmets for aesthetic reasons, a BASt study has researched how they perceive the use of helmets if an influencer shows herself on Instagram wearing one.

Eye-tracking analyses and scripted interviews were deployed upon showing corresponding images to the interviewees. The results show that the way helmets are depicted can already influence whether wearing a helmet is even considered. Images showing bicycle helmets in everyday situations and from a style perspective, thus offering women an identification potential, can lead to social comparisons. Women then associate the images with their own experience and attitude and think about them. Conversely, it has become clear that heavily staged images resembling advertising campaigns do attract the beholders' visual attention,

Instagram helmet use campaign (author's own representation; image from the eye-tracking study).

but at the same time are quickly classified as influencing attempts and dismissed at first glance. Thus, they do not lead to thinking about the matter in more detail.

Furthermore, BASt's online experiment confirmed that young women suspecting an Instagram contribution as an attempt to influence them to wear helmets, perceive both the source and its message as untrustworthy. To make prevention messages trustworthy, the source's intrinsic motivation to deal with road safety should be clearly recognisable. This can be achieved based on the communicators' job-related or personal experience.

Authentic influencers offering both a connection to the campaign and an identification potential for the teenage target group are thus the most important preconditions for successful social media campaigns. At the same time, their contributions need to live up to the target group's high quality standards.

Medial evolution of preventive measures

While communicative measures address mobility-related attitudes, educational measures target the understanding of rules and the training of safety-relevant behaviour. As teenagers have a deep media affinity, BASt is also researching the potential of digital teaching and learning methods in road safety work. The #AUGENBLICKWINKEL360[1] project is an initial educational concept to show how virtual reality can be used for experience-based learning. In this concept, teenagers take on the perspective of cyclists and other road users. The immersive experience of the situation enables them to identify potential hazards in road traffic independently and perceive that mutual understanding and considerate behaviour are reasonable, without a third party having to explicitly convey this message.

1 www.augenblickwinkel-360.de [12.12.2022]

Study with senior cyclists on bicycle simulator – a feasibility study

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While studying road user behaviour with the help of passenger car simulators has been well-established in road safety research for many years, research projects using bicycle simulators are still pioneering internationally. This also applies to the first feasibility study using BASt's bicycle simulator, which specifically focused on senior cyclists. Due to both their increasing mobility and increased vulnerability, they are an important target group in road safety research.

The objectives of the feasibility study

The study's aim is to generate an initial understanding of the preconditions, possibilities and limits of the use of bicycle simulators in observing road user behaviour. The following study aspects were key: suitability of familiarisation training, road user behaviour and experience, immersion into the virtual world and the tolerability

BASt's bicycle simulator.

of the bicycle simulator. The latter refers to the potential occurrence of symptoms of "simulator disease" (a form of sickness similar to motion sickness) which may influence the driving behaviour and also lead to early dropouts.

Implementation

Before the test drive itself, the test persons participated in a familiarisation training which consisted of three short test rides of about 2–3 minutes each. The training included lane keeping, accelerating and braking, changing gears and operating the Pedelec gears, observing the right of way, turning with hand signals and following navigation instructions. The test stretch proper, which has a cycling time of about 7 to 15 minutes, then took place in a slightly more complex urban scenario and included a number of critical traffic scenes.

Besides observing the cyclists' behaviour and capturing driving data (here: measuring speed), various questionnaires were used for data collection.

Senior cyclists at the centre of road safety research.

In order to analyse the potential impact of age, cyclists older than 65 (experimental group) and also cyclists between 25 and 50 years of age were included in the study for comparison (control group).

Bicycle simulator

The bicycle simulator, including SILAB software, was developed by the Würzburg Institute for Traffic Sciences (WIVW). A real trekking bicycle equipped with sensors on a passively flexible carrier base was used as a model. The virtual environment is displayed using 10 large-format monitors that enable a 300-degree horizontal and a 100-degree vertical field of vision. Driving and background noise as well as navigation instructions are provided with a headset.

Results

In the experimental group, the sample comprised 35 older cyclists (age range: 65 to 89; 11 of these test participants were 75 or older; share of women: 34.3 per cent) and in the control group 32 cyclists (age range: 25 to 50; share of women: 51.6 per cent). The share of test participants with prior experience using car driving simulators was 22.9 per cent in the experimental group, and 58.1 per cent in the control group.

The relatively high ratio of dropouts among the senior cyclists (51.4 per cent) was striking; in older senior cyclists (75 or older) it even amounted to 72.7 per cent. By comparison, only 2 test participants (6.5 per cent) in the control group dropped out before the test was finished. The reason for people dropping out already at the familiarisation stage was primarily that they had problems handling the bicycle simulator. Dropouts at a later stage during the test drive had to do with simulator sickness.

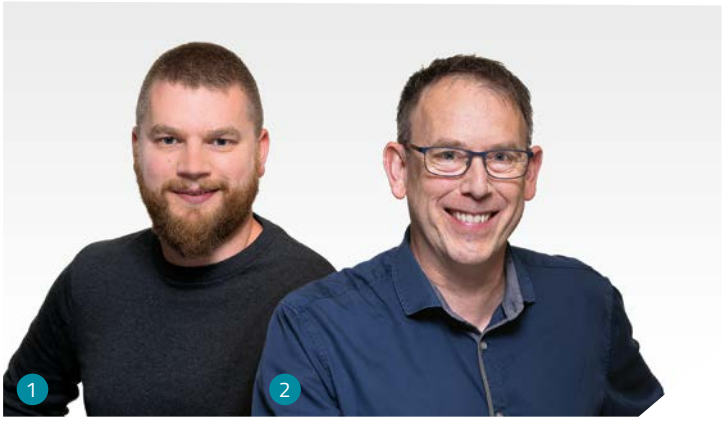
Compared to the other study participants (experimental group: n = 17; control group: n = 29), senior cyclists showed insecure and significantly slower driving behaviour. The overall number of driving errors was relatively high in both groups of participants, which was attributed, among other factors, to vehicle dynamics that can still be optimised. Looking at the experimental group in a purely descriptive manner revealed that driving errors dominated, such as unintentionally leaving the lane, wrong turns and turning without hand signal.

In comparison, more collisions and errors concerning right-of-way were observed in the control group. It is important to consider that due to their higher driving speeds, the test participants of the control group were exposed to more critical traffic situations than those in the experimental group. One positive effect of the study to be mentioned is that it enabled gathering initial indications of how to bring about a successful immersion.

Recommendations

It is recommended that future studies better adapt the familiarisation training to the needs of senior cyclists by establishing a slower and more systematic development of the difficulty levels. The focus should first be on the group of younger senior cyclists between 65 and 74 years of age. The study has also shown a need to further develop the vehicle dynamics, particularly in terms of steering, braking and speed. As a follow-up to the study, these aspects were optimised. It is intended to test their validity (real-world fidelity) in future studies by systematic comparisons with cycling in real life.

Potential of airbag-based head protection systems



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In 2021, the rate of bicycle helmet use was at slightly lower than 32 per cent. Cyclists often claimed as a reason for not wearing a helmet to find covering their head disturbing, outweighing fearing the potential effects of an accident. Head airbags do not enclose the head at all times but only in case of an accident. Does that mean they are an alternative for those resisting helmets? Since 2015, BASt has been researching the function and protective effect of head airbags in typical accident scenarios. Test were conducted to determine the cushioning effect of an inflated airbag upon impact on a car's bonnet.

A comparison to a headform protected by a bicycle helmet did not show any advantages with the head airbag. At 3 individual positions on the bonnet, the airbag achieved a head acceleration that was respectively about 10 per cent higher, 16 per cent lower and in one case comparable to the bicycle helmet. Crash tests with passenger cars at speeds of 20 and 40 kilometres/hour (km/h) hitting cyclists also showed that an airbag does not offer a superior protective effect compared to a bicycle helmet. The reasons were at times insufficient recognition of an accident and inflation before head impact. In some cases, the airbag was not able to follow the colliding head fast enough to position itself between the head and the front of the vehicle as protection. The airbag sensors did not recognise a crash test at 30 km/h and did not deploy, thus failing to have any protective effect. As a final step, additional tests were conducted with different hairstyles. The focus was on the inflation and positioning of the head airbag. The airbag's inflation in case of short and long hair was studied by video. The airbag was able to fully cover the head in either hairstyle, but the time until full inflation depended significantly on the hairstyle.

Component tests on bonnet (top left); head impact on passenger car front at insufficient positioning of the airbag (top right); airbag inflation in short hairstyles (bottom left); airbag inflation in long hairstyle (bottom right).

The airbag was fully inflated after 62 milliseconds in a short hairstyle, but took three times as long in the case of a longer hairstyle. Conclusion: the head airbag cannot take the place of a bicycle helmet. Due to the complexity of the individual sequence of events in accidents, recognising them often falls short.

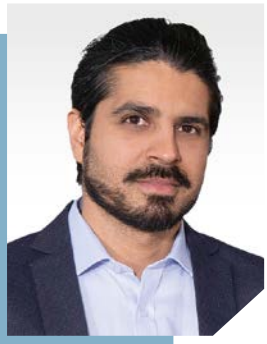
Heavy long hairstyles or dynamic movements can result in the airbag's failure to deploy and position itself in a timely manner. The protective effect of the head airbags tested is considerably lower than that of a conventional bicycle helmet, though of course still better than no protection at all.

Our principles

"We encourage and expect a consistently high quality in our scientific work, multi-disciplinary and international cooperation and continuous further qualification of our employees."

**Dr Markus Schumacher, psychologist,
head of section in the "Behaviour and Safety" department**

"We are continuously improving our processes and promoting innovations, bearing in mind the economic efficiency of our work and our recommendations."



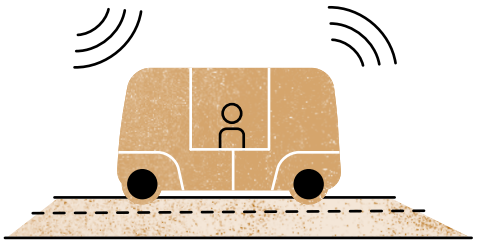
**Dr Mehdi Kalantari, M. Sc. Eng in engineering
in the "Highway Construction Technology"
department**

"We are utilising all the possibilities for scientific exchange and promoting young researchers."

**Elisabeth Shi, M.Sc. in psychology in the
"Automotive Engineering" department,
PhD student at the Technical University Munich**

Working in your car, watching films or even sleeping, being able to rely on your car completely and arrive safely: scientists all over the world are researching how to further develop automated and autonomous driving. It is intended to gradually turn the vision of an autonomously acting vehicle into reality: one day such vehicles will transport people and goods from A to B without their active participation. The Federal Highway Research Institute (BASt), as an internationally acknowledged player and driving force in the field, commits to this goal with its expertise. Its research findings are preparing the market access of automated and connected vehicle functions. Furthermore, BASt as a neutral scientific institute of the Federal Ministry for Digital and Transport is developing national and international requirements and standards for vehicle safety systems and vehicles.

3. Automated and connected driving



These require meticulous preparation and a long lead time. Topical findings from basic and applied research are needed particularly in the fields of human-machine interaction, driver training, establishing new forms of steering such as remote operation, and the exchange of vehicle and mobility data. One of BASt's main tasks is to provide unbiased advice to policymakers and support them with its expertise. BASt is preparing science-based solutions for decision-making as to how new forms of mobility can be designed more sustainably and safer in the future. This also helps the automotive industry on its journey from pure car manufacturers today to providing manifold mobility services tomorrow.

Machine-readable road

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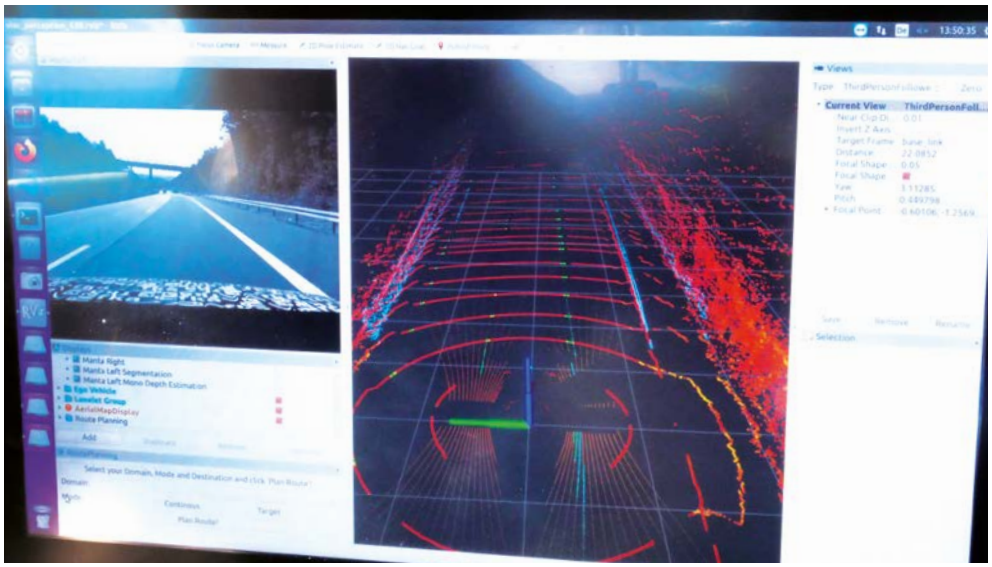
In the foreseeable future, great importance will be attached to road markings for automated and connected driving. One core question is what requirements need to be covered in the future so that both human drivers and automated vehicles can identify road markings reliably. The requirements for road markings to date are tailored exclusively to humans.

In contrast, there is hardly any knowledge about what additional requirements may result from detection with in-vehicle sensor systems. This is why BASt has commissioned a research project to study the properties of road markings crucial for machine detection. On the basis of its findings, a review will be conducted to determine what modifications in designing and renewing markings can simplify the introduction of autonomous and connected driving. Additionally, BASt is preparing an update of the current quality assurance management of road markings for the purposes of autonomous and connected driving. The following applies to markings with novel properties just as with conventional road markings: only if the characteristics of the marking that are relevant for machine detection are durable



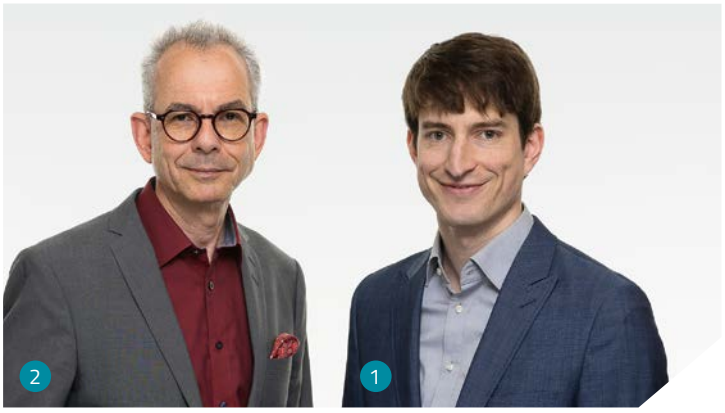
Detection of road markings using LIDAR in a test drive with a research vehicle of the fka GmbH.

and remain unchanged under any weather conditions are they suitable for use in practice. As a consequence of this, road markings designed for both humans and automated and connected driving will also need to undergo a suitability test on BASt's circular test track in the future. The circular test track is the laboratory procedure with which the longevity of road markings is assessed for their use in Germany by using accelerated traffic loads and measured structural condition surveys as a precondition. Measuring methods for new requirements that cameras and LIDAR systems, for instance, impose on road markings need to be developed, verified and integrated into the European standardisation process. These new measuring methods must then become part of the process of the markings' suitability testing.

This is the only way to ensure that authorised markings will be available in practice.

To be able to conduct corresponding research and adapted tests in a laboratory, a new circular test track has been planned. This will create the preconditions for the use of new measuring methods, tools and sensors.

Mobility Data Space – safe data exchange for tomorrow's mobility



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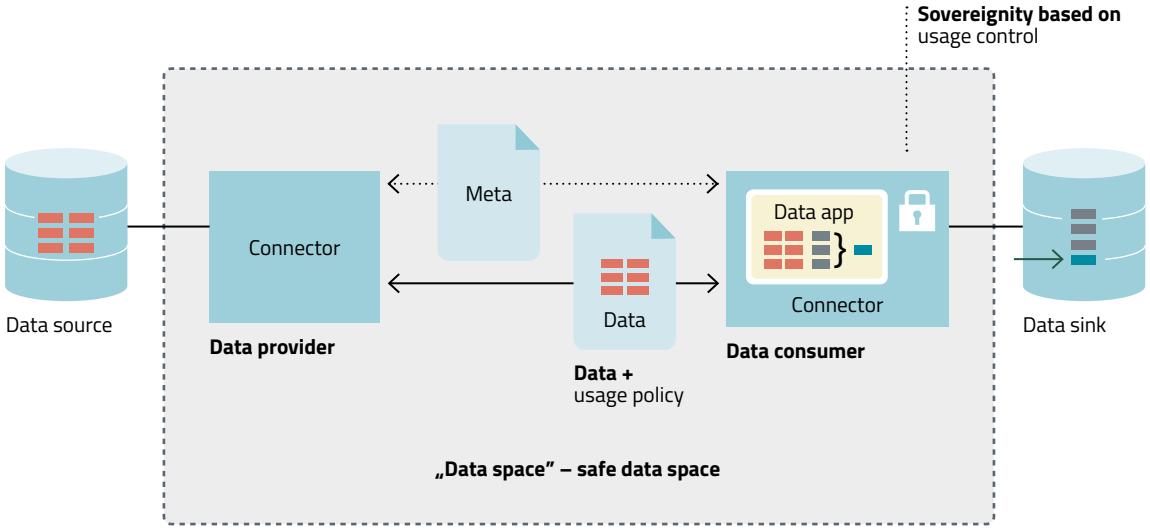
Data is the fuel for digitalisation. This is also true in the field of mobility, where more and more data is being collected. Data offers enormous potential for data-based services which will render transport and travelling safer, more efficient, more environmentally friendly and more convenient. The potential is far from being fully utilised. Particularly the exchange of data among various mobility providers, such as road operators, car manufacturers, public transport operators and car-sharing providers, is performed only to a very limited extent.

BASt has already been providing technical and organisational support for a non-discriminatory, safe and reliable exchange of data for a long time with its Mobility Data Marketplace (MDM), the national access point for mobility data. When informational self-determination, data privacy and the non-disclosure of trade secrets play a central role, exchanging data via a marketplace such as the MDM is not an ideal solution. This is why BASt is an active participant in the "Mobility Data Space" research project, funded by the "mFund" modernity fund of the Federal Ministry for Digital and Transport (BMDV). The concepts of the International Data Spaces Association were intended to enable a mobility data ecosystem that makes even sensitive data accessible and usable for third parties by technically ensuring data sovereignty. Furthermore, the aim was to better connect the other numerously existing data platforms.



Conceptual presentation of the Mobility Data Space.

Picture source: Fraunhofer IVI

The graph shows the basic principle for a data exchange between two participants of a data space. Each participant operates a connector, enabling and controlling a safe exchange and processing of data while maintaining the data sovereignty from the data provider's perspective. Usage control enables the processing and sharing of data in accordance with the data provider's usage policy.

Central institutions for certification and identity checks are necessary to ensure trust in the proper functioning of the technical components and in the authenticity of the participants. Furthermore, metadata registries, vocabularies and logging information simplify finding and processing data, creating transparency.

Within roughly 3 years, the project developed the foundation for the Mobility Data Space of the same name: in the meantime, it has become operative in a newly founded company with numerous renowned participants from the mobility industry. BASt was also able to use the findings in newly developing the Mobilithek mobility library as the successor for MDM and the BMDV's mCloud, a central access point for open data.

Evaluating dummies for new concepts of a car's interior

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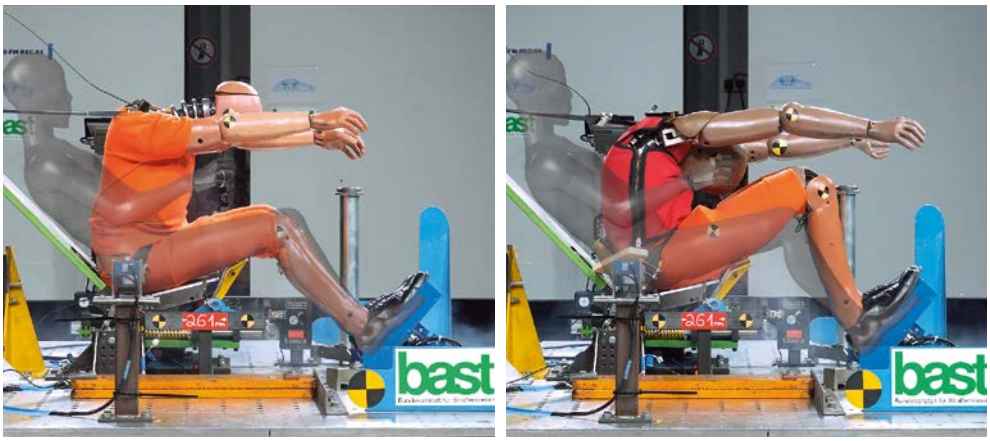
The increasing automation of vehicles towards autonomous driving enables drivers to engage in non-driving-related activities. The vision of novel concepts for a vehicle's interior and seating positions is becoming reality – such as passengers fully reclining in their seats or car seats turned towards the centre of the vehicle with passengers sitting opposite each other.

Accidents will, however, still occur in mixed traffic of automated and non-automated vehicles. Therefore, these vehicles and their novel interior design need to be evaluated with regard to occupant safety. Conventional dummies used to evaluate occupant safety were developed for upright seating positions and can show the occurring loads and injury patterns. It is not clear whether these dummies can also be placed in reclining seating positions to assess the associated changes in loads and injury patterns. These are pelvis and lumbar spine fractures, in particular, and submarining – the body slipping beneath the lap belt in a collision. Conventional dummies were updated to address these types of problems.

In recent years, BASt has evaluated various conventional and updated dummies in static and dynamic tests. A reclining angle of 45 degrees was chosen for the tests, about twice the inclination of customary seating positions.



Novel seating positions were tested in sled tests.

