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Protection of Critical Bridges and Tunnels in a Road Network

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Abstract

An effective and secure road network is essential in order to guarantee mobility and supply for the whole population. Particularly bridges and tunnels are key elements of the road network. Restrictions of the availability of these infrastructures may lead to intense traffic interferences on the surrounding road network resulting in negative effects on the road user, high economic follow-up costs and negative environmental impacts.

In order to improve the protection of transport infrastructure the national research program "Research for Civil Security" was initiated and funded by the German Federal Government. On March 1st, 2008 the research project "Protection of critical bridges and tunnels in a road network (SKRIBT - Schutz kritischer Brücken und Tunnel im Zuge von Straßen)" started.

The aim of the project SKRIBT is to identify decisive threat scenarios which could directly affect bridges and tunnels and their users, investigate their effects on the structures and their users and determine the benefits of different protection measures. The result of the project should be a holistic methodology for the determination of effective and efficient structural, operational and organizational protection measures which increase the security of road users and ensure a high availability of road transport infrastructures.

This paper gives an overview about the content and structure of the project SKRIBT. First results of the threat analysis (WP1) and the outline for the catalog of protection measures (WP2) will be given in the presentation.

Protection of Critical Bridges and Tunnels in a Road Network

1 MOTIVATION

The German road network plays an important role for the Trans-European road network, caused by its central position in Europe (FIG. 1). The road network must cope with the greatest share in goods and passenger transport of all transport modes already today. In 2005 about 70 % of goods transport and more than 88 % of the passenger transport was processed via the road network in Germany (1). The road network must take increasing traffic loads in the future because of the extended European market. Current forecasts predict an increase in goods transport on roads by 30 % until the year 2020 (2). In addition, the road network is the most important service system for other transport modes like rail, air transport and shipping.

Therefore an effective and secure road network is very important in order to guarantee mobility and supply for the whole population. In this context especially a high availability is an essential task for the owners and operators of road transport networks. Already small disturbances by traffic restrictions or by the failure of single parts of the road network may lead to intense traffic interferences on the surrounding road network resulting in negative impacts on the road user, high economic follow-up costs and negative environmental impacts. Due to the interdependence of the road transport network with other traffic modes like rail, air and shipping traffic, a failure of important connections could have a domino effect.

FIGURE 1 Trans-European road network in Germany (3).

2 SCENARIO

Particularly bridges and tunnels are key elements of the road network. Due to their bottleneck function often based on geographical constraints they have a high importance for the traffic on Federal Highways (FIG. 2). On the other hand these transportation infrastructures may constitute attractive terrorist targets because of their accessibility and great potential impact on human lives and on economic activity.

FIGURE 2 Bridges are very important infrastructures with a high importance for the road network (Source: BASt).

The damage to or even the complete loss of critical structures, for instance bridges crossing big rivers (FIG. 2) or important tunnel connections (FIG. 3), by terrorist attacks, natural disasters or other incidents could lead to massive and considerable economic damages and can significantly affect the functioning of other important infrastructure elements.

FIGURE 3 Tunnels are important for short connections on Federal Highways (Source: BASt).

The protection of these structures with regard to the current increasing threat situation caused by terrorism but also by aspects of climate change and other hazards is of central importance. In addition to the damage to structures themselves, a large number of users of these structures is exposed to a great danger during incidents or is concerned with required traffic diversions indirectly during the repair and maintenance activities resulting from incidents. Such events can also lead to negative psychological consequences, such as tunnel fear. In every case the security feeling of the users as well as of the society is considerably affected and this can possibly lead to a changed user behavior. The use of alternative routes for avoiding specific structures could result in traffic shifts in the road network. This could influence the flow of traffic on the remaining routes negatively and cause further considerable economic costs and negative environmental consequences.

3 BRIDGES AND TUNNELS ON GERMAN FEDERAL HIGHWAYS

Bridges and tunnels are the most expensive investment parts of highways, namely not only concerning initial investment costs for the construction of these structures but also with regard to later costs of operation, maintenance and preservation.

