TUNNEL SAFETY MANAGEMENT IN CONTEXT WITH THE EU-DIRECTIVE

Hörhan R.,
Ministry for Transport, Innovation and Technology, Austria

ABSTRACT
Tunnel safety management is a subject of many national and international activities since the last years. In this connection basic trends and developments can be found out. On the international level a need for harmonisation of safety requirements is requested aiming at an integrated view of all safety aspects of road tunnels. Safety management systems should fulfill these requirements by an integrated approach of tunnel safety. The EU-Directive 2004/54/EC is an international legislative document providing an integrated approach for a tunnel safety management system.

The background for tunnel safety management systems and their application on the EU-Directive is described.

Keywords: tunnel safety management, safety requirements, risk analysis

1. INTRODUCTION
Tunnel safety management plays a key role for many initiatives funded at the European and international level. Many countries agree on the fact that there is a need for a framework in which all relevant aspects of tunnel safety, such as regulations, technical and operational measures, safety assessment operating experiences are taken into account in a holistic way.

In this context the EU Directive 2004/54/EC on minimum safety requirements for tunnels in the trans-European road network implies the standardization of the institutional, organizational and operational aspects of tunnel safety management systems across the member states of EU.

2. OBJECTIVES OF TUNNEL SAFETY MANAGEMENT
A basic prerequisite for providing an integrated view of the tunnel safety management system is to define its major objectives and outline its basic elements and structure. A tunnel safety management system involves a set of measures in order to safeguard the efficient and safe operation of the tunnel.

The definition of the objectives of safety management systems are the same in various international activities of the last years. Both the international work of PIARC (report on fire and smoke control in road tunnels of 1999), the UN ECE report of the group of experts on road tunnel safety of 2001 and European Union (Directive on Minimum Safety Requirements for Tunnels in the Trans-European Road Network) agree in following basic objectives:

1. Prevent critical events that may endanger human life, the environment and tunnel installations
2. Reduce the consequences of accidents, such as fires by creating the prerequisites for:
   - people involved in the incident to rescue themselves;
   - road users to intervene immediately to prevent greater consequences;
   - ensuring efficient action by emergency services;
   - protecting the environment; and
   - limiting material damage.
Prevention is of course of primary importance, but unfortunately it is not possible to prevent all incidents. In case of an accident or fire, the most effective response is self-rescue of users inside the tunnel. The experience of past large fire incidents shows that an intervention of the fire brigade can be ineffective after e.g. ten minutes or emergency services cannot reach the fire place in such a short time.

The above mentioned objectives are connected with the definition of risks as product of the tunnel incident probability and the incident consequences. This definition implies that risk mitigation can be achieved through the provision of a set of preventive and repressive measures in order to minimize the probability of tunnel incidents and reduce the tunnel incident consequences.

3. INTEGRATED VIEW OF SAFETY

An illustration of all safety aspects in road tunnels is the "bow-tie" model (see figure 1) contained in the European research project Safe-T. This model incorporates the different stages of an accident. In most cases, incidents are determined by certain pre-conditions (causes), in other words a disruption of the normal course of the traffic. An accident is composed of different stages, beginning with an incident. The accident development process determines the seriousness of the accident effects. This can be expressed graphically by regarding the incident as a nodal point between the pre-conditions.

The chain with causes - incident - effects has the shape of a bow tie. Both tie sides contain the points of action to influence the events before or after the incident. On the one hand, attention should be given to incident prevention (e.g. brake overheating of trucks). On the other hand, the mitigation and suppression of accident effects (e.g. smoke or toxic gases) is of crucial importance.

