Dipl.-Phys. Carina Herrmann
Federal Highway Research Institute (BASt)
herrmann@bast.de

# ADAPTION OF THE ROAD INFRASTRUCTURE TO CLIMATE CHANGE

# 1 Introduction

The road transport infrastructure has a huge economic importance. Currently, about 70% of the goods are carried by road and the trend is rising (Ickert *et al.*, 2007). The road transport infrastructure is facing many changes and will have to be adapted to them. These challenges are: globalization, sustainability, technological and demographic change, increase of goods transport and climate change.

In contrast to the perception of many people, the climate of our planet was never stable. But in recent years the average global temperature has been rising quite strongly. And due to the fact that the $CO_2$ concentration in the atmosphere continues to increase, there will be a further rise in temperature. So we have to ask, how the climate will change and how we can adapt to that.

To answer the first part of the question, we have to deal with emissions scenarios and climate models. In 2007 the Intergovernmental Panel on Climate Change (IPCC) published the Fourth Assessment Report (IPCC, 2007), where different emission scenarios were described. These scenarios represent different assumptions for the development of the world, e.g. the rate of increase in population, the rate of economic growth, the use of fossil or non-fossil energy sources, etc. These scenarios are integrated in climate models and have been frequently used to make projections of future climate change. For Germany an increase of extreme weather events, such as heat periods and heavy rain events is predicted.

# 2 THE ADAPTATION STRATEGY TO CLIMATE CHANGE

## 2.1 THE GERMAN ADAPTATION STRATEGY

As a reaction to the warning of the climate scientists the Federal Government of Germany has passed the “German Adaptation Strategy to Climate Change (DAS)” (Bundesregierung, 2008) in 2008. This creates a framework for adaptation to the impacts of climate change in Germany. The aim of the strategy is to create a national framework for action in order to avert dangers to the public, natural habitats and the national economy. This framework is intended to make it easier to identify impacts and adaptation needs, and to plan and implement measures. For instance, early incorporation of adaptation aspects into planning can save climate costs in the future.

Besides outlining the current status of knowledge on the anticipated climate changes and the impacts these could entail, the strategy also highlights possible climate impacts and options for action for 14 sectors and selected regions.

In the sector road transport/road transport infrastructure there are two key aspects for the medium term need for actions:

- adaptation of the dimensions of the drainage infrastructure to more extreme rainfall and
- adaptation of pavements affected by heat through the use of modified materials.

On that basis the government adopted the “Action Plan to the German Adaptation Strategy to Climate Change" (Bundesregierung, 2011) in 2011.

One aim of the “Action Plan” is to develop a set of indicators for the German Strategy for Adaptation to Climate Change.

Here, the climate impacts and individual adaptation methods in the sectors covered by the DAS are described. By using existing data changes in each sectors are documented and results for public activities are deduced.

In the road transport/road transport infrastructure sector the Federal Highway Research Institute was involved in the development of three indicators (Schönthaler *et al.*, 2011):

- weather-related road accidents
- road condition
- use of de-icing salt on federal roads and highways

## 2.2 The Strategy of the Federal Highway Research Institute

The German road network consists of more than 53,000 km of roads and more than 38,000 bridges and tunnels. The expected service life of roads is 30 to 50 years and for bridges 80 to 100 years. With respect to this, we have to adapt the guidelines and standards to the impacts of the projected climate change now already. The Federal Highway Research Institute developed a roadmap (figure 1) how to reach this ambitious aim.

