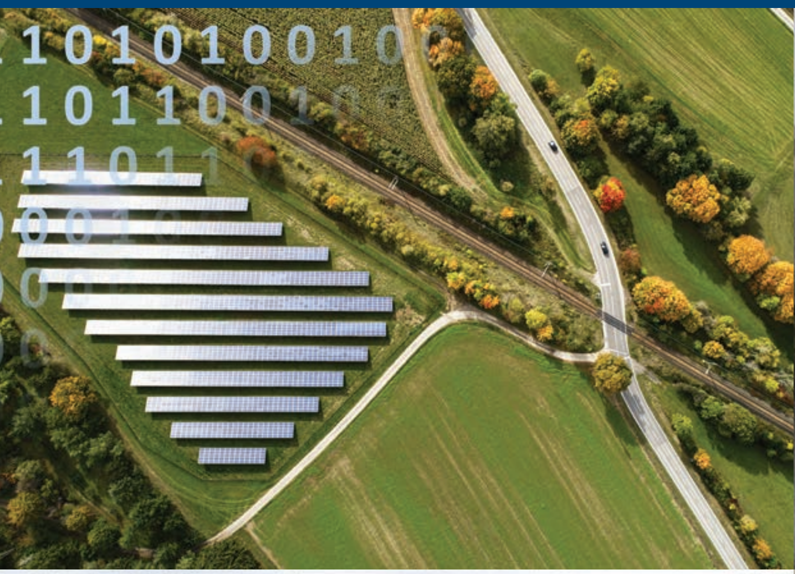
Federal Ministry
of Transport and
Digital Infrastructure

BMVI Network of Experts
Knowledge Ability Action

The BMVI Network of Experts „Knowledge – Ability – Action“

Synthesis Report on the Research Phase 2016 - 2019



Bundesamt für Güterverkehr

BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

bfg German Federal Institute of Hydrology

bast Federal Highway Research Institute

BAW Federal Waterways Engineering and Research Institute

DWD Deutscher Wetterdienst
Wetter und Klima aus einer Hand

German Centre for Rail Traffic Research at the Federal Railway Authority

Foreword

Dear Readers,

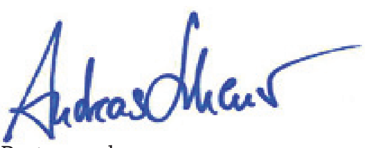
Progress and innovation would not be possible without the scientific community. Curiosity leads to research, which in turn produces a sound information basis, identifies solutions, delivers fresh insights and developments – and, in the best of cases, inspires and evokes enthusiasm. There is hardly any other field to which this applies more than that of mobility. While we are endeavouring to respond to demographic change, meet climate change targets and relieve congestion on our roads, mobility is undergoing radical transformation – be it through digitalisation, automation, interconnection or electrification.

This transformation affects all modes of transport. Therefore, it is both more efficient and promising to develop common solutions and innovative strategies for all modes: rail, road and waterway. This will allow us to obtain maximum benefit for the entire transport system and for our country. However, we cannot do this without the scientific community.

The Federal Ministry of Transport and Digital Infrastructure (BMVI) has outstanding departmental research facilities with a high level of expert knowledge and academic reputation. In order to fully tap and make accessible this potential, in 2016 we launched the BMVI Network of Experts under the leitmotif “Knowledge – Ability – Action” as a cross-departmental research format. Its mission is to provide academically sound answers to important questions of the future – across all modes of transport, in a creative manner and with a focus on implementation. How can we better protect our transport routes from extreme weather events? How can we apply artificial intelligence to modernise and speed up construction projects? How can we generate renewable energy from transport soft estate? In the quest for answers to these and other questions, we are striving to combine theory and practice and connect the scientific community with the users. The insights and results obtained are quickly implemented both by the transport authorities as well as here at the BMVI.

This synthesis report provides an overview of the most important results of our first research phase (2016–2019). It focuses on the areas of climate change, environmental protection, strengthening of infrastructure and digital technologies. Further information can be found on the Internet at
https://www.bmvi-expertennetzwerk.de/EN/Home.

And our work continues. The BMVI Network of Experts has been established with a long-term mission. Until 2025, we will continue to explore the current topics and also add new ones. We’re constantly and intensively networking to firmly establish the study of these extremely important topics in the research community. I’m convinced that the BMVI Network of Experts is the right format for addressing these topics and providing major impetus across all modes of transport. With its help, we will succeed in rethinking mobility and generating innovations suited for everyday use.



Best regards,
Andreas Scheuer, Member of the German Bundestag
Federal Minister of Transport and Digital Infrastructure

Statement by the Heads of the Participating Institutions

The transport infrastructure of the 21st century is facing diverse challenges which will have a defining impact on the future of mobility. We, as the main government institutions active in the areas addressed by the BMVI, advise the German Federal Government on issues of future importance with the goal of offering solutions, both across transport modes and for each of them individually. Our services are based on the latest scientific insights and findings and therefore provide a sound basis for the efficient interplay and coordination of all transport modes.

Since January 2016, our institutions have strengthened their collaboration by establishing the BMVI Network of Experts. By working together in joint research projects under the umbrella of the Ministry of Transport and Digital Infrastructure, we are enabled to pull on one rope and provide consistent advice and input. Importantly, we are also learning from one another and generating synergies, in addition to harmonising our investigative and study approaches. This makes it possible for us to provide joint, coordinated support for national and international projects conducted by our institutions for standardising processes. In addition, this exchange contributes to coordinating the practical application of research findings and places the advice we provide to the BMVI and other stakeholders on a broader foundation. This enhances the ministry's external image and the success of its research activities in general. Numerous new points of contact among all our institutions have arisen from our work in the BMVI Network of Experts. Greater sharing by our scientists is enabling our respective institutions to pull together more tightly and generate greater value for everyone.

The jointly achieved results of the first research phase from 2016 to 2019 clearly illustrate the success of this intensified networking and cooperation. By developing common modelling and analysis systems and harmonising recommendations for action on a practical level, during this relatively brief period a great deal was achieved across all modes of Germany's transport system. As a result, now a number of new, innovative options are available for driving resilient, environmentally sound advances in this sector.

We're therefore eagerly looking forward to the second phase (2020-2025) of research activities by the BMVI Network of Experts, in which we will intensify both our cooperation and the ongoing dialogue with those who apply our results.

Andreas Marquardt
(President of the Federal Office for Goods Transport)

Dr. Birgit Esser
(Head of the German Federal Institute of Hydrology)

Prof. Dr. Christoph Heinzelmann
(Head of the Federal Waterways Engineering and Research Institute)

Gerald Hörster
(President of the Federal Railway Authority)

Dr. Karin Kammann Klippstein
(President of the Federal Maritime and Hydrographic Agency)

Stefan Strick
(President of the Federal Highway Research Institute)

Prof. Dr. Gerhard Adrian
(President of the Deutscher Wetterdienst, German Meteorological Service)

Contents

1 Networked Research for Answering Questions on the Future of Transport

The BMVI Network of Experts "Knowledge – Ability – Action"

In 2016, the German Federal Ministry of Transport and Digital Infrastructure (BMVI) created the BMVI Network of Experts "Knowledge – Ability – Action" to find answers to the mobility challenges of the 21st century. For the first time, cross-modal transport approaches took centre stage in a research concept and in the ministry's interests.

Box 1: The BMVI Network of Experts in figures
Start: 1 January 2016
Participating institutions: 7 (BAG, BASt, BAW, BfG, BSH, DWD, DZSF/EBA)
Staff: 70+
Funding: approx. € 7 million/year

The principal goal of the BMVI Network of Experts during the first research phase (2016–2019) was to develop solutions which make railways, waterways and roads, for example, better able to resist the effects of extreme weather events while minimising the environmental impacts of transport operations.

The following institutions are involved in the BMVI Network of Experts: the Federal Office for Goods Transport (BAG), the Federal Maritime and Hydrographic Agency (BSH), the German Federal Institute of Hydrology (BfG), the Federal Highway Research Institute (BASt), the Federal Waterways Engineering and Research Institute (BAW), the Deutscher Wetterdienst (German Meteorological Service, DWD) and the German Centre for Rail Traffic Research (DZSF) at the Federal Railway Authority (EBA). Scientists of these research facilities closely cooperate to develop interdisciplinary solutions for diverse aspects of the national transport system (Figure 1). This ensures that the BMVI receives competent, forward-looking advice.

The BMVI Network of Experts has elaborated a long-term Research Strategy 2030[1], which describes how the BMVI Network of Experts will address current challenges such as climate change, environmental protection and ageing infrastructure.

During the first phase (2016–2019), the research activities of the BMVI Network of Experts were assigned to five topic areas, the principal results of which are illustrated by examples in Chapter 3:

- Adapting transport systems and infrastructure to extreme weather events (2016–2019)
- Environmentally appropriate design of transport systems and infrastructure (2016–2019)
- Increasing the reliability of transport infrastructure (2016–2019)
- Consistent development and application of digital technologies (2016–2019)
- Tapping the potential of renewable energies for transport and infrastructure to a greater extent (2017–2019).

1 BMVI Network of Experts (2018): Forschungsstrategie des BMVI-Expertennetzwerks Wissen – Können – Handeln (Research strategy of the BMVI Network of Experts "Knowledge – Ability – Action"). German Federal Ministry of Transport and Digital Infrastructure (BMVI). Bonn (available in German only).