An adapted restraint system with dual lap belt tensioning was also deployed to reduce the risk of submarining. It was possible to fit all dummies into a reclining seating position. Constraints occurred, however, with the conventional dummies – in contrast to the updated ones. It was possible to prevent submarining in dynamic tests using the modified restraint system. However, in terms of kinematics (see pictures), pelvis rotation and strain on the lumbar spine in particular, there were major differences between the dummies.

The tests have indicated the need for further research with regard to updated dummies and the necessity for biomechanical comparative data with humans. The pelvis and lumbar spine section is a particular area of focus to enable addressing future injury patterns of relevance. BASt will work on this in the years to come, including in the European research consortium ENOP (Enable New Occupant seating Positions).

Can vehicles already autonomously drive us along motorways?

Author:

Oliver Bartels,
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"Active Vehicle Safety and Driver Assistance" section

Automated driving, where humans are merely passengers and do not do the driving themselves, is coming closer step by step. Since January 2021, vehicles systems autonomously taking over the entire driving activity within one lane for speeds of up to 60 kilometres per hour can be approved for motorways and motorway-like roads. The United Nations classifies such systems in the vehicle regulations number 157 (UN R 157) under the term ALKS (Automated Lane Keeping Systems). An ALKS is thus the first system in a vehicle with which the vehicle does the driving entirely on its own for time intervals – for instance in a traffic jam on a motorway. Human drivers only intervene with a sufficient time buffer once the limits of the system have been reached. This is why the regulation defines stringent technical requirements for such a system, as it needs to function safely without a driver when activated. The human drivers' obligations required are defined in national driver conduct regulations. These had to be transferred into appropriate technical requirements for the vehicle system. Another challenge lies in designing the requirements in such a way that a safe transition back to manual driving is ensured.

Initial mass-produced systems were approved for use in vehicles in December 2021. Users can now drive these vehicles with the regular use of an ALKS in road traffic in countries such as Germany, where the national laws permit the regular deployment of self-driving cars.

Well-known systems that are commercially available under system-related or functional names such as "Autopilot", "Full Self Driving", "Super Cruise", "ProPilot" and others do not constitute an ALKS as such, but are only driver assistance systems supporting drivers to a greater or lesser extent in their driving activity. In these systems, the responsibility for

Sample test scenario "forming emergency corridor" for an ALKS

Sample test scenario “lane change after overtaking” for an ALKS.

Sample test scenario “motorcycle at the tail end of a traffic jam”.

driving always remains with the drivers, in contrast to an active ALKS.

As a next step, the UN R 157 regulation was expanded at the initiative of the Federal Transport Ministry and with extensive support from BASt. Higher maximum speeds of up to 130 km/h and automated lane changes are now possible for these vehicles, which means they can be approved as full “motorway chauffeurs”. This regulation will also apply to trucks and buses in the future. This amendment to UN R 157 was put to a final vote at the United Nations in June 2022; after being adopted, it entered into force in January 2023.

Since then, approval has been possible for automated driver systems which, for example, can handle a complete motorway drive from access point to exit. For an approval under UN R 157, proof needs to be provided that the systems comply with the requirements outlined there. This includes passing comprehensive tests derived from real traffic situations. The tests simulate driving situations that the vehicle needs to master safely. During these tests, the parameter space defined in the regulation (for example speed, course of the road, traffic situation, other road users) can be varied (see sample pictures) in order to be able to test the vehicle’s conduct in an as representative and robust a manner as possible for use in real traffic later.

The legislation thus enables the implementation of a “motorway chauffeur” in mass-produced vehicles, so that the first vehicles could soon autonomously drive us along motorways.

User-compatible communication during automated driving

Authors:

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Changes in the Road Traffic Act in 2017 and 2021 have enabled automated and autonomous driving modes on public roads. The anticipated gain in road safety is based on the proper use of the systems. BASt has developed a user-centred illustration of manufacturer-independent automation to inform road users. It differentiates between assisted, automated and autonomous modes. Users and their driving-related activities are at the foreground. This illustration is fully compatible with the terminology used in the legislation referred to above and with the international standards used in the field. Explicitly, it does not address experts in the field, but all road users.

The three automation modes

1. Assisted mode

Assistance systems available today enable the assisted mode. Its essential feature is that drivers are only assisted in their driving activities, never fully replaced.

Systems such as Tesla's Autopilot can influence both driving speed (longitudinal control) and continuously keep a vehicle in the middle of the lane (lateral control). This changes drivers' subjective experience: the more extensively assistance systems support the driver, the less they need to actively contribute to continuously steering the vehicles. The difficulty for them is that

Assisted mode

Automated mode

despite active systems they are responsible for the driving activity at all times, even if it does not feel that way for them. This means they need to continuously monitor the system and the environment and, if necessary, intervene with corrective action.

2. Automated mode

The automated mode changes the role of the person in the driver seat for the first time: after the system is switched on, it fully takes over the driving activity within the traffic environment for which it was designed, for instance, driving in a traffic jam on a German motorway. With this, the person in the driver's seat thereby switches from the role of driver to the new role of user.

While the system is driving the vehicle, users can turn their attention to non-driving-related activities such as reading and writing emails. The precondition is that they remain alert to the extent that they can resume control when prompted by the system – sleeping, for instance, is not permitted.

If the system recognises that it can no longer perform the driving task, it prompts the user to take over the driving task again. The system leaves a minimum of 10 seconds for resuming control. Once prompted in this way, users need to get back into the driving role. To do so, they need, for example, to gain an overview of the traffic situation they find themselves in. After switching off the automated system, they resume control of the vehicle as the driver, confirming that they are again fully responsible for continuing to drive.

In December 2021, the first vehicle enabling an automated mode was type approved. The vehicle can drive on motorways in traffic jams in automated mode.

Autonomous mode

In the automated mode, users may engage in non-driving-related activities.

3. Autonomous mode
In autonomous driving, the system takes over the entire driving activity. In this mode, all persons on board are passengers and have no driving-related tasks. This is why this mode can also be envisaged in vehicles with no steering mechanism or other control elements for manual driving. In such a case, the design itself already makes it clear that none of the passengers on board need to contribute to driving in any form. The same applies if the system is installed in other vehicle types (such as passenger cars, trucks, construction site vehicles) that still have a driver seat.

Understanding one's role in the vehicle – using a video tutorial

In collaboration with the "ORCA Affairs GmbH" agency, BASt has developed a video tutorial for non-specialists explaining the different automation modes and the tasks they entail for drivers.

The video aims at helping drivers understand their role while using the various systems. For this purpose, the video shows each automation mode from two perspectives:

- 1. explaining the function of the vehicle systems,
- 2. demonstrating and commenting on the users' driving-related task.

A range of design elements are deployed which, based on empirical findings, promote learning motivation and learning success.

The video can be found on BASt's YouTube channel under:
https://youtu.be/v5SMnmM7PC4

Further information:
www.bast.de/autonomous-driving

Automated driving – drivers' situational awareness after resuming control

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"Automated Driving" section

While drivers' attention is always focused on road traffic during manual driving, the situation differs in automated driving: drivers have the possibility to engage in other activities. They can, for instance, read a book and turn away from the traffic environment.

When the system prompts drivers in specific situations to resume the driving task – for example, before entering a roadworks site – with an adequate time buffer, they need to re-establish their awareness of the ambient traffic environment (situational awareness).

To be able to study this process, a study was conducted involving test participants using a test vehicle on a motorway. 40 test participants drove along a test stretch, manually and sometimes with automation. During the manual drive, the test participants received questions via a loudspeaker about the traffic environment to capture their situational awareness. They had two Yes/No buttons installed on the steering wheel to provide answers. Reaction times and the number of correct answers served as a measure for the speed and accuracy of the situational awareness they established. Furthermore, the test participants' gaze behaviour was recorded to enable conclusions to be drawn on how they oriented themselves.

The drivers have the possibility to engage in other activities during an automated drive and turn away from the traffic environment.

A novel display concept was analysed with which drivers can be supported in establishing situational awareness in the future. Drivers see the remaining time until they need to resume control as a countdown. This means they can better plan their other activities during the automated drive and can orient themselves towards the traffic environment early on. The sample of test participants consisted of two groups: one countdown group and one control group. Initial results show that the test participants in the countdown group concluded their other activities, such as putting away their phones, already about one minute before the system's signal to become aware of the traffic environment and prepare for resuming control. The test participants said that they were able to finish their activities without disruption and thus to focus on resuming control.

There was, however, no difference observed between the groups in reaction times or the number of correct answers. This suggests that a time of 10 seconds to resume control was sufficient for all test participants to establish a situational awareness in a regular hand-over scenario.

Safety and acceptance in automated mixed traffic

Author:

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Automated and autonomous driving is intended to contribute to rendering road traffic safer, more efficient and more sustainable in the future. It is assumed that vehicles driving in an automated mode (Level 3 of the Society of Automotive Engineers (SAE)) or autonomous mode (SAE Levels 4 and 5) (hereinafter called "highly automated vehicles") will move in the same road environment together with non-automated road users, such as car drivers, cyclists and pedestrians. This leads to automated mixed traffic. Only if the interactions between automated and non-automated road users take place safely and efficiently, can the safety-related goals of automated and autonomous driving be reached.

This, in turn, is an important precondition for achieving high societal acceptance of automated and autonomous driving. Currently, there are hardly any findings available about the impact automated mixed traffic might have on road traffic situations.

Interactions in automated mixed traffic

Experts assume that highly automated vehicles will behave differently in certain situations compared to a relevant share of motor vehicles controlled by human drivers. For the time being, the assumption is that highly automated vehicles will strictly comply with the German Road Traffic Regulations (StVO) at all times and will tend to show a defensive and cooperative driving style. Furthermore, highly automated vehicles exclusively use technology-based communication means. This changes communication in automated mixed traffic. The vehicles cannot use gestures like human occupants or establish eye contact with other road users to, for instance, convey their intention.

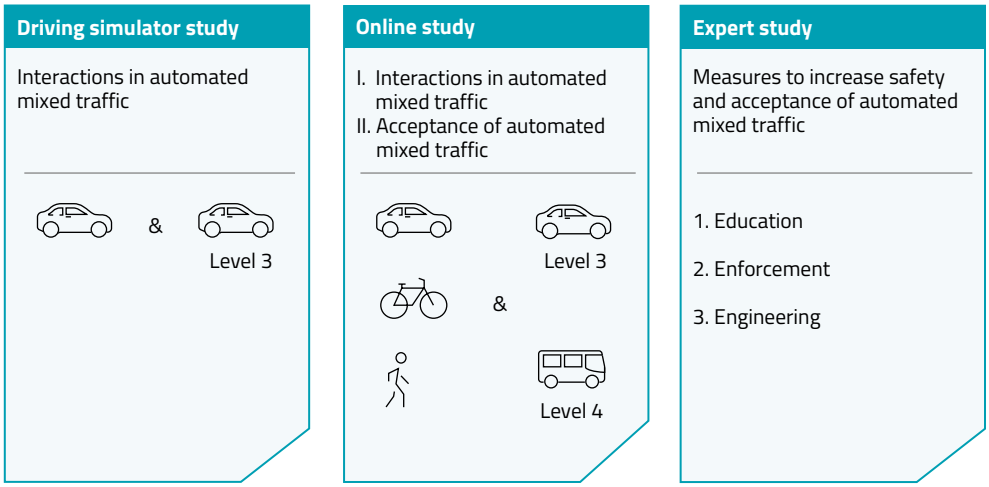
Relevant influencing factors for the cooperation in mixed traffic are being analysed.

In the scope of an internal research project with a total of 3 studies, BASt is analysing the effects of the special characteristics of highly automated vehicles on the experience and behaviour of non-automated road users. The project will also study the factors influencing the acceptance of mixed automated traffic by non-automated road users. A driving simulator study (N = 42), an online study (N = 2048) and qualitative interviews with experts (N = 12) were conducted. These are currently in the evaluation phase.

Study focus and method

The BASt project aims at an in-depth analysis of the safety and acceptance of automated mixed traffic in Germany. The focus is on the experience and behaviour of non-automated road users. It is intended to focus the initial analysis on a robust study of the interactions between highly automated vehicles and different groups of non-automated road users. One crucial goal is to identify relevant influencing factors for interactions in automated mixed traffic and analyse their impact. A driving simulator study will, for instance, systematically analyse how and to what extent the surrounding space (built-up area, non-built-up area without motorway, motorway) influences the interactions in automated mixed traffic. Furthermore, another focus is on whether the effects of highly automated vehicles can be mitigated when these are marked with "automated driving". Another research question is whether novice drivers experience interactions with highly automated vehicles differently and deviate in their behaviour from more seasoned drivers. The focus of the project's second study, a video-based online study, was an analysis of interactions on urban streets with varying right-of-way/priority regulations, where car drivers, cyclists and pedestrians meet interaction partners exhibiting various levels of automation. The online study includes, for instance, an analysis of whether non-automated road users will perceive a vehicle that is automated but has a person sitting in the driver seat differently from autonomously driving vehicles without a driver seat. Furthermore, the question arises how such perception affects the behaviour of non-automated road users.

The project's second study focus is to conduct a more in-depth analysis of the acceptance of mixed automated traffic. More than 2,000 drivers, cyclists and pedestrians were interviewed with regard to their attitudes towards highly automated



Various studies were conducted as part of the project.

vehicles and their willingness to move in the same road environment with these vehicles. The results of the survey enable determining the current acceptance of mixed automated traffic in Germany. They form the basis for a more in-depth acceptance analysis. To this end, it is intended to develop a model as part of the project to explain and predict the acceptance for mixed automated traffic and to review it on the basis of the data collected.

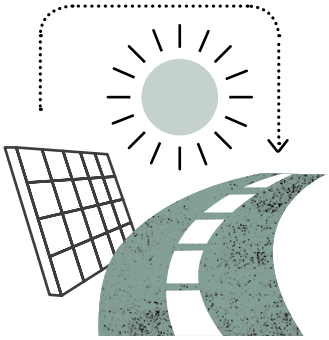
In order to do justice to the interdisciplinary nature of automated and autonomous driving despite the project's primary focus on traffic psychology, a number of interviews with experts from different disciplines will be conducted. The primary objective is to find out what measures enable a safe and efficient implementation of automated mixed traffic and how to increase its acceptance. The experts will have a background in "education" (knowledge creation and training), "enforcement" (guidelines and regulations) and "engineering" (technical measures), thus covering as much diversity as possible. Overarching recommendations for measures will be derived based on the measures identified here and on other project findings.

Outlook

Results from the BASt project on researching the safety and acceptance of automated mixed traffic are scheduled to be available in spring 2023. Follow-up studies will then use this as a basis to study interaction forms that have not been studied before, as well as the experience and behaviour of cyclists and pedestrians in automated mixed traffic. It is envisaged to include studies using a bicycle simulator and BASt's VR laboratory. The aim of this and other studies is to contribute to a better understanding of getting along together in automated mixed traffic and to support the introduction of automated and autonomous driving.

Developing a stable and autonomous energy structure on the basis of climate neutral power generation is one of the most urgent tasks of our time. Road infrastructure can and must contribute to this. A flexible and resilient energy system requires an adjustment of energy consumption, demand-driven power generation, intelligent storage and targeted provision of the energy needed. The integration of fluctuating renewable energy calls for a coupling of sectors, i. e., a conceptional coupling of the transport and energy sectors to respond to impending technical issues. One case in point is that mounting photovoltaics on noise abatement walls may not adversely affect either their function or structural stability. In view of the currently very dynamic development, innovations particularly in the field of energy supply and their potential use need to be evaluated from the technical perspective, obstacles that may hinder innovations need to be dismantled, and technical regulations need to be adapted. It is also important to consider the latest developments in vehicle and drivetrain engineering accordingly in this context. A climate-neutral operation of road infrastructure requires intelligent solutions in road construction, highway equipment and traffic engineering, taking into account the needs of various types of usage.

4. Sustainable use of energy



The potential of digitalisation needs to be exploited to the full extent also in this context. The Federal Highway Research Institute (BASt) is focusing on the following fields of action in the scope of its activities:

Sustainable operation of federal trunk roads, using road infrastructure for energy functions, technical aspects of generating regenerative energy from road infrastructure, safe and resilient energy operations, coupling the energy and transport sectors and optimising the transformation process, particularly including digital solutions.

BASt's technical organisation units involved (Traffic Engineering, Highway Construction Technology, Bridges and Structural Technology, Automotive Engineering, Digitisation) are acting together with central partners from the transport and energy sectors in Germany and abroad as well as infrastructure operators, road construction and highway equipment companies, car manufacturers, energy providers, supervisory and licensing authorities at Federal and Länder levels, other research institutions and many more.

Electric Road Systems

Author:

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Finite fossil resources and climate targets necessitate alternative drive systems to combustion engines. Electrical drive systems use renewable energy either directly or converted into fuel. An electrical drivetrain in heavy goods traffic has the highest energy need in the case of road vehicles and constitutes the biggest challenge. This is why special concepts are needed to bring energy into the vehicles.

Charging technologies that enable charging while driving can increase vehicles' range without increasing the need to stop. Such Electric Road Systems (ERS) are being tested internationally using a variety of technical approaches. BASt too is studying the suitability of various linear charging technologies.

Charging with overhead power cables

The option to supply energy to electric road vehicles via a current collector (overhead power cable) in analogy to rail transport is nothing new and is frequently deployed in city buses.

At the beginning of the millennium, the idea arose to adapt this technology for long-distance heavy goods traffic as well. Many years of experience with the system that was already available was seen as a major advantage as it promised less development time and thus faster implementation.

In Germany, the development of dynamic charging by means of overhead power cables is being funded by the Federal Environment Ministry in several successive projects. In the initial phase, 2 projects were conducted to develop a system using test tracks outside the public road environment. In the "Electric mobility for heavy commercial vehicles as environmental relief for conurbations (ENUBA)" project, potential solutions to electrify heavy goods transport were developed with BASt involvement.

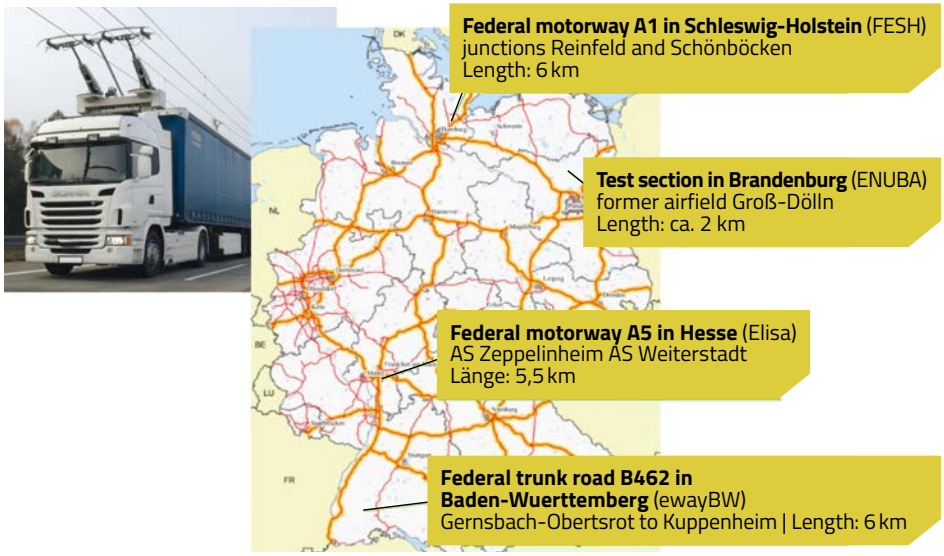
In phase 2, the technology was installed in 3 pilot sections of the public road environment on which drives with initial pre-series vehicles regularly operated by road haulage companies could take place. This led to operational experience with the vehicles, as well as to economic and ecological findings.

Power rail systems

A power rail is a different charging technology in which the vehicle taps into the power supply by means of a sliding contact with energised rails embedded in the road. As a matter of principle, this solution can be a charging option for all vehicle types. A first experimental test was conducted in Sweden. Additional studies and developments addressing installation methods and operational reliability will be conducted.

Inductive charging

Inductive charging enables a contact-less transmission of energy into the vehicle. For this, loop-shaped cables (primary coils) that create an electro-magnetic field are installed within road pavements. Cable loops are also installed in the vehicles as "energy recipients" with which the vehicle can absorb power to charge its battery while driving over the cable loops in the road.



Test sections for using overhead power cables for trucks.

Two different solutions for this charging method are currently being tested and evaluated on the duraBASt premises with regard to their feasibility in terms of road and electrical engineering. Besides the installation process, the service life of the different constructive solutions with heavy goods traffic loads is also being studied. The maximum charging performance the systems can reach in practice is an important parameter. The higher it is, the shorter the length of the charging sections for batteries need be.

Outlook

All linear charging concepts require significant investments into the infrastructure. At least for heavy goods traffic, it is not yet clear which drive system will prevail.

To facilitate a decision, BASt compiled a catalogue of criteria that can be used to evaluate new charging systems. The catalogue covers the fields of infrastructure, vehicle safety, construction as well as maintenance and operation. Assessments of feasibility, function, effort in terms of infrastructure and operational safety are important criteria. A comparison of the level of technical maturity of the systems' charging capacities and an assessment of the technologies will be used for this purpose.

As is the case with stationary charging stations and filling stations, the operators of the road infrastructure are not necessarily the operators of the charging infrastructure in linear charging sections at the same time. This is why legal and technical framework conditions need to be defined prior to a potential application to enable the cooperation of all stakeholders in the first place. These also need to be coordinated at the European level to ensure a broad application of the technologies. The in-vehicle components also need to be standardised at least at the European level. Initial initiatives for this purpose have already been started. BASt is participating in a number of initiatives to initiate the international standardisation process for these systems. Findings from the ongoing tests are an important basis for sustainable decisions for this as well.

Photovoltaics on federal trunk roads

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Dr Birgit Kocher, (not in the picture), geoecologist, deputy head of section

5 **Cyrus Schmellekamp** environmental scientist

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The increased use of renewable energies is significantly contributing to achieving the climate targets, protecting the environment and to Germany becoming largely energy self-sufficient. The network of federal trunk roads offers considerable potential for expanding photovoltaics (PV). The technical energy potential of noise abatement walls in the network of federal trunk roads were analysed in a BASt project. In the future, the administrative overall conditions needed to derive the usable potential from the technical potential will be analysed.