In the last two decades the number of bridges and especially the number of road tunnels in Germany has increased disproportionately compared with the increase of the total road net. This was caused mainly by the big number of infrastructure projects after German reunification in the 1990ies. The amount of highway tunnels has more than doubled from 90 in 1992 to 217 in 2006. In the same period the total length of tubes increased from 50 to almost 214 km, which corresponds to an average tube length of 665 m statistically (FIG. 4). The biggest amount of bridges in Germany is older than 30 years and was built between 1960 and 1980. Currently there are more than 37,000 bridges with a total length of more than 1,900 km and a total bridge deck area of almost 28 million sqm on German Federal Highways (FIG. 5). The value of the bridge assets in Germany amounts to approximately 45 billion €.

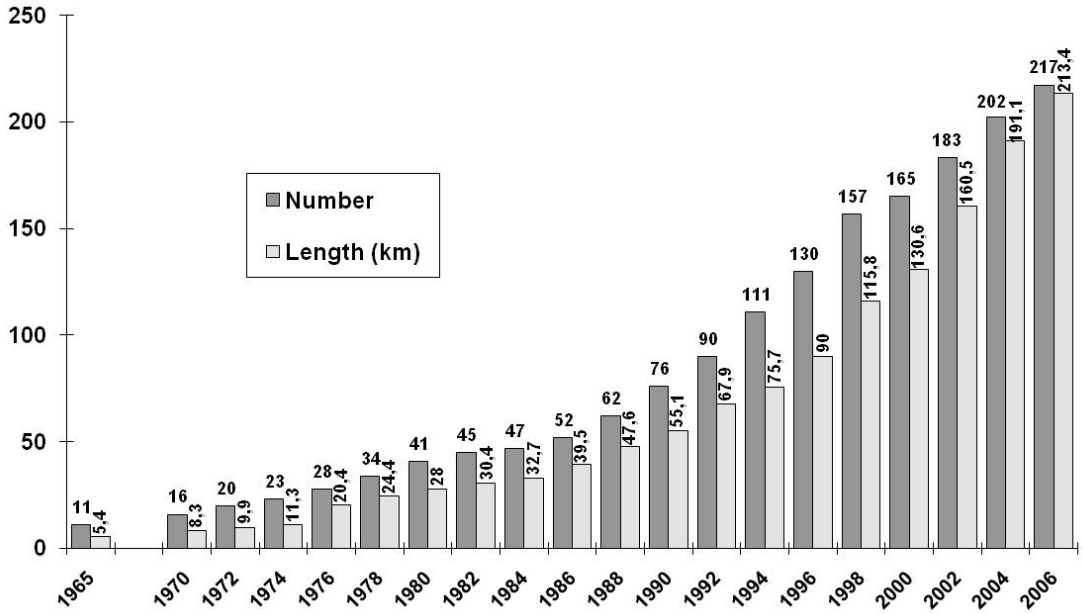

FIGURE 4 Tunnels on Federal Highways (Source: BASt).