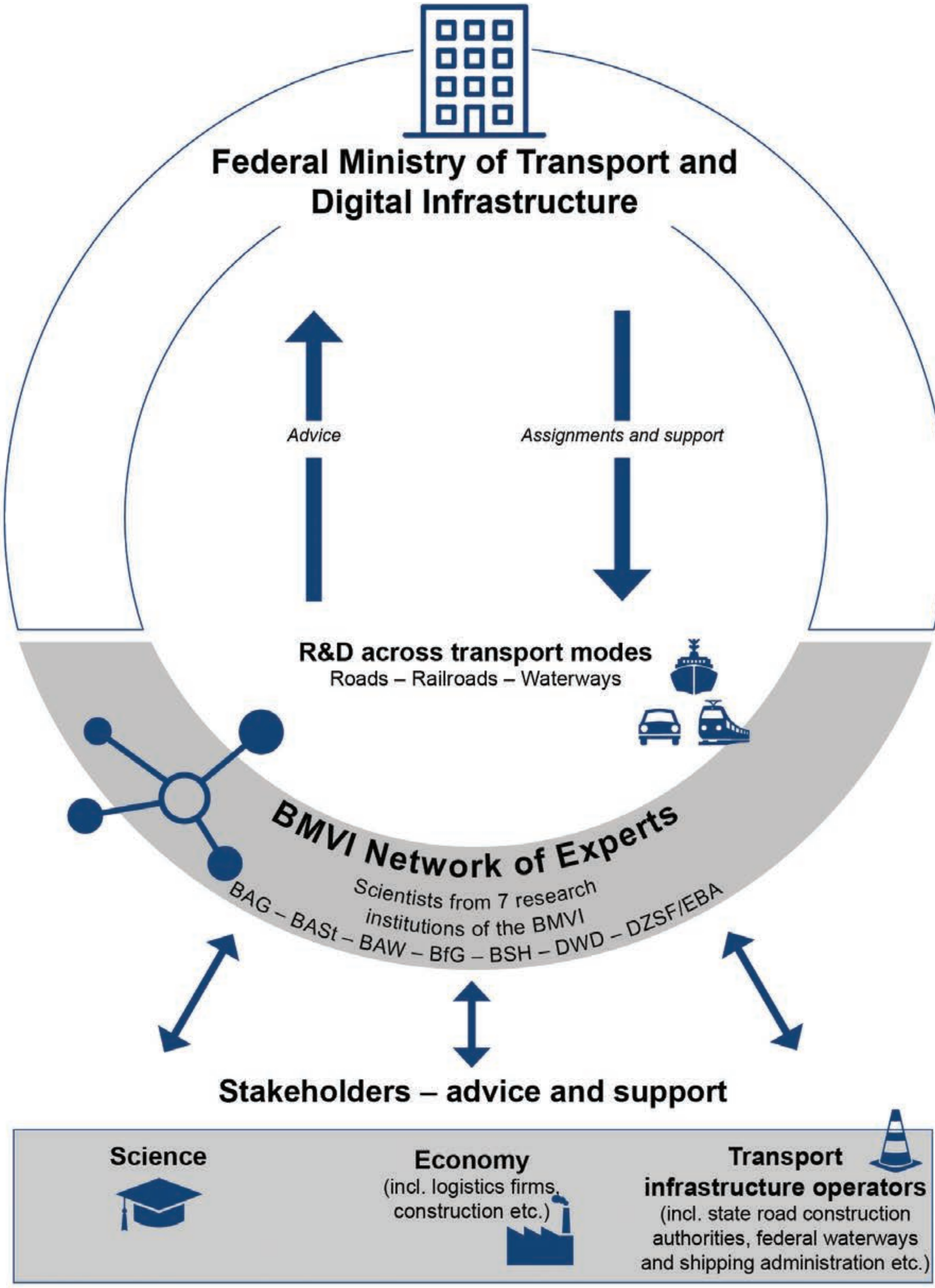


Figure 1: Activities of the BMVI Network of Experts

User-focused research and development

The research activities of the BMVI Network of Experts generate application-specific results. They are embedded in the BMVI's strategic research framework[2] and address topics such as "improving transport infrastructure", "integrated and networked mobility" and "sustainable and safe mobility".

Various economic and government players such as Deutsche Bahn AG, the German Federal Waterways and Shipping Administration (WSV) and the state road construction authorities are involved in the BMVI Network of Experts on an ongoing basis.

This synthesis report presents examples of major research results of the BMVI Network of Experts between 2016 and 2019. Detailed reports are available (in German) at www.bmvi-expertennetzwerk.de/publikationen. The reports on the individual topic areas are listed in box 2 on the right. The results of the BMVI Network of Experts have also been presented at over 250 events (specialist conferences, committees, dialogues with users etc.) and described in numerous scientific publications. Special attention is called to the conference "Transport and Infrastructure in 2018" on 14 June 2018, at which the BMVI Network of Experts presented its (interim) results to a general audience of experts.

2 German Federal Ministry of Transport and Digital Infrastructure (BMVI) (2020): Strategischer Rahmen der Ressortforschung (Strategic Research Framework). Berlin (available in German only).

Box 2: Topic area reports on phase 1 of the BMVI Network of Experts (available in German only)

BMVI Network of Experts (2020): Adapting transport systems and infrastructure to climate change and extreme weather events. Report on the results of topic area 1 of the BMVI Network of Experts in the 2016–2019 research phase, German Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

BMVI Network of Experts (2020): Environmentally appropriate design of transport and infrastructure. Report on the results of topic area 2 of the BMVI Network of Experts in the 2016–2019 research phase, German Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

BMVI Network of Experts (2020): Increasing the reliability of transport infrastructure. Report on the results of topic area 3 of the BMVI Network of Experts in the 2016–2019 research phase, German Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

BMVI Network of Experts (2020): Consistent development and use of digital technologies. Report on the results of topic area 4 of the BMVI Network of Experts in the 2016–2019 research phase, German Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

BMVI Network of Experts (2020): Tapping potential uses of renewable energies for transport and infrastructure to a greater extent. Report on the results of topic area 5 of the BMVI Network of Experts in the 2016–2019 research phase, German Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

These reports are available in German only with executive summaries in English. These and other reports are available on the website of the BMVI Network of Experts on www.bmvi-expertennetzwerk.de/publikationen or https://www.bmvi-expertennetzwerk.de/EN, resp., and are continually supplemented by new publications.

2 Innovative Solutions in Transport Management

The expectations of the economy and society with regards to future mobility clearly reveal a need for networked, cross-modal concepts. Engineering innovations, the use of renewable energies and the introduction of new digital technologies are important tasks for the future. It is therefore crucial to develop solutions which simultaneously safeguard our environment and meet future mobility requirements.

The BMVI Network of Experts is pursuing the following avenues:

"We are identifying innovative cross-modal solutions for responding to climate change."

- As a consequence of anticipated climatic changes, more frequent and more intensive extreme weather events can also be expected to impact transport systems. The new Germany-wide maps which the BMVI Network of Experts has prepared showing high and low water levels, mass movements (such as landslides) and storms are important tools for planning transport systems going forwards. The multistage cross-modal approach of "climate impact analysis" makes it possible to leverage knowledge of climatic factors for prioritising decisions on adaptations in real-world applications.

- A transport system's ability to withstand extreme weather events without suffering serious damage can be improved by making innovative adjustments in the areas of information, regulation, management, materials and structures. Cross-modal solutions can also help achieve these goals. The BMVI Network of Experts has enabled major advances here.

"We are accelerating construction processes."

- The BMVI Network of Experts has shown that innovative approaches such as remote sensing and artificial intelligence (AI) have great potential for speeding up the processes of planning and building transport infrastructure.

- Choosing more resistant and more environmentally compatible materials will be simplified by an IT-based research platform which is being implemented within the scope of the BMVI Network of Experts.

"We are boosting the effectiveness of digital inspections of structures."

- More effective inspections are being enabled, based on new findings of the BMVI Network of Experts, by visually capturing changes in the state of building structures with the aid of innovative digital systems such as virtual and augmented realities (VR/AR).

"We are tapping the potential of areas adjacent to transport routes for serving as biotopes and sources of renewable energy."

- The BMVI Network of Experts has been able to show that areas adjacent to transport systems in Germany possess great importance as habitats, also for protected and endangered species. They also have potential for generating renewable energy around transport systems.

"We are looking more closely at pollutant emissions."

- In order to improve air quality, all transport modes (depending on location) must be addressed. The BMVI Network of Experts has found that the breakdown of pollutant emissions can vary greatly at different locations. Measures to control them must take this into account.

The pace of developments in fields such as digitalisation, remote sensing and artificial intelligence is very rapid. The BMVI is taking advantage of them to derive new insights for administrative action, which it is making available for management and operational tasks. "Knowledge" is thus transformed into "abilities" which are useful in daily or long-term strategic "action", in keeping with the motto of the BMVI Network of Experts, namely *"Knowledge – Ability – Action"*.

3 Major Insights

3.1 Adapting transport and infrastructure to climate change and extreme weather events

Robust decision-making criteria are vital for adapting our transport systems to climate change. The BMVI Network of Experts provides data, methods and information for assessing impacts of climate change on the federal transport system and develops recommendations for dealing with potential negative effects. The experts are helping to preserve and improve the transport systems' reliability, performance and ability to meet the current and future mobility requirements of Germany as a place for doing business.

Major results to December 2019

"Where and how is the transport system affected by climate change?"

- ✓ Climate impact analyses carried out by the BMVI's Network of Experts quantify the degree to which coastal and inland transport infrastructure is affected by climate change and extreme weather events. The extent to which the transport system is exposed to the impacts of flooding, low water, rising sea levels, landslides etc. will continue to increase towards the end of the 21st century.
- ✓ For the first time, an analysis has been carried out to determine the nationwide impacts of climate change on railways, roads and waterways by applying consistent scenarios and methods across different transport modes. Index maps have been prepared showing areas with increased exposure to flooding, low water, landslides and storms, which can be used to analyse the impacts of climate change on transport and other activities.

"Alternative routes are possible but time-consuming and costly."

- ✓ Passenger and freight transport via the Middle Rhine as a section of a very important European transport corridor will continue, even in highly unlikely, extreme scenarios. However, other routes or transport modes than usual come into play in these scenarios, which in turn requires the availability of sufficient additional vehicles and vehicle operators. This will result in major delays and potentially high additional costs.

"More frequent high water levels in the Kiel Canal (connecting the North and Baltic Seas)?"

- ✓ In future, climate change will also impact operations on the Kiel Canal: high water levels which today only occasionally occur and interfere with shipping and ferry traffic will presumably happen more frequently towards the end of the 21st century. Adjustment options for preventing long-term restrictions are being explored.

"Climate-proof operating rules and planning"

- ✓ Potential adaptations for offsetting expected climate changes have been analysed and described. For example, the technical standards for rail operations have been reviewed, various aspects of waterway management in coastal and inland areas analysed and the heat sensitivity of road paving materials studied.
- ✓ Adapting transport modes to future climatic conditions is of great importance for ensuring the availability of transport infrastructure and mobility. Transport infrastructure operators such as Deutsche Bahn AG and the German Federal Waterways and Shipping Administration are already applying the findings of the BMVI Network of Experts today.

"Comprehensive adaptation strategies"

- ✓ Long-term climate changes and their impacts on transport and transport infrastructure have been analysed. Stress tests based on designed extreme scenarios are illuminating how disruptive events affect regional transport. Available rerouting and buffering capacities and possible cost effects have been considered. The pilot studies are attracting considerable interest from planning units within the BMVI and will be continued on a joint basis.
- ✓ By contributing insights, data, and methods, the BMVI Network of Experts is helping to build and develop further an operational Climate Change Information Service established by the German Federal Government within the scope of the overarching "German Strategy for Adaptation to Climate Change". Among other things, this service is helping infrastructure operators plan and implement adaptation strategies for coping with climate change in compliance with new legal requirements.

Effects of climate change and extreme events on the transport system

The BMVI Network of Experts has evaluated ongoing and expected future climate changes and potential impacts on the national transport system across three transport modes, while applying a consistent climate database and methodology. For this purpose, scientists have analysed large-scale and regional climate projections and generated suitable inputs for specific climate impact models. Numerous data, indices and methods for quantifying the impacts of climate change on transport have been made available to a variety of players in that sector. In Germany, air temperatures will continue to rise and there will also be a greater tendency for the frequency and intensity of temperature extremes to increase (Figure 2). Precipitation patterns will change, resulting in more days of heavy precipitation (Figure 3). The findings also suggest that the flow conditions of rivers will change: flood discharges will increase in many river sections while low-water periods will last longer. An accelerated rise in sea levels and altered tidal dynamics (Figure 4) are also expected. Climate changes will vary both geographically and over time, thus triggering regional and seasonal differences in future impacts on railways, roads and waterways. The results have also been applied to the German government's intersectoral climate impact and vulnerability analyses, which support the development of the German Strategy for Adaptation to Climate Change.