Together with the Federal Ministry for Digital and Transport's (BMDV) Network of Experts, BASt commissioned a study in the field of "renewable energy" to show that both the technologies and business models for a corresponding regulatory framework are available for the commercial use of renewable energies along transport routes (BASt, 2022).

PV on top of or attached to engineering structures and on sealed surfaces

The installation of PV systems on top of or attached to engineering structures and on sealed surfaces offers the benefit of a dual use of these areas, thus usually not causing additional adverse effects to nature conservation interests. Along federal trunk roads, this includes the premises and buildings of rest and service areas, road maintenance depots, machinery and equipment yards, bridges and operating buildings of road tunnels. PV systems can also be installed in the field of noise abatement walls, provided that emission control and road safety are not adversely affected. Ideally, energy can be supplied directly to adjacent consumers such as maintenance depots or industrial establishments.

PV on government-owned soft estate

Open spaces along federal trunk roads can also be used for regenerative power generation. Furthermore, measures at a distance of 40 to 100 metres from motorways and 20 to 40 metres from federal trunk roads may not restrict road safety nor smooth flow of traffic.

PV noise abatement wall along federal motorway A 94 near Töging.

In the case of PV systems on such soft estate, the diverging interests of agriculture and forestry, nature-based solutions, insect protection and nature conservations have to be considered. Weighing up these interests can result in finding out that in these cases using the land also to install PV systems obstructs nature conservation and the Federal Government's sustainability strategy.

Framework conditions

Framework conditions must be established to enable an expansion of PV systems along federal trunk roads that is in line with road safety and routine road maintenance. It is particularly important that traffic can flow without impediments or sources of glare in lateral roadside areas, and that a commercial and safe operation with regular inspections is ensured.

The selection of a suitable location is crucial for nature-compatible PV systems. The accompanying support of experts in ecology and soil science before and during the construction work can ensure that nature conservation and soil protection criteria are taken into account in selecting and installing of the modules (Competence Centre for Nature Conservation and Energy Transformation (KNE), 2021).

Conclusion

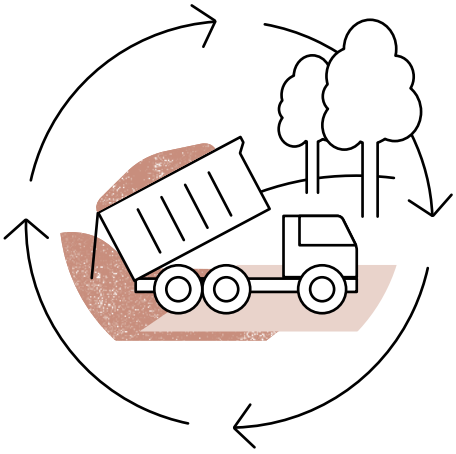
There is significant technical potential for generating renewable energy along federal trunk roads. This can make a substantial contribution to achieving national climate targets. A suitable expansion of PV systems should be promoted in particular at sites that have been deemed compatible after weighing different interests. Areas and buildings that are already sealed are a particularly good option. A need for further research on PV systems is seen with regard to road maintenance issues and a design to be compatible with nature conservation. BASt is planning additional research projects in this context and also a regional analysis in the scope of the BMDV Network of Experts covering the PV potential across all modes of transport.

BASt (2022): *Intermodal exchange of renewable energy.* Verkehrsträgerübergreifender Austausch von Erneuerbarer Energie. Berichte der Bundesanstalt für Straßenwesen, Verkehrstechnik, Heft V 364

KNE (2021): *Criteria for a design of solar installations in open spaces in line with nature conservation.* Kriterien für eine naturverträgliche Gestaltung von Solar-Freiflächenanlagen. Übersicht und Hinweise zur Gestaltung. 6 S.

Roads and engineering structures, such as bridges and tunnels and installations for non-motorised traffic, constitute the basis for a functioning transport infrastructure. They ensure sustainable mobility and are an essential precondition for our world economy with its division of labour. Continuously maintaining, adapting and further developing its functionality is therefore of great significance for the common good. However, the raw materials needed to produce and operate the structures and, in particular, the resulting emissions are enormous. This is why innovative approaches with which to significantly reduce these effects need to be developed and implemented swiftly. To achieve this, it is necessary first and foremost to extend the service life of roads, engineering structures and the equipment for them by broadly increasing their quality in all phases. Moreover, the manufacturing of concrete and asphalt as building materials needs to be optimised in terms of greenhouse gas emissions by means of modified processes. This approach will both reduce costs and save valuable building material and energy resources. With its expertise and project experience as well as testing facilities, the Federal Highway Research Institute (BASt) actively supports further developing a type of building process which,

5. Sustainable construction



besides costs, increasingly focuses on other aspects of sustainability. Based on practice-oriented research, BASt wants to be a driving force in the fields of planning, building and operating. Greenhouse gas emissions, circular economy and economic efficiency will be included here, as well as adapting the road infrastructure to climate change and taking other essential environmental aspects into account. Civil engineering solutions will be funded by the “Innovation Programme for Roads” and tested using the duraBASt demonstration, testing and referencing premises, which are unique in Europe. In addition, it is intended to render the use of sustainable approaches in all lifecycle phases of the road infrastructure more attractive. To this end, BASt together with other players in the field will develop sustainability assessments for all phases in the planning, building and operating phases and make them available to both the Federal Ministry for Digital and Transport and the authorities responsible for the construction and maintenance of federal trunk roads. These assessment procedures are also an integral part of the Federal Government’s overarching sustainability management.

Current developments in continuously reinforced concrete pavements on federal trunk roads

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"Concrete Pavements" section

Traffic loads and the proportion of heavy goods traffic on German roads and motorways are increasing almost continuously. Other important factors are the effects of climate change, scarcer resources and an increasing skills shortage. It is necessary to perform construction in a way that ensures maximum service life and minimum maintenance efforts, while necessitating only a minimum of traffic disruptions and labour costs during the entire lifecycle. Continuously reinforced concrete pavement (CRCP) is one option which has the potential to do this. In this method, a continuous longitudinal reinforcement is placed in the middle of the road with concrete pavement.

Thin transverse cracks at distances of roughly 0.7- to 1.4 metres will occur, instead of transverse joints at regular intervals. Internationally, more than 50,000 kilometres have been constructed using this method, and they show a positive long-term behaviour with longer service lives, more driving convenience, less maintenance – but also initially higher investment costs.

This method is in its testing phase in Germany. Between 1997 and 2021, 6 test stretches were installed on sections of motorways, on one federal trunk road and one private road. The experience gained and the expertise about this method are described in the "General Information on Continuously Reinforced Concrete Pavements" (H DBB) of the Road and Transport Research Association (FGSV).

In a research project of the ISAC GmbH, the RWTH Aachen university, the AB Roads consulting office from Brussels and BASt, the test sections in place were analysed and compared to corresponding sections in Belgium. The test pavements were manufactured using concrete of the C30/C37 to C35/45 grades and thicknesses between 22 to 25 centimetres.

The image shows how the test stretch A61 near Boppard was built in July 2021.

BSt 500 reinforcement steel with 16 and 20 millimetre-diameters was deployed at reinforcement ratios of 0.62 to 0.75 per cent. Asphalt base courses, fleece, or asphalt intermediate layers on hydraulically bound base materials, or reinforcements were used as base courses. The sections with a service life ranging from one to 24 years all show positive behaviour with uniformly high load carrying capacities, high-level driving convenience and no visible damages in the form of erosions, corrosion of the steel reinforcement, formation of ledges or concrete spalling. In the long term, such positive behaviour will remain unchanged and free of maintenance for the coming decades. One case in point is the E40 motorway near Leuven, one of Belgium's main transport routes.

Optimisation potential was nonetheless identified in the scope of the studies.

This refers to new approaches from Belgium and the US to control cracks, improvements in quality with regard to pavement thickness and post-processing, utilisation on smaller bridges and culverts and the end sections. A CRCP is particularly suitable for an asphalt cover construction (vertical composite structure). No additional measures are necessary at the open transverse cracks. Covering the pavement while it is new provides additional benefits, as installing the concrete is simplified.

Even without the optimisation potential mentioned above, CRCPs achieve a service life of 50 years and more at high traffic loads. With the potential described here, maintenance measures can be reduced even further and the service life extended.

Currently, the FGSV working group 8.3.4 is preparing a "Fact sheet on continuously reinforced concrete pavements", which will make a crucial contribution to a new standard construction design.

Making sustainability visible

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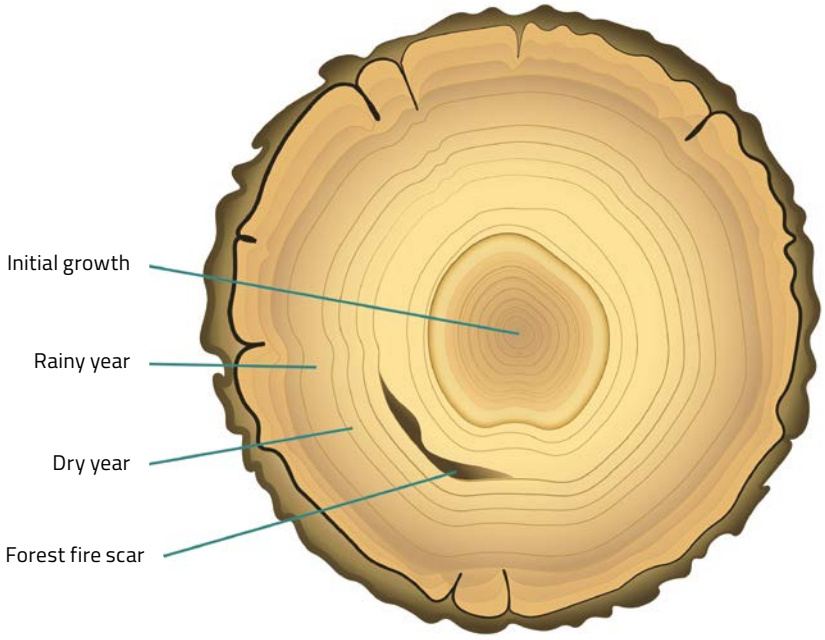
The topic of sustainability has been gaining increasing significance in every area of public life over the past years. It is important not only to think and act sustainably but also to recognise and show successes already achieved or potential shortcomings. BASt has developed a concept for sustainability monitoring as a contribution to increasing visibility. This will enable tracking the implementation of the German Sustainability Strategy in road construction. The Sustainable Development Goals (SDGs) of the German Sustainability Strategy that are applicable to road construction are identified for this purpose and adapted to the conditions in the road construction sector.

The main starting points in the implementation are, in particular, direct reductions in both energy consumption (SDG 7) and greenhouse gas emissions (GHG, SDG 13) and direct and indirect improvements in resource efficiency (SDG 8). It seems logical to transfer the approaches of the German Sustainability Strategy directly to road construction when it comes to implementing the sustainability strategy. The challenge here, however, is that there is no sufficient data base. The consumptions in road construction are usually merged in the data of the general construction industry and cannot be differentiated any further.

In order to establish practicable indicators despite this challenge, a number of variants were proposed per protection target. These variants aim to gradually enable swift but also future implementation which complement each other and build on each other. This procedure is explained below using the protection target of primary energy consumption as an example (SDG 7.1.b).

The three variants proposed for this target consist of a proxy indicator, a base data indicator and a BIM indicator. The proxy indicator is the fastest form of implementation. In analogy to a tree's annual rings, which can be seen as proxy indicators for the climate conditions during its growth, energy savings achieved by alternative construction designs can provide proxy values. In this context, the focus is on saving energy by using temperature-reduced asphalt, warm and cold asphalt as well as Portland slag cement (CEM II/B-S) and blast-furnace cement (CEM III/A). It is intended to test and document the use of these alternative



A tree's annual rings are proxy indicators for climate developments during its growth period. Wide rings indirectly represent rainy periods, narrow rings periods with low rainfall.

construction designs. This will not directly capture the entirety of energy consumption, but will indicate energy savings as a measure for the industry's development.

The second variant, the base data indicator, uses the data from a standardised road design which is described in more detail in the article on "Evaluating sustainability – lifecycle and potential" on page 74. Focusing on a pre-defined structure and specific construction designs significantly reduces complexity and thus increases the practicability of the considerations. At the same time, it enables a more detailed understanding of how much energy is consumed by the construction designs presented, delivering an initial standard model in road construction. Complementary research projects have already been envisaged to include also other construction designs.

The third variant uses the energy data from a BIM application in road construction. Energy consumption cannot be detected directly within a BIM system, but it is possible to identify the entire consumption of building material for each layer. The consumption of such building material can then be converted into energy consumption using energy-specific parameters from eco databases or methods from the base data indicator. A full documentation of the consumption of building materials constitutes a very good basis for establishing indicators and, at the same time, provides increased transparency in the construction process.

These and other indicators ensure that sustainable efforts can be appropriately documented and tracked now and in the future with the aim of further advancing sustainability in road construction in a targeted manner.

Assessing sustainability – lifecycle and potential

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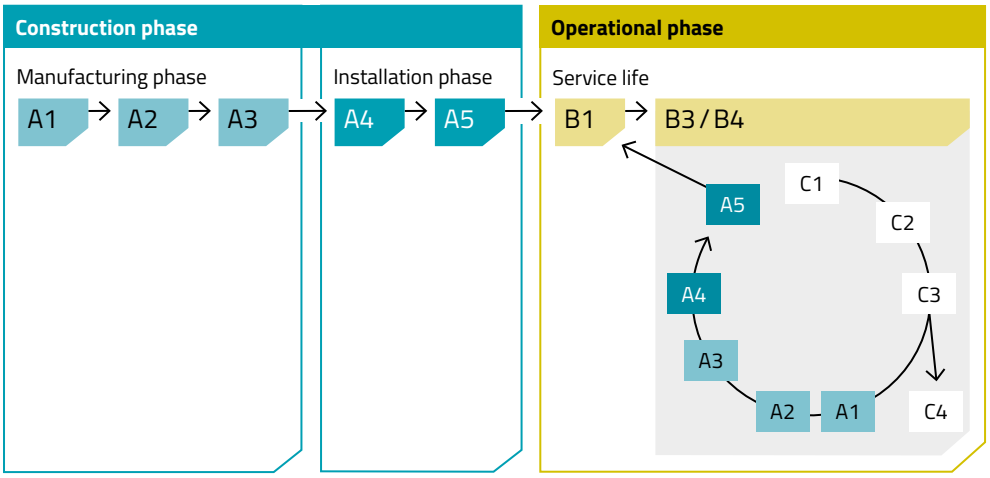
By changing the Federal Climate Change Act, the Federal Government has introduced tighter climate action regulations and set out the goal of greenhouse gas neutrality by 2045. To achieve this together with the goals of the German Sustainability Strategy and the Agenda 2030, the Federal Government is addressing important topics such as climate action, energy and the circular economy. What can road construction contribute here?

Ongoing research projects such as the "Sustainability potential in road construction with a focus on greenhouse gas emissions, energy needs and resource efficiency" project (FE 04.0341/2021/ARB) are essential contributions towards a sustainable design of road infrastructure. On the one hand, the aim is to identify the sustainability potential of using various asphalt methods such as rolled asphalt and mastic asphalt and different concrete methods with washed concrete and grinding surfaces in the lifecycle of a road structure. On the other hand, the focus is on developing pertinent optimisation proposals to lower greenhouse gas emissions and the consumption of energy and resources. The overall goal is to enable a lifecycle-oriented assessment of the ecological quality. The object of research is a 5-kilometre-long motorway section with a standard RQ 31 cross section, load category BK 100, an average daily traffic of 52,000 motor vehicles per 24 hours and a service life of 50 years. The compositions of the individual asphalt layers (AC 32 T, S, AC 16 B S, SMA 11 S, MA 11S) and concrete layers (OB 0/8-millimetre top layer as washed concrete, OB 0/22-millimetre top layer with a grinding surface, UB 0/32-millimetre bottom layer) on which the studies are based, correspond to formulas customary in practice.

To quantify the environmental effects referred to above, it is necessary to have defined process flows and to monitor energy and material flows. A lifecycle assessment of a road structure provides an essential framework for this. In accordance with the DIN EN 15643 standard "Sustainability of construction works – Framework for the assessment of buildings and civil engineering works", the definition of the lifecycle of structures was adapted to the specific concerns of road construction. The lifecycle has a modular set-up and primarily consists of a construction and an operational phase. The construction phase itself, in turn, consists of a manufacturing and an installation phase. The manufacturing phase basically contains the information modules material supply or raw material extraction (A1), for example aggregates in quarries; transport (A2) and the production of the building material itself (A3), for example, in cement mills, concrete and asphalt mixing factories. This is followed by the installation phase which consists of transporting the building material (A4) to the roadworks site and installing the road structure (A5). Until the road is used (B1), the processes of manufacturing and installation are thus of a linear nature. Only when regular maintenance measures become necessary, such as repairs (B3) or renewals (B4), does the linear process turn into a circular process. During partial dismantling (C1), which then becomes necessary, for example, by milling off the wearing course,



A1: Supply of material
A2: Transport
A3: Manufacturing
A4: Transport
A5: Installation

B1: Use of installed products
B3: Maintenance
B4: Renewal

C1: Dismantling
C2: Transport
C3: - Waste treatment
- Recovery
- Recycling
C4: Waste disposal

Lifecycle of a road structure (modified on the basis of DIN EN 15643).

followed by transporting (C2) and processing of waste (C3), some of the materials leave the cycle and are transferred to waste disposal (C4). Building material for recovery, in contrast, is integrated back into the process chain of manufacturing and installation (A1 to A5) of parts of the road structure within its service life.

Moreover, an evaluation of literature concerning individual lifecycle phases identified the highest emission and energy consumptions during the manufacturing phase, primarily during the production of the building materials (A3). Potential to improve the quality can be found, for example, in using drier aggregates, low-clinker cement, excavated asphalt, modified asphalt and temperature-reduced asphalt. Deploying secondary building material, using e-vehicles and innovative construction designs can also contribute to reducing greenhouse gas emission, energy consumption and resources.

With the aim of achieving the goals named above, the analyses of reduction potential for greenhouse gas emissions, energy and resources along the lifecycle will be concluded in a timely manner. This includes setting up process flows and a comprehensive data base, including process and material data, and calculations to verify the recommended optimisation proposals. Data retrieval will include the eco inventory data bases ecoinvent, GaBi and ÖKOBAUDAT. The project will then be concluded by synthesising the research findings, including a lifecycle assessment using the pertinent SimaPro software and by conducting a sensitivity analysis to validate the findings.

It is intended to use the knowledge gained not only for guidance documents to support work steps and decisions in future road construction project tenders focusing on sustainability. This knowledge will also be used as a basis for further research, for instance, the joint German-Austrian-Swiss project “Road construction designs – Lifecycle Assessment for Sustainability (SABINA)”.

Improving the availability of federal motorways – fundamental aspects of road construction

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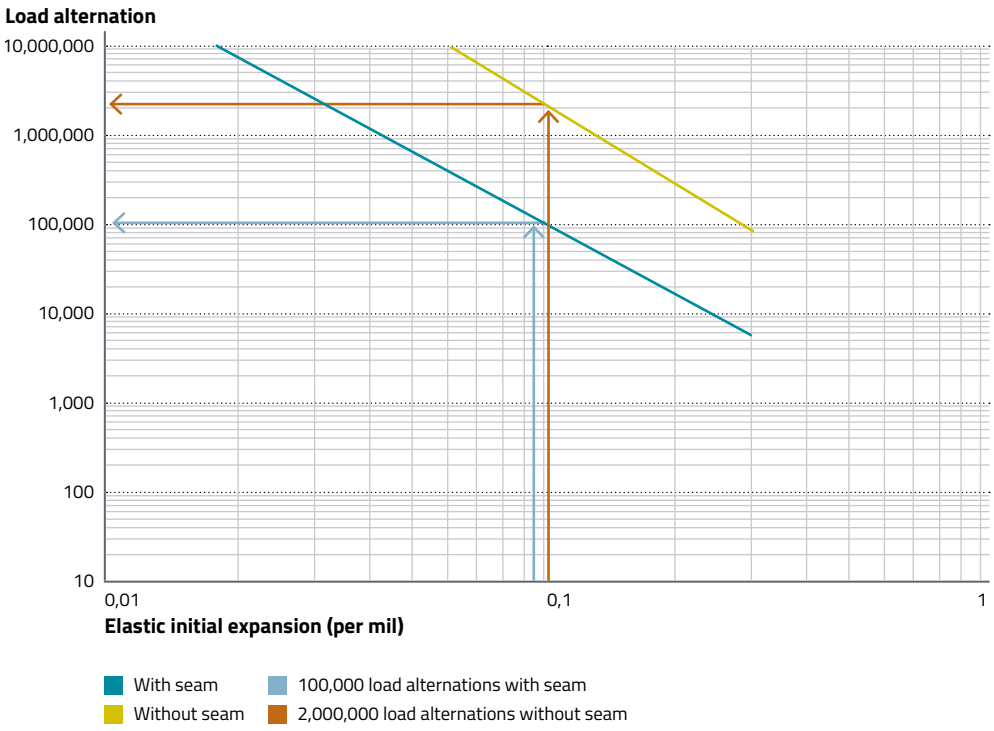
Roads are still the most important transport mode in the Federal Republic of Germany. A major proportion of the annual mileage of motor vehicles takes place in road traffic on federal motorways, although they account for only about 6 per cent of supra-regional roads. A motorway free of congestion is thus at road users' focus. Unfortunately, the situation on the ground shows a different picture. In 2021, roughly 685,000 traffic jams on motorways were registered in the statistics with a total length of about 850,000 kilometres.[1]

The traffic jams were caused not only by the network's frequently high degree of utilisation but also by a great number of roadworks.

Road construction needs to address this issue and reduce the number and duration of roadworks. This is particularly true for maintenance measures on federal trunk roads. To do so, the intervals between maintenance measures need to be extended significantly. Ideally, roadworks could be avoided entirely. To pursue this goal, the "Highway Construction Technology" department has founded the "Availability" issue group which will work on the following priority tasks:

- Shortening construction measures
- Strengthening construction design for a longer service life
- Reducing and optimising the maintenance measures required

1 https://presse.adac.de/meldungen/adac-ev/verkehr/adac-staubilanz-2021-fast-so-viele-staus-wie-vor-corona.html; abgerufen: 29.11.2022



Fatigue functions from dynamic tensile tests on samples from the asphalt's base course with and without seam.