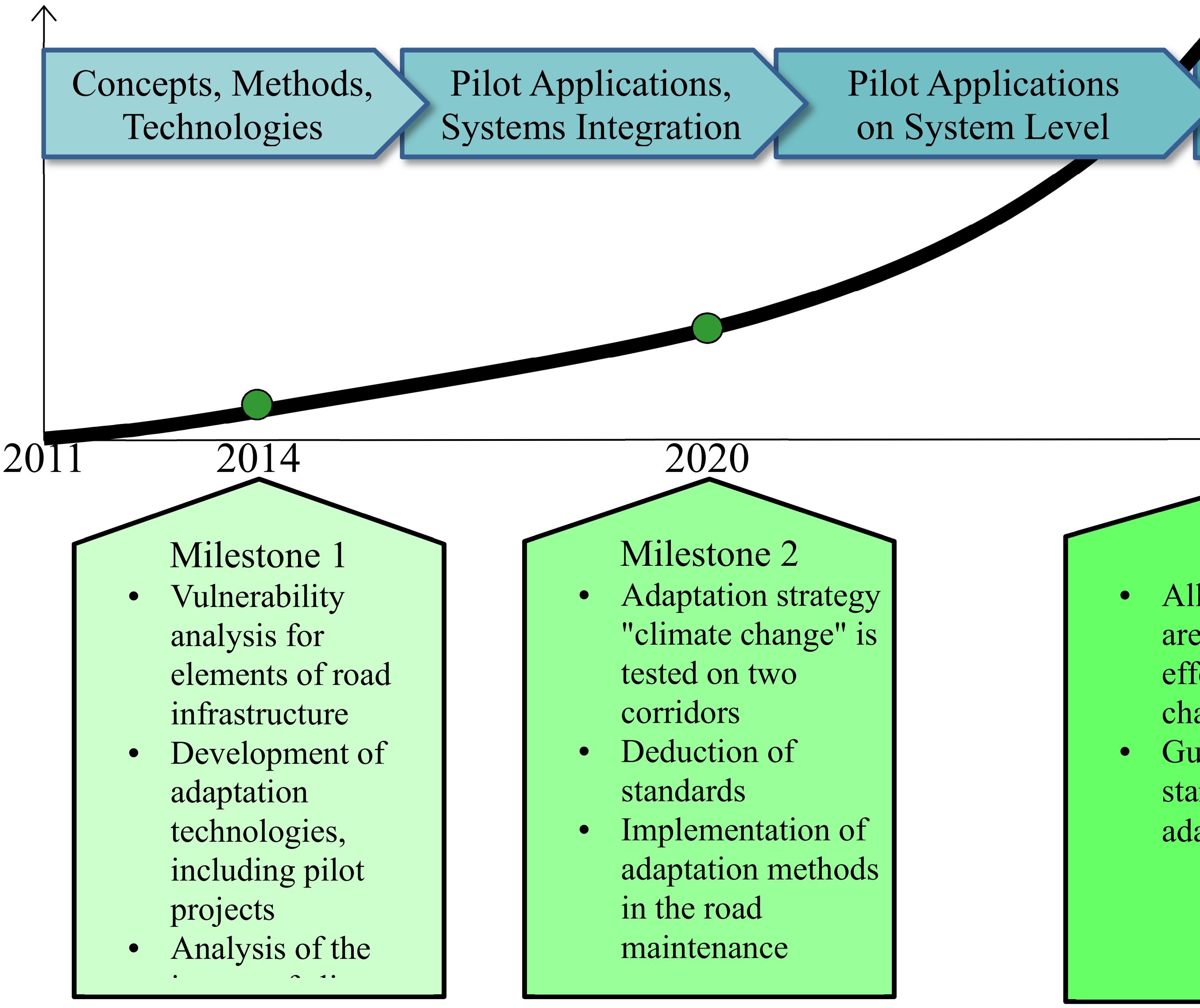


*Figure 1: Milestones of the BASt roadmap to the adaption of the road infrastructure to climate change*

Until 2014 vulnerability analysis for 10% of the German roads, bridges and tunnels is performed and first adaption technologies are developed and tested in pilot projects. Besides the impacts of the climate change on the road maintenance, especially the winter services are analyzed. For milestone 2 the adaptation strategy "climate change" is tested on two corridors, standards are defined and the adaptation methods for road maintenance are implemented. At last in 2030 all main corridors are resilient to the effects of climate change and the guidelines and standards are adapted.

The implementation of this roadmap is a very complex task. To reach milestone 1 the Federal Highway Research Institute initiated the program "Adaptation of the Road Infrastructure to Climate Change (AdSVIS)" (Tegethof *et al.*, 2011), which consists currently of 15 projects.