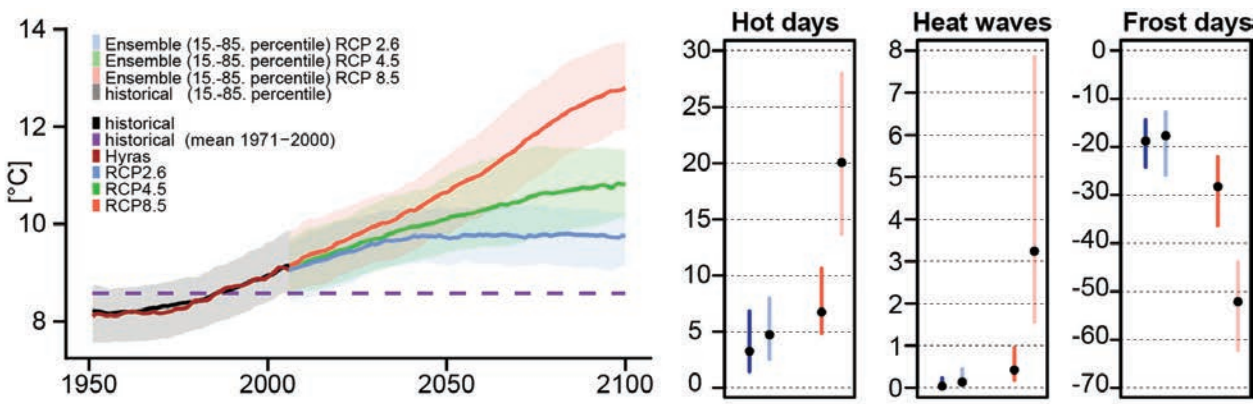


Figure 2: Mean and annual air temperatures over Germany (1951–2100 as a 30-year moving average, **left**) in a climate change mitigation scenario (RCP2.6), a moderate scenario (RCP4.5) and a business as usual scenario (RCP8.5). In each case, the ensemble median is indicated by a bold line and the bandwidth of the model ensembles as shaded areas. Changes in temperature indices (**right**) in the near (2021–2050, dark colour) and distant future (2071–2100, light colour) compared to the reference time period (1971–2000) assuming either the climate change mitigation scenario (blue) or the business as usual scenario (red).

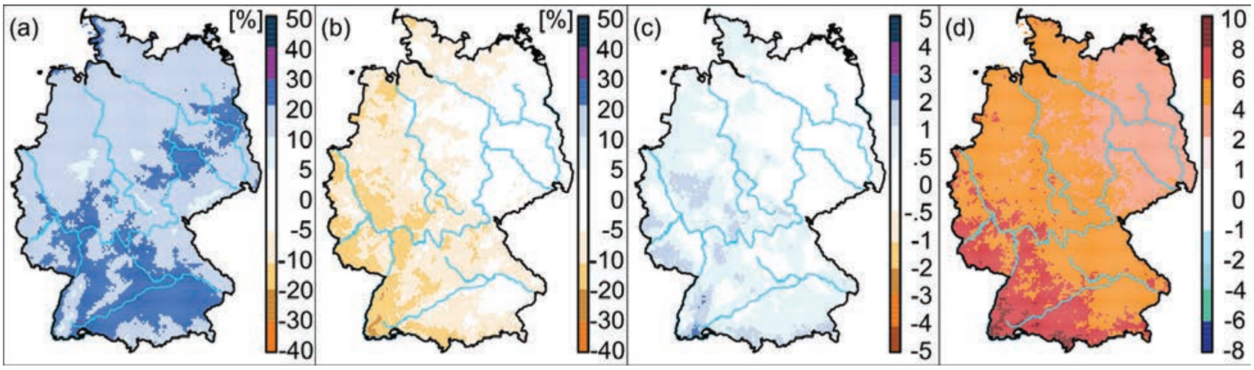


Figure 3: Changes in the median of the daily mean precipitation in winter (a) and summer (b), the number of days with heavy precipitation (> 20 mm) during winter (c) and the number of dry days (< 1 mm) in summer (d) for the business as usual scenario in the distant future (2071–2100) compared to the reference time period (1971–2000) in Germany. Changes are indicated in (a) and (b) as percentages and in (c) and (d) in days.

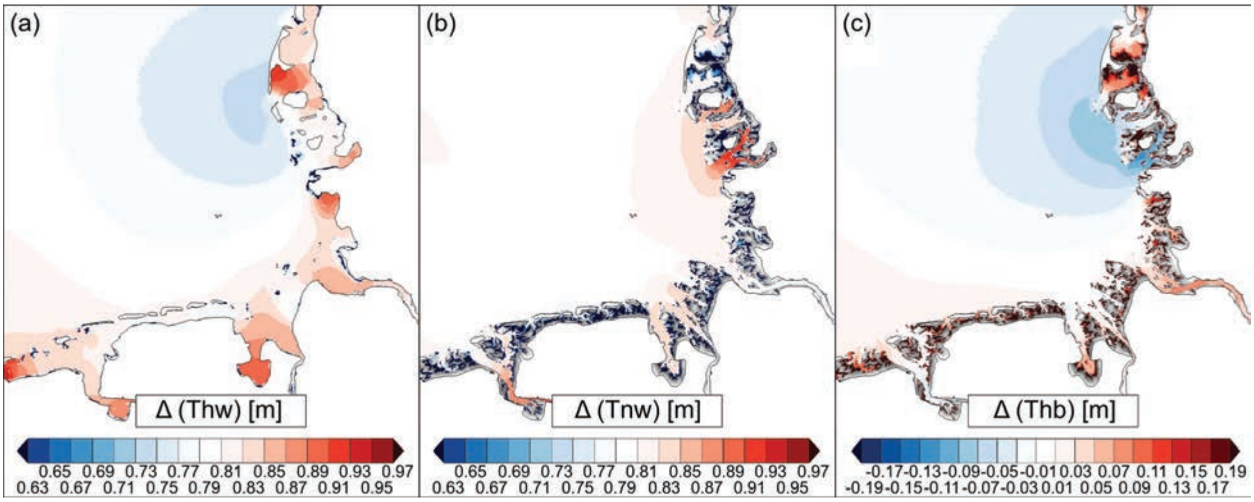


Figure 4: Changes in high (Thw) (a) and low tide levels (Tnw) (b) and tidal range (Thb) (c) relative to a sea level increase of 0.8 m. These are the results of hydrodynamic sensitivity experiments for the German Bight.

To what extent is climate change adversely affecting roads, railways and waterways?

Although rail, road and waterway transport activities are strongly interlinked, they are affected by climate change in different ways. Decisions on possible adaptations call for approaches that are comparable for all three modes. For the first time, the BMVI Network of Experts has established a consistent basis for projecting how future climate changes will affect transport conditions. Analyses of the effects of climate change apply a general three-step evaluation scheme and are based on the same climate change data:

1. Exposure analysis: The first step is to analyse spatial variations in climatic impacts (Figure 5), for example the exposure of railways to strong winds.
2. Sensitivity analysis: In the second step, the susceptibility of infrastructure to specific climatic impacts is identified. For example, electrified railway sections are more vulnerable to storms due to the presence of overhead wires.
3. Criticality analysis: The third step is to determine the relative importance of individual sections within the context of the overall system. It can be assessed, for example, which sections are

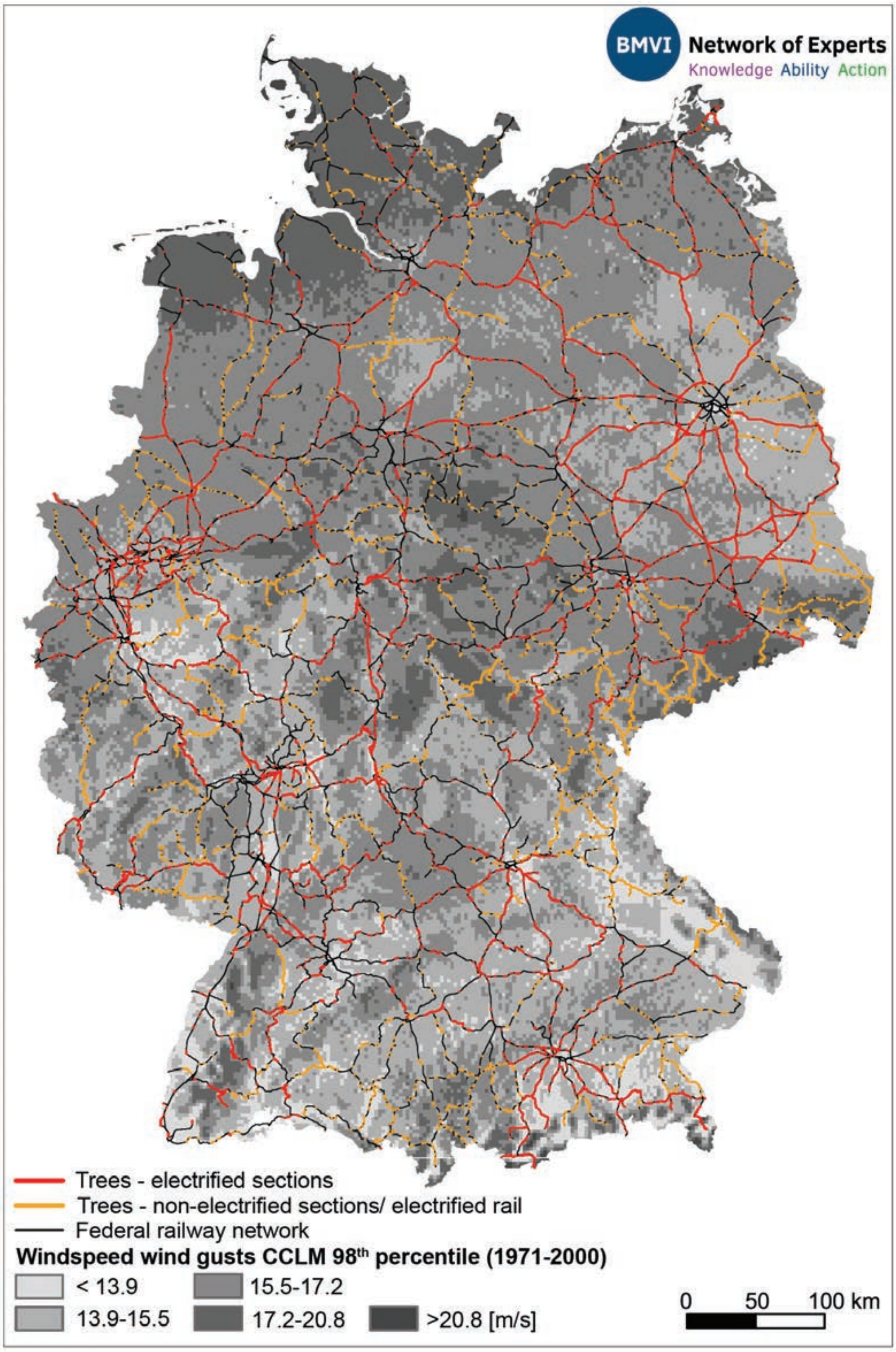


Figure 5: Map showing the current exposure and sensitivity of the national railway network to windthrow at high wind speeds (98th percentile) in a climate simulation run (CCLM). Rail routes are depicted by black lines. Lines with trees along unelectrified sections are displayed in yellow, and those with trees along electrified sections in red.

particularly critical with regard to freight and passenger transport in the event of climate-induced interruptions.

Climate impact analysis (see the example of low flow and navigation in Figure 6) helps prioritise possible adjustments. Index maps highlighting increased exposure to specific climatic impacts or influences are being developed within the BMVI Network of Experts and already used in practice. Some analyses have been carried out on a national scale (showing storms, river floods, low water levels and mass movements such as landslides), while others have focussed on specific regional effects (e.g. along the Lower Rhine, the Elbe, the German Bight, and the Kiel Canal).

How resilient is the transport system to extreme weather events?

In addition to evaluating changes in mean levels, analyses have also been carried out to determine the transport system's exposure to individual extreme weather events. The scientists have devised scenarios in which transport flows are heavily affected by extreme, long-lasting events such as flooding, low water or landslides. Studies have focussed, for example, on the area of the Middle Rhine, which is an important part of the European Rhine-Alpine transport corridor. Here, the redistribution of traffic flows on roads, railways and waterways has been modelled assuming the failure of between one and all three transport modes. In the designed extreme scenarios, this has revealed extensive impacts on transport flows, including ad hoc route changes within the same transport mode, shifts to another transport mode and significant delays. The costs of transport also increase considerably in some cases.

The scenario of a 180-day low-water event would be associated with substantial shifts of transport volumes from waterways to railways and to some extent also to roads. Over its entire duration, this scenario generates the highest additional costs. A flooding event lasting three weeks with simultaneous blocking of railways, roads and waterways would stress the transport system of the Middle Rhine to a greater extent than the other studied scenarios, in which only one or two transport modes are affected. This is reflected, among other things, in the greatest increase in daily transport costs. Across all scenarios, under the assumed conditions (which in reality do not always occur) affected passenger and freight transports can often only be

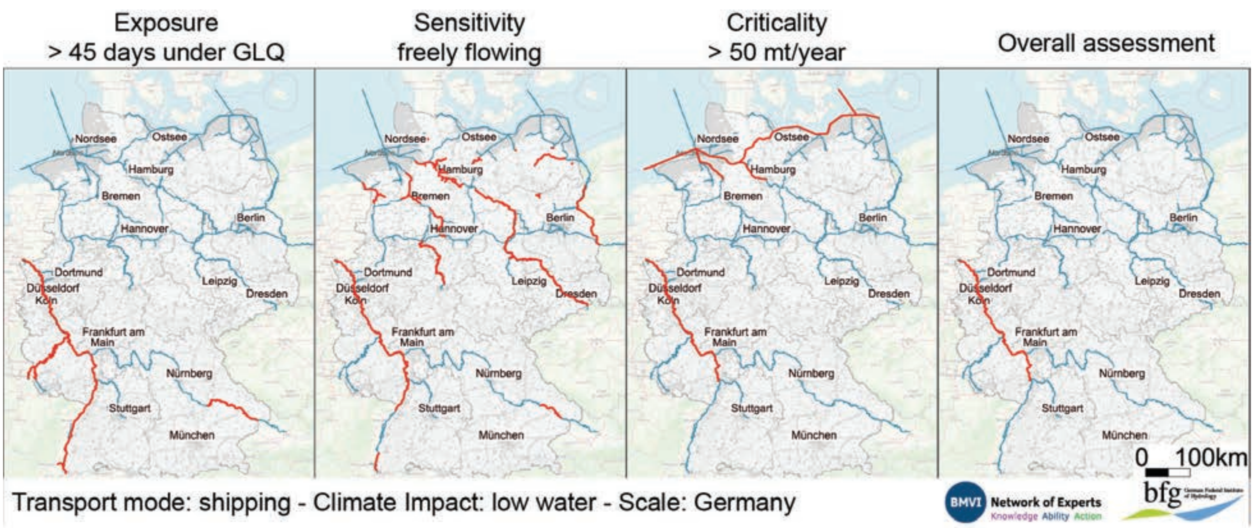


Figure 6: An integrated climate impact analysis for the German federal waterways addressing the causal chain "drought → low flow → insufficient depth → reduced draught" assuming the *business as usual scenario in the distant future* (2071–2100). The red lines in the rightmost panel (integration) indicate parts of the waterway network which are classified as priority regions by intersecting individual analyses of exposure (number of days of low water below the critical "GlQ" threshold, left), sensitivity (freely flowing river sections, left-centre), and criticality (freight volumes, right-centre). GlQ: design low-flow discharge.

successfully completed with considerable additional costs and resources such as vehicles or hub capacities.

Another case study explored the effects of climate change on the operation of the Kiel Canal. This is an important shipping route which also drains large parts of the state of Schleswig-Holstein. It is affected by climate change both where it meets the sea (e.g. due to changes in sea level and tidal dynamics) and inland (e.g. due to changed precipitation and runoff). In the past, when high outer water levels have coincided with heavy and/or persistent precipitation within the canal's catchment area, this has occasionally caused such high water levels in the canal that it has been necessary to reduce or halt shipping and ferry traffic. Towards the end of the 21st century, situations of this type will presumably occur more often. The BMVI Network of Experts is therefore developing possible adaptation options.

Options for making the transport system more robust

Today the transport sector already possesses a variety of adaptation options for dealing with the consequences of climate change. Adaptation types involve information services tailored to users, technical standards, engineering measures, and traffic and infrastructure management measures. With regard to expected climatic trends, however, some technical standards and measures need to be revised and the available toolkit enlarged. The BMVI Network of Experts has developed new ideas for all of the mentioned areas. For example, it reviewed 59 technical standards on the maintenance of railway systems. The analysis looked at 1650 entries, about 20% of which were found to be in considerable need of adjustment to take expected climatic changes into account.

Where asphalt surfacing of roads is concerned, studies have been carried out to identify ways of modifying the materials used in order to, for example, prevent ruts from forming, which otherwise reduce roads' useful lives when these are subjected to greater thermal loads during the summer months. There is also potential for improving the situation by utilising lighter-coloured road surfacing to reduce its temperature, or by using asphalt with reduced thermal conductivity in binder and base courses.

A case study was carried out on the Lower Rhine to identify appropriate maintenance and improvement measures for waterways in response to changed flow rates, especially when water levels fall excessively (Figure 7). It is becoming apparent that when severe low-water events occur, the conventional ways of responding to these situations, such as dredging, are running up against their limits and giving way to other approaches.

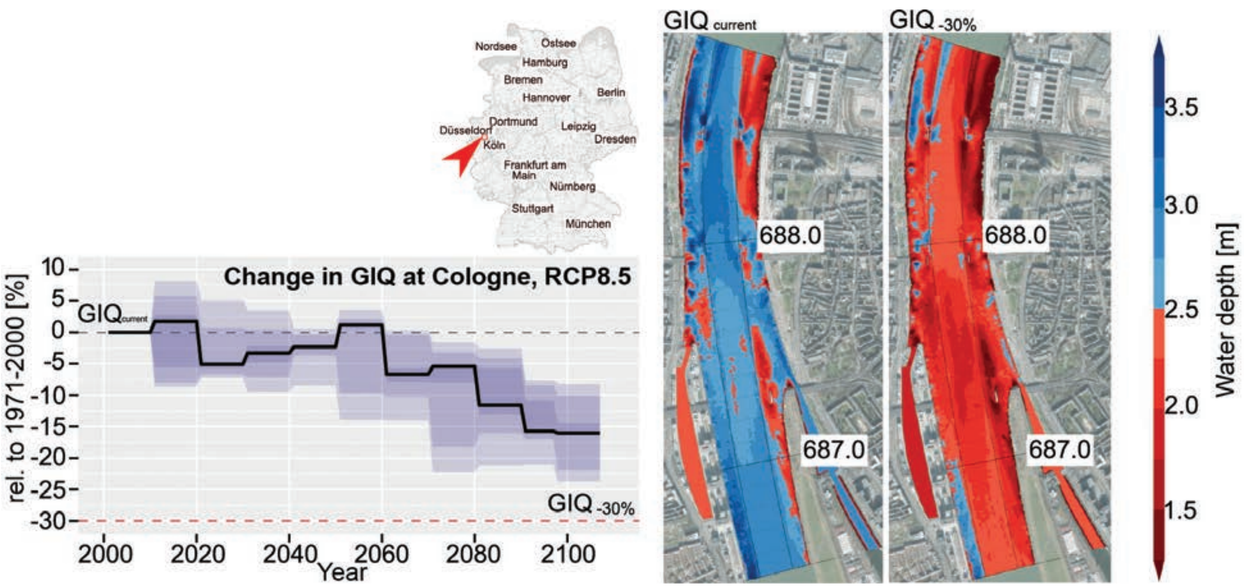


Figure 7: **Left**: Projected development of low-water runoff ("steady flow" parameter for waterway maintenance and improvement) in the business as usual scenario (RCP8.5, incl. margin of uncertainty). **Right**: Calculated water depths around the Deutzer Platte (a shallow stretch in the Rhine near Cologne) for GlQcurrent and GlQ-30% (extreme scenario for the late 21st century). At a greatly reduced GlQ, the guaranteed minimum water depth of 2.5 m in the shipping channel is no longer ensured over a large area. The broken lines indicate the shipping channel (lengthwise) and its breakdown in hectometres (crosswise) (aerial photograph: German Federal Agency for Cartography and Geodesy).
GlQ: design low-flow discharge.

3.2 Designing environmentally appropriate transport and infrastructure

A sustainable transport policy meets both growing mobility needs and environmental protection requirements. One of the special abilities of the BMVI Network of Experts is developing tailored approaches for evaluating and mitigating environmental impacts for all transport modes and generating new insights which can be applied to safeguard the environment more effectively.

✓ Major results to December 2019

Biodiversity: areas alongside transport routes can be put to good use!

- ✓ It has been possible to show that areas adjacent to transport routes possess enormous, hitherto untapped potential for serving as biotopes within our landscapes, also for protected and endangered species. This potential can be taken advantage of to a greater extent for preserving and enhancing biodiversity (e.g. by protecting insect species).
- ✓ It has been shown that cross-modal approaches hold particularly great promise for this. Corresponding concepts are therefore now being developed.
- ✓ Appropriate measures which can be applied across transport modes are now being implemented to promote biodiversity by networking habitats.

Invasive non-native species: "stowaways"

- ✓ For the first time, invasive non-native species inhabiting areas adjacent to transport routes have been catalogued and the ecological threats they pose assessed.

- ○ Measures able to minimise the negative impacts of invasive species have been identified for transport routes.
- ○ The CASPIAN dispersion model has been developed for predicting the potential spread of neobiota via transport routes and traffic.
- ○ A Web-based neobiota information system has been developed and made available.

Protection from corrosion: useful life prolonged!

✓ The causes of premature delamination of protective coatings on steel structures have also been illuminated by simulating the exposure of epoxy coatings to weather conditions.