Individual tasks within each priority area that build on internal and external research projects are assigned to all the collaborating sections. Cases in point are:

- Analysis of the construction-related behaviour of mastic and compact asphalts based on data from the structural condition survey and assessment (ZEB)
- Use of continuously reinforced concrete pavements
- Using prefabricated concrete components
- A survey of experts on the feasibility of conducting roadworks at night and at weekends
- Studies concerning the influence of seam formation on asphalt pavements

The last point showed that longitudinal seams in asphalt road construction, resulting from needing to use multiple installation strips, actually significantly weaken the pavement's surface. Fatigue tests revealed that samples taken from the seam area were capable of tolerating only 5 per cent of the load alternations.

Overall, the research work showed that the availability of the network of federal motorways can be increased by targeted measures in road construction.

50 years of the “Guidelines for licensing test centres for building materials and material mixes in road construction” (RAP Stra)

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Contract-based inspections are used to test the suitability of building materials and material mixes with regard to contractual requirements, intended end use, technical regulations and finished products and services. These tests are to ensure that durable and thus sustainable roads are built. On 27 November 1972, the “Guidelines for licensing and monitoring test centres for building materials and material mixes in road construction” (RAP Stra) were introduced by the Federal Transport Ministry.

This constituted the basis to ensure that only licensed test centres would perform these contract-based inspections.

The developments in road construction regulations from Technical Instructions to Additional Technical Terms of Contract as well as from national to European standards were taken into account in RAP Stra’s 5 editions to date. While initially restricted to bituminous and mineral building materials, the current edition of RAP Stra now covers 11 subjects and thus all relevant building materials and testing procedures in road construction.

Licenses are granted by the relevant highest road construction authority. BASt has been involved from the outset to ensure a uniform procedure across Germany.

The basic prerequisites for licensing, qualified test centre management, qualified specialists, economic independence and a minimum equipment with test devices have existed since the first edition.

Licensing procedures pursuant to RAP Stra have become an integral part of the regulatory framework over the past 50 years and enjoy high acceptance by all contract partners. BASt has been participating in drafting, revising and implementing the guidelines for licensing test centres from the start. BASt's scope is to be extended in the future to also include the quality assurance of the tests. The nation-wide round robin tests BASt has been organising since 2018 covering all subject areas are the basis for this. This year, the Federal Trunk Road Authority together with the individual highest road construction authorities will take over the tasks involved in licensing test centres.

Subject areas			Application	Type of test				
				0	1	2	3	4
				Inspection of incoming building material	Suitability testing	Third-party monitoring tests	Verification tests	Referee tests
	A	Soils including soil improvements	ZTV E-StB		A1		A3	A4
	BB	Bitumen for road construction and ready-to-use polymere-modified bitumen	ZTV Asphalt-StB, ZTV BEA-StB				BB3	BB4
	BE	Bitumen emulsions	ZTV Asphalt-StB, ZTV BEA-StB				BE3	BE4
	C	Joint fillers	ZTV Fug-StB	C0[1]	C1	C2	C3	C4
	D	Aggregates	ZTV SoB-StB, ZTV Pflaster-StB, ZTV Beton-StB, ZTV Asphalt-StB, ZTV BEA-StB, ZTV BEB-StB	D0[2]			D3	D4
	E	Concrete pavement, concrete base course	ZTV Beton-StB				E3	E4
	F	Surface treatment, thin asphalt wearing course in cold surfacing, thin asphalt wearing course in hot surfacing on sealed grounds	ZTV BEA-StB			F2	F3	F4
	G	Asphalt	ZTV Asphalt-StB, ZTV BEA-StB				G3	G4
	H	Base course with hydraulic binders, soil sealing	ZTV Beton-StB, ZTV E-StB		H1		H3	H4
	I	Layers without binders and material mixes and soil material for earthworks	ZTV SoB-StB, ZTV E-StB, ZTV Pflaster-StB,		I1	I2	I3	I4
	K	Geosynthetics in earthworks	ZTV E-StB	K0			K3	K4

Combinations that are not possible in the scope of RAP Stra licensing based on applicable regulations

1 Only for joint fillers and grouts complying with DIN EN 14188

2 Only for aggregates and material mixes subject to quality control pursuant to TL G SoB-StB

Combination of test types and subject areas.

Reusing asphalt – can it be even more successful?

Members of the „Granulated asphalt" working group

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Reusing granulated asphalt is not a new topic in German road construction – in fact, granulated asphalt has been recycled for decades. Statistics[1] show, however, that the reuse ratio is slightly declining compared to the figures of about 10 years ago, stagnating at 82 to 84 per cent in recent years.

According to national rules and regulations, the reuse of granulated asphalt is not permitted in individual mixed goods of asphalt wearing courses in general, and only a few federal states have supplementary regulations that permit it, which is owed to a range of experiences. Reusing granulated asphalt is standard in asphalt base and binder layers but has the drawback that high-quality granulated asphalt from the upper layers is sometimes used in the bottom layers and thus not available for the respective cycle.

This critical analysis shows that the asphalt industry has made good headway, but also that it does not make full use of the potential of granulated asphalt, even though it could be a strong lever for the sustainability of this type of construction. The working group on "Granulated asphalt" which was founded within the "Sustainability" issue group of the "Highway Construction Technology" department has committed itself to enabling a complete reuse of granulated asphalt to the greatest possible extent while ensuring or even improving the asphalt's quality. As a first step, it identified where research is still required.

1 https://www.asphalt.de/fileadmin/user_upload/downloads/AsphaltPDez-2021.pdf, 30.11.2021

The asphalt industry is making good headway.

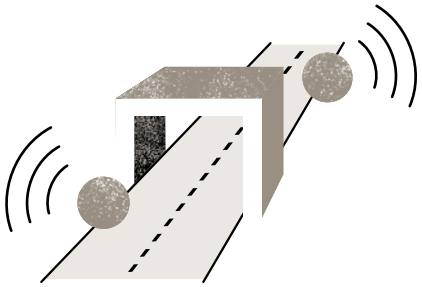
The research subjects are multi-faceted and can be categorised as follows:

- Optimising the production and processing of granulated asphalt
- Improving the input method and increasing the input volume of granulated asphalt during mixing
- Assessing the quality of mixed asphalt products and asphalt layers
- Innovative binder tests to assess the asphalt's cold-weather and cracking sensitivities

The projects that will be conducted internally and externally over the next few years will focus on topics such as the possible separation of mortar and rock, targeted individual processing of mortar while taking its chemical and mineralogical "fingerprint" into account and adapting the production of granulated asphalt.

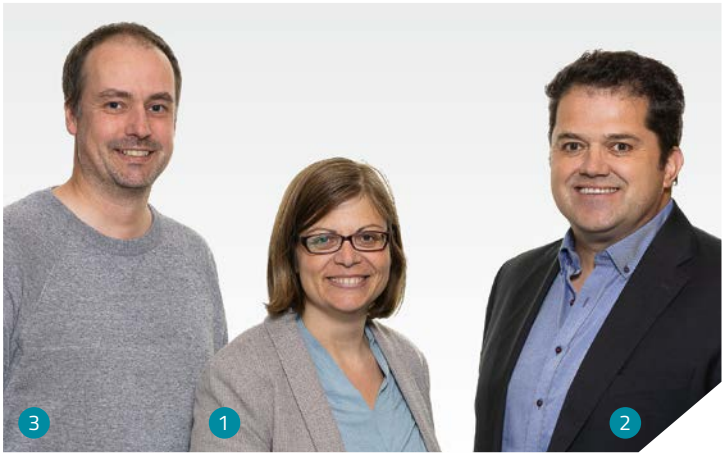
The physical infrastructure in the network of federal trunk roads is exhibiting structural shortcomings due to increased traffic loads, the advanced age of structures, a backlog in maintenance measures and faulty construction. Already today, this sometimes leads to impaired functionality and thus restricted availability of roads. To efficiently address the challenges, it is important to have an agile infrastructure management in place that makes it possible to notice changes at an early stage and thus react adequately, in terms of predictive lifecycle management. In this context, a structural condition survey and assessment in conjunction with forecasting tools and innovative civil engineering solutions paves the way to systematically plan optimised measures in the lifecycle of the structures at the object and network levels. Changes in the lifecycle of road infrastructure can thereby be actively integrated into decision-making processes. The innovative components of an agile infrastructure management can help reduce unplanned disruptions or closures, thus achieving a better availability of the road infrastructure. Modernisation and compensatory measures are becoming easier to plan.

6. Predictive infrastructure management



Negative effects can be reduced. Using predictive approaches and optimised (civil) engineering solutions can also improve the road infrastructure's resilience, making a significant contribution to a sustainable road infrastructure. The Federal Highway Research Institute (BASt) has for many years been very active in researching aspects of structural diagnostics/ structural condition surveys and assessments and management systems. Furthermore, BASt researchers are long-standing members of the relevant bodies and committees. This has led to an accumulation of expertise, and in this way BASt can become an enabler for the innovative solutions and components of agile infrastructure management, including from the perspective of the owners and the authorities responsible for the construction and maintenance of federal trunk roads.

Computer-aided tool kit for evaluating the resilience of engineering structures and prioritising measures



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Introduction

The flooding incidents in July 2021 caused substantial damages to motorways and railroads, particularly in Rhineland-Palatinate and North-Rhine Westphalia. Once again, it became clear that it is necessary to adapt existing transport infrastructures and render them more resilient to ensure their availability.

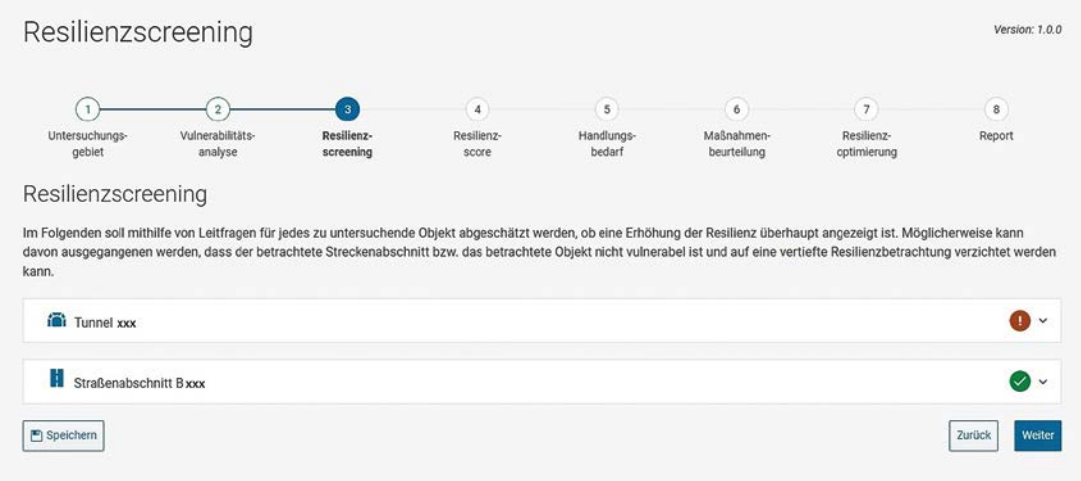
BASt has been dealing with these topics for many years, specifically focusing on the resilience of transport infrastructure and its capability to cope with damages after disruptive incidents, and thus be able to quickly return back to service.

In the scope of a research project funded by the Federal Ministry for Digital and Transport's (BMDV)[1] Network of Experts and overseen by BASt, a computer-aided tool kit was developed with which to evaluate the resilience of engineering structures and prioritise measure.

From theory to practice

A purpose-built IT prototype was deployed here, characterised by both intuitive usability and easy web-based user access. This new IT tool for roads not only constitutes an important milestone for the integration of resilience evaluation as an integral part of transport infrastructure management, but also lays the foundation to transfer theoretical concepts from the field of research to practical application.

1 The BMDV Network of Experts was founded in 2016 as a research format across all modes of transport in government-commissioned research under the motto „Knowledge-Ability-Action". Visit the website of the BMDV Network of Experts www.bmvi-expertennetzwerk.de for further information.



Surface graphics of the IT prototype to assess the resilience of transport infrastructure.

In this way, decisions in infrastructure management to maintain roads' functionality can be better prepared in the future, and measures and investment measures can be selected and justified more easily.

The IT prototype comprises the following steps (see figure):

- 1. Vulnerability check
- 2. Resilience screening
- 3. Selecting measures
- 4. Optimising resilience

Outlook

The findings and methods gained can be utilised beyond their application in road traffic to include other transport modes, and contribute to the BMDV Network of Experts' overarching goal of "making transport systems resilient and environmentally compatible".

Further steps to transfer the methodology of resilience assessment and the IT tool to the transport modes railroads and waterways will take place over the coming years until 2025.

Reinforcing steel bridges

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Older steel bridges can show visible damages. A considerable increase in traffic and deficits, such as construction details vulnerable to fatigue due to how they were planned and designed, are responsible for these damages. Provided they are not already at an overly advanced stage, they can be repaired by reinforcing the bridges. In this article, we are focusing on damage category 1 that affects the connections on the sheet cover [1; 2].

Reinforcement measures are structural measures associated with improving load bearing capacity and durability. The sheet cover in steel bridges is reinforced to reduce local tension and deflection. Various reinforcement measures can be used for which the customary requirements for bridge surfacing (imperviousness, skid resistance, gradient compensation and durability) apply, regardless of the type of the measure. [2; 3]

High-strength concrete

In reinforcement measures using high-strength concrete, the old bridge surfacing will be replaced by a reinforced high-strength steel fibre concrete. The method is originally from the Netherlands, and not only deploys high-strength fibre concrete, but it also does away with dowelling connecting joints. A bridge pavement with high-strength concrete leads to reducing wheel loads, absorbing the dynamic load, improved connection with the steel sheet and increased imperviousness and durability. The load distribution resulting from the composite concrete reduces tensions in both the welds and the deflection, thus reducing fatigue-related damages. With its dense structure, high-strength concrete is instrumental in protecting the reinforcement and steel construction against corrosion and expanding bridges' service life, while complying with load-bearing requirements and road safety.

Experience has shown that high-strength concrete can be manufactured and installed at a consistent quality regarding the fresh and hardened concrete properties. However, stringent quality assurance measures in concrete technology are required for this. Because of their pilot characteristics, the construction measures at the steel bridges Beimerstetten (near Ulm), Maxau (near Karlsruhe) and Günthersdorf (near Leuna) were intensively studied as regards these aspects [4, 5].

BASt was involved in all these measures, including by giving its expert opinion in individual cases for the purpose of seeking approvals, by providing technical support, and by developing the requirements for planning guidance documents in workshops. All 3 bridges showed proof that the intended reinforcement effect was achieved.

Bonded sheets

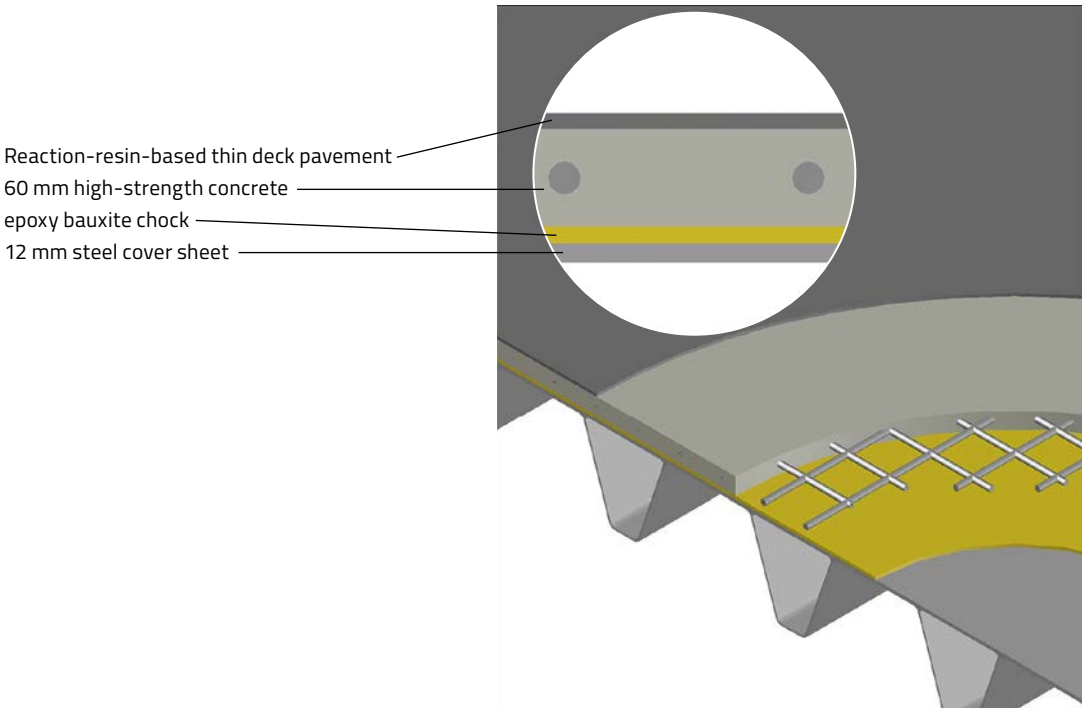
In this measure, additional steel sheets are placed between the sheet metal cover and the road pavement. These reinforcement sheets are bonded to the sheet cover in a force-fitting manner, creating a better tension and force distribution. This solution was analysed both numerically and in a laboratory in the scope of 4 related BASt projects:

Using the example of the orthotropic slab of the Duisburg-Neuenkamp bridge over the Rhine River, the "Numerical studies" project has shown in a numerical model that the reinforcement of the metal sheet cover is an expedient measure to effectively reduce both the tensions in the slab and local deflections of the sheet cover.

The "Bonding technology" project describes the development of a practicable bonding method that takes the specific framework conditions into account that arise when maintaining orthotropic pavement slabs.

The "Fatigue strength studies" project focuses on a complex testing programme using practice-oriented endurance-swelling-bending tests. This project provided proof, inter alia, that the bonding systems can sustainably withstand the dynamic loads of typical traffic conditions.

The "Joints and pavement edge formation" project developed and tested the suitability of concepts of sequencing joints and designing edge enclosure. In analogy to the "Fatigue strength studies" project, tests were used to verify sufficient fatigue stability.



Reinforcement using high-strength concrete with steel fibres.

The laboratory tests as part of the "Reinforcing the sheet cover of steel bridges by gluing on steel sheets" were successfully completed in the autumn of 2022. The findings are an essential basis for initial pilot applications in practice.

The different methods to reinforce steel bridges offer good possibilities to increase a bridge's service life and thus to comply with the requirements of an available and functioning infrastructure.

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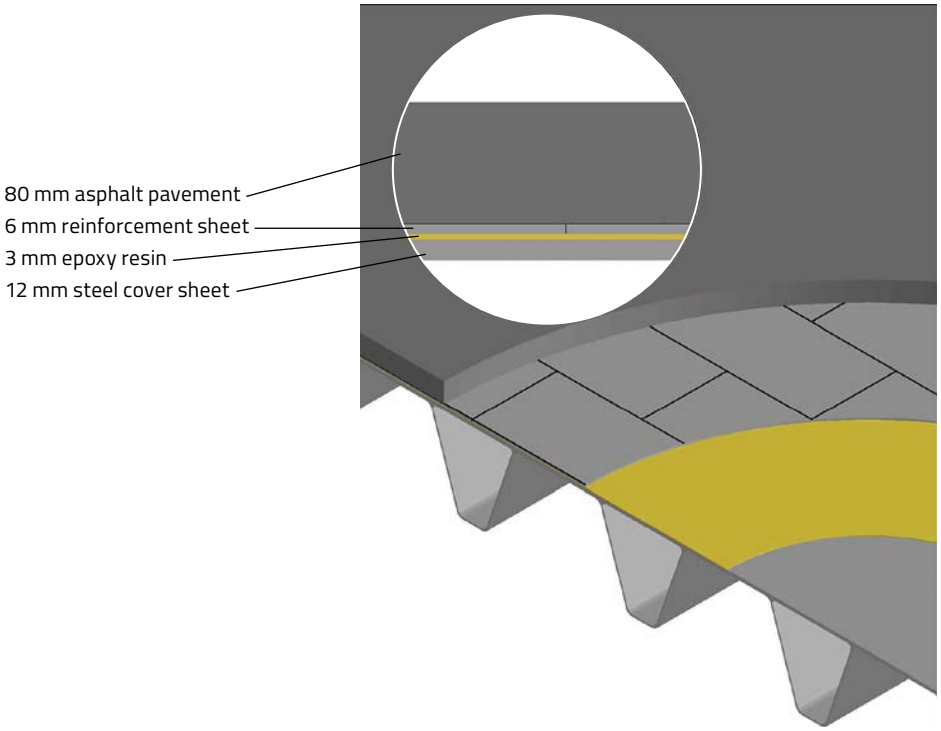
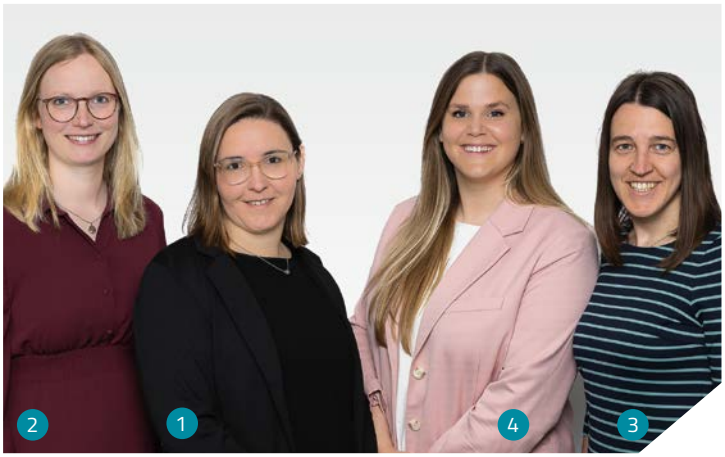


Reinforcement using bonded sheets.

