Adaptation of road-traffic infrastructure to climate change

Markus Auerbach
Working group climate change
Overview

1. Motivation
2. Strategy
3. Actions
   • European perspective
   • National perspective
Overview

1. Motivation

2. Strategy

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   • European perspective
   • National perspective
Challenges

- Globalisation
- Strong increase in freight traffic
- Technological change
- Demographic change
- Climate change
- Sustainability
Road infrastructure

Roads
- total: 53,000 km
- Highways: 12,000 km
- Trunk Roads: 41,000 km
- Dimensioning for 30-50 years

Bridges
- total: 39,039
- Highways: 17,422
- Trunk Roads: 21,617
- Dimensioning for 100 years (01.03.2012)

Tunnels
- total: 240
- Length: 217 km
- Dimensioning for 100 years

Assets
- 360 Bn. €

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Consequences of Climate Change

- Increase in rutting
- Landslides
- Flooding (fluvial)

Heat waves / droughts and extreme precipitation

- Flooding (pluvial)
- Inundations of Bridges/Tunnels
- Storm-caused accidents
Overview

1. Motivation

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   • European perspective
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DAS German Strategy for Adaptation to Climate Change (2008)

APA Adaptation Action Plan (2011)

Pillar 3: Activities in immediate federal responsibility, Part Infrastructure/Federal Roads

BMVBS/BAST: Assessment of Adaptation requirements for Design, Construction, Operation and Maintenance

Vulnerability Analysis

- Adaptation Options
- Adaptation Measures
- Evaluation incl. Cost-Benefit-Aspects
Network Vulnerability (BMU/UBA)

- Network of Federal authorities (BASt, BBK, BBSR, BfG, BGR, DWD, RKI, THW, UBA, vTI, GIZ and PT-DLR)
- Development and application of a nation-wide and cross-sectoral vulnerability assessment (15 sectors)
Roads in the 21. Century
The safe and reliable road

Climate change
By means of adaptation measures and mitigation strategies, the roads of the future are to ensure sustainable infrastructure, thereby safeguarding mobility.

... all major routes are to be provided with optimum protection against the impact of climate change, and the routine road maintenance services will be equipped to cope with extreme weather events.

... and for the development of analyses to determine vulnerability to impacts caused by Climate change or to any other safety-related impacts.
Level

Climate data
Regional Projections (Temperature, Wind, Precipitation, Irradiation)

Impact-chains
Road
Bridges
Tunnels
Drainage
Flooding (fluvial)
Landslides
Guidelines

Vulnerability analyses
RIVA
Blue Spot
Hazard map
Adaptation of Guidelines

Risk for:
Road
Bridges
Tunnels
Drainage
Flooding (fluvial)
Landslides

Adaptation measures
New Pavements
Design
Design
Levees, Polders
Reinforcement, Rerouting
Updating Guidelines

Cost/Benefit-Assessment

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Adaptation der Straßenverkehrsinfrastruktur an den Klimawandel
Adaptation of the road-traffic infrastructure to climate change
## Status AdSVIS

### Finalised Projects
- Impacts of climate change on road maintenance
- Adaptation of pavement designs for asphalt and concrete constructions
- Standardized asphalt pavements due to changing temperature boundary conditions
- RIVA - Risk analysis of key goods and transit axes including seaports

### Current Projects
- Cross-linking and communication of the AdSVIS projects
- Development of climate impact models and design parameters for bridges and tunnels
- Comparison of meteorological parameters near federal roads and grid data of climatologic prediction models
- Development of a model for estimating landslide risk areas and development of a national hazard map
- Evaluation of the design of road drainage systems regarding climate change

### Future Projects
- AdSVIS – Server
- Inventory of road drainage systems in selected sections of the TEN-T
- Impacts of weather extremes on concrete road pavements
- Vulnerability analysis of bridges and tunnels
- Analysis of measures to reduce the vulnerability of bridge and tunnel structures
- Asphalt pavements and extreme temperatures
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FOREVER OPEN ROAD
Redefining Highway Transport for the 21st Century

The Adaptable Road

- Porous, low noise surfacing, light reflecting for night-time driving
- Adaptable to freight, transport communications, location and monitoring requirements
- Flexible, durable surface, self-repairing/self-cleaning and instant crack repair
- In-built sensors for traffic monitoring/condition and condition monitoring
- In-built power system for electric vehicles
- In-built use control/vehicle guidance
- Removable/self-cleaning drainage reseats, feeding carbon capture planting
- Adaptable/replaceable communication/power channels for lane-control, traffic monitoring, driver information and condition monitoring
- Low carbon sub-base and pavement
- Pre-fabricated inter-locking sub-base with integrated drainage, services and communications channels
- Energy harvesting grid and storage for solar energy to power lighting, signs and sensors
- In-built system for replacing and adding lane infrastructure, eg barriers, signs and sensors

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The Resilient Road

- Planting and soil stabilisation for storm water protection.
- Drainage system and reservoirs for storm control and water management.
- Pavement to building heat exchange for resilience to extreme weather.
- Integrated road de-icing system.
- In-vehicle weather, incident warning and information system.
- Geothermal and solar energy harvesting for resilience to extreme weather.
- Demand and condition responsive traffic control for extreme weather conditions.
- Real time local weather forecast information system.
Milestone 1
- **Corridors**
  3 European corridors selected, agreed and assessed on risks
- **Methodologies**
  - Risk Assessment TEN-T network developed
  - Adaption Measures identified
  - Adaption Strategies drafted
- **Technology**
  Key Single Technologies proven in practice

Milestone 2
- **Corridor and Sub-System**
  - Implementation of climate resilient technologies
  - Application of risk based methodologies
  - Modification of Adaption Strategies
- **Technology**
  - Corridor and Sub-System proven to be available under all weather conditions
  - 50% reduction of down time

Milestone 3
- **Roll out plans agreed:**
  - On regional/national scale
  - On EU scale (TEN-T)
- **Regulatory/legislative framework set on a European scale**
FORx4 Initiative

- Forever Open Road
- Forever Open Rail
- Forever Open River
- Forever Open Runway

Shared Technology
Shared Infrastructure
Shared Governance
Shared Customers
CEDR call 2012
“Road Owners adapting to Climate Change”

Research Area

• Identification and modeling of climate change effects regarding trans-national highway networks (TEN-T) to provide a unified input data base

• Development and application of risk based vulnerability-assessment of trans-national highway networks (TEN-T)

• Development and application of adaptation technologies
CEDR call 2012 Climate Change

Programme Executive Board: M. Auerbach (D, chair),
Kees van Muiswinkel (NL),
Gordana Petkovic (NOR),
Henrik Larsen (DK)

- 8 Proposals
- 2 Projects funded
  - ROADAPT
  - CliPDaR
Roads for today, adapted for tomorrow (ROADAPT)

- RIMAROCC follow up
- Consortium: Deltares, SGI, Egis, KNMI
- Duration: 24 months
- Methodologies and tools enabling tailored and consistent climate data information for road owners
- Quickscan method for Risk analysis „RIMAROCC light“
- Socio-economic Impact-Analysis
- 3 case studies
Climate Projection Data base for Roads (CliPDaR)

- DWD, ZAMG
- Duration: 6 months
- Recommendations for harmonised climate projection data throughout Europe in cooperation with road authorities
Overview

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   • National perspective
Level: Operation, Maintenance, Design/Cons.

Climate data: Regional Projections (Temperature, Wind, Precipitation, Irradiation)

Impact-chains:
- Road
- Bridges
- Tunnels
- Drainage
- Flooding (fluvial)
- Landslides
- Guidelines

Vulnerability analyses:
- RIVA
- Blue Spot
- Hazard map
- Adaptation of Guidelines

Risk for:
- Road
- Bridges
- Tunnels
- Drainage
- Flooding (fluvial)
- Landslides

Adaptation measures:
- New Pavements
- Design
- Design
- Levees, Polders
- Reinforcement, Rerouting
- Updating Guidelines

Cost/Benefit-Assessment

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Objectives of the RIVA-Project

Development of a method for risk assessment of road-traffic infrastructure regarding climate change

- Which regional climate impacts and changes therein can occur?
- Which elements of road infrastructure are affected?
- What consequences do the impacts have on
  - infrastructure
  - traffic
- How can the risk be appraised?
Inspired by RIMAROCC

1. Context Analysis
2. Risk-identification
3. Risk-analyse
4. Risk-evaluation
5. Risk-mitigation
6. Implementation of measures
7. Monitoring, Review, Capitalisation

RIVA: identify need for adaptation on a network level
Develop adaptation measures and implement them

Communication
Feedback loop
## Risk elements / Climate impacts

<table>
<thead>
<tr>
<th>Risk elements of transport infrastructure</th>
<th>Klimaereignisse</th>
<th>Klimaeinflüsse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingenieurbauwerke</td>
<td>Thermische Ereignisse</td>
<td>Niederschlagsereignisse</td>
</tr>
<tr>
<td>1. Brücken</td>
<td>Hohe Temperaturen</td>
<td>Starkkälte</td>
</tr>
<tr>
<td>2. Tunnels</td>
<td>Temperaturen schwankungen</td>
<td>Schnee</td>
</tr>
<tr>
<td>3. Tunnel &amp; Trogbauwerke</td>
<td>Niedrigere Temperaturen</td>
<td>Nässe</td>
</tr>
<tr>
<td>4. Stützbaueinrichtungen</td>
<td>Strahlung</td>
<td>Nebel</td>
</tr>
<tr>
<td></td>
<td>Schnee und gefrorener Regen</td>
<td>Starkwind</td>
</tr>
</tbody>
</table>

**Risk elements of transport infrastructure**

1. Brücken
2. Durchlässe
3. Tunnel & Trogbauwerke
4. Stützbaueinrichtungen, Hang- und Felsversicherungen
5. Ausweitungen
6. Strecke
7. Fahrzeuge - Asphalt
8. Fahrzeuge - Beton
9. Ausstattung, Verkehrs-Brücken, Lärmschutz
10. Entwässerung (Abflussysteme)
11. Regenbecken
12. Verkehrsteilnehmer (Fahrzeuge und Personen)