- ○ The useful life of coatings applied to steel structures can be significantly extended by preventing the intermediate epoxide layer from being exposed to the weather. The required measures have already been incorporated into the corresponding technical standards.

System to support the selection of environmentally compatible, long-lasting building materials

✓ In future, both users and experts at building authorities will be able to use a new IT system to search for appropriate eco-friendly, long-lasting building materials as soon as the newly developed approach has been implemented.

Air pollutants: identifying sources and recommending targeted measures

✓ The findings of a transport mode-specific analysis of traffic emissions in major German metropolitan areas are now available.

- ○ An analysis carried out on pollutant emissions shows that the contribution of railways, roads and waterways can vary greatly from site to site. These findings underscore the need to employ transport mode-specific measures instead of generalised approaches or prohibitions.

Traffic noise: a new tool for assessing noise levels when multiple transport modes coincide

✓ This guide describes a method for considering the overall noise caused by all transport modes. It can be applied in noise abatement projects when there is more than one source of noise. It has been shown that cross-modal approaches are particularly promising for this. Appropriate concepts are now therefore being developed.

Identifying “green potential” and promoting biodiversity

Transport routes divide originally contiguous habitats with negative consequences for plants and animals. Territories are carved up, rendering migratory corridors impassable. Roads, train tracks and waterways are not solely obstacles, however; they can also connect different parts of the landscape. Particularly areas alongside transport routes, which account for approximately 3% of Germany’s total land area (by way of comparison: national parks make up only 0.6%) and therefore possess enormous “green” potential for maintaining and increasing biodiversity (Figures 8 and 9). The studies carried out in the BMVI Network of Experts show that areas adjacent to routes of the three most important transport modes, namely roads, railways and waterways, exhibit large similarities in terms of the communities of species which occur in them. Overall and across regions, this applies both to habitats and to animal and plant species. There is therefore great potential for increasing connectivity here. A comparison of the manuals used by personnel of different transport modes for maintaining these areas reveals that a wide variety of suitable measures exist for promoting biodiversity and can be successfully applied across transport modes. This potential can be tapped to an even greater extent and make a major contribution to boosting biodiversity throughout Germany.

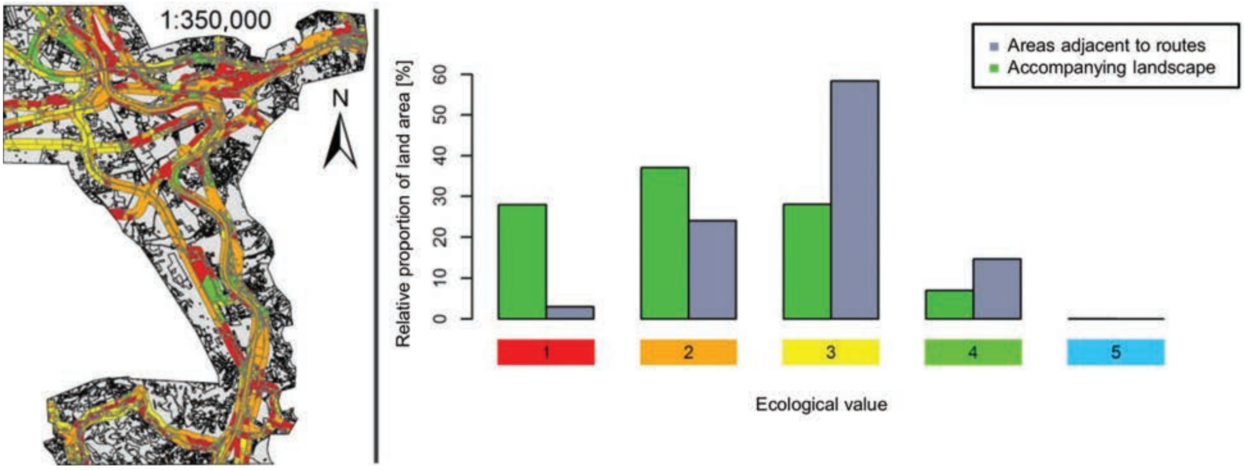


Figure 8: Ecological value of areas adjacent to transport routes and accompanying landscapes. Left: Map of the studied area. Right: Classification of the biotopes of areas adjacent to transport routes and accompanying landscapes on the basis of size. Level 1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high (Map basis: OpenStreetMap).

Figure 9: Linear arrangement of transport routes (railways, waterways and motorways) and adjacent areas along the river Saar near Fremersdorf (photograph: German Federal Institute of Hydrology).

Understanding and mitigating the spread of invasive non-native plant and animal species via transport routes

Invasive neobiota are plant or animal species which are not native to Germany and have only succeeded in becoming established there as a result of human activities. They negatively impact indigenous species, communities or biotopes and are regarded as one of the greatest threats to the diversity of indigenous species. Nor is that all, some of the species also directly inflict economic damage and harm human health. Transport and transport infrastructure play a major role in helping invasive species to spread, allowing them to hitch rides on cars, lorries, trains, ships or planes as "stowaways". For the first time, the BMVI Network of Experts has systematically searched for and identified numerous neobiota on the hulls of inland vessels and recreational boats as well as in harbours and in areas alongside transport routes. As measures to eliminate already established invasive species are quite personnel-intensive and costly to implement, it is important to take proactive action to limit their dissemination. The BMVI Network of Experts has therefore developed a new model which forecasts how fast neobiota are likely to spread along which transport routes (Figures 10 and 11). In future, a Web-based neobiota information system will provide early warnings which make it possible to preventively combat invasive species considerably earlier than is now the case.

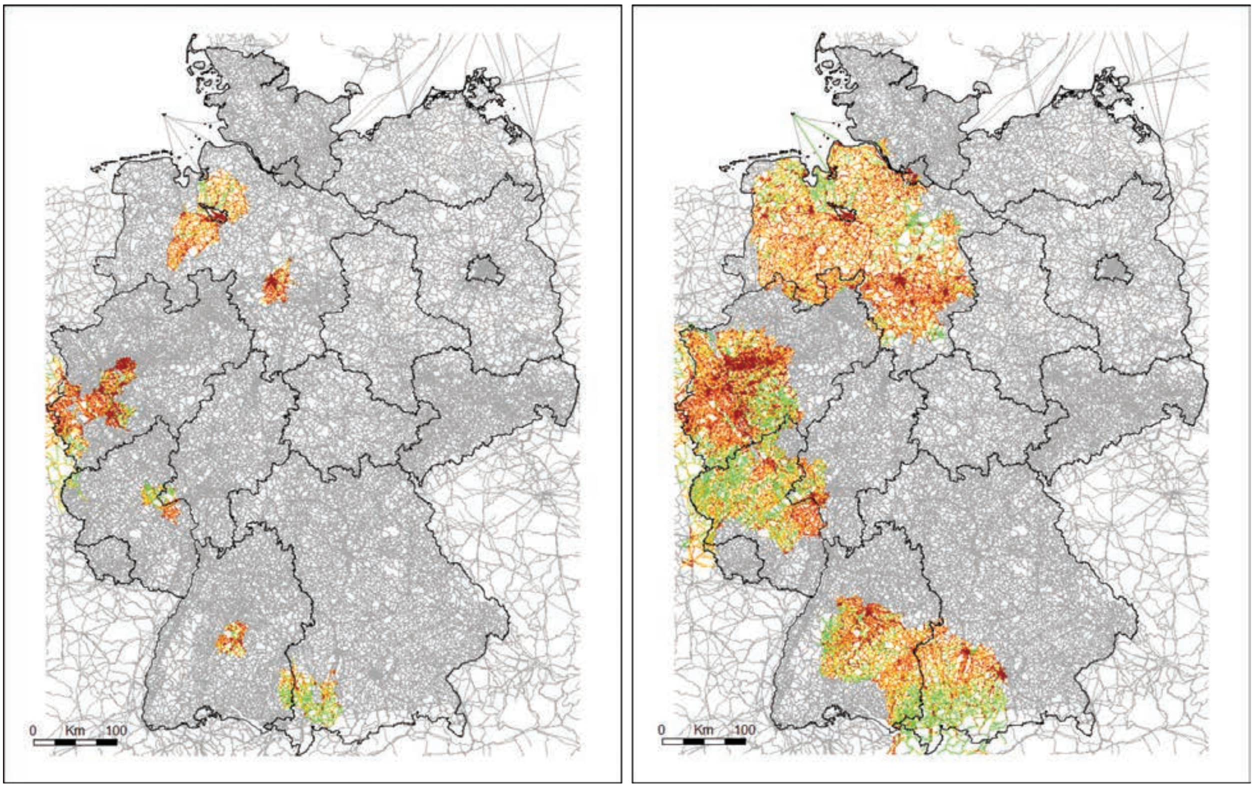


Figure 10: Simulation of the spread of the South African ragwort (Senecio inaequidens) via roads and railways after four months (left) and five years (right). Green: low probability of invasion, red: high probability of invasion (map from OpenStreetMap).

Figure 11: South African ragwort (photograph: German Federal Institute of Hydrology).

Detecting pollutant sources and recommending targeted measures

Air pollutants emitted by traffic are harmful to health and the environment, and it is important to reduce them as mobility increases over the years ahead. The BMVI Network of Experts has used radio-and satellite-assisted traffic data to analyse in detail the emissions of individual transport modes (e.g. lorries, inland shipping, railways and seagoing vessels). In addition, pollutant emissions in the Hamburg, Duisburg and Frankfurt am Main metropolitan areas have been analysed while applying a complex modelling approach. The results show that when air pollutants exceed the permissible limits it is virtually impossible to ascribe this to individual types of transport. Rather, the cause is predominantly a combination of greatly varying emissions from shipping, road traffic, aircraft and trains (Figure 12). It follows that targeted measures must be developed locally in each individual case instead of relying on large-scale approaches.

Alongside air pollution, noise emissions from transport are also relevant. Many people in Germany feel constantly bothered by noise from transport. Traffic-related noise sources are characterised by differing frequency spectra, which need to be taken into account for determining overall noise levels (Figure 13). The BMVI Network of Experts has studied various representative areas in a model city with the goal of deriving measures for reducing noise from multiple sources.

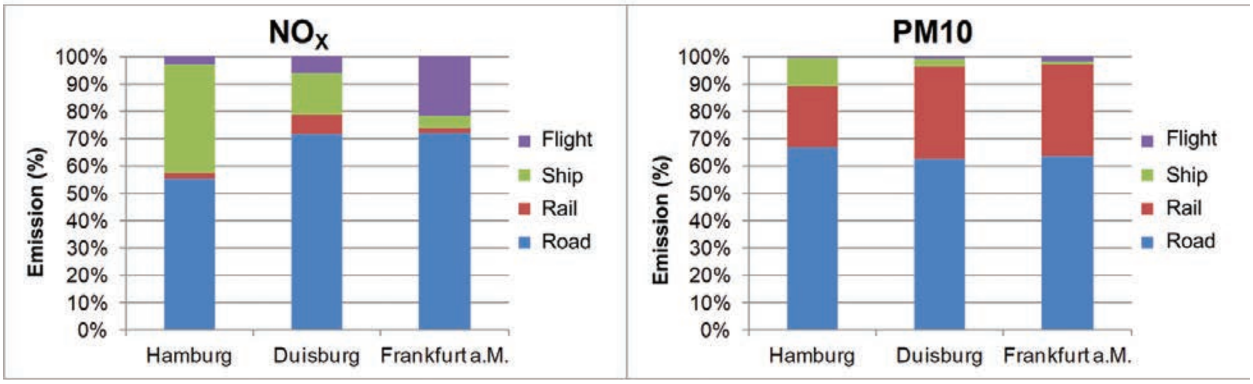


Figure 12: Shares of emissions of different types of transport in three metropolitan areas (Hamburg, Duisburg and Frankfurt am Main) in 2016: nitrogen oxides (NOx, left) and fine dust particles with an aerodynamic diameter less than 10 micrometres (PM10, right).