Digital twin for bridges – concept, use cases and precursor using the example of the duraBASt bridge



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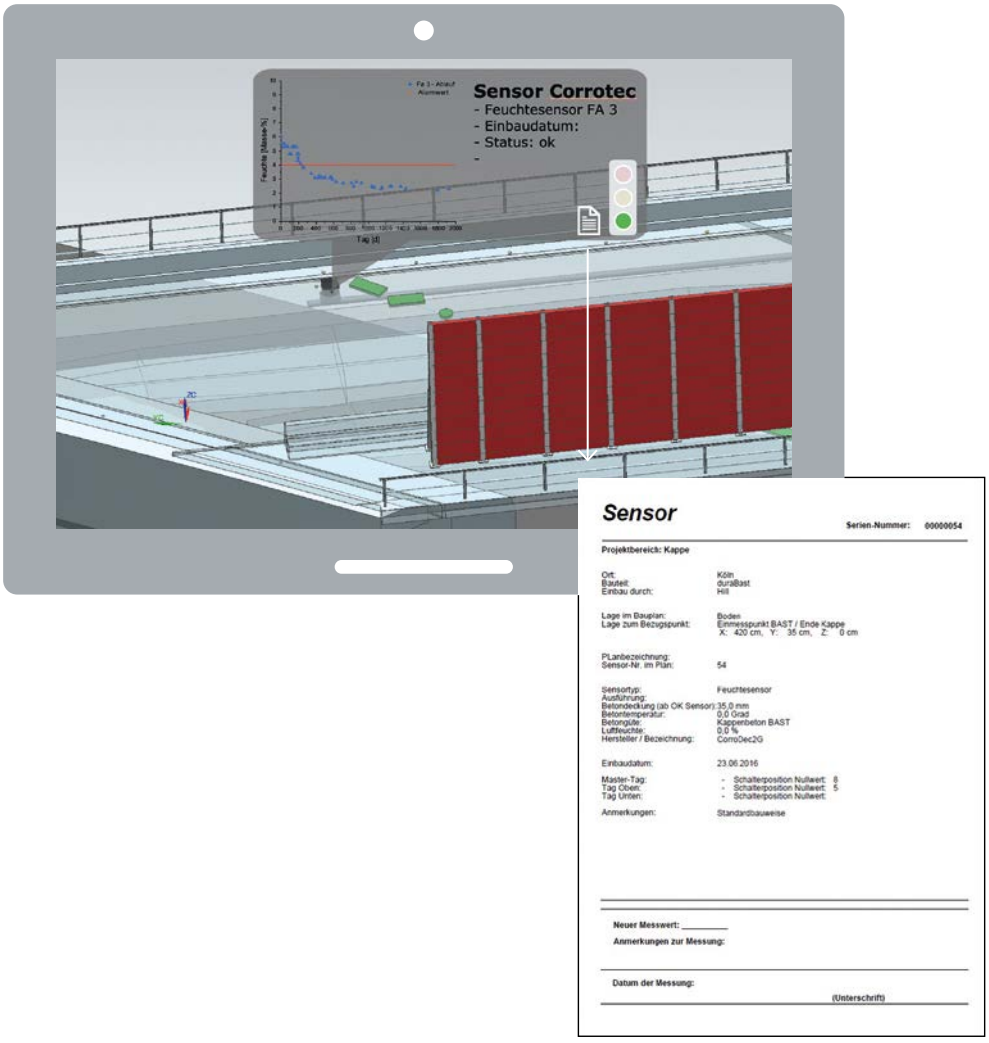
Predictive lifecycle management offers the potential to better confront the manifold challenges in the network of federal trunk roads such as ageing engineering structures, increased traffic volumes and the backlog in maintenance. The topic of digital twins plays an important role in the context of this type of lifecycle management.

Digital twins are virtual depictions of real objects regularly updated using data and information. In their highest developmental stage, they are in bidirectional exchange with the real object, i. e., signals are transmitted in both directions. During the operational phase, they support the decision-making of the operators of the structure, by, for instance, structural condition analysis and predictions, and can also be used for conducting virtual experiments.

In the scope of a BASt research project, a modular concept of a bridge digital twin is being developed, and individual developmental steps are being discussed with future users. Use cases which are either based on the digital twin's defined purpose and on existing business processes and applicable regulations are at the core of the concept. A distinction is made between mandatory and non-mandatory use cases. Mandatory use cases create the data base needed for the digital twin to function, while non-mandatory use cases provide additional services. Where applicable, one can be integrated into the other.



Operating model with sensor information from a humidity sensor at the digital shadow of the duraBASt bridge.

It is intended to then exchange and incorporate additional use cases through clearly defined interfaces. In a workshop with future users, potential use cases in the fields of operational processes, planning and performing maintenance measures and a strategic lifecycle management system were discussed.

With the aim of gaining an overarching understanding of the processes and their input and output data, the participants prepared profiles for each of the 4 high-priority use cases as a basis for the modular concept. The use case profiles were created on the basis of the sample profile developed by BIM Germany for federal trunk roads.

In a subsequent step, the concept of the bridge digital twin will be supplemented by additional technologies, their level of detail will be described and finally presented to future users. BASt is conducting parallel projects in which precursors and partial aspects are demonstrated in prototypes to pave the way for the developments to be used in practice.

Precursor using the example of the duraBASt bridge

A digital twin can exist at various levels of development. At the highest level, it is characterised by an automated data flow between the digital and the real object. The digital shadow is classified as a precursor. This means there is a manual data flow from the digital to the real object.

The bridge on the duraBASt premises serves as a digital shadow in studying different questions arising from creating a digital twin. The aim is to transmit and make available all the information concerning the bridge in the form of an operating model to be used in offices or on the bridge itself. With the help of a mobile application, it will become easy to add new information such as photos or damage details while on site.

Much work has already been done at the duraBASt bridge which can be used as a basis, for instance, to create a bridge digital twin at a later point in time. As a result of previous work, various models and measured values are available from monitoring activities and from non-destructive testing. On this basis, parametric, semantically-enriched, three-dimensional BIM models of the duraBASt are combined with information about the bridge that is already available. Thereafter, the aggregated data will be used to establish an operating model.

In order to localise existing and future measurement data within the operating model, a sensor model of the already installed sensors was created, enabling a direct combination with the data measured. The digital shadow of the duraBASt bridge thus constitutes a data base for analysing potential use cases in the scope of BIM-aided operation and maintenance. Using a corresponding software, a pilot project is testing the implementation of the "structural inspection" use case as a process. This aims to provide a clear, complete and digitally connected overview of relevant information and steps to those responsible for inspections.

Artificial intelligence and augmented reality in bridge inspections

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Bridges are an integral component of a high-performance transport infrastructure. Structural inspections pursuant to DIN 1076 provide the basis to ensure their safety, reliability and availability. Though digital technologies offer enormous potential for use in inspecting engineering structures, they are thus far being deployed only to a very limited extent. An exchange with specialists made it possible to identify possibilities for overcoming specific challenges. These include up-to-date and complete documentation of existing structures as well as the provision of such documentation, the localisation of damages, data exchange and the objectivity of information.

A research project commissioned by BASt showed in its conclusion that particularly the augmented reality (AR) technology offers possibilities to provide important information during arms-length bridge inspections clearly, to collect additional data and to keep the data up to date (Hill et al. 2022). Using artificial intelligence (AI) can provide further support by identifying potential damages, preselecting them, visually marking them and adding information about them in a smart application.

As part of the work in the Federal Ministry for Digital and Transport's Network of Experts, an external research project is under way which analyses combining augmented reality and artificial intelligence and its application in the context of bridge inspections (König et al. 2022). The developed concept envisages that visible damages on the bridge are automatically captured and evaluated in an interaction with the inspectors.

Demonstrator used in a test on a bridge.

AR goggles recording damage images on the bridge will be deployed to this end (see illustration). A trained AI network architecture is used to identify and colour-code damages on the basis of the recorded images.

Besides exemplary types of damages, the magnitudes of the damage can also be identified using depth information from the camera. AI provides the results in an augmented reality to the inspectors in the form of virtual superimposition to support their decision-making. In the scope of the project, the concept was tested in a prototype, and the demonstrator established was tested in a real-life environment. Initial reactions indicate that such a digital system particularly requires an improved tracing of damages, structured documentation and presentation of extensive data, objectivity of information and more efficient workflows.

The feedback from specialist staff should be used to derive recommendations and draw conclusions for a potential application in practice.

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Integrated and reliable assessment of the weighted longitudinal profile (WLP)

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The evenness of a road is a decisive criterion in road safety and road users' driving convenience. Uneven road sections are, in addition, subject to increased wear caused by the vehicles' higher dynamic axle load. There are already various key indicators in place to assess the evenness of a road, but they are limited in their detection capabilities, i. e., determining particularly disruptive periodic unevenness. Moreover, they provide only relatively low precision in localising the damages.

To eliminate this shortcoming, an advanced parameter can be found in the "weighted longitudinal profile (WLP)" value. This evenness parameter can help classify, weight and evaluate all the different kinds of unevenness occurring in practice. This new parameter is necessary, because time and again deficits in driving convenience occur in isolated cases, even though measurements have not indicated any problems.

In order to establish WLP as a new measure for longitudinal evenness, the system of surveying the road surface profile is to be further developed by means of fast-travelling measurement systems using laser sensors in the right wheel path. For instance, the spacing of measurement points which to date is 10 centimetres needs to be reduced to one centimetre. Only by doing this can transitions to bridges, joints or installations and their connections to the ambient traffic area be safely evaluated.

Testing the laser sensor system on the duraBASt premises.

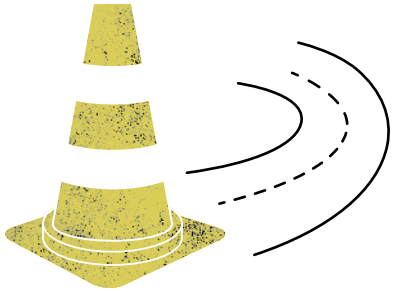
By adapting the WLP evenness indicator to what is then higher measurement precision, it would be possible to detect imperfections with significantly higher accuracy and to assess a road's evenness in a holistic manner, i. e., in both the short-wave and long-wave ranges, including periodic unevenness.

As BASt is also responsible for the quality assurance of measuring systems, it has expanded its possibilities to test laser sensors. For this purpose, BASt installed metal plates consisting of hardened steel into the duraBASt surface and milled different test specimens into it. With the help of these, laser sensors with a higher definition can also be tested using fast-travelling measuring systems in order to be able to provide an even more reliable assessment of roads' longitudinal evenness.

A central goal of transport policy in Germany is to enable everyone to safely participate in road traffic, be it on foot, by bicycle, motorcycle, truck or passenger car. The Federal Highway Research Institute (BASt) is conducting research with the purpose of reducing the number of road accidents in Germany, or at least reducing their consequences. BASt research in this area is guided by the Federal Government's Road Safety Programme 2021 to 2030 (VSP).

In 2021, Germany registered the lowest rate of road traffic deaths since statistical records began more than 60 years ago. Not only the Covid-19 pandemic is closely associated with this positive development, but also BASt's road safety research. Changing mobility needs, societal changes – such as those due to the demographic shift – and new technologies and forms of mobility are posing growing, ever-changing challenges. Proactive road safety work is the key to safer road traffic. This includes identifying risks and developing strategies to address them at an early stage.

7. Proactive road safety



With the aim of getting one step closer to "Vision Zero" (zero deaths and as few injuries as possible in road traffic), proactive road safety was developed by BMDV and BASt. BASt's activities in road safety research are an important component. They respond to such long-term transformation processes as the demographic shift, advancing automation and increasing digitalisation. The rise of active forms of mobility (cycling, walking) and new ones (electric bicycles, e-scooters), automated driving and the connectivity of vehicles and infrastructure will influence road traffic in the future and are taken into account here. Digitalisation offers new possibilities and opportunities for preventive measures and mobility education that should be exploited. The design and equipment of roads, as well as automotive engineering, must meet the new requirements. BASt is conducting interdisciplinary research to this end. The aim is to contribute to continuing the successful road safety work in Germany and to explore new safety potential.

Safety assessments for road tunnels – current challenges

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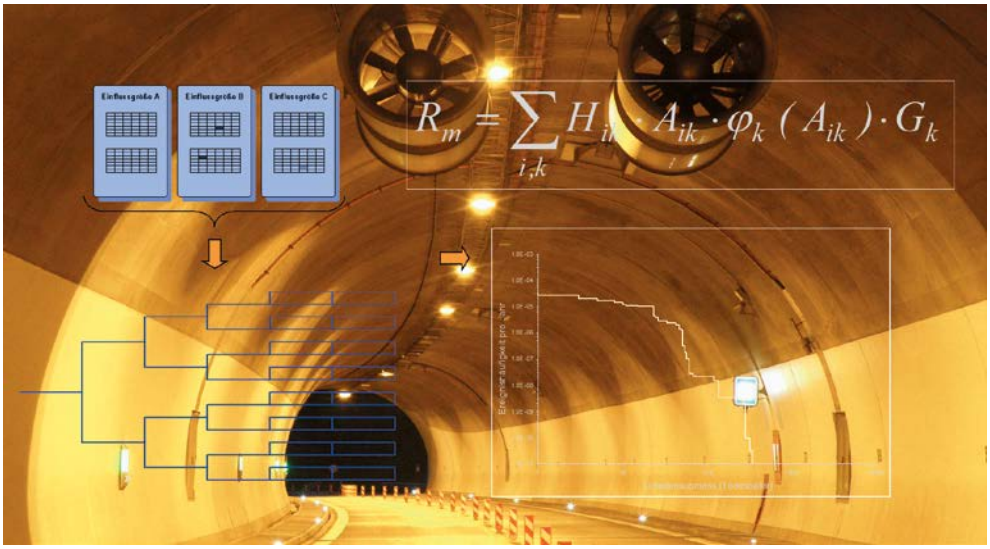
A road tunnel's safety level is defined on the basis of regulatory requirements and specifications. An evaluation is performed by comparing the existing with the required equipment (e. g., in the ventilation system). However, not every tunnel can be built and equipped in strict accordance with regulations, which is the reason why justifiable deviations are permitted. These include:

- deviations in existing tunnels for which adaptations to the regulations are either not possible or only at disproportionate effort and expense.
- special conditions that arise from a combination of several safety-relevant factors such as inclination, traffic intensity or tunnel entry and exit, which, each on their own, would not cause a problem.
- deviations as a result of technical innovations.

To make these influences on a tunnel's safety level measurable, the specification-based comparison was supplemented with a risk-based comparison. This consists of a methodology to determine and assess a tunnel's safety and to plan measures. The residual risk resulting from linking the likelihood of a certain incident (e. g., an accident) with the respective extent of damage expected is used as a measure for safety. The safety is then assessed by a relative comparison of the risks of a tunnel structure equipped in compliance with regulations with the tunnel in question that has been planned or needs to be retrofitted. The risk-based methodology has been deployed for many tunnels since 2009.

It is BASt's task to assess when scientific or empirical findings are available or are required to initiate an adaptation of the methodology.



Regulatory requirements and specifications define the safety level of road tunnels.

Such an adaptation has proved to be necessary on the basis of findings from a multi-annual application – for example, due to modified or newly added structural, transport- or safety-related parameters: details can be found in the BASt report "Assessing the safety of road tunnels – reviewing assumptions and parameters for risk-analyses" (B183). There are, however, still challenges in identifying risks of future influencing factors and developments.

These include the impact of technical innovations and rapidly advancing digitalisation, as well as the development of new drive technologies (e. g., electrical vehicles) or the data exchange between vehicles and tunnel infrastructure. Therefore, BASt continues reviewing the methodology and its input parameters as to how up-to-date they are, adapting them if necessary. This includes a timely implementation of the individual research findings into the relevant regulations.

Guidelines for road markings

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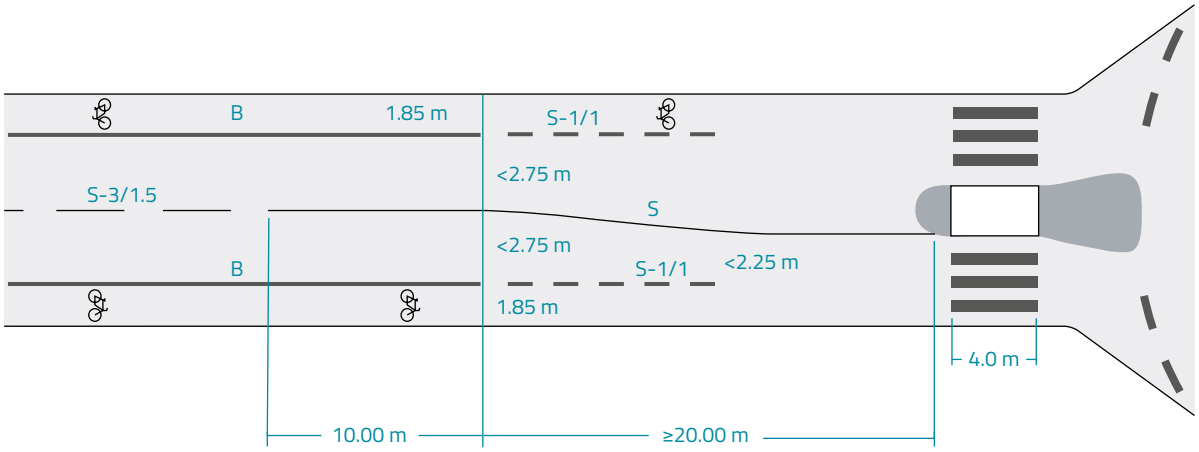
The "Guidelines for road markings" (RMS) were published for motorways in 2019. For city and rural roads, however, the RMS introduced in 1980 still apply, though, however, they no longer correspond to today's conditions and requirements in essential aspects. This is why they were also thoroughly revised in the competent body of the Road and Transport Research Association (FGSV), with substantial participation by BASt.

Numerous road traffic-related developments and amendments to the German Road Traffic Regulations (StVO) and the Administrative Regulations of the German Road Traffic Regulations (VwV-StVO) referring to the RMS were the basis for the revision. The RMS, as an attachment to the VwV-StVO, thus constitute a "link" between technical design regulations and road traffic-related requirements. This necessitated an alignment of the terminology to the StVO and to the VwV-StVO as applicable. Moreover, the draft was intensively discussed under BASt chairmanship with the Federal Government-Länder "StVO" expert committee (BLFA-StVO) and the FGSV body responsible.

The RMS's structure was also revised by adapting it to the structure of FGSV's technical design regulation, which had been fundamentally revised since 1980, to include the integrated guidelines for the road types mentioned above. As a result, there are now individual sections specifically tailored to the requirements of each of these road types.



Marking of the entry and exit into roundabouts with a cycle lane.

The RMS deal with road markings that are planned in accordance with the Guidelines on designing motorways (RAA), rural roads (RAL) and city roads (RASt). The RMS implement the road traffic-related requirements as a basis to achieve uniform road markings. Standard plans that were developed with BASt participation provide ample information for practical use by using typical solutions as examples, enabling compliance with the StVO and VwV-StVO even in special cases. The differences to the solely technical geometric design regulations that arise specifically from road-traffic aspects are described for practical use using a multitude of examples and standard plans.

Furthermore, new technical developments such as markings for dotted advisory cycle lanes, cycle-only lanes and markings for roundabout traffic were incorporated into the RMS as part of the revisions.

The illustration shows an example of markings of the entry and exit into roundabouts with a cycle lane.

It is intended to finalise the RMS for city and rural roads in the course of 2023 and to publish them pursuant to VwV-StVO provisions in consultation with the highest authorities in the individual federal states.

The new EU Directive on road infrastructure safety management

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The European Union intended to use EU Directive 2008/96/EC on road infrastructure safety management to advance toward its transport policy goals of significantly reducing the number of traffic accident victims and to mitigate the severity of the consequences of accidents. 10 years after it entered into force, the European Commission commissioned a review of the previous requirements.

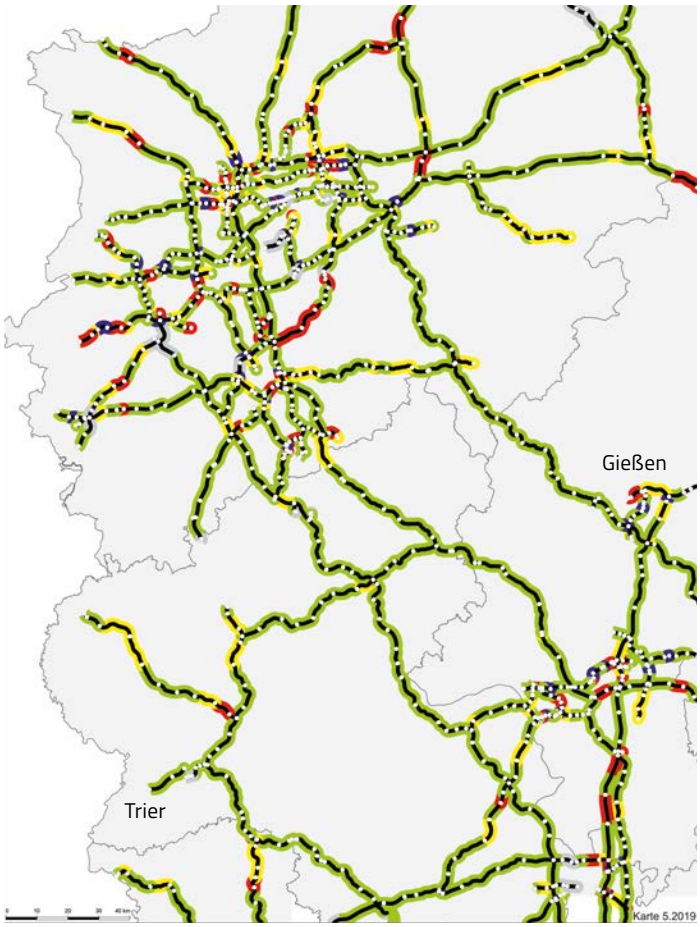
This resulted in a proposal to revise the directive dating from 2008. The proposal was initially negotiated in the scope of an EU legislative process, before final publication as Directive (EU) 2019/1936 on 26 November 2019.

The Member States were then given 2 years' time to transpose the new EU provisions into national law. For Germany, this was done based on the General Circular Road Construction (ARS) No. 25/2021. BASt supported the Federal Ministry for Digital and Transport (BMDV) in the negotiations concerning the amendment of EU Directive 2008/96/EC at the outset and subsequently provided support in developing the basis for its transposition into national law.

With regard to

- Road Safety Impact Assessment (RSIA) – Article 3,
- Road Safety Audit (RSA) – Article 4 and
- Road Safety Inspection (RSI) – Article 6

there were hardly any or only few changes.