Figure 1: Bow tie model applied to tunnel accidents with fire and smoke

In the past regulations concerning tunnel safety were mostly dealing with infrastructure. The first international regulation with a holistic approach was published by the UN ECE. A multidisciplinary group of experts on road tunnel safety (with members of PIARC and ITA) was launched 2000 in Geneva and published 2001 the final report of UN ECE which includes recommendations on all aspects of road tunnel safety: user, operation, infrastructure and vehicles. The current state of international regulations and research works are based on this holistic approach of tunnel safety.
4. **THE EU- DIRECTIVE 2004/54/EC**

The EU- Directive 2004/54/EC on minimum safety requirements for road tunnels follows this trend but provides more safety measures regarding the infrastructure and operation and only information campaigns for users. Other EU legislations will deal with vehicles. But the EU Directive 2004/54/EC provides additionally several levels of responsibilities, a risk analysis and procedures for the different planning stages of tunnels.

4.1. **Responsibilities**

The EU Directive regulates the responsibilities in the tunnel safety management designating the following actors involved within the tunnel safety management:

- **Administrative Authority**
  shall ensure that all aspects of safety of a tunnel are assured and shall assess their compliance with the requirements of the Directive both for tunnels in the designing stage, before opening for the public traffic and existing tunnels. Several tasks are defined in detail e.g. that regular inspections are carried out by the inspection entity.

- **Tunnel Manager**
  is responsible for the management of a tunnel in the design, construction and operating stage. The Tunnel Manager nominates with the prior approval of the Administrative Authority one Safety Officer for each tunnel, who can be a member of the tunnel staff or the emergency services.

- **Safety Officer**
  shall coordinate all preventive and safeguard measures to ensure the safety of users and operational staff. He is responsible for assessing the effectiveness of the tunnel safety measures and ensures the coordination of the tunnel manager and the emergency services with respect to the emergency response planning.

- **Inspection Entity**
  is established by each Member state in order to perform evaluations tests and inspections by or on behalf of the Administrative Authority on the technical and operational conditions of the tunnel.

- **Emergency services**
  including police services, fire brigades and rescue teams, intervene in the event of an incident.

4.2. **Risk analysis**

The European Directive requires a minimum safety level for new and existing tunnels and provides various parameters for a systematic consideration of all aspects of the safety system. For tunnels with special characteristics regarding the mentioned parameters, e.g. percentage of heavy goods vehicles, additional safety measures should be proven to reduce the risk in the tunnel by the use of a well-defined risk analysis methodology. The type of risk reduction measures is entirely up to each member state to determine. The risk analysis shall take into consideration possible accidents, which clearly affect the safety of road users in tunnels and which might occur during the operating stage and the nature and magnitude of their possible consequences.

The Austrian risk model for road tunnels was developed on a system based approach, consisting of a quantitative frequency analysis and a quantitative consequence analysis.
4.3. Safety measures

The safety measures proposed by the EU Directive shall be implemented at a minimum in order to ensure a minimum level of safety in all relevant tunnels. They are prescriptive i.e. they are depending on limits as traffic volume or on the length of a tunnel and consists of following infrastructure measures:

- Structural measures
- Lighting
- Ventilation
- emergency stations
- Water supply
- Road signs
- Monitoring systems
- Communication systems

According to the EU Directive, the tunnels should be provided with the essential operating means that ensure the safety of the traffic flow inside the tunnel. In addition, proper traffic arrangements should be applied when maintenance works are performed. These arrangements refer to the traffic inside and nearby the tunnel.

Traffic management plans should be developed covering the procedures of closing the tunnel in case of an emergency situation.

4.4. Tools for safety tunnel management

The European Directive stipulates tools for safety tunnel management to ensure a constantly safety throughout the life of a tunnel. For this purpose general demands are defined for safety documentation, collection and analysis of incident data and safety inspections of tunnels.

The tunnel manager shall provide safety documentation for the three different stages of a tunnel project: The design stage, the commissioning stage before opening the tunnel for public traffic and the operation stage. The safety documentation shall contain all safety-relevant information about the respective tunnel as defined in the European Directive:

- a precise description of the tunnel e.g. the geometry, emergