Protection of vulnerable Infrastructures in a Road Transport Network

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Abstract

Road transport networks are of major importance for the economy and equally for the mobility of the citizens in the European countries. In order to improve the protection of transport infrastructures and the robustness of the European road network research projects are currently in process on national and European level. A main focus of these investigations is to analyze the specific vulnerabilities of bridges and tunnels concerning structural, operational and organizational aspects and to identify critical objects. But also infrastructures, which are critical due to their location and function in a road network, must be identified. For this the resulting regional and supra-regional impacts due to the failure of certain infrastructures have to be investigated on network level. In order to increase the security of road transport infrastructures and whole road networks the most effective security measures have to be determined.

This paper gives an overview about the content and first results of current European and German research projects on road transport security.

1. Introduction and motivation

The European road network is of major importance for the European economy and equally for the mobility of the European citizens. Especially roads of the Trans-European Transport Networks (TEN-T) and planned TEN-T road projects (like E55 Dresden – Prag - Linz, Elbe crossing A22 or Fehmarnbelt crossing) play an important role. Therefore, a major task of owners and operators of highways and roads in Europe is to ensure a high availability of all important links. Even smaller disruptions due to traffic restrictions or failure of some elements of the road network may lead to intense traffic interferences resulting in 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.

Especially the German road network plays an important role for the Trans-European road network, caused by its central position in Europe (Fig. 1). The German 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 (BMVBS, 2006). 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 (acatech, 2006).
Particularly bridges and tunnels are key elements of the road network due to their bottleneck function often based on the geographical constraints. They may constitute attractive terrorist targets because of their accessibility and great potential impact on human lives and economic activity.

The damage to or even the complete loss of critical structures, for instance bridges crossing major rivers or important tunnel connections, 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.

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.
2. Current national and European research projects

2.1 National projects

In Germany the German Federal Ministry of Education and Research (BMBF) has started an extensive security research initiative in 2007. In the context of the program “Research for Civil Security” which is part of the “High-Tech Strategy” of the German Federal Government there are more than 35 projects being currently funded in 3 different calls (34 more projects are “in the pipeline”). 2 projects deal with security of road transport infrastructure. One of these projects, dealing with the development of effective protection measures for road bridges and tunnels and their users, is the collaborative project “Protection of critical bridges and tunnels in a road network (Schutz kritischer Brücken und Tunnel im Zuge von Straßen – SKRIBT)”. The project, under the lead of the Federal Highway Research Institute (BASt), consists of 10 partners who come from Federal Institutions, Research Institutes and private companies. This paper will focus on the method and first results of SKRIBT in chapter 3. The other German security research project deals with intelligent sensor technology for tunnel linings (project AISIS).

Other national security research projects dealing with road transport were executed in different European countries. In Austria the new National Security Research Programme called KIRAS, issued by the Austrian Research Promotion Agency (FFG), is dedicated to enhance the research on safety and security issues at a national level. Results of Austrian research projects dealing with road transport security are not published so far. In Switzerland a recently finished research project deals with the vulnerability assessment of the Swiss road network (Erath, 2009). Other projects in the USA deal mainly with road transport network robustness and the calculation algorithms for alternative routes (Sullivan, 2009), (Ukkusuri, 2009).

2.2 European projects

Under the Seventh Framework Programme for Research (FP7), the European Commission supports currently about 45 security research projects (security call 1 and joint ICT & security call). There is one project among these first security research initiatives dealing with road transport network security: the collaborative project “Security of Road Transport Networks (Seron)”. The aim of SERON is to improve the protection of transport infrastructure and the European road network. The project has been initiated by PTV Planung Transport Verkehr AG and BASt, bringing together seven partners from six European member states. The project started in November 2009. This paper will focus on the research approach of SERON in chapter 4.

3. Investigations on object level

Comprehensive investigations on object level dealing with bridge and tunnel structures and user behavior are carried out in the research project SKRIBT. Some of the results of SKRIBT and of other national security research projects could be used as input for the project SERON. In the following the research approach chosen for SKRIBT (Krieger, 2008) and the current status of work is described (Krieger, 2009).