Federal motorway sections with safety potential pursuant to procedure in the Recommendations for a Safety Analysis of Road Networks (see also https//www.bast.de/DE/Verkehrstechnik/Fachthemen/v1-sicherheitsanalyse.html).

Relevant changes affect, in particular,

- expanding the previous scope to go beyond the Trans-European road network (Article 1),
- demanding joint safety inspections of the tunnel's access areas by tunnel and road safety experts (Article 6 (3)) and
- conducting targeted or incident-related safety inspections (Art. 6A) as a follow-up to an upstream network-wide safety analysis (Article 5)

Former Article 5 "Safety ranking and management of the road network in operation (NSM – Network Safety Management)" was subject to the largest change in method during the amendment of the directive. Safety rankings used to be based on the Recommendations for the Safety Analysis of Road Networks. The process in place until now is a purely reactive one, based on analysing the accident situation in the road network in question. Since 2004, BASt has regularly calculated the safety potential of the network of federal motorways pursuant

to the Recommendations for the Safety Analysis of Road Networks.

As a consequence of the amended EU directive, the formerly reactive approach needs to be supplemented by more preventive aspects, namely visually assessing roads' design characteristics. In the scope of a research project commissioned by BASt, the foundation for conducting a network-wide safety assessment and ranking as required by EU Directive 2019/1936 was prepared for federal trunk roads. The idea of "layering" is at the core of this new process. In layering, a number of reactive (accident analysis) and proactive (infrastructure characteristics) individual assessments are layered in a transparent manner. On the basis of today's knowledge and bearing in mind considerations of data availability, it is intended to take the following characteristics into account when conducting a proactive safety assessment for federal trunk roads:

- elements of horizontal routing.
- unprotected obstacles on the side of the road (mainly trees),
- elements of the road's cross-section
- pavement condition (skid resistance)
- low-drainage zones and
- areas separated from motor vehicle traffic for pedestrian and cycle traffic in longitudinal direction.

The data processing necessary is decisive for conducting safety assessments. This applies, in particular, to relevant infrastructure features that need to be taken into account in the scope of a proactive safety assessment. In some cases, the data needed is available at a sufficient quality. In others, however, it does not have the quality necessary for a proactive, network-wide safety assessment. Other data still needs to be collected or merged from databases that exist in the federal states. Creating the required data foundation, merging the data into a joint network base (ASB) and processing it for an integration into the Federal Highway Information System (BISStra) is a task to be fulfilled by BASt in cooperation with the federal states and the Autobahn GmbH, before a first network-wide safety assessment for federal trunk roads will be conducted in 2024.

The completed research project also provides the basis for updating the Recommendations for a Safety Analysis of Road Networks (ESN) by the relevant body at the Road and Transportation Research Association.

Passive safety of support structures

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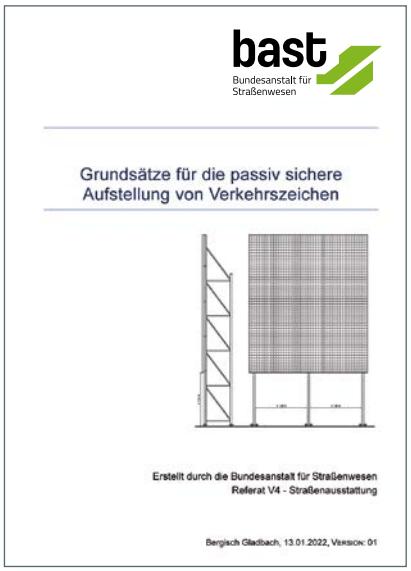
It is an interesting peculiarity of the German language that the word "umfahren" has two totally different meanings depending on which syllable is stressed. It can mean either to travel around something or to knock over something. Passive safety in highway equipment falls under the second meaning of the word. Thus, it is of significance when a vehicle hits an obstacle next to the road. Time and again, such run-off accidents including collision with an obstacle lead to severe injuries or death of vehicle occupants.

One possibility to reduce the consequences of accidents in these situations is the use of objects that can be knocked over, or generally speaking, passively safe objects. These objects are not obstacles for vehicles swerving off the lane as they can be sheared off or "flattened".

If a new object is to be installed next to a driving lane, it makes sense from a road safety perspective, to deploy a passive safe design. With the aim of creating options for the highway authorities of the federal states and the Autobahn GmbH, a BASt research project reviewed the passive safety of the most common support structures for traffic signs in Germany.



Run-off accidents including collision with an obstacle often lead to severe injuries.

The structures were tested using impact tests and numerical simulations, and their properties were evaluated. In some cases, the constructions were modified to increase their passive safety.

The findings of the research projects were then bundled last year, and after coordinating with representatives of the industry and the federal states and the Autobahn GmbH, were merged into a new document as “Principles for a passively safe installation of traffic signs”.

Beside general information on passive safety, the principles also contain construction drawings for traffic sign support structures that are verifiably passively safe. Support structures that are in line with these construction drawings are not considered obstacles and can be used adjacent to a driving lane without further safeguards. The Federal Ministry for Digital and Transport introduced these principles in its General Circular Road Construction 02/2022.

Safe installation of traffic signs on vehicle restraint systems

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Traffic signs are often installed on top of vehicle restraint systems (VRS) that are made of steel and concrete using various ways to fasten them, although setting them up behind the VRS, if there is one, should always be the preferred option. The Guidelines for passive protection on roads by means of vehicle restraint systems (RPS 2009) state that these attachments may not adversely affect the function of the VRS. In addition, they may not constitute a danger to vehicle occupants or third parties. When looking at roads, various other auxiliary equipment can be found near traffic signs mounted on VRS, such as attached delineators, curve warning signs, climbing aids, marking and snow indicator signs, anti-glaring installations and attached parapets.

With BASt as the lead agency, a working group developed a guidance document with instructions to be considered when attaching additional installations onto VRS to ensure that safe types of fastening and mounting can be used for all kinds of auxiliary equipment. This working group consisted of representatives of the federal states, manufacturers of vehicle restraint systems and manufacturers of auxiliary equipment. Besides general instructions, such as how individual auxiliary equipment can be attached, and besides the basic principle that auxiliary equipment should not have any sharp edges or aggressively shaped parts on the side facing the road (including the head area of VRS), specific instructions are provided for the different types of equipment. The requirements are also differentiated by the type of auxiliary equipment: permanently or temporarily attached to permanent VRS installations.

Permanent attachments at vehicle restraint systems

Attached parapets, anti-glare installations and attached delineators are some of the auxiliary equipment elements that are exclusively attached to vehicle restraint systems on a permanent basis. They need

Safely (?) mounted traffic sign on a vehicle restraint system.

to be tested together with the VRS in accordance with the European standard DIN EN 1317. Attached delineators do not require an impact test, in contrast, provided that the combination of the delineator and the attachment post and material weighs less than 2 kilograms. Moreover, at motorcycling sections, only self-righting attached delineators can be installed to render these sections safer.

Temporary attachments at vehicle restraint systems

No impact tests pursuant to DIN EN 1317 are necessary when attaching traffic signs to vehicle restraint systems, as these are mounted on vehicle restraint systems exclusively in the run-up to or within roadworks sites.

There are, however, requirements as to the location and type of attachment. Moreover, a proof of structural stability (wind load test) is required.

Outlook

The instructions are intended as guidance for authorities' tendering processes to select auxiliary equipment. They also constitute a basis for new developments in auxiliary equipment and their attachments to enable mounting innovative and safe constructions on different vehicle restraint systems in the future based on nationally uniform requirements.

Safety assessment of the active systems of passive vehicle safety as part of the type approval process

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An informal working group at the United Nations is developing testing and assessment procedures for active systems of passive vehicle safety in the scope of European whole vehicle type approval with significant participation of BASt. These systems can mitigate potential head injuries in pedestrians upon impact in car-pedestrian collisions. In a first step, the focus was on systems with contact-based sensors for pedestrian recognition and raisable bonnets which generate an additional deformation path to reduce the kinetic energy of head collisions.

A number of preconditions have to be fulfilled before component tests are performed in testing laboratories to ensure the systems' functionality in real-life accident situations. Tests at low speeds, at which the system would not deploy yet, first need to demonstrate compliance with minimum requirements for passive safety. Moreover, the active system's speed window must reliably detect pedestrians in the case of a collision. Tests using a pedestrian surrogate for the lower extremities are conducted within a precisely defined detection range. To establish the activation condition of the system during type approval tests, the pedestrian's head impact times (time from initial contact with the vehicle's front to head impact on the vehicle's surface) need to be compared to the system's overall response time (time from initial contact to the system's full positioning). In an initial phase, the head impact time is determined by numerical simulations using qualified human models and a model that corresponds to the vehicle to be type-approved. Depending on the degree of compliance, the approval tests are performed on a statically raised system or dynamically on a self-raising system. In dynamic tests, the launcher is synchronised with the activated raising system for each

Testing the sensors of an active systems in an impact test against a pedestrian surrogate.

impact area on the vehicle's front. This is accomplished by a linear interpolation of the simulation results (head impact time as a function of the wrap-around distance) of human models of various sizes. Besides a quantitative estimate of the system's effectiveness in real accident situations, car manufacturers also need to ensure that the deformation path generated under the raised bonnet is not significantly reduced by the mass of the human torso before the actual head impact. Furthermore, the system should also provide protection at higher speeds than the speed tested (40 kilometres per hour vehicle speed as an equivalent of a head impact speed of 35 kilometres per hour), which is comparable to the protection by a purely passive system.

The testing and evaluation procedure that was developed addresses both the requirements of vehicle type approval and of self-certification. It fulfils the requirements of the parties to the 1958 Agreement (United Nations regulations) and those of the Parallel Agreement dated 1998 (UN Global Technical Regulations) to the same extent.

In a later phase, the aim is to include experimental tests in the test specifications to determine the head impact times while using pedestrian dummies and also an empirical formula; the latter still needs to be developed, taking into account specific parameters of the vehicle front's geometry.

Travelling safely in a camper van

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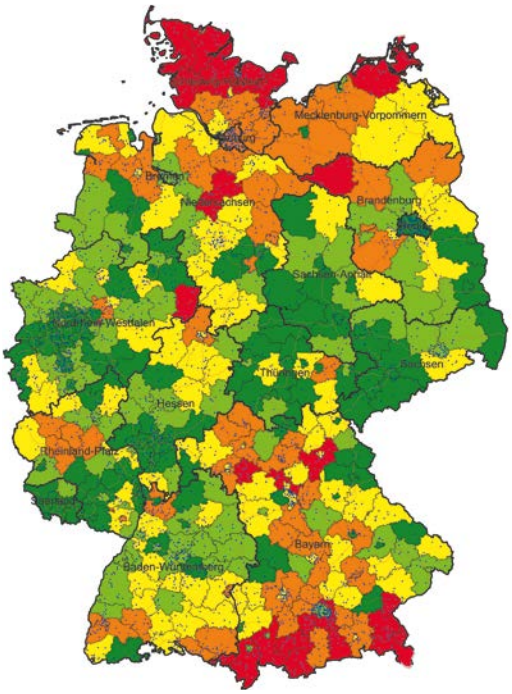
Camper van holidays are increasingly popular in Germany. The numbers of registered camper vans published by the Federal Motor Transport Authority have shown an annual increase for some years now. Also during the Covid-19 pandemic – perhaps caused by the far-reaching bans on hotel accommodation – a lot of people spent their holidays travelling in a camper van. The rise in the number of accidents involving camper vans is one negative side effect of the boom.

An analysis of the regional distribution of accidents involving camper vans shows that these accidents occur with above average frequency in coastal regions and the foothills of the Alps. This is probably an indication of the purpose of camper vans, as more camper vans are travelling on the roads in tourist regions and thus are more frequently involved in accidents.



Proportion camper van A (P) in %
Average share: 0.32%
- ≥ 0.00 – < 0.21 (131)
- ≥ 0.21 – < 0.32 (92)
- ≥ 0.32 – < 0.45 (90)
- ≥ 0.45 – < 0.70 (64)
- ≥ 0.70 – < 2.00 (24)

Proportion of accidents resulting in personal injury involving camper vans compared to all accidents involving motor vehicles between 2016 and 2020.

Source: Map base GFK Geomarketing GmbH (RegioGraph), calculations by BASt

In 2019, 920 accidents resulting in personal injury were registered in which camper vans were involved. This is an increase of 24 per cent compared to the beginning of the review period in 2010. By comparison, the number of accidents resulting in personal injury involving passenger cars has remained at the same level over this period. In 2019, a total of 12 people were killed and 265 were severely injured in accidents involving camper vans. Among these, however, only 2 deaths and 79 severe injuries were registered for people inside camper vans.

Nonetheless, a differentiation of the severity of accidents between drivers and passengers indicates where to start with safety improvements. On average, in the period between 2010 and 2019, passengers in camper vans had significantly more severe injuries than drivers. The indicator "severe personal injury in reference to driver or passengers" shows 70 severe personal injuries per 1,000 passengers and 35 severe personal injuries per 1,000 drivers.

This means that camper vans are not a focal area of accident situations. Nonetheless, looking at the consequences of accidents in Germany among passengers shows that there is room for improving their safety. In view of the low number of accident victims, however, the improvement potential should not be overrated.

Jahr		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]
Accidents resulting in personal injuries involving **camper vans**		743	714	643	686	742	773	786	823	863	920	766
Camper van occupants	Deaths	4	3	4	4	6	3	7	4	4	2	5
	Severe injuries	62	58	46	65	63	71	60	59	66	79	70
	Minor injuries	280	257	267	255	273	287	329	324	340	354	278
Severe personal injuries per 1,000 drivers		40	41	28	32	43	47	39	36	39	35	47
Severe personal injuries per 1,000 passengers		53	50	57	83	55	60	53	46	52	70	64
Total number of accidents resulting in personal injuries involving **passenger cars**		236,798	249,176	244,929	238,231	245,412	248,921	250,320	244,817	245,117	236,675	195,099
Occupants of Passenger cars total	Deaths	1,840	1,986	1,788	1,587	1,573	1,620	1,529	1,433	1,419	1,363	1,170
	Severe injuries	27,504	29,413	28,835	28,235	28,960	29,559	29,810	29,483	28,869	28,270	21,946
	Minor injuries	183,925	185,680	185,307	182,592	186,041	189,931	192,251	188,791	182,529	177,638	135,805
Severe personal injuries per 1,000 drivers		44	47	47	47	48	49	49	49	49	49	49
Severe personal injuries per 1,000 passengers		41	44	44	44	46	46	46	45	46	46	46

1 Covid19 pandemic

Comparison of accidents involving camper vans and passenger cars, 2010 to 2020.

Indicators to assess road safety

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Since the publication of the European Union's policy framework on road safety for the 2021-2030[1] period, at the latest, performance indicators have played a significant role in European road safety. The European Commission defined essential indicators that are intended to contribute to preventing deaths and severe injuries.

As a supplement to the established figures on accidents and accident victims, it is intended in the future to use road safety indicators also for monitoring the Federal Government's 2021-2030[2] road safety programme. BASt is developing an SPI concept (Safety Performance Indicators) for this purpose. The indicators already available in Germany focus on the conduct of road users. BASt has been identifying some of those for many years now.

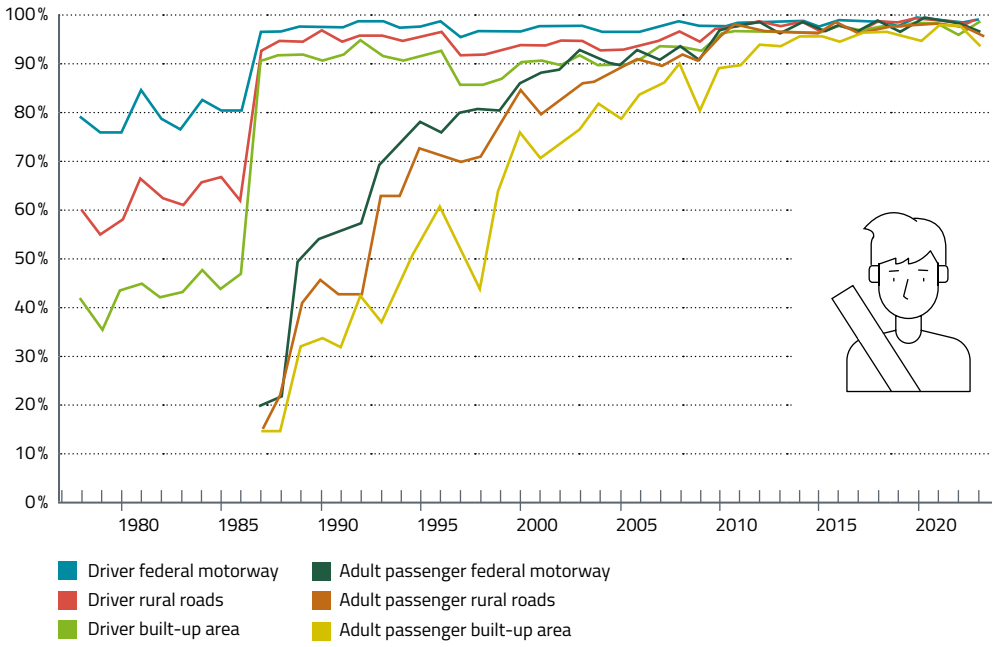
The aim of the ongoing development of the SPI concept is to enable mapping the safety level on Germany's roads as comprehensively and reliably as possible using as few indicators as possible. The indicators already available are the starting point.

Currently, the following 4 aspects are taken into account for assessing road safety based on indicators:

Safe road use – road user conduct

Road user culture is shaped by how the interaction of road users is perceived and evaluated. Interviews[3] are used as a means to collect data. In 2020, BASt initiated a project with the aim of determining an indicator concerning the observance of rules in road traffic. Distractions due to smart phone use is a relevant root cause for accidents. The frequency of passenger car drivers using smart phones[4] while driving was first surveyed in 2019. An indicator for the frequency of driving under the influence of alcohol has been available since 2022, based on interview results. Surveying safety-related conduct in passenger cars, two-wheelers and heavy goods traffic is conducted using observations that have been ongoing in road traffic at regular intervals for a long time[5]. Determining seat-belt-wearing rates

1 https://data.europa.eu/doi/10.2832/80948 (03.12.2022)
2 https://bmdv.bund.de/SharedDocs/DE/Anlage/StV/broschuere-verkehrssicherheitsprogramm-2021-bis-2030.pdf (03.12.2022)
3 www.bast.de/DE/Publikationen/Berichte/unterreihe-m/2022-2021/m316.html (30.06.2022)
4 https://bast.opus.hbz-nrw.de/opus45-bast/frontdoor/deliver/index/docId/2455/file/M300_barrFrei.pdf (11.04.2022)
5 www.bast.de/DE/Publikationen/DaFa/2022-2021/2022-02.html (09.05.2022)



Development of seat-belt-wearing rates of adult occupants in passenger cars.
(until 1996: only western federal states, starting in 1997: overall federal territory)

is one example. Since 2007, quotas for the usage of daytime running lights[6] have also been determined by observations. The extent to which reflecting garments and reflecting accessories are used by cyclists and pedestrians is being discussed at the moment as another indicator, as well as deficient driving competence, which can lead to accidents and risky conduct.

Safe vehicles

Surveys commissioned by BASt[7] and conducted biannually since 2013 provide an understanding of the market penetration (installation rates) of vehicle safety systems in privately used cars. Currently, BASt is reviewing the suitability of a vehicle fleet assessment based on the Euro NCAP (European New Car Assessment Programme) as an indicator for vehicle safety.

Safe infrastructure

Currently, BASt is also discussing and researching various indicators in the field of infrastructure-related road safety.

Emergency services after traffic accidents

One criterion for the performance of emergency services is their response time, the time between the reporting of an accident and the arrival of first responders on site. Since 1977, BASt has been regularly evaluating the performance data of emergency services.

6 www.bast.de/DE/Publikationen/DaFa/2022-2021/2021-02.html (11.04.2022)

7 www.bast.de/DE/Publikationen/DaFa/2022-2021/2022-01.html (28.06.2022) and https://bast.opus.hbz-nrw.de/opus45-bast/frontdoor/deliver/index/docId/2618/file/M327+Gesamtversion+BF.pdf (05.07.2022). The 2021 survey had not yet been published at the time of preparing the report.

The Federal Government's reporting on road safety – Road Accident Prevention Report

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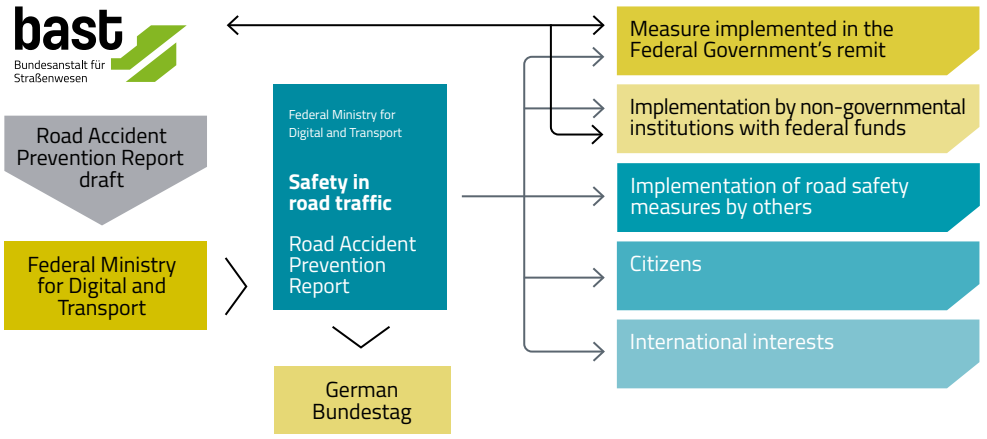
"Safety Concepts, Safety Communication" section

The number of people killed in German road traffic was at a peak in the early 1970s. The Bundestag therefore, in its decision dated 14 June 1973, petitioned the Federal Government to compile an annual Road Accident Prevention Report. Since 1975, the report has had to be presented biannually. It provides information about the developments of accident figures and the performance of the emergency services and also provides overviews about the Federal Government's national and international road safety policies and initiated measures and research activities to increase road safety.