The AdSVIS program is based on two pillars (Figure 2):

- the metrological/geographical pillar and
- the adaptation pillar

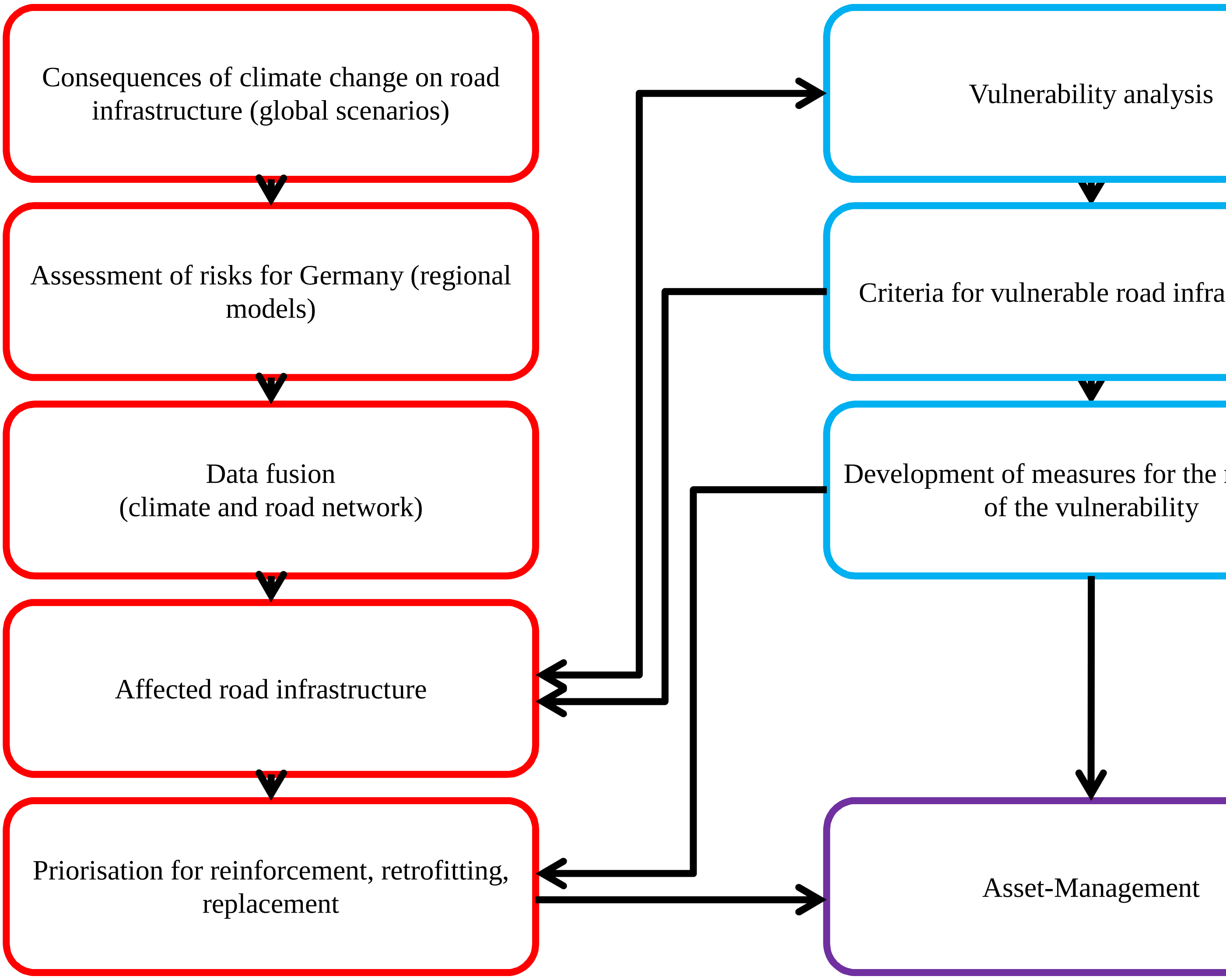


*Figure 2: Structure of "AdSVIS - Adaptation of the Road Infrastructure to Climate Change"*

The aim is to integrate this adaptation strategy into a holistic and sustainable asset management.