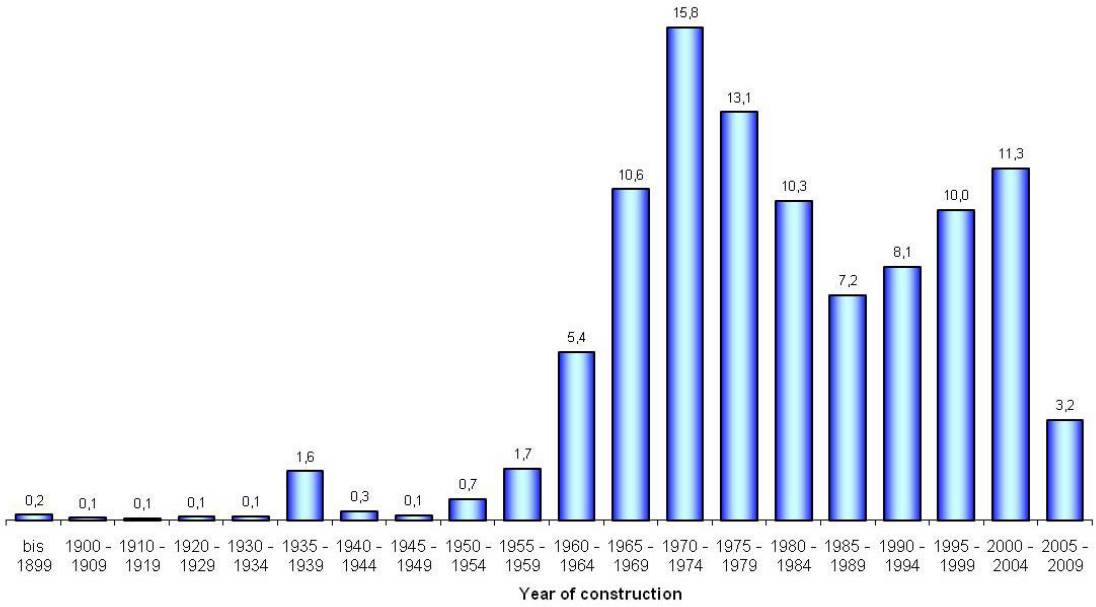

FIGURE 5 Age distribution of bridges on Federal Highways by bridge deck area [%] (Source: BASt).

4 PROJECT AND CONSORTIUM

For providing efficient and reliable connections engineering structures like bridges and tunnels are indispensable and represent in the road network particularly endangered infrastructures. With the aim of identifying possible dangers and developing effective protection measures and thereby reducing the vulnerability of bridges and tunnels and their users a national research project has been initiated in Germany. Under the title "Protection of critical bridges and tunnels in a road network (Schutz kritischer Brücken und Tunnel im Zuge von Straßen – SKRIBT)" the project focuses on road bridges and road tunnels during the planned duration of 3 years. The project in the context of the program "Research for Civil Security" is part of the "High-Tech Strategy" of the German Federal Government and is funded by the German Federal Ministry of Education and Research (BMBF).

The 10 partners of SKRIBT come from Federal Institutions, Research Institutes and private companies:

- Federal Highway Research Institute of Germany (BASt),
- German Federal Office of Civil Protection and Disaster Assistance (BBK),
- Fraunhofer-Institute for High-Speed Dynamics, Ernst-Mach-Institut (EMI),
- HOCHTIEF PPP Solutions GmbH,
- PTV AG,
- Institute for Tunnelling, Pipeline Technology and Construction Management (TLB), Ruhr-University Bochum,
- Schüßler-Plan Consulting Engineers Ltd.,
- Siemens AG,
- Institute for Lightweight Structures and Conceptual Design (ILEK), University of Stuttgart,
- Chair in Psychology I, University of Würzburg.

The interdisciplinary composition of the consortium ensures a holistic treatment of the research theme.

5 LAYOUT OF THE PROJECT

The structure of SKRIBT as well as the work packages is shown in FIG. 6. Ten work packages (WP) have been established to achieve the objectives of the SKRIBT project. The WP 1 until WP 6, each based on the results of the previous one, are supported by the cross section WP 7 until WP 10 which run through the full project duration.

The research approach chosen for SKRIBT is based on relevant threat scenarios, which are developed by a comprehensive threat analysis in WP 1. All natural and man-made threat scenarios are taken into account ("all-hazard approach") and all aspects of the structure are examined such as structural engineering, operational and security equipment, organization of the operation and of the rescue services.

Parallel to the work in WP 1 suitable additional protection measures to increase the security and redundancy of vulnerable bridge and tunnel infrastructures are identified in WP 2. Special attention is paid to sensitive construction details (e.g. cables of a bridge). Concerning the point in time, when the derived protective measures take effect, a holistic approach is chosen, too. Effective measures are developed for the prevention and early diagnosis before possible events, for the reduction of the extent of losses during events as well as for the repair and reopening after events.