As part of the reporting process, BASt retrieves information from state and non-state institutions and prepares a draft report for the Federal Ministry for Digital and Transport. The report includes measures under the Federal Government's remit, as well as measures for which federal funds are utilised or which are supported by the Federal Government in some other ways. BASt research activities constitute a major part of the report.



Process flow of compiling and publishing the Road Accident Prevention Report.

The ongoing "Road Safety Programme of the Federal Government 2021 to 2030" (VSP)[1] is part of the "Road Safety Pact"[2] and sees itself as dynamic and adaptive. The degree of implementation of the measures from the Road Safety Programme is to be reviewed at regular intervals. The Road Accident Prevention Report as a monitoring tool is intended to provide an essential contribution to this aim in the future. To this end, its structures has been revised and extended. The current report, for example, has already assigned the roughly 280 measures described to the 12 action fields of the Federal Government's Road Safety Programme.

In addition to the analysis of road accident statistics already established, the report shows road safety indicators that enable describing the changes in the traffic system's safety levels in more detail.

The report is published as a Bundestag printed paper and is accessible online. It is expected to be available as of spring 2023.

1 https://bmdv.bund.de/SharedDocs/DE/Artikel/StV/Verkehrssicherheit/verkehrssicherheits-programm-2021-bis-2030.html [3.12.2022]

2 www.paktfuerverkehrssicherheit.de [3.12.2022]

Our principles

"By applying modern leadership principles and transparent decisions, we are creating scope for employee action and development, where performance, personal responsibility and team spirit can thrive."

Dr Kirstine Lamers, lawyer, head of the "Administration" department

"We treat each other and others in an atmosphere characterised by a speak-up culture, trust, mutual respect and tolerance."

Sandra Eimermacher, communication electronics technician and B. Sc. in computer science in the "Highway Construction Technology" department

„We take into account the diversity of people's circumstances and interests and commit ourselves to equal opportunities."

Ayhan Toptas, IT administrator, interim head of section in the "Administration" department

By means of innovations in transport and transport infrastructure, mobility is to be maintained and improved in harmony with humankind and the environment. BASt is analysing predictive approaches in this context, thus contributing to an environmentally-friendly transport system that complies with the principles of sustainability, protects the environment and improves the quality of life. One aim, for example, is to show in a manner verifiable by third parties that vehicles can be operated in all operating modes in accordance with regulations and with as low emissions as possible. Collecting data on real emissions of motor vehicles in flowing traffic by means of remote sensing devices, for example, could improve determining emission factors and the models based on them. Starting with emissions, looking at their impact on humankind and the environment, shows that also the environment's positive effects are also of interest. Under certain circumstances, forests along transport routes, for example, can contribute to reducing noise pollution and its consequences for human health.

8. Environmentally friendly transport

Roadside vegetation and the great number of compensation areas can contribute to maintaining and promoting biodiversity in Germany, for example, by developing and connecting biotopes. It is important to further develop the care of roadside vegetation from ecological and economic perspectives to make use of this potential, which to date has only insufficiently been utilised. Environmental compatibility is taken into consideration not only in the maintenance and operation of transport systems but also in road construction. Material-oriented assessment concepts can ensure, for example, that emissions from construction material and secondary construction material are quantifiable depending on the construction method, which is important in building new roads and also increasingly in retrofitting and extending roads using and (secondary) construction material. When these findings about the construction methods are taken into account, emissions into soil and water bodies can be reduced, even avoided altogether.

Environmentally friendly transport – assessment concepts for a substance-oriented environmental compatibility of transport-mode-related structures

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As part of the priority topic of construction- and infrastructure-related emissions/ impacts on waters and soils in the scope of the Federal Ministry for Digital and Transport's Network of Experts, concepts for different scenarios are being developed for the transport modes rail, road and waterways (including offshore) and for the environmental media inland waters, seawater, soil and groundwater, with which to derive environmentally-compatible emission values for engineering structures in the transport infrastructure.

The construction of transport routes and offshore facilities uses a multitude of different construction materials in large quantities. Environmentally relevant substances can be released in doing so due to the influence of weather conditions. Construction supervision provides rules and regulations that contain permissible emission values for specific installation situations. The "Evaluation principles for the impact of building products on soil and groundwater" (DIBt 2011), for instance, describe the bases of the values required in the "Model Administrative Regulation Technical Rules for Construction (MVV TB) 2021/1" (DIBt 2022), which the Land Building Codes use as a reference. The values are usually identified by creating scenarios. The measurable substance-related emissions from construction materials are compared hereby with reference values from environmental legislation for each environmental medium. The installation situation, as well as substance retention, decomposition and dilution are taken into account, enabling an assessment of substance-related emissions.

Currently, an assessment concept for geosynthetics is being developed which takes into account installing structures

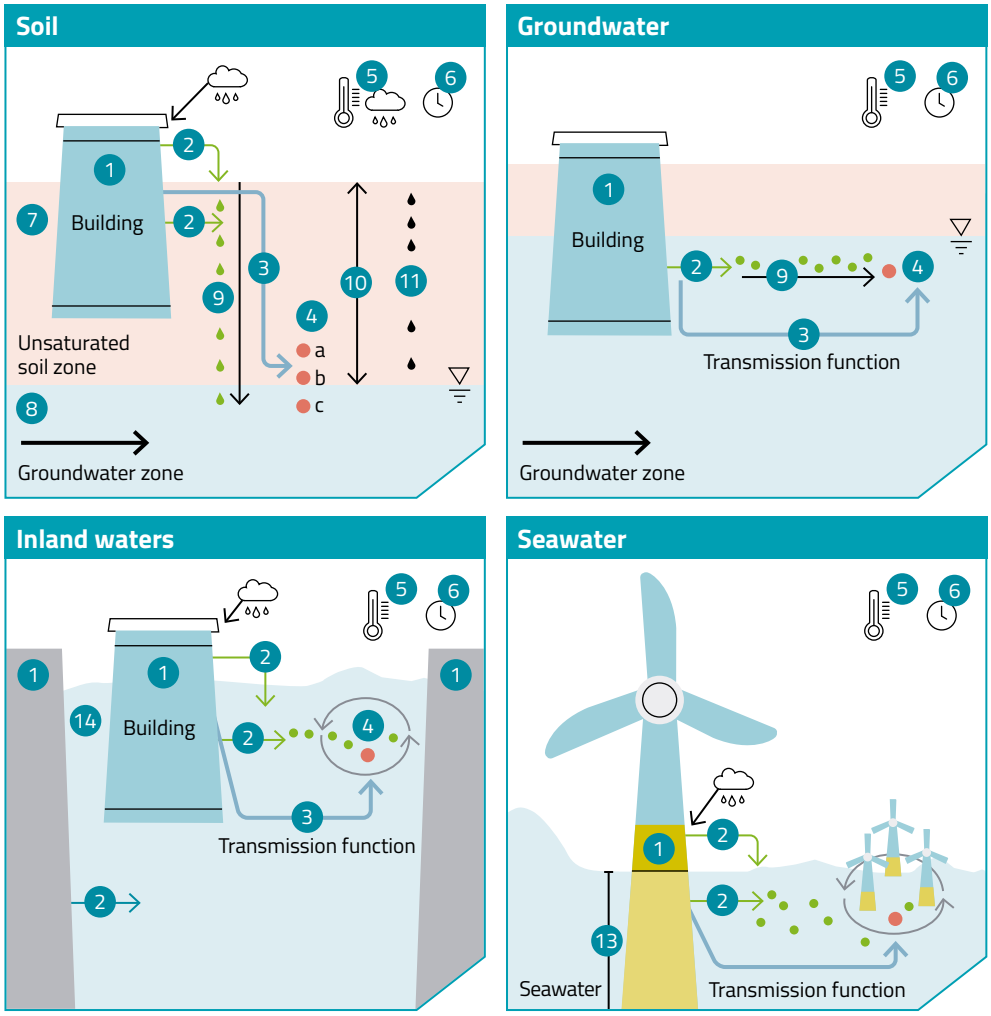

Illustration of the four surface scenarios water, groundwater, inland waters and seawater. Substance-related emissions (green) of a building structure and the environmental transport to the location assessed (red circle) in the environmental medium described depends on different parameters (1 – 14); these need to be described and defined to create scenarios.

near inland water bodies and soil. Reference values from the Surface Waters Ordinance and the Federal Soil Protection Ordinance are used in this context. For inland waters, the ratio is calculated between a model water body and the surface of the geosynthetics material, and the transport of substances in the soil is mapped using a substance transport programme. This enables comparing the environmentally compatible emission values identified with the results from reviewing the emission release of a product. This simplifies selecting environmentally friendly construction material and improves soil and water protection.

Roadside vegetation – biodiversity habitat

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What does a windscreen have to do with biodiversity loss?

Those born in the 1980s and earlier can probably still remember: stopping at a service station was a must during long car rides as numerous insect remains had to be removed from the windscreen. And today? Germany has 75 per cent fewer winged insects today than in 1989 (Hallman et al. 2017) and car windscreens stay clean. The sharp decline in the individual numbers and species is not restricted to insects, but is a trend showing across all fauna and flora. Roughly one million animal and plant species are currently threatened with extinction (IPBES, 2019). In times of climate change and also societal, geopolitical and economic changes, a decline in biodiversity may be only one of many threats. But biodiversity, meaning the diversity of species, genes and ecosystems, is a pillar of the natural substance cycles, and thus of existential significance as a foundation for our lives and our environment.

But are biodiversity and transport opposites or not?

An honest answer would be: yes and no. Negative effects such as habitat fragmentation and pollutant loads cannot be overlooked. These effects, however, can be reduced by countermeasures. Roadside vegetation, in particular, offers great potential that to date has been only insufficiently utilised. In rural areas strongly marked by agriculture, roadside vegetation is of particular significance as a habitat for animals and plants. BASt studies have shown that different types of meadow-biotopes in such landscapes are hosts to more species in the roadside vegetation than in the surrounding landscape. Some especially valuable biotopes are even found exclusively in roadside vegetation. They in turn offer a habitat for many butterfly species. During a representative study period in Lower-Saxony, 7 of 9 butterfly species registered as (critically) endangered or on the Red List's early-warning list were confirmed solely in roadside vegetation.

And what can be done to specifically promote the potential of roadside vegetation?

A multitude of measures are already in place which have a positive impact on the biodiversity of roadside vegetation. One change in the maintenance routine already has a great influence: maintenance by section, i. e., alternating between mowing and leaving the vegetation as is, offers animals spaces to retreat and enables a continuous availability of resources. This measure is already being applied in some federal states, and it is planned to incorporate it in the current revision of the Fact Sheet on Maintenance of Green Areas for routine road maintenance. Though not removing mowed grass is not in line with the conventional aesthetic ideal of a well-maintained green space, leaving it is important in winter, as many insects hibernate in such heaps. Large-scale mulching, as is currently often practiced, is a threat to biodiversity because of the constant enrichment with nutrients and is a high risk for arthropodes, which includes insects. Innovative mowing machines could be an alternative for the future. This includes machines with a reduced risk of killing arthropodes by having a scraping

Common heather (calluna vulgaris) on roadside vegetation.

device placed in front of the mowing unit. In the scope of a study covering Germany, Austria and Switzerland, such machines are currently being tested and reviewed for their suitability in use at maintenance depots. As a matter of principle, a heterogeneous structure is usually a good precondition for a species-rich habitat. Uneven soil surfaces, dead wood and stone piles should thus remain or be intentionally placed on areas of roadside vegetation, provided they are no obstacle for maintenance. Moreover, it is important to control invasive species, as they pose a severe threat to biodiversity. A guidance document concerning problem plants provides information on how to prevent the introduction of such species into roadside vegetation and lists specific eradication measures for selected species.

Conclusion

Though transport routes are generally considered harmful for nature, they can nonetheless make a positive and valuable contribution. The targeted design and maintenance of roadside vegetation promotes biodiversity and connects habitats. There are initial sustainable measures for habitat connection in the transport sector, and BASt is instrumental in enabling a future biodiversity-supporting type of maintenance in routine road maintenance by developing innovative methods and concepts.

References

Hallman, C.A., et al. (2017):
More than 75 percent decline over 27 years in total flying insect biomass un protected areas. PlosOne 12(10): e0185809

IPBES (2019): Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E.S. Brondizio, J. Settele, S. Díaz, and H.T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages

Further information: https://www.bast.de/DE/Verkehrstechnik/Fachthemen/Daten/Praxishilfe-Problempflanzen.pdf

Noise reduction potential of forests

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Forests can undoubtedly be called interdisciplinary allrounders: protecting soil and water, providing nature conservation and climate action, improving air quality, offering a recreational area and much more – there is (almost) nothing a forest cannot do!

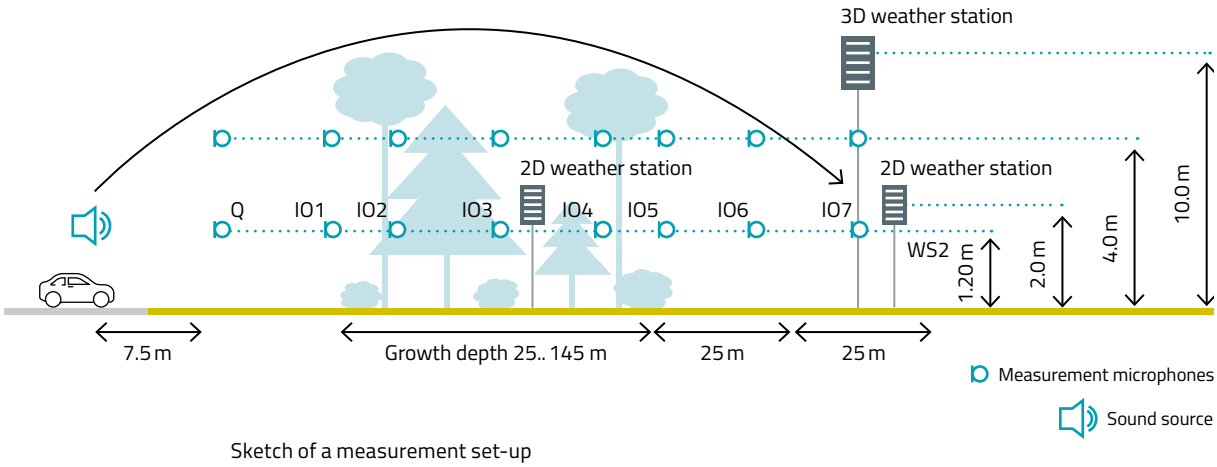
The acoustic properties of forests have also been a subject for research since the late 1940s. Noise-absorption properties of different forest types and vegetation structures were studied in numerous field campaigns and calculation models. The aim was to be able to describe the acoustic impact in relationship to forest-specific parameters. The noise propagation model defined in ISO 9613-2 already provides a simple approach to taking into account the physical reduction of noise levels when sound is propagated through dense forests. But to date, it has not been possible to transfer this to real situations and integrate it into the guidelines for noise abatement on roads (RLS), as there is no guaranteed continuation of forests and due to the great variety of relevant influencing parameters and diversity of study findings.

This is the starting point of the "Acoustic Effectiveness of Vegetation" research project that Acoustic Engineering Dresden conducted for BASt. The overarching goal was to identify the frequency-dependent noise reduction potential of various narrow strips of forest (25 to 150 metres) adjacent to federal trunk roads. It was intended to develop a methodology that enables including strips of forest in sound propagation calculations for individual analyses.

Sound reflection and acoustic scattering at tree trunks, leaves and crowns of trees, sound reflection and dissipation on the ground, sound dissipation through thin branches and leaves and sound diffraction at crowns of trees were identified as the most significant effects in sound propagation through vegetation. On the basis of a literature analysis, forest- and terrain-specific and ambient conditions were defined for the research areas for the purpose of field campaigns. 8 forest measurement sites were selected in the Saxony and southern Brandenburg regions

Acoustic measurements at a forest strip along the rural road B97 near Hoyerswerda.

Source: Acoustic Engineering Dresden GmbH



Sketch of a measurement set-up

Source: Acoustic Engineering Dresden GmbH

to map a wide range of forest-specific parameters (e. g., deciduous or coniferous forest, varying undergrowth and varying trunk diameters). In addition, 2 open field measurement sites were defined as references for acoustic forest measurements.

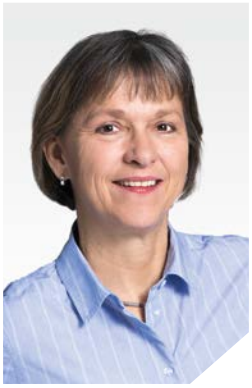
To ensure a better transferability to practical use cases, the only emission source used was real road traffic. Noise emissions were measured in front of the forest as well as inside and behind it with 8 pairs of microphones at 2 heights and at varying distances to the traffic lane. Moreover, the meteorology inside and behind the forest was captured. There was a summer and a winter measurement of the sound propagation, and forest-specific parameters were determined. A methodology was developed to evaluate the measured data, enabling a comparison among the different measuring sites despite variations in the geometrical conditions (such as forest depth, forest-road distance, traffic intensity) and a juxtaposition with the results from the open field measurements.

For most of the measurement sites, an almost linear relationship was observed in the difference of the sound pressure levels (the lower source microphone was used as reference) in relation to the logarithmised distance. As a measure for the acoustic effectiveness and quantitative comparison of the different measurement sites, an additional sound level reduction (in decibel) per distance doubling (dB/dd) compared to free-field sound propagation was selected. The values measured range from a deterioration by 0.9 dB/dd up to an improvement by 2.6 dB/dd. For almost all measurement sites, however, an increase in the absorption of sound was observed.

The research project thus succeeded in confirming based on measurements that in some cases forests significantly reduce noise levels compared to a free-field sound propagation of road traffic noise. High growth density and a high degree of noise absorption by the soil is particularly important for a forest's acoustic effectiveness. Transferring the results into a corresponding model now enables including strips of forest in propagation calculations pursuant to RLS-19.

The research project thus provides systematic and convincing proof for the noise abatement potential of forests, thereby constituting an important step toward a valid, quantitative acoustic assessment of forests.

Remote sensing – measuring emission during real-life operation



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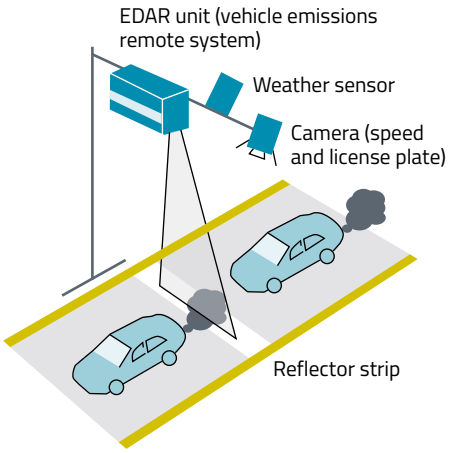
Background

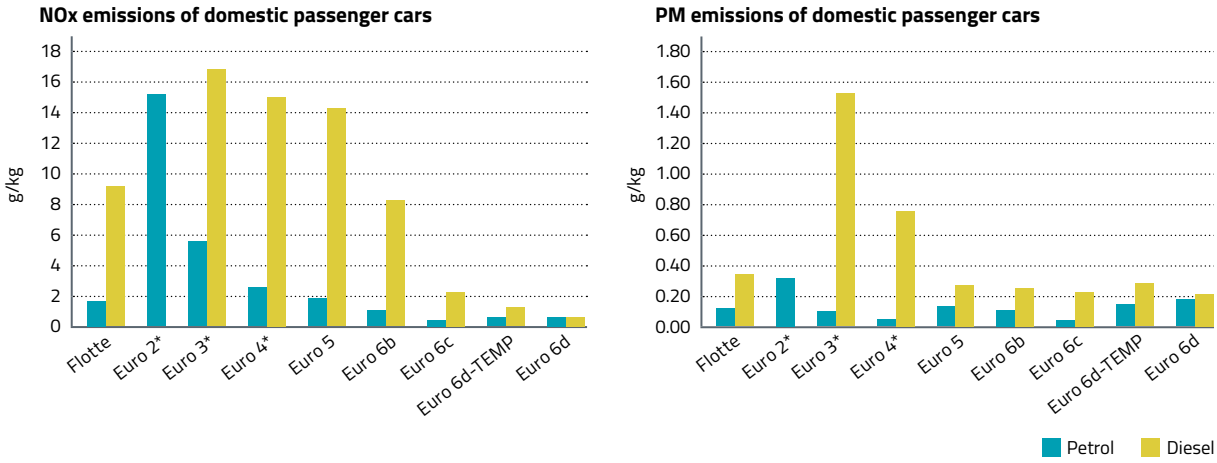
There are two measurement systems to collect data in the exhaust plume of vehicles in flowing traffic in a contactless way. One works horizontally, the other vertically. Both determine the pollutant concentration in the exhaust gas plume by looking at the absorption of laser rays of a certain wavelength. These two methods are used internationally for surveying pollutant concentration directly on roads. Most of the documented measurements are conducted in traffic-intense conurbations and at speed ranges below 60 kilometres per hour (km/h).

Measuring and evaluating

In a BASt research project, a measurement method was deployed to capture the pollutant emissions of vehicles at speeds over 80 km/h. The vertical measuring system of the "Hager Environmental & Atmospheric Technologies" company (HEAT) was used on a federal motorway for this purpose. The system consists of a laser-based measuring system that is positioned above the road and a reflector that was glued onto the road for the measurements. This enabled measuring and visualising the concentration of carbon monoxide and dioxide, nitrogen monoxide and dioxide, hydrocarbon, particle mass and temperature in the entirety of the exhaust plume. For further evaluations of the emission values measured, it was necessary to know the motorisation of the vehicles measured. This information can be accessed for domestically registered vehicles on the basis of licence plates, complying with data privacy regulations, at the Federal Motor Transport Authority (KBA). For this reason, licence plates were



Schematic illustration of the EDAR measuring system and image of the facility on the federal motorway BAB A61 in June 2022.



Nitrogen oxide and particle mass in g/kg fuel separated into diesel and petrol vehicles, averaged as vehicle fleet and clustered by Euro emission category.

also recorded in the measurements. Moreover, it was necessary to also include data on the weather conditions at the time of the measuring period to further evaluate the measurements, continuously recording the weather conditions and separately allocating them to each measurement. Commissioned by BASt, HEAT conducted measurements in June 2022 using the Emissions Detection and Reporting (EDAR) system. The criteria for selecting where to put up such a system are manifold; only a limited number of locations along motorways in North Rhine-Westphalia proved suitable. The illustration on the left shows the installation on the BAB 61 federal motorway. The measuring system was active there for 12 days and captured the emissions and licence plates of roughly 124,000 vehicles. Data privacy regulations required a separation and anonymisation of the emission values before engine-specific data could be received from KBA. As a next step, the engine values were linked to the emission values.