Figure 13: Noise measurement on the Rhine at Koblenz (photograph: German Federal Institute of Hydrology).

Facilitating the choice of environmentally sound materials

Structures forming part of the transport infrastructure are subjected to considerable stresses as a result of weathering and use-induced wear. This causes damage to the structures themselves, but also releases substances whose environmental impacts are unknown. The BMVI Network of Experts has succeeded in shedding more light on the causes of premature degradation processes (Figure 14) in surface coatings which are frequently used on steel supporting structures. Targeted measures which have been jointly developed by scientists and users can significantly prolong the useful life of surface coatings of steel structures used in roads and bridges as well as in waterways. These recommendations of the BMVI Network of Experts have already been adopted in practice and incorporated into the corresponding manuals. In addition, the BMVI Network of Experts has laid the foundation for creating a decision-making system which will help users choose long-lasting, environmentally friendly building materials for specific purposes. The system will provide information on their durability and the release of environmentally relevant substances, in addition to warnings on hazards associated with their installation or use.

Figure 14: Damage to a bridge abutment with delamination of a blue polyurethane coating (photograph: German Federal Highway Research Institute).

3.3 Increasing the reliability of transport infrastructure

Growing traffic volumes, ageing of transport infrastructure, climate change and extreme weather conditions, along with high quality expectations despite limited budgets, pose enormous challenges in transport infrastructure management. The BMVI Network of Experts is merging innovative approaches drawn from the transport modes of railways, roads and waterways to identify and exploit possibilities for improving inspections of existing structures, evaluating their reliability and speeding up construction work. It is thus also making a contribution to ensuring a reliable and resilient transport system going forwards. So far attention has focused on engineering structures and integrating the individual systems into an overarching network.

✓ Major results to December 2019

Inspection and maintenance of structures: supplementary tools which keep pace with the times

- ✓ Remote sensing, artificial intelligence and trained neuronal networks are available for speeding up inspections of infrastructure.
- ✓ Effective and economic "smart repair" methods have been developed for anticorrosion coatings used on steel waterway structures.
- ✓ Workshops and e-learning methods are being used to train staff of the German Federal Waterway and Shipping Administration in "smart repair" methods. These are attracting great interest from users, who are enabled to apply their newly acquired knowledge in practice.

Evaluation framework for a more robust transport system

- ✓ A cross-modal conceptual evaluation framework has been developed to increase the resilience of the transport system to adverse events such as extreme weather phenomena (e.g. caused by climate change).
- ✓ A guide and a user-friendly software-based tool are available to support the road construction administration.

Greater standardisation of bridges

- ✓ Proposals by the BMVI Network of Experts for greater standardisation of railway bridges up to 16 m long are being incorporated into a new edition of the corresponding guideline of Deutsche Bahn.

Use of drones and artificial intelligence for inspecting structures

Although it is important to regularly inspect engineered structures to ensure they are safe, it is a very work-intensive activity. This is especially true of “hands-on” inspections in which engineers directly look at all parts of a structure in order to, for example, detect and assess cracks. The BMVI Network of Experts has carried out case studies in which state-of-the-art remote sensing and artificial intelligence technologies are combined to ascertain the condition of structures more efficiently and effectively. Flight paths and camera positions for drones were automatically generated (Figures 15 and 16) to quickly obtain digital images of all relevant parts of structures with a minimum of personnel. Neuronal networks were trained to scan images and automatically identify any damage (Figure 17). This is excellent preparation for direct inspections and lets them be carried out considerably faster.

Figure 15: The use of drones greatly simplifies the work of determining the condition of structures. Shown here: a drone being used at the Koblenz weir on the river Mosel on 27 November 2018 (photograph: German Federal Waterways Engineering and Research Institute).

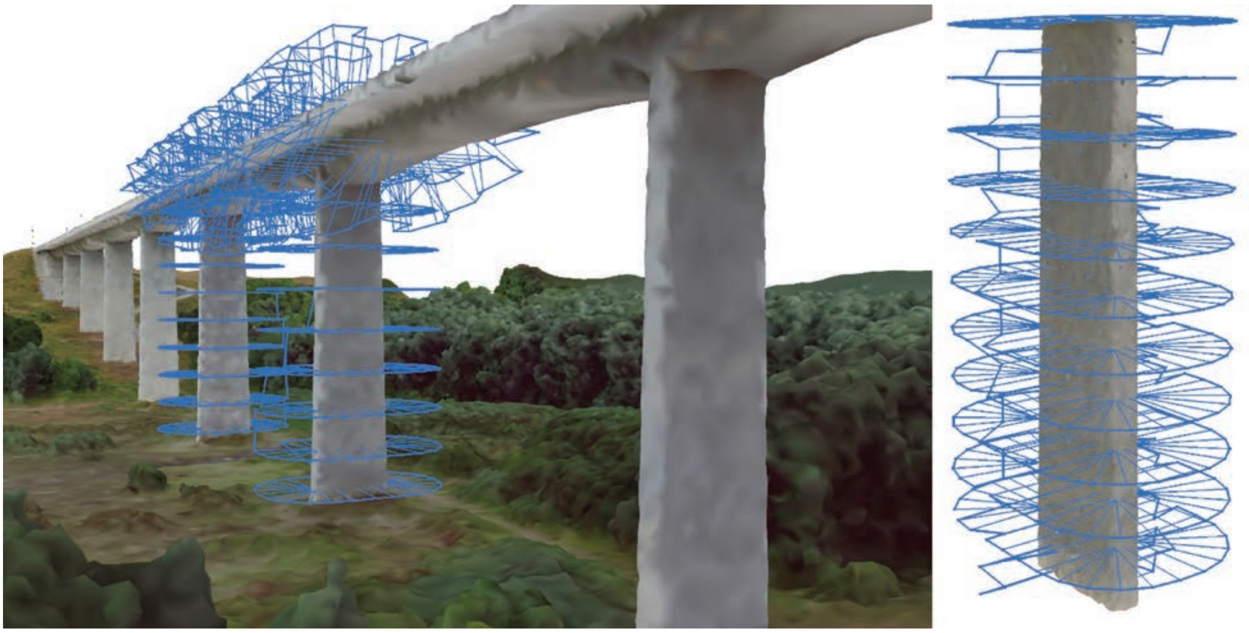


Figure 16: Flight paths for drones can be automatically generated. This makes it possible to optimise the location and orientation of photographs. Lessons learnt from field trials were combined with methods used in building construction and remote sensing (photograph: Morgenthal et al.[3]).

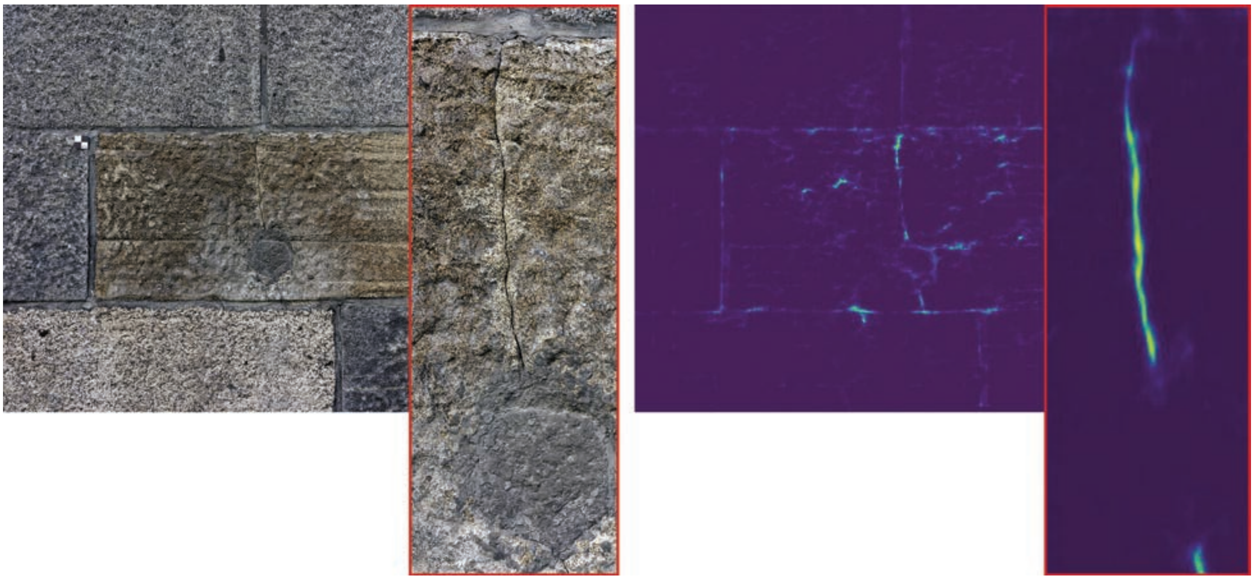


Figure 17: Automatic image analysis with artificial intelligence makes it easier to detect and locate damage. Shown here: a crack in a bridge pile (photograph: Morgenthal et al.[3]).

3 Morgenthal, G.; Rodehorst, V.; Hallermann, R. Supported inspection as per DIN 1076 with (semi-)automatic image evaluation, also by unmanned aerial vehicles (UAVs). Final report on FE 89.0334 for the German Federal Highway Research Institute (BASt).

Ready for emergencies

In a transport system, “disruptive events” can cause disturbances and interrupt traffic. These can include accidents, fires and also extreme weather events, which are expected to occur more frequently in future as a consequence of climate change (see section 3.1). The goal of transport infrastructure management is to design transport systems to be “resilient”, in other words resistant, to such events. The BMVI Network of Experts is helping to achieve this goal by creating a conceptual evaluation framework for all transport modes and systematically advancing the development of methods. For example, a methodology for roads has been developed for analysing the resilience of existing transport infrastructure and determining the effectiveness and cost-benefit ratio of possible measures. For railways, for example, worthwhile changes to current regulations have been identified against the background of extreme meteorological events. In the case of waterways, improved methods for generating short-term advance warnings (“nowcasting”) have been tested. These enable predictive control of barrages to protect transport infrastructure when there is heavy precipitation.

Speeding up construction work with innovative methods and standardisation

The bar is set very high for the availability and reliability of transport infrastructure. It is essential to minimise the amount of time during which its use is suspended or considerably reduced in order to carry out maintenance or new construction work. In addition, it is important to optimally utilise available resources while taking into account the overall life cycles of different structures. The BMVI Network of Experts is addressing these aspects by working to develop further efficient and innovative construction and repair approaches and making contributions to comprehensive life cycle management.

