Modelling & Simulation for Underground Operations

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INTRODUCTION

Due to the increasing volume of traffic and the resulting efforts of the society to reduce traffic in urban areas and settlements, to build bypasses or due to the topography to move this partially underground. Resulting in an increasing number of complex traffic and safety concepts, which include underground infrastructure. From a fire safety perspective, hazards are manageable and risks are largely calculable. The scenario of a dangerous goods accident in a road tunnels or the release of chemical agents into underground facilities is treated very sparingly (if at all), neither are military concepts for underground operation. However, the attack with Sarin on Tokyo's subway in 1995 shows that underground facilities in particular have a particular vulnerability here.

Figure 1: complex emergency Tokyo 1995

When assessing tunnels, quantitative risk analyzes are carried out by default, but these primarily relate to the effects on personal safety in the tunnel and also on the tunnel itself. Concrete considerations regarding the safety of response units are not carried out. Tunneling projects of the trans-European road network have a special significance throughout Europe and are subject to specific directives of the European Union. First and foremost, this is Directive EU No. 2004/54 / EC (2004). The Road Tunnel Safety Act transposed Directive EU No. 2004/54 / EC (2004) into the Austrian legal system. The road tunnel safety law for federal highways is enforced in accordance with federal highway law and a tunnel length of more than 500 m. For tunnels outside this scheme (tunnels on provincial, district and municipal roads or tunnels less than 500 m in length), the Road Tunnel Safety Act will apply mutatis mutandis.

For the transport of dangerous goods by road (according to ADR or dangerous goods transport law) restrictions apply to the passage through road tunnels. National restrictions are also found in BGBl. II No. 395/2001 (2001). Further traffic prohibition regulations are carried out on the basis of the road traffic regulations. In addition, there are nationally the holiday travel ordinance, which regulates driving bans on

weekends in summer, as well as the "regulation on the restrictions for transport units with dangerous goods when driving on motorway tunnel", which regulates and restricts the passage through single-tube road tunnels for dangerous goods transport. The topic of the transport of hazardous substances in tunnels can be found in numerous legal documents and guidelines. For the planning, dimensioning, commissioning and accident management, the Austrian Road-Rail-Traffic Association provides the Road Regulations, which are supported by the Federal Ministry of Transport, Innovation and Technology of the motorways and freeways financing corporation (ASFINAG) and the federal states and were declared binding in the area of federal highways.

For tunnels, a quantitative risk assessment of hazardous substance transports with a risk-oriented assessment approach is currently under consideration of alternative routes. Essentially, this only derives from an allocation with regard to any traffic restrictions for the transport of dangerous goods and the restriction category. Furthermore, a quantitative tunnel risk analysis is carried out to determine the overall risk. In addition to dangerous goods accidents, the risk of tunnel fires and mechanical accidents is also considered. On the one hand, this results in the assignment to a hazard class and, on the other hand, a requirement for additional risk-reducing measures. These consist e.g. from structural measures in the area of drainage and aim to quickly collect liquid pollutants and divert into water protection systems. Furthermore, structural measures are taken to prevent the spread of fire through the drainage system. Structural measures for the reduction, e.g. of explosive effects are not yet sufficiently investigated or not available. On the other hand, there is a limited detection by the installation of ventilation systems, as well as permanent metrological monitoring of carbon monoxide.

STATE OF THE ART

The general level of knowledge regarding the propagation and effect of hazardous substances in underground traffic void structures is rather low. Pollutant dispersion calculations are practically only for smoke and traffic emissions. Experience in the field of release of chemical agents (toxic industrial materials and chemical warfare agents) is very limited. The current knowledge is based mainly on theoretical considerations without real scientific proof. Dangerous goods accidents in tunnels, as well as the release of chemical agents in underground facilities in general is a particular challenge for emergency services. Long approaches, a large number of potentially vulnerable people, complex building services and restrictions in the field of personal protective equipment of the emergency services, limit the options for action.

Current scientific studies on accidents in tunnels mainly relate to the fire scenario. Although in alarm and operational plans, hazardous goods events are generally dealt with, for lack of in-depth knowledge on this topic, as well as mostly missing operational concepts, only very basic specifications are made here. Here are detailed calculations, ventilation concepts and application concepts, which allow to dominate tunnel fires largely. Already the decision on meaningful fan control at dangerous goods release leads regularly to discussions. This shows the relative uncertainty as a result of insufficient knowledge and lack of experience. Different ventilation concepts for flammable gases, toxic heavy or neutral gases depending on the tunnel infrastructure are not available. In most tunnels ventilation systems are taken out of service in the event of an incident, the advance of forces is thus not actively supported. In railway tunnels are largely no ventilation aides available. It is also not known how events (such as explosions) and ventilation will affect outside the tunnel. In subway systems in particular, many exhaust vents are located directly in urbanized areas and represent a potential source of danger in the specific case. Corresponding impact analysis away from traffic-related pollutant emissions is missing here (toxic heavy gases, warfare agents, combustible gases, etc.).