On the basis of the identification of the threats and the fusion of the climate and road network data, the road transport infrastructure which might be affected is to be determined. For this purpose, it is first of all necessary to carry out vulnerability analyses and to establish the criteria for the elements of the road transport infrastructure which are at risk. At the same time, possible adaptation measures will be developed and their effectiveness assessed in a holistic approach. Subsequently, a prioritization for the implementation of the adaptation measures can be performed for the entire network.

Each of the 15 AdSVIS projects is assigned to one of the pillars. The projects are listed in Table 1 and are described in detail below.

| **Projects** | **Status** |
|---|---|
| Networking of the AdSVIS projects | [red] |
| AdSVIS server | [red] |
| RIVA - Risk analysis of key goods and transit axes including seaports | [green] |
| Comparison of meteorological parameters near federal roads and grid data of climatologic prediction models | [green] |
| Development of climate impact models and design parameters for bridges and tunnels | [green] |
| Vulnerability analysis of bridges and tunnels | [red] |
| Analysis of measures to reduce the vulnerability of bridge and tunnel structures | [red] |
| Development of a model for estimating landslide risk areas and development of a national hazard map | [green] |
| Evaluation of the design of road drainage systems regarding climate change | [green] |
| Inventory of road drainage systems in selected sections of the TEN-T | [red] |
| Adaptation of pavement designs for asphalt and concrete constructions | [green] |
| Standardized asphalt pavements due to changing temperature boundary conditions | [red] |
| Asphalt pavements and extreme temperatures | [green] |
| Impacts of weather extremes on concrete road pavements | [red] |
| Impacts of climate change on road maintenance | [green] |

Table 1: The status of the AdSVIS projects: green: running, red: planned

# 3 THE ADSVIS PROJECTS

## 3.1 THE RIVA PROJECT

The most important project of AdSVIS is “RIVA - Risk analysis of key goods and transit axes including seaports”. The aim of the project is the development of tools for the determination of the need for action due to the projected climate change. For this project the method, which was developed in the ERA-NET ROAD project RIMAROCC (Bles *et al.*, 2010), is used. This method consists of seven steps (Figure 3). The first four steps: context analysis, risk identification, risk analysis and risk evaluation answers to the question what could happen. The need of action is described. With the other three steps: risk mitigation, implementation of action plans and monitoring, review, capitalization is described, what choices exists and how they have to be implemented and validated. In this project the first four steps were handled.

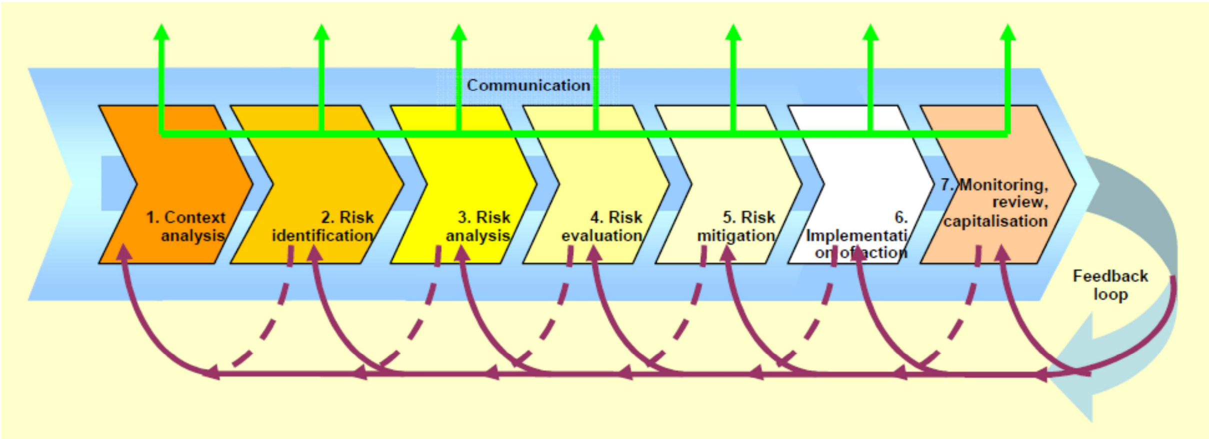


*Figure 3: The RIMAROCC method* (Bles *et al.*, 2010)

**The first step: context analysis**

Conditions have to be defined, road test sections have to be chosen and a common sense of the meaning of considered risks and components of risks has to be developed. Besides a lot of data and information, e.g. road network data, structure data, condition data, traffic data, climatologic data, etc. has to be collected.