3.1 Research approach of SKRIBT

The structure of SKRIBT as well as the work packages is shown in Fig. 2. 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.
3.2 Current status of work and first results of SKRIBT

The work packages WP 1 and WP 2 have been finished. Within WP 1 a comprehensive scenario-catalogue has been developed in which the numerous scenarios are distinguished according to terrorism and criminal actions, natural incidents, human and technical failure, loss of critical infrastructure and incidents with a very low probability. Simultaneously to WP 1 the second
work package (WP 2) has been worked out. In the course of WP 2 protective measures have been collected with regard to construction technique, operation and organization. Thereby every presently potential protective measures as well as in future imaginable protective measures are considered and accumulated. Within the scope of WP 3, which started after the first two work packages in late 2008, a methodology to identify critical bridges and tunnels is currently developed. This methodology is taking all the different aspects of criticality into account and is one of the key elements of the SKRIBT project (Fig. 3). A current analysis of the weak points complemented by computer simulations concerning the critical construction and operation components as well as simulations related to human behavior in tunnels and in emergency situations are under progress (Fig. 4, 5, 6). First results concerning the effects of blast loads on critical parts of bridges (e.g. bridge cables) are published in (Stolz, 2009). Results of the investigation of the human behavior in tunnels in the event of fire are published in (Eder, 2009).

Figure 3: Methodology to identify critical infrastructures (Source: SKRIBT)

Figure 4: Simulation of high-speed dynamic events (Source: FhG EMI)
Finally the research results of SKRIBT should help owners and operators of road networks to identify critical infrastructures in their network and to determine the suitable effective protection measures for critical objects in order to make road tunnels and bridges more secure in the future.

4. **Investigations on network level**

The main objective of the SERON project is to investigate the impacts of possible terrorist attacks on the transport network, in particular the resulting regional and supra-regional impacts.
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on transport links and their economic impacts. SERON has its focus on the development of a methodology which is to help owners and operators to analyze critical road transport networks or parts hereof with regard to possible terrorist attacks. SERON evaluates planned protection measures for critical road transport infrastructures concerning their impact on security and cost-effectiveness of the whole road network.

In order to reach this objective, an innovative and holistic approach will be applied. It brings together interdisciplinary expertise in order to derive the necessary innovations regarding object and network data handling, simulation methods, sensor technology, protection technology, quantitative risk assessment strategies and cost-benefit analyses, so that a functioning methodology will result from this project.

Eight work packages have been established to achieve the objectives of the SeRoN project. They are broken down into object and network level. The object level deals with specific infrastructure objects (bridges and tunnels). In WP 100, the possible threats are analyzed so that critical infrastructure objects can be identified in WP 200 (input from national research projects e.g. SKRIBT). The gathered knowledge is concentrated in WP 300, the knowledge database to be established, the structure of which is a main achievement of the SERON project. The knowledge database is the link to the network level. In case of an attack on one or several infrastructure object(s), its impacts and consequences on the transport network will be investigated. WP 400 analyzes the impacts of the destruction of an infrastructure object for the network. WP 500 assesses possible protection measures. The methodology is applied and validated in WP 600. Dissemination of project results, input of external advice and the formulation of project recommendations is done in WP 700. WP 800 consists of the overall project management. Figure 7 illustrates the work package structure.

Figure 7: SERON structure and work packages (Source: PTV)
5. Conclusions and outlook

Finally the two projects SKRIBT and SERON will give adequate recommendations concerning possible current and future threat situations and the corresponding most effective security measures which increase the security of road transport infrastructures and road transport networks and their users. The implementation of the measures will finally lead to a significant improvement of the levels of security, performance and resilience of the European road transport system.

The research results of SKRIBT will be worked out in a holistic way in recommendations for the implementation of measures as described in section 3.1. 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. 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.

The developed and validated innovative methodology of SERON will provide a common framework for the identification of critical road infrastructure objects with respect to their importance within the European transport network by means of an interdisciplinary interaction of expertise and innovative simulation methods. Furthermore, using this methodology, possible protection measures can be suitably chosen and be evaluated regarding their cost-effectiveness. The newly developed methodology could later be applied to identify critical infrastructures and effective protection measures for road networks or parts hereof, for instance, main European traffic corridors which handle the most important traffic flows. The methodology could also be transferred to transport networks used by other traffic modes (e.g. railway links).

6. References