The field of tunnel fire has been intensively treated by the emergency services for many years. The deployment concepts are based on many experiments, exercises, but also on operational experience of recent years. Due to the developments in the automotive industry, the energy supply (natural gas, hydrogen, etc.) and the change in the security police situation, focal areas have shifted and expanded. The area of dangerous

goods as well as chemical agents in the broader sense are currently only present in the risk analyzes which are generally used for the assessment of tunnel safety. There is a need for research throughout the event-handling system of chemical agent events in underground facilities.

Recent advancements in augmented and mixed reality applications now enable the use of the technology in corporate settings. In industry, virtual and mixed reality is used to train work processes. Corporations, authorities and military organizations worldwide are using mixed reality glasses or are conducting research to integrate them into their existing infrastructure. Real time 3D reconstruction and combination of 3D data, as well as supplementing it with external information, is an innovation that can be used for simultaneous localization and mapping (SLAM) algorithms that are used in a variety of domains such as robotics and autonomous driving. Automated detection and classification extend the state of the art concerning robust algorithms that are resistant to data inconsistencies (motion blur, distortions, smoke…) and can work with a small amount of data. The standardized interfaces innovate the adaptability towards highly dynamic processes, which are prevalent in emergency operations underground.

EVENT DETECTION AND VERIFICATION

In the field of sensors, there are currently systems for early fire detection, for dangerous goods accidents or the release of chemical agents such systems are usually not available. Currently mainly the permanent metrological monitoring of carbon monoxide and visibility clouding is considered. It is currently not known whether due to the propagation behavior of different substances early detection with sensors is even possible or where the use of sensor systems is targeted.

WARNING AND ALARMING

Although, in operational plans, hazardous goods events are generally dealt with, for lack of in-depth knowledge on this topic, as well as mostly missing operational concepts, only very basic specifications are made here. Already the decision on meaningful fan control at dangerous goods release leads regularly to discussions. This shows the relative uncertainty as a result of insufficient knowledge and lack of experience. Safety and shut-off areas can only be determined on the basis of assumed effects, and there are no definite studies on the endangerment of emergency personnel depending on the specified operational areas.

SAFETY AND SECURITY

On-site security requires a thorough understanding of the implications of different scenarios, especially when comes to military intervention. Currently largely unappreciated is the impact on operational personnel deployed in such events. In the area of tunnel firing, the targeted design of safety equipment has ensured that, on the one hand, escape and, on the other hand, intervention by emergency personnel is possible. At present it is still unclear how an intervention in tunnels can be designed in case of increased danger of explosion or after the release of toxic substances or what risk exists for response services. It lacks an evaluation basis for the decision where and under what conditions can be intervened and what technical and tactical possibilities are there to allow intervention.

Currently used types of protective clothing and respiratory protection systems allow only very short operation times, which cannot be used in underground facilities due to the long transportation and deployment times (even at short cross-pass distances). Also unclear is the subject in case of incidents within response units or respiratory emergency. Rescuing intervention personnel with chemical protective suits is an additional challenge compared to standard emergency response. Again, the above parameters of long distances and physical burden, further has main impact on air supply and mission time. Basis for a rescue

and intervention concept could be on the one hand ventilation measures, but possibly also the use of new technologies.

Due to the existing research-related deficits, further developments in connection with the challenges above are hindered and innovations slowed down. The complexity of the topic makes a cooperative research approach necessary to develop the scientific basis for interventions in the presence of chemical agents in underground facilities. Especially with regard to the technical equipment of tunnels and with regard to new ventilation concepts in conjunction with the measures of the emergency services. In addition, results provide starting points for further research in the field of respiratory protection or the personal protective equipment.

OUTLOOK

With the results it should be possible to create an evaluation basis for the intervention in underground facilities. It is to be clarified under which conditions interventions are possible. For this purpose, the focus will be on the spread of CBRN agents and the effects of explosives. Further aims are to identify gaps in risk analysis of tunnels and to identify starting points for innovations in enhanced equipment. By modelling and simulation activities for underground operations the following results are expected:

- Analysis and documentation of organizational aspects of operational concepts
- Analysis of TTPs and development of CONOPS
- Beahviour of neutral, light and heavy gases or vapors
- Investigation of fire and explosion impact
- Evaluation of results in terms of risk areas for civilians and operational personnel
- Determination of effects of different analyzed scenarios on the infrastructure (explosion pressures, corrosion effects, temperature profiles, etc.)
- Analysis of the effects of pollutant releases in the environment of above-ground facilities
- Preparation of hazard and risk information as a basis for the development of a rating system