On the basis of the threat scenarios which could directly affect bridges and tunnels and their users, the vulnerability of different bridge and tunnel types are analyzed and different decision criteria for a general classification of bridges and tunnels are derived (WP 3). Suitable and effective protective measures are developed for critical structures (e.g. due to easily vulnerable components like cables of a cable stayed bridge) in order to enhance their security under consideration of cost-effectiveness (WP 4). This is done by using specially adapted methods of risk and scenario analysis. The calculation of risks includes the impact assessment for the respective asset based on different occurrence scenarios with related event trees. The vulnerabilities are then estimated using the local traffic conditions and simulations, e.g. escape simulations, explosives and smoke propagation simulations. Improvements of security are determined by applying measures to the respective infrastructure. The monetary and economic impacts of the different measures are also examined by means of cost-benefit analyses so that the most effective security measures can be determined.

In WP 5 the determined effective protection measures are worked out as recommendations for the implementation of measures for the different target groups: owner, operator and user of road infrastructures as well as rescue services and operating personnel. Finally some of the determined effective protection measures like e.g. new detection technologies, new operating strategies for the event case and planning of structural retrofitting or repair measures are demonstrated at selected bridges and tunnels (WP 6).

By the interdisciplinary cooperation of engineers with psychologists the human behavior of the different target groups in different event scenarios is taken into account for the derivation of effective (primarily, preventative) protective measures in WP 7. Cross section WP 7 is designed to have impacts on nearly all other WP's in questions of user behavior in crisis situations and behavior of rescue and operating personnel. The human behavior in tunnels and on bridges is also investigated by using techniques of virtual reality with measurement of all relevant body and brain functions of the test persons.

A project accompanying evaluation of research results regarding ethical and legal aspects (WP 8) should guarantee that the research results directly satisfy these aspects. This should also lead to a prompt "putting into practice" of the identified measures. An

overall coordination of results (WP 9) and project management (WP 10) is installed in order to guarantee an effective dissemination of research results and operation of the interdisciplinary project consortium.

6 RESULTS

The research results of SKRIBT will be worked out in a holistic way in recommendations for the implementation of measures as described in section 5. The gained knowledge shall find entrance in future recommendations, national and European guidelines and standards. The effective protective measures will be commercialized by the industrial partners correspondingly. The knowledge on the human behavior in crisis situations is considered in the planned security measures as well as for the structural design of security relevant equipment for bridges and tunnels. These results will contribute to an “intuitively correct” user behavior in tunnels and on bridges.

The immediate exploitation of all results achieved is guaranteed by a direct participation of one or several partners of the consortium in the relevant national and international committees and by immediate putting into practice by the involved industrial partners on national, European and international level. Finally the methodology developed by SKRIBT should help owners and operators of road networks to identify critical infrastructures in their network and to determine the suitable effective protection measures in order to ensure a high availability of all important traffic links and to make road tunnels and bridges more secure in the future.

Further information about SKRIBT is available on the Internet at www.skribt.org.