In the RIVA-project 10% of the German part of the Trans-European Transport Network (TEN-T) are analyzed. For this 9 road sections have been selected by the following criteria:

- Regional distribution, i.e. different climatic and geographic conditions
- roads with high and low traffic
- connections to seaports and neighboring countries
- different types of construction
- different conditions and age of the road sections

**The second step: risk identification**

The sources of risk, areas of impacts and unwanted events have to be identified and risk has to be defined.

Risk is a function with the parameters: threat, vulnerability and consequences.

**Risk = function of [Threat, Vulnerability, Consequences]**

Threat implies all possible weather conditions including their typical sequence and variations. The weather events are characterized by the frequency, period and intensity.

Vulnerability describes how the risk elements with respect to weather related hazards are affected. The environment of a risk element may enhance or weaken the vulnerability.

Consequences indicate disruptions in the road system, human and socioeconomic impacts. It is an indicator for the relevance of the road section from an economic perspective.

**The third step: risk analysis**

The cause and effect relations are presented, valuation procedures are adjusted and further effects such as the risk to people, damage of infrastructure and environment, image loss and economic consequences are examined. The aim is to provide a risk overview.

**The forth step: risk evaluation**

The probabilities of the results of the analyzed risk scenarios are summarized in a risk matrix (Figure 4). Climate related risks are compared with the road infrastructure risks. It is determined which risks are acceptable for the owner or for the public and which require a treatment strategy.

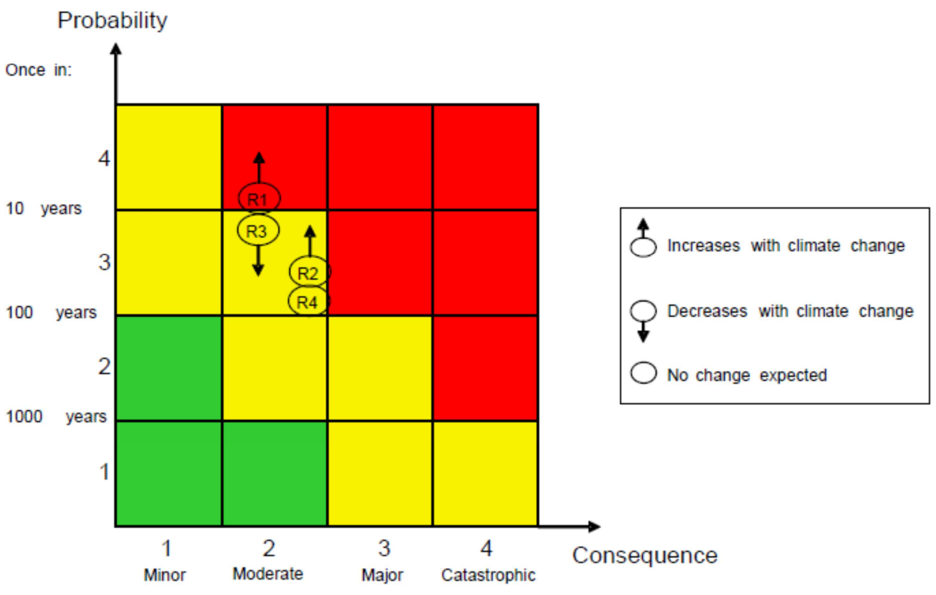


*Figure 4: Risk matrix* (Bles *et al.*, 2010)

## 3.2 Comparision of Meteorological Parameters and Grid Data of Climatologic Prediction Models

Weather stations rarely are near to roads and also climate projections provide data for a specific grid. In these grids, the average values of an area are independent of topography, land use or cultivation. In this project algorithms, which compare the data of weather stations (temperature, precipitation) with weather data at roads, are created. Different types of construction and the location of the roads are considered. In the next step the procedure is extended for projected climate data. Thus, the effects of climate change (e.g. rising temperatures) to road constructions are estimated. With this information adaptation measures are developed and performed.

## 3.3 Networking of the AdSVIS Projects

All AdSVIS projects are cross-linked with each other and the results and interim results are exchanged already during the lifetime of each project. E.g. the areas prone to future landslides (project: Development of a model for estimating landslide risk areas and development of a national hazard map), could be integrated in the risk analysis of the RIVA project. Furthermore the results of AdSVIS should be presented on national and international events.

## 3.4 AdSVIS Server

Almost all AdSVIS projects require network data of road infrastructure and climate projection data. The network data and data for civil engineering structures are contained in various databases. To simplify the handling of the different databases and to provide a consistent data base to all users an all-encompassing database should be established. Furthermore climate projection data of different climate scenarios and a digital terrain model should be integrated. So all projects have access to consistent data and the results are comparable to each other.

## 3.5 Development of Climate Impact Models and Design Parameters for Bridges and Tunnels

The result of the pilot project “Impacts of climate change on existing pre-stressed concrete bridges” was that adaptations are necessary in particular for frame bridges made of pre-stressed concrete which were built before 1981.

This project is aimed at determining site-related and design-relevant climate parameters in order to obtain projections of climate impact which are as realistic as possible for structures which are located in regions particularly affected by climate change.

## 3.6 VULNERABILITY ANALYIS FOR BRIDGES AND TUNNELS

The aim of this project is to identify critical structures so that the relevant procedures can be taken at the structure in order to reduce its vulnerability. Thus, it may be possible to reduce the cost of repair or reconstruction of a damaged or destroyed structure.

## 3.7 ANALYSIS OF MEASURES TO REDUCE THE VULNERABILITY OF BRIDGE AND TUNNEL STRUCTURES

This project is based on the results of the project "Vulnerability analysis of bridges and tunnels". It should develop a catalog of measures to reduce the vulnerability of bridges and tunnels. The analysis should consider constructional and organizational provisions of existing engineering structures as well as for future engineering structures. The catalog should be guidance for road authorities and help to design and build new constructions and reconstruct and adapt existing constructions.

## 3.8 DEVELOPMENT OF A MODEL FOR ESTIMATING LANDSLIDE RISK AREAS AND DEVELOPMENT OF A NATIONAL HAZARD MAP

In the pilot project "Assessment of the risks of landslides by the increase of extreme weather events" past landslide events have been analyzed and evaluated for three regional cases. In this project landslide events are studied nationwide for Germany and additionally to the slope inclination, which was solely used in the pilot project, other parameters like geology, geomorphology, groundwater, exposure and vegetation are considered. In combination with the climatic parameters a climate-engineering geological model for estimated landslide risk areas and a national hazard map for landslide risk areas along roads will be developed.

## 3.9 Evaluation of the Design of Road Drainage Systems Regarding Climate Change

This project is intended to review the current design concepts in accordance with the guidelines for the design of roads – part: drainage (RAS-Ew) and in accordance with the guidelines for structural measures at roads in water protection zones (RiStWag) with regard to:

- hydraulic efficiency while observing soil and water protection and
- structural designs.

The results of this research project are to serve as a basis for the revision of the regulations.

## 3.10 Inventory of Road Drainage Systems in Selected Sections of the TEN-T

In the context of this project information of road drainage systems (open/closed) and retention basins should be prepared and be implemented in the AdSVIS server. Could also be used by the RIVA project.

## 3.11 Adaptation of Pavement Design for Asphalt and Concrete Constructions

The methods currently used to take account of weather conditions for the design of road pavements (in the case of new construction as well as maintenance) are based on long-term meteorological observation series. This project is to investigate the extent to which climate change modifies the input parameters which are subject to weather conditions. This means those parameters which are integrated into the guidelines for the standardization of pavements of traffic areas (RStO) as well as into the computational dimensioning (guidelines RDO asphalt and RDO concrete). It is intended to prepare the relevant adaptation proposals for dimensioning (30 years as a rule).

## 3.12 Standarized Asphalt Pavements due to Changing Temperature Boundary Conditions

Asphalt shows a strongly temperature-dependent, elastic, plastic and viscous behavior causing potential cracking in winter and permanent rutting in summer.