Efficient and cost-effective “smart repair” methods for anticorrosion coatings developed for steel hydraulic structures can now be implemented at an early stage by those responsible for maintenance without the need to rely on external service providers (Figure 18). This makes it possible to significantly reduce the frequency of servicing and repair work and considerably prolong the useful life of steel structures. For railway bridges over roads with lengths up to 16 m (accounting for 80% of the total), suggestions have been made for more extensive standardisation, among other things. The mentioned cross-modal collaboration has created a basis for sharing and fine-tuning lessons learnt in

Figure 18: Smart repair. Accelerated ageing and increased corrosion of test plates of many different materials with a variety of anticorrosion coatings was simulated by continuously subjecting them to salt spray. The large body of information generated in this way now makes it possible to quickly identify the best repair method, thus simplifying and speeding up the repair and maintenance of steel parts (photographs: German Federal Waterways Engineering and Research Institute).

connection with railways, roads and waterways. The goal of reducing the duration and frequency of closures is now much closer to being achieved as a result.

Practical relevance

The first steps have already been taken for putting what has been learnt from the described activities into practice. Recommendations on assessing resilience and measures for improving the response and restoration phases for road traffic infrastructure subsequent to disruptive events have been formulated and incorporated into a guide for road construction administrations. What has been learnt in connection with model-based predictive barrage control has been applied for improving the control structure of a barrage on the river Neckar. It may also be worthwhile to apply similar processes for managing railways better.

3.4 Consistent further development and use of digital technologies

The research approach taken by the BMVI Network of Experts and its partners' wide-ranging knowledge provide a space and incentive for jointly exploring new applications for digital technologies. The cross-institutional work processes of the government bodies collaborating in the BMVI Network of Experts are not all which stands to benefit from the work being done in the fields of Big Data, virtual and augmented reality standardisation, automation and autonomisation. By learning from one another and consistently developing new digital technologies, the participants are also generating new ideas for the transport system and mobility as a whole.

The term “Big Data” refers to very large data volumes which greatly exceed current processing capabilities. The challenge in connection with Big Data is to evaluate datasets which in many cases are present in more than one data medium or computer, change rapidly and have mutually incompatible structures.

“Virtual reality” and “augmented reality” refer to possibilities which let people visually perceive digital data. In virtual reality, everything is virtually depicted, in other words also one's surroundings. In the case of augmented reality, information is inserted into the user's field of vision, typically with the aid of a special headset.

Another topic of importance for the future is autonomous transport. In the case of automated, and eventually autonomous, shipping, for example, interconnection of onboard systems and exchanging of information with digitalised maritime infrastructure on land are important prerequisites for increasing safety and environmental friendliness by optimising onboard processes and traffic at sea and on waterways. Of crucial importance here is, once again, standardisation of data formats to ensure effective exchanging of information between the individual systems and applications.

Major results to December 2019

Digital technologies prepared for practical use

- ✓ The BMVI Network of Experts has contributed to applying current digitalisation themes to complex processes for planning, operating and inspecting transport systems.
  - Complex flight weather data have been integrated in a standards-compliant and machine-readable format for a global initiative to harmonise the exchange of aeronautical, weather and flight information for all airspace users and stakeholders ("SWIM" or System Wide Information Management).

Practical benefits of digital trends assessed

- ✓ Current trends and potential in the field of automated and autonomous shipping have been analysed and current challenges assessed.
  - Networking of onboard systems and exchange of information with digitalised maritime land infrastructure are prerequisites for achieving increasingly automated and, eventually, fully autonomous shipping to increase safety and environmental friendliness at sea by optimising onboard processes, such as by appropriately controlling engines to reduce fuel consumption and improve transport processes.
- ✓ The efficiency of inspection processes is boosted in connection with maintaining infrastructure by making it possible for new digital systems to capture changes in the state of structures.
  - “Big Data”, “virtual realities” or ”augmented realities”, “System Wide Information Management” and “building information modelling” can contribute to the acceleration, quality control, integration, automation, and autonomisation of many process steps in the transport sector.

Speeding up data flows and workflows with Big Data technologies and standardisation

It is not uncommon for collaboration across institutional boundaries to be hindered by the use of different data formats. In the context of interdisciplinary research, this can be due, for example, to the development of a wide range of different software, in part for special research activities. The BMVI Network of Experts has analysed the current situation and the potential of the participating government institutions. In addition to improving some internal processes, a highly promising approach is mutual learning within a network in conjunction with processing of large data volumes. Some data processing approaches involving standardised tools have been developed in connection with “Big Data” applications. Standardising interfaces between systems is another key to managing transport more efficiently. The benefits of harmonised data exchange were first demonstrated for air transport. Specifically, it proved possible to integrate complex weather data in a standard-compliant and machine-readable format for use in a newly created flight data infrastructure ("SWIM" – System Wide Information Management) along with improved data exchange techniques.

Tapping innovative trends for transport-related processes

Advances in the transport sector have always been highly technology-driven. The BMVI Network of Experts has studied current trends in the context of digitalisation and illuminated their potential with various examples. For example, virtual simulated or enhanced realities can be very useful when technologies are employed to make it easier to grasp complex data structures (e.g. simulation results) or to make it possible to quickly understand and absorb a variety of information. In doing so, the BMVI Network of Experts has analysed how augmented reality and virtual reality technologies can help improve the efficiency of inspection processes in connection with maintaining infrastructure by visually presenting relevant data on a structure and changes in its state to the responsible specialists.

Another topic of importance for the future is the autonomisation of transport. A survey of autonomous shipping by the BMVI Network of Experts revealed great potential for improving safety at sea and the environmental friendliness of shipping. As more processable information becomes available, it is anticipated that automated systems will, in the long run, make better decisions which will in turn lead to fuel savings.

In the field of infrastructure management, the topic of “building information modelling” (BIM) has great potential. This is a method for network planning, executing and managing structures with the aid of software. This instrument is primarily geared to building construction projects, but will also be extended to include transport structures based on a strategy developed by the BMVI. The BMVI Network of Experts has identified steps with which BIM can be developed further in the direction of a single unified system for managing structures throughout the transport network.

Practical relevance

The first steps for making the insights from the above-mentioned activities usable in practice have already been taken. Recommendations for revising the rules on automated driving on railways and waterways have been drawn up and discussed by the responsible technical bodies. For standardising data storage and transmission, an internationally developed proposal (SWIM) has been supported and defined. The data storage practices of various institutions have also been surveyed, giving rise to initial ideas for cross-institutional sharing of data.

Figure 19: A high-performance mainframe computer (photograph: the German Federal Waterways Engineering and Research Institute)

3.5 Tapping and utilising renewable energy sources for transport and infrastructure

Climate protection has been integral to efforts to achieve sustainability since prior to the signing of the Paris Agreement of 2015. Also, with regard to transport, which accounts for about 20% of Germany's greenhouse gas emissions (in 2019[4]), it is vital to continue searching for ways to utilise energy more efficiently and increase the share of renewable energy sources. The German Climate Action Plan 2050[5] and the German Climate Protection Programme 2030[6] launched by the German Federal Government underscore the importance of cutting down on greenhouse gas emissions. As the BMVI is involved in a wide range of relevant initiatives, the BMVI Network of Experts has paid special attention to analysing the aspects of transport infrastructure and operation.

✓ Major results to December 2019

Potential uses for renewable energy systems revealed

- ✓ The suitability of new, high-resolution climate data sets for practical economic feasibility analyses was demonstrated.
- ✓ Taking a perspective across multiple transport modes is helpful for identifying potential uses of renewable energy sources for transport and infrastructure.

Paths towards climate-friendlier transport management

- ✓ There is considerable potential for using renewable energy in transport systems. For example, the share of renewable energy used to operate the pumps on the Elbe Lateral Canal and the Mittelland Canal would increase from 14% to over 99% if, in addition to surfaces of local facilities of the German Federal Waterways and Shipping Administration, photovoltaic panels were also installed on noise barriers along nearby roads.
- ✓ Possibilities for and barriers to increasing the climate-friendliness of vehicle fleets have been revealed. The cost-effectiveness of battery-powered drives compared to conventional diesel engines largely depends on the extent to which self-generated electricity is used, as no grid charges and associated taxes and fees must be paid for the latter.
- ✓ The presented possibilities for climate-friendly developments in the areas of transport (e.g. service vehicle fleets), transport operation (e.g. optimised control of the damming of shipping canals) and transport infrastructure are driving current initiatives such as one to make the German Waterways and Shipping Administration climate-neutral as well as a programme of the Federal Highway Research Institute to encourage innovations in which road maintenance services are also involved as stakeholders.

4 BMU (2020). Klimaschutz in Zahlen – Fakten, Trends und Impulse deutscher Klimapolitik (Climate Protection in Figures). German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Berlin (available in German only).

5 BMU (2016). Roadmap to a climate-neutral Germany. Climate Action Plan 2050 – Germany's long-term low greenhouse gas emission development strategy. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Berlin.

6 BMU (2019). Climate Action Programme. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Berlin.

Optimising energy consumption on the basis of detailed analyses of requirements

Railways, roads and waterways all share a need for sufficient energy in order to manage and maintain their infrastructure and continue operating. Before steps are taken to optimise their energy consumption or take advantage of renewable energy, it is necessary to know in detail how and when energy is mainly consumed and the possibilities for reducing this consumption. The cross-modal study approach of the BMVI Network of Experts has made it possible to shed considerable light on these aspects.

Where roads are concerned, the energy consumption of various facilities, including motorway maintenance facilities (power, heat and fuel) and traffic control centres (power) was examined. It emerged that motorway maintenance centres consume more energy, with more frequent peaks, in the winter months. In the case of waterways, attention focused on analysing the energy requirement of selected pumping plants. In contrast to roads, these consume less energy in the wintertime. Regarding railways, analysis of the needs of passenger stations revealed a need to optimise larger passenger stations on a case-to-case basis, while it is sufficient to develop a standard approach for smaller stations. Thanks to the work of the BMVI Network of Experts, decision-making processes for achieving more efficient energy use can now take greater account of cross-modal aspects.