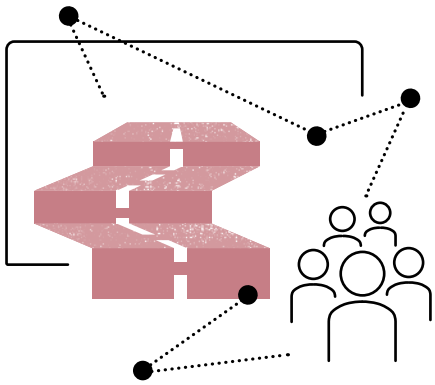
The linked data that can now be evaluated further provides information for many emission- and emission impact-related topics, such as the distribution of emissions among the vehicle fleet by EURO exhaust emission category, emissions development in individual vehicle groups during their lifecycle, allocating emissions to passenger car- and truck-shares or identifying emission factors for the Handbook Emission Factors for Road Transport (HBEFA).

To illustrate the multitude of possibilities, a diagram shows as an example the amount of nitrogen oxide emitted and the particle mass of the domestic vehicles measured, classified separately by diesel and petrol engines, and maps them by Euro emission category in measurements on the federal motorway BAB61.

Conclusion and outlook

The data from the evaluated remote sensing measurements of various projects conducted across Europe is valid. However, each measured value only shows one snapshot of a vehicle or its driving condition at a specific point in time. A broad data base for multiple use can only emerge when many measurements are merged. The measured values of several field campaigns conducted across Europe are currently being bundled with the agreement of many research donors. By merging and updating the data, ageing effects in the exhaust systems of vehicles, inter alia, can also be integrated.

9. Securing the supply of skilled personnel

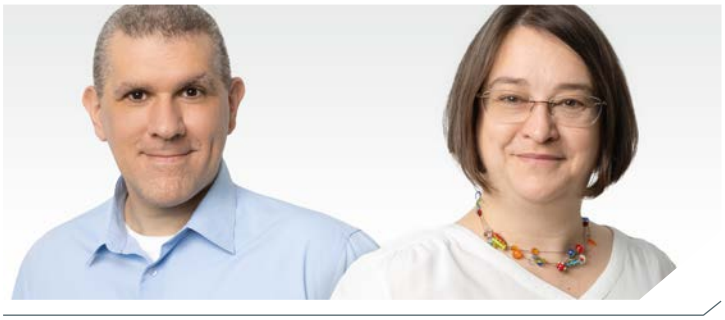


Traffic engineering integrity, the expansion of sustainable, innovative structures and the maintenance of necessary and safe – sometimes even critical – transport infrastructures are one cornerstone of the economic prosperity of the Federal Republic of Germany.

Maintaining, operating and sustainably further developing the systems requires skilled personnel that is currently in short supply. Due to the demographic shift and declining population figures in Germany, the traditional systems of education no longer suffice to qualify skilled personnel.

BASt is striving to develop the scientific foundation on which to recruit, secure and qualify skilled personnel for the road and transport sector. Educational concepts would then effectively correspond to its specific needs.

Sustainability through innovation – systematically securing the supply of skilled personnel



Fotos: © Daniel Carreño / hatandcap.de

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The "Academy of Sustainable Highway and Traffic Engineering" office was established in March 2022. Its central task is to develop a scientific foundation for the research, evaluation and quality assurance of sustainable, innovative and practicable concepts to recruit, secure and qualify skilled personnel for the road and transport sector. Traditional systems of education often fail to offer sufficient solutions here.

This can be derived from an analysis of the figures concerning the skills shortage in the road and transport sector, the demography-based need for replacement, the development in population figures and the development in numbers of students at universities. An innovative, systemic solution is called for. The foundation for such a solution was developed by the Academy and addresses not only university students as a target group, but also international skilled personnel as well as lateral entrants and those re-joining the labour market.

Moreover, the gap that was identified between employers' real requirements and the competences of university graduates showed there is a need for action in the following fields:

- Qualifying people with a foreign degree for the German labour market.
- Modernising teaching – including lifelong learning aspects.
- Supporting authorities and the private sector.
- Setting up a network and knowledge and action alliances.
- Offering new educational formats – primarily in the so-called third educational route.

This approach was presented to the BMDV summit on skilled personnel in October 2022 and was well received by policymakers and businesses. This positive reception was proved, for example, by a fund of 4.5 million euros that, despite tight budgets, was granted to implement it in a parliamentary procedure.

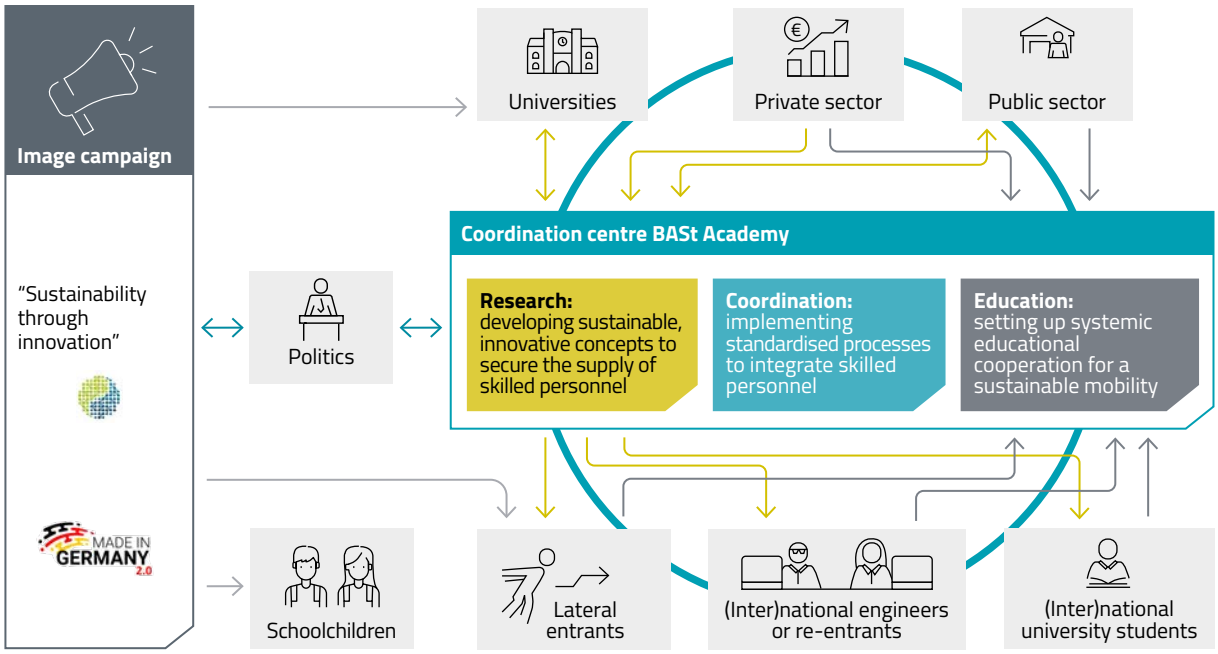


Illustration of the concept of the coordination centre BASt Academy and its stakeholders.

With BMDV support, the following steps were initiated; some have already been implemented:

- A comprehensive educational grants programme amounting to several million euros is in its tendering phase. It aims to generate formates to integrate people with a foreign degree – inter alia at universities, in a close exchange with the new network.
- Additional fundamental and in-depth findings were gathered in BASt's own nation-wide interviews with graduates from secondary schools, university students and authorities.
- An initial pilot project commissioned and supported by BMDV – "BIM (Building Information Modelling) radar"– collects data concerning BIM-relevant topics and content in module manuals and curricula at German universities. This data will be merged and maintained in a data base available on the Internet which is unique so far.
- Projects with the Autobahn GmbH and road administration authorities at Länder level are being coordinated and are intended to be pilot projects for recruiting new skilled personnel.
- Presentations at engineering education conferences and further publications of research findings have been planned; some have already undergone peer reviews.
- A comprehensive concept covering all measures has been developed to bring about a systemic approach.

From the idea to the academy – the concept

The concept envisages establishing an organisational structured based on the 3 pillars of consultancy, coordination and education.

In the consultancy field, contact persons will be available for employers and (inter) national interested parties concerning all areas of securing the supply of skilled personnel in engineering. They will provide

guidance to connect interested students and various authorities and certification centres. This area will help coordinate the organisation of applications, job placements, identifying qualification targets, recognising degrees and providing supplemental qualification.

In the coordination field,

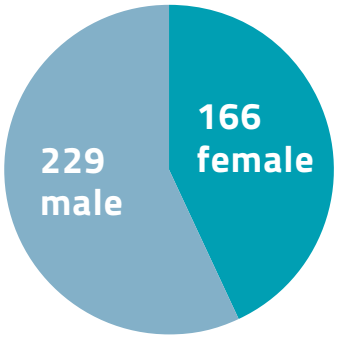
- BMDV funding programmes focusing on integrating people with a foreign degree and lateral entrants and re-entrants will be managed,
- Measures concerning recruiting and securing the supply of skilled personnel will be analysed, evaluated and developed,
- Information about existing and planned measures (including third-party measures) will be collected and processed in a freely accessible database,
- An exchange platform for services in the field of education and jobs will be set up and
- a structural alliance of all stakeholders in the field of securing the supply of skilled personnel, recruiting and qualifying skilled personnel will be coordinated.

It is intended to prepare a joint image campaign (Sustainability through Innovation, Made in Germany 2.0).

The education field is the provider of further education and certification for post-graduate (international) engineers and for lateral and re-entrants from the third educational route. It focuses on technical, language-related and cultural topics. This field prepares and teaches additional concepts and methods for lifelong learning and develops open educational resources (VR/AR applications) and supplements (courses) for corresponding seminars. These will also be made available to interested universities.

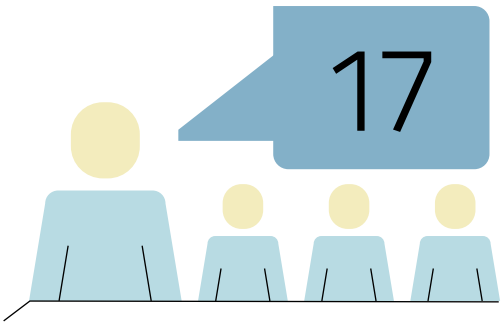
Further information can be found under: www.bast.de/academy

Facts and figures



395

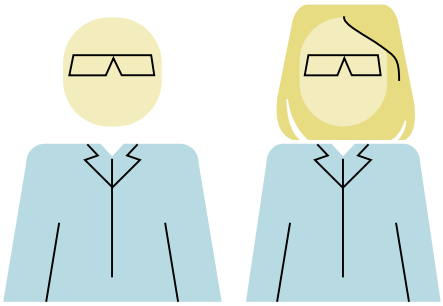
Employees



Trainees

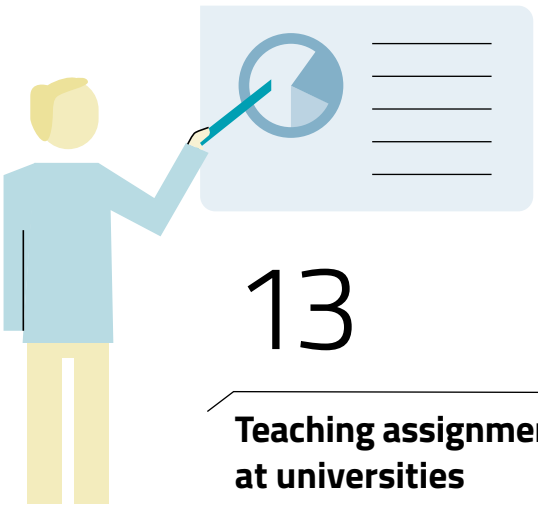
73

Reports



191

Scientists

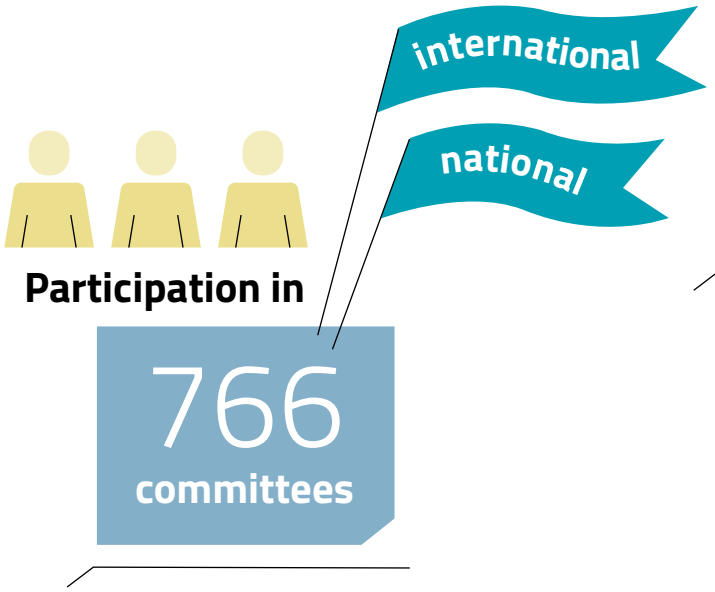


13

Teaching assignments at universities

47

Employees' average age



Participation in

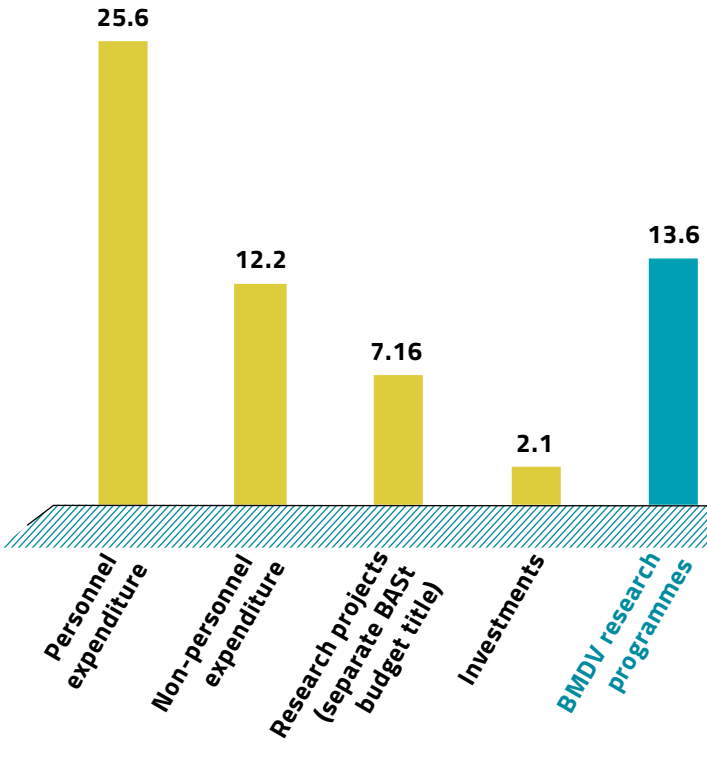
766
committees

18

Ongoing projects with third-party funding –
overall budget of ca. 7.7 million euros

Roughly 270 projects of our own

Participation in roughly 300 external projects



47.2 million

BASt's budget

Teaching assignments and PhDs

Jennifer Bednorz,
teaching assignment at the Technical University of Applied Science Cologne in the "BIM in bridges and engineering structures" M.Sc. module

Dr Dirk Jansen,
teaching assignment in highway engineering at the University Siegen.

Dr Andre Eggers,
teaching assignment in "Passive safety of vehicles" at the Bergische University Wuppertal.

Dr Mehdi Kalantari,
received his PhD in Engineering at the University Siegen.

Dr Claudia Evers,
teaching assignment in traffic psychology at the German Psychologists' Academy (DPA) Berlin.

Dr Ingo Kaundinya,
teaching assignment in tunnel planning (M.Sc. course) at the University of Applied Science in Aachen.

Ralph Holst,
teaching assignments in the fields of structural inspection and management of engineering structures at the Bauhaus University and the Bauhaus WBA Weimar.

Dr Bernhard Kollmus,
received the academic degree of "Doctorate in Engineering" at the Technical University Dresden.

Teaching assignment in "Road Safety in Planning, Drafting and Operating Roads" at the Technical University Dresden.

Photo: BASt – Daniel Carreño; hat&cap

Univ.-Prof. Dr-Ing. habil. Markus Oeser,
teaching assignments in tunnel planning and tunnel operation (M.Sc. course) at the RWTH Aachen and in Climate Change Impact on the Automotive Sector at the University of Applied Science Aachen.

André Wiggerich,
teaching assignment in psychological methodology and statistics at the Rheinische University of Applied Science Cologne.

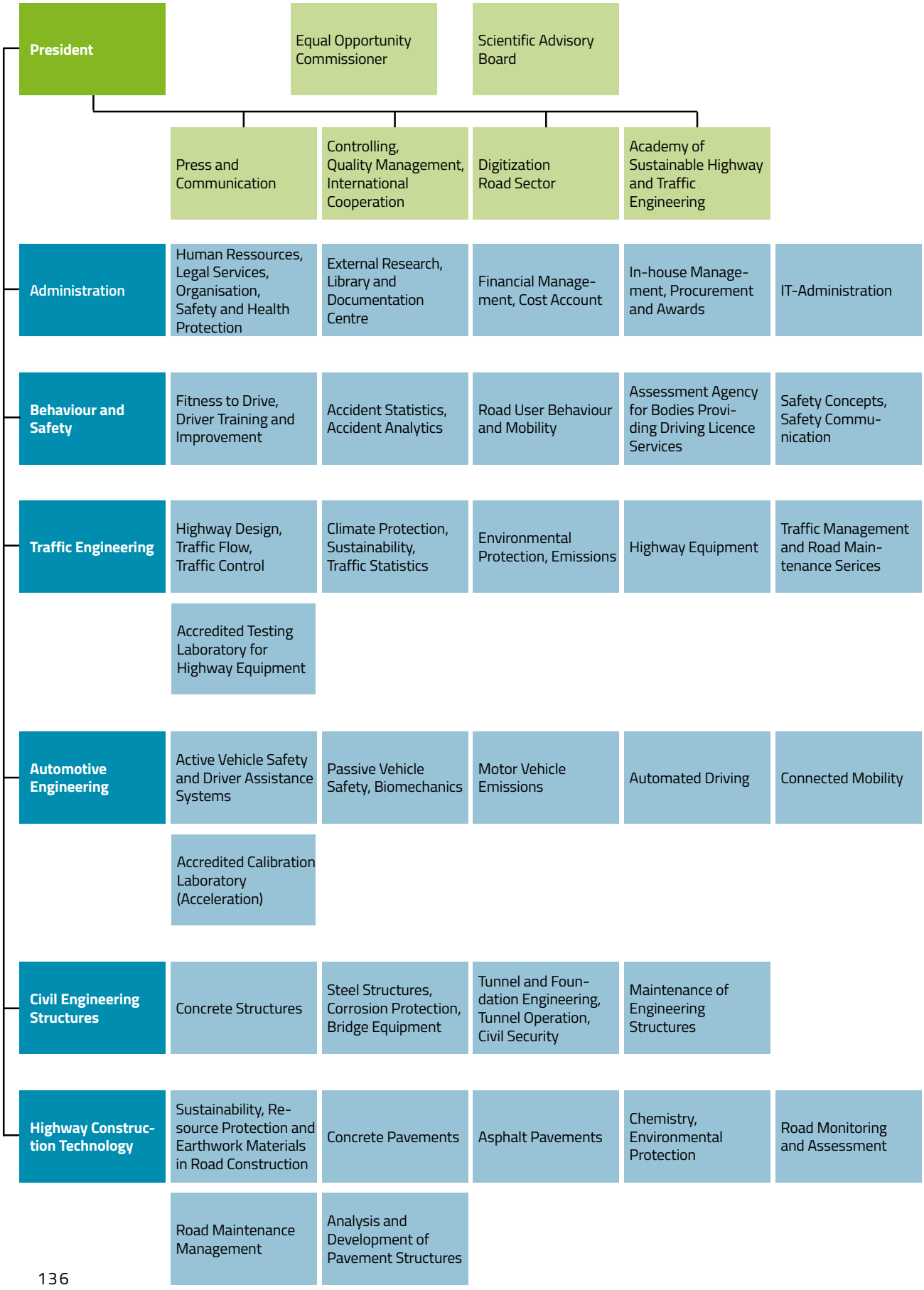
Andre Seeck,
teaching assignments in vehicle safety at the Dresden International University and the Technical University Graz.

Prof. Dr Ulf Zander,
teaching assignment in road construction at the University Siegen

Dr Patrick Seiniger,
teaching assignment in automotive engineering of motorcycles at the Technical University Darmstadt.

Elisabeth Shi,
teaching assignment in statistics for psychology and business psychology courses at the Rheinische University of Applied Science Cologne.

BASt Organisation Chart



Publication data

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The series consists of the following sub-categories:
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B - Bridges and Structural Technology
F - Automotive Engineering
M - People and Safety
S - Highway Construction Technology
V - Traffic Engineering

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Federal Highway Research Institute (BASt)

The Federal Highway Research Institute (BASt) is a practice-oriented, technical and academic research institute of the Federal Government with a focus on the road sector. It is dedicated to the diverse tasks resulting from the relationships between people, traffic, infrastructure and environment.

Its mission is to improve the roads' safety, environmental compatibility, economic viability and efficiency.

BASt provides science-based support to the Federal Ministry for Digital and Transport (BMDV) for decisions on technical issues and transport policy. Its tasks range from planning, coordinating and conducting multi-year research projects to short-term responses to questions in its support for the BMDV's current work.

It plays a leading role within networks among national and European top research institutes in the road sector and is instrumental in developing regulations and standards.

BASt's tasks also include consultancy and expertise activities. Moreover, it conducts tests and is a certification centre and also an assessment agency for bodies providing driving licence services.

It was founded in 1951 and has had its headquarters in Bergisch Gladbach since 1983. BASt has been the central institute for road accident research in Germany since 1970.

www.bast.de

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