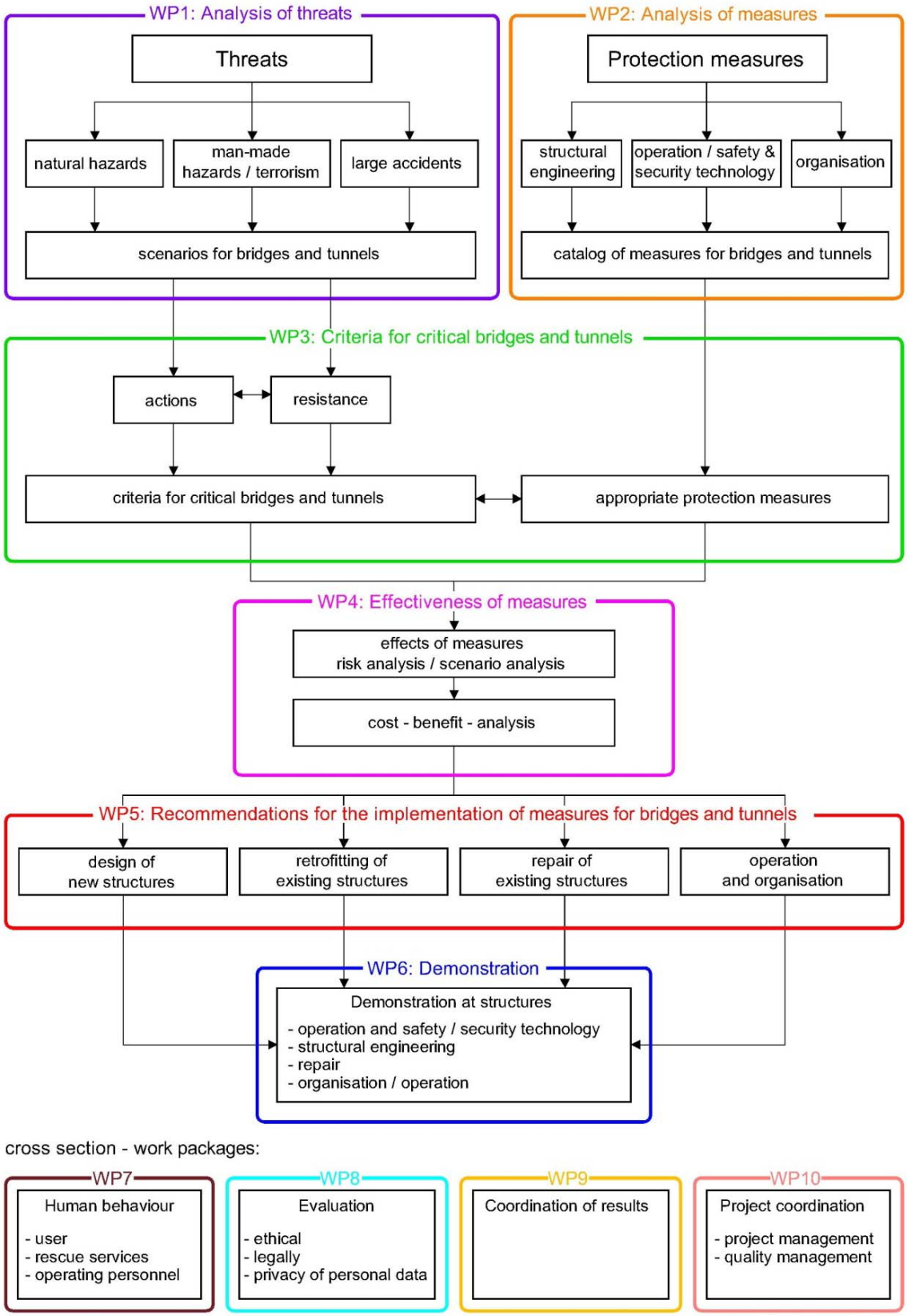

FIGURE 6 Structure and work packages of SKRIBT (Source: SKRIBT).

7 REFERENCES

(1) Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS): Verkehr in Zahlen 2006/2007, S. 237 bzw. 213, DIW Berlin, Eurailpress-Verlag Hamburg ,2006.

(2) acatech - Konvent für Technikwissenschaften der Union der deutschen Akademien der Wissenschaften e.V.: Studie „Mobilität 2020 – Perspektiven für den Verkehr von morgen“, Fraunhofer IRB Verlag 2006.

(3) European Parliament and European Council: Decision No 1692/96/EC of the European Parliament and of the Council of July 23th 1996 on Community guidelines for the development of the trans-European transport network, Publication on 9.9.1996 in EN Official Journal of the European Union L 228, page1.