Utilising transport infrastructure for generating renewable energy

The BMVI Network of Experts is supporting ongoing BMVI initiatives like the one to make the Federal Waterways and Shipping Administration climate-neutral by reducing emissions of greenhouse gases in the transport sector. Germany's railway, road and waterway networks and

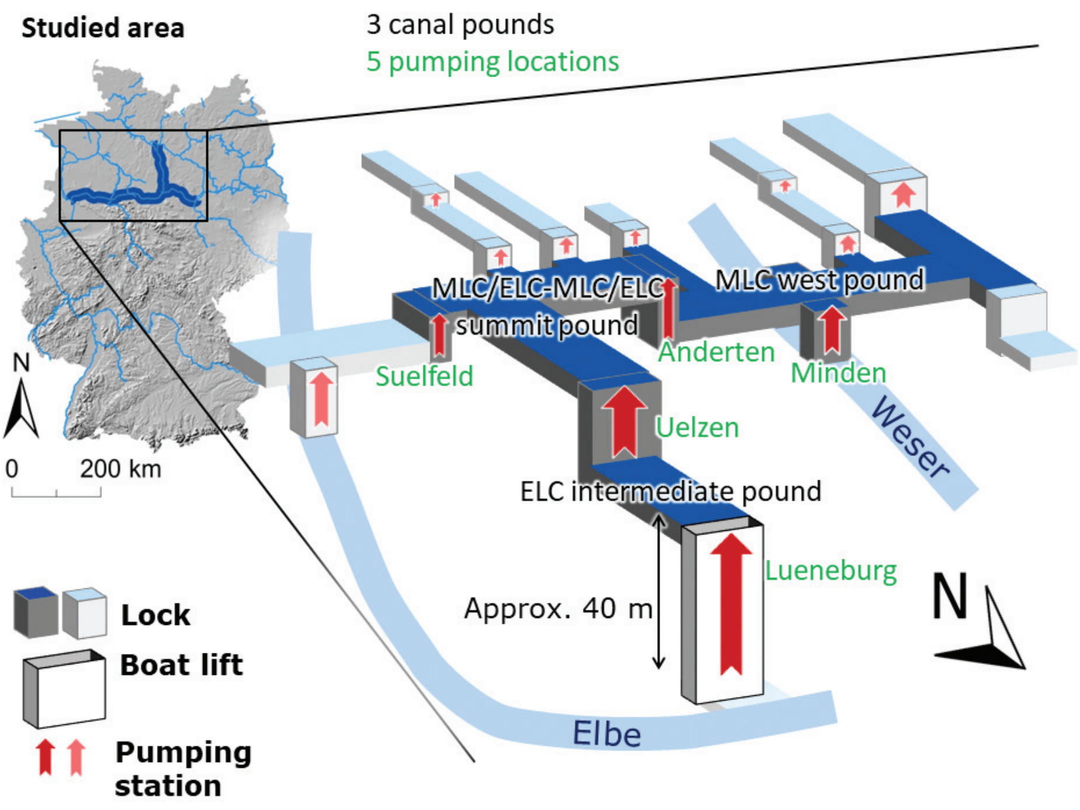


Figure 20: Schematic of the Elbe Lateral Canal and Mittelland Canal (ELC and MLC). Possibilities for using renewable energy to drive pumping stations were investigated in this case study.

associated properties are extensive. All transport operators thus have numerous possibilities at their disposal for installing photovoltaic systems, which have potential for being substituted for a significant portion of the fossil fuels now consumed. The BMVI Network of Experts has studied how these areas could be taken advantage of to drive the pumps of the Elbe Lateral Canal and the Mittelland Canal with renewable energy from photovoltaic systems (Figure 20).

In the studied area, five pumping stations are connected to the canal system to overcome differences in height in the waterway of up to 61 m. The potential for generating renewable energy from solar radiation and wind can be determined with the aid of meteorological data. It is necessary to capture in detail the spatial and temporal variability of solar radiation and wind. Based on the latest findings, 14% of the power requirement of the pumping stations can be met with renewable energy if only the roofs of the local waterway facilities are covered with solar panels. The share of renewable energy could increase to as much as 99% if the surfaces of noise protection walls along nearby roads were also taken advantage of for this.

Utilising alternative drive technologies for service vehicles

The vehicles used for operating and maintaining transport infrastructure also provide opportunities to make transport climate-friendlier. The BMVI Network of Experts studied the vehicles of motorway maintenance centres which are equipped with alternative, battery-operated drives and powered with electricity from renewable sources. Their cost-effectiveness was compared with that of conventional diesel-driven vehicles. The significant secondary factors were, besides the required continuous availability of the vehicles, possibilities for and obstacles to integrating on-site systems for generating renewable energy. The BMVI Network of Experts was able to show that the cost-effectiveness of battery-powered drives, as opposed to conventional diesel engines, greatly depends on the extent to which self-generated power is used, as this eliminates the need to pay fees and other charges for using the power grid.

Figure 21: Solar panels alongside a motorway (photograph: Henglein & Steets/GettyImages)

4 Networked research by government bodies improves the quality of advice provided to policymakers and generates greater synergies for operations

With the motto “Knowledge – Ability – Action”, the six departmental research facilities of the BMVI – those of the Federal Maritime and Hydrographic Agency (BSH), the German Federal Institute of Hydrology (BfG), the Federal Highway Research Institute (BASt), the Federal Waterways Engineering and Research Institute (BAW), the Deutscher Wetterdienst (German Meteorological Service, DWD) and the German Centre for Rail Traffic Research (DZSF) at the Federal Railway Authority (EBA), supplemented by the Federal Office for Goods Transport (BAG) – joined forces to engage in cross-modal, interdisciplinary research. By pooling their specific know-how and establishing a broader, shared basis for cooperation, they have generated fresh synergies. The BMVI established the BMVI Network of Experts in response to a call from the Science Council of the German Federal Government to improve networking of the agencies involved in studying the transport sector, thus activating untapped synergies and eliminating redundant activities. This has spawned a new brand of collaboration for conducting research activities and advising policymakers.

The BMVI Network of Experts carries out interdisciplinary activities at the junction of science, policy and application. Thanks to its cross-modal perspective, the target groups within the BMVI and users elsewhere can take advantage of results which could not have been achieved in any other way. The network supplements the existing research and development activities of the participating institutions. The complex challenges of the future – from implementing Germany’s strategy for adapting to climate change across the German sustainability strategy to designing the future transformation of mobility – call for systemic, cross-modal solutions.

The participating institutions both carry out research and development work and provide scientifically substantiated advisory and informational services. The research topics of the BMVI Network of Experts are – as is generally the case with research activities conducted by government institutions – relevant to practice and problem-oriented, and during the first research phase from 2016 to 2019 addressed current and future challenges in five topic areas:

Illuminating and adapting to the consequences of climate change: Even if the German Federal Government’s climate protection goals are achieved, measures will be required to adapt to the climate change which is already taking place. The research activities of the BMVI Network of Experts on the topic of “adapting to climate change” are wide-ranging and extend far beyond the results which are presented here by way of example. This ongoing research work provides the BMVI with scientific insights and tools for targeted assessment of the effects of climate change and extreme weather events on the transport system. This makes it possible to initiate suitable adaptation measures at an early stage for mitigating the anticipated effects. The transport operators’ needs for application and use are anticipated and taken into account so they can quickly proceed to practical implementation.

Environment and transport: The environmental research conducted by the BMVI Network of Experts is yielding a plethora of insights on environmental challenges associated with developing the transport infrastructure further, especially in connection with managing pollutants, noise and biodiversity. These range from selecting and using eco-friendly building materials across more realistic assessment of associated effects prior to beginning construction and maintenance work all the way to dealing with issues associated with creating wildlife corridors and making a major contribution to the EU action plan for preventing and managing the introduction and spread of invasive non-native species. The newly developed tools of the BMVI Network of Experts are delivering new insights and an offering which extends far into the practical level. All this makes it possible to pay much better attention to environmental requirements in connection with infrastructural measures.

Reliable transport infrastructure: It is predicted that Germany will experience significant growth in freight and passenger transport volumes[7]. At the same time, the expenditure and effort required to maintain and optimise the functionality and performance of structures are also growing. Here the BMVI Network of Experts is making a decisive contribution by developing innovative methods

[7] German Federal Ministry of Transport and Digital Infrastructure (BMVI) (2016). National Traffic Forecast for 2030. Berlin.

for capturing and assessing existing facilities, evaluating their reliability and carrying out construction work without interrupting operation, thus providing users with scientifically substantiated support. By applying the research findings of the BMVI Network of Experts, it is possible to carry out minor maintenance measures at an early stage without significantly interrupting use and thus considerably prolong the useful lives of facilities.

Digital technologies: Digitalisation is constantly giving rise to new possibilities for designing transport for greater simplicity and safety and facilitating the practical work involved. The BMVI Network of Experts identifies and evaluates new technologies and applies its cross-modal perspective to promote the transfer of knowledge among the institutions participating in the BMVI. In addition, standardisation of data formats and tools is facilitating the practical introduction of new technologies. As a result, important new technical competencies and innovative work processes are becoming established in research activities across government institutions.

Renewable energy: The ambitious climate protection goals of the German Federal Government call for joint action across all sectors. In addition to the required adjustments of transport infrastructure to the consequences of climate change, transport administrations are able to make additional active contributions to climate protection by switching to renewable sources for meeting their energy requirements. The BMVI Network of Experts is studying possibilities for using renewable energy for operating and maintaining infrastructure across all transport modes. There is also considerable potential for these to generate renewable energy on their own land. Surveys of requirements and energy generation possibilities have quickly generated important insights and ideas for more climate-neutral transport management.

The findings of the BMVI Network of Experts have been presented at over 250 events (specialist conferences, committees, dialogues with users etc.) and in numerous publications[8] and are thus contributing to making the research activities of the BMVI visible both nationally and internationally. The publications allow more users active in practice and research to also take advantage of the results and products which come out of the BMVI Network of Experts. Moreover, by engaging in cooperation and awarding research contracts, the BMVI Network of Experts is promoting networking of the research landscape across all transport modes. All of this ensures that the BMVI takes an up-to-date approach to advising policymakers on the current state of science and technology.

8 https://www.bmvi-expertennetzwerk.de/publikationen or https://www.bmvi-expertennetzwerk.de/EN, resp.

About this publication

Publisher
Federal Ministry of Transport and Digital Infrastructure
Invalidenstrasse 44
10115 Berlin
Germany
Website: www.bmvi.de
E-mail: poststelle@bmvi.bund.de

Writers
Daniel Esser (BfG), Stephanie Hänsel (DWD), Frank Kaspar (DWD), Enno Nilson (BfG), Markus Reinhardt (DZSF/EBA), Franz Schöll (BfG), Katharina Schütze (BfG), Christoph Stephan (BAW), Teresa Werner (BASt), Thomas Ternes (BfG)

Finalised
June 2021

Design | Printing
Federal Ministry of Transport and Digital Infrastructure
Division Z 32, Prepress | In-House Printshop

Picture Credits
Front cover:
Top left: Thomas Winz/gettyimages
Top right: Moorefam/gettyimages
Bottom left: Patrick Havel/German Federal Institute of Hydrology
Bottom right: Federal Waterways Engineering and Research Institute
Page 1: https://www.andreas-scheuer.de/presse/

Suggestion for referencing this source
BMVI (2021). The BMVI Network of Experts "Knowledge – Ability – Action": Synthesis Report on the Research Phase 2016-2019. German Federal Ministry of Transport and Digital Infrastructure. Berlin. DOI: 10.5675/ExpNBMVI2021.2021.02

Original German edition
The original German edition is titled "Das BMVI-Expertennetzwerk „Wissen-Können-Handeln: Synthesebericht zur Forschungsphase 2016-2019". Published by the German Federal Ministry of Transport and Digital Infrastructure in December 2020.
DOI: 10.5675/ExpNBMVI2020.2020.17
Translated into English by Greg Woods, Frankfurt am Main

www.bmvi.de