**Klimaereignisse**

- Hohe Temperaturen, Hitze
- Niedrigere Temperaturen
- Strahlung
- Nässe
- Starkkälte
- Schnee und gefrorener Regen
- Starkwind
- Nebel

**Klimaeinflüsse**

- Starkkälte
- Schnee
- Nässe
- Nebel
- Starkwind
Failure mode category as classification unit

From a matrix of risk elements and relevant climate impacts, a catalogue of failure mode categories was devised. (32 technical und 3 ref. to traffic participants)

<table>
<thead>
<tr>
<th>Risk element</th>
<th>Climate impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bridges</td>
<td>1 High Temperatures (5)</td>
</tr>
<tr>
<td>2 Culverts</td>
<td>2 Day-Night-Variation (2)</td>
</tr>
<tr>
<td>3 Tunnels &amp; Troughs</td>
<td>3 Frost-Thaw-Cycles (1)</td>
</tr>
<tr>
<td>4 Supporting structures</td>
<td>4 Low-Temperatures (5)</td>
</tr>
<tr>
<td>5 Embankments</td>
<td>5 Irradiation (1)</td>
</tr>
<tr>
<td>6 Pavement – Asphalt</td>
<td>6 Extreme Rainfall (8)</td>
</tr>
<tr>
<td>7 Pavement – Concrete</td>
<td>7 Average Rainfall (4)</td>
</tr>
<tr>
<td>8 Highway equipment</td>
<td>8 Snowfall (1)</td>
</tr>
<tr>
<td>9 Drainage</td>
<td>9 Droughts (2)</td>
</tr>
<tr>
<td>10 Water treatment</td>
<td>10 Storm (0)</td>
</tr>
</tbody>
</table>

Failure mode category:
Damages and restrictions on concrete surfacings due to frost
RIVA Indicator Model
RIVA Indicator Model

Failure mode category
### Beispiel Indikatorkombination

<table>
<thead>
<tr>
<th>Klimaindikator</th>
<th>Wert (2041-2070)</th>
<th>Ausprägungsstufen</th>
<th>Zuordnung</th>
<th>Wichtung</th>
<th>Kombiwert (2041-2070)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-01.1 - Anzahl [d] heißer Tage im Jahr</td>
<td>15,58</td>
<td>X &lt; 10</td>
<td>niedrig</td>
<td>25%</td>
<td>0,5</td>
</tr>
<tr>
<td>K-01.2 - Anzahl [d] Sommertage im Jahr</td>
<td>49,07</td>
<td>10 ≤ X &lt; 20</td>
<td>mittel</td>
<td>20%</td>
<td>0,4</td>
</tr>
<tr>
<td>K-01.3 - Anzahl [n] der Hitzeperioden pro Jahr</td>
<td>0,7</td>
<td>20 ≤ X &lt; 30</td>
<td>hoch</td>
<td>30%</td>
<td>0,3</td>
</tr>
<tr>
<td>K-01.4 - Anzahl [d] der Tropennächte im Jahr</td>
<td>5,02</td>
<td>30 ≤ X &lt; 65</td>
<td>sehr hoch</td>
<td>5%</td>
<td>0,2</td>
</tr>
<tr>
<td>K-01.5 - Höchsttemperatur in der Periode [Tmax in °C]</td>
<td>39,87</td>
<td>65 ≤ X</td>
<td>hoch</td>
<td>20%</td>
<td>0,6</td>
</tr>
</tbody>
</table>

Kombiwert = 2,000
Ca. 10% of highway network

- 8 sections with lengths from 60 to 130 km
- Various regions, climatic and geographic conditions
- High and low traffic volume
- Sections close to borders
- Various construction types
- Range of age and condition of surface
Beispiel für ein Risikomodell
07b-Frostbedingte Schäden und Einschränkungen an Betonfahrbahnen - für die Periode: Beobachtungswert

Legende:
- nicht vorhanden
- 1,0-1,2
- 1,2-1,4
- 1,4-1,6
- 1,6-1,8
- 1,8-2,0
- 2,0-2,2
- 2,2-2,4
- 2,4-2,6
- 2,6-2,8
- 2,8-3,0
- 3,0-3,2
- 3,2-3,4
- 3,4-3,6
- 3,6-3,8
- 3,8-4,0

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im Rahmen des Forschungsprojektes:
RIVA Risikoanalyse wichtiger Güter- und Transitverkehrsachsen
unter Einbeziehung von Sachläufen
FE 09.0147/2011/ARB
Preliminary results from AdSVIS

- For some impacts, adaptation can be mode specific.
- Others can only be tackled in a cross modal approach because adaptation measures have to be developed in a joint effort (EU Flood risk management directive)
Summary

AdSVIS will

- allow for a complete vulnerability analysis of the road infrastructure,
- deliver cross modal vulnerability analyses,
- develop adaptation measures and evaluate them.

- Vulnerability analyses will become a permanent task (IPCC update every 5 years)
- Guidelines and standards must be updated regularly
Thank you for your attention

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