On the basis of the guidelines for the computational dimensioning of the surface of traffic areas with asphalt pavement (RDO asphalt) it is to be examined to what extent a rise of the average annual temperature and of the impact of traffic permit the use of standard asphalt construction methods/dimensioning in order to reach the usual service life. Failure to reach the full service life will lead to new standards for material adaptation and/or alternative binding agents.

## 3.13 ASPHALT PAVEMENTS AND EXTREME TEMPERATURES

In asphalt construction, the structure is achieved by changing of the layer thickness or by changing of material properties. The thermo-physical properties of the asphalt construction have been neglected. In this project asphalt construction should be adapted to climate change especially to higher temperatures by changing the asphalt or the mineral aggregate.

## 3.14 IMPACTS OF WEATHER EXTREMES ON CONCRETE ROAD PAVEMENTS

The aim of the project is to investigate the impact of various weather extremes on concrete pavements and to analyze if service lifetimes were reduced. With the study critical or sensitive design should be identified and repaired. The project is necessary because a sudden collapse of the road construction, e.g. by a "blow up", is very dangerous.

## 3.15 IMPACTS OF CLIMATE CHANGE ON ROAD MAINTENACE

To determine the impact due to clime change on road maintenance, projected climate events have to be known. Hence, attention is paid to all services like removing of snow and ice, de-icing, mowing of grass, pruning of wood, cleaning of roads, cleaning and maintenance of drainage systems, removing of storm damage, etc. Contrary road traffic also contributes to climate change. Particularly traffic jam produces pollution e.g. greenhouse gases and contributes to climate change. The aim of the project is to enhance maintenance services and to reduce the influences and consequences of the climate change.

# 4 Conclusion

Due to climate change, extreme weather events like storms, heavy rainfall and heat waves will increase and the road transport infrastructure has to be adapted to them. Thus the Federal Government of Germany passed the “German Adaptation Strategy to Climate Change (DAS)” and the “Action Plan to the German Adaptation Strategy to Climate Change”. The Federal Highway Research Institute was involved in the development of three indicators in the road transport/road transport infrastructure sector.

In 2009 the Federal Highway Research Institute started with research in the range of climate change and developed an adaptation strategy. This strategy is implemented in the research program “Adaptation of the Road Infrastructure to Climate Change (AdSVIS)”. AdSVIS consists currently of 15 projects, with particularly importance to the RIVA project. The aim of RIVA is the development of tools for the determination of the need for action due to the projected climate change. So risks for the infrastructure are reduced and mitigated. Other projects of the AdSVIS program concern the adaptation of guidelines to climate change especially the adaption of pavements and the design of drainage systems. Eight projects already started and more are planned.

# 5 LITERATURE


Bles T., Y. Ennesser, J.-J. Fadeuilhe, S. Falemo, B. Lind, M. Mens, M. Ray, F. Sandersen (2010). Risk Management for Roads in a Changing Climate - A Guidebook to the RIMAROCC Method, ERA-NET ROAD

Bundesregierung (2008). Deutsche Anpassungsstrategie an den Klimawandel, www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/das_gesamt_bf.pdf

Bundesregierung (2011). Aktionsplan Anpassung der Deutschen Anpassungsstrategie an den Klimawandel, http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/aktionsplan_anpassung_klimawandel_bf.pdf

Ickert, L., U.Matthes, S. Rommerskirchen, E. Weyand, M. Schlesinger, J. Limbers (2007). Abschätzung der langfristigen Entwicklung des Gütherverkehrs in Deutschland bis 2050, ProgTrans AG, Basel

IPCC (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Schönthaler, K., S. Andrian-Werburg, D. Nickel (2011). Entwicklung eines Indikatorensystems für die Deutsche Anpassungsstrategie an den Klimawandel (DAS), Umweltbundesamt, Dessau-Roßlau, http://www.uba.de/uba-info-medien/4230.html

Tegethof, U., M. Bürger, B. Hartz, O. Ripke, C. Schmellekamp, M. Wieland, A. Wolf (2011). Anpassung der Straßenverkehrsinfrastruktur an den Klimawandel (AdSVIS), Bundesanstalt für Straßenwesen (BASt), Bergisch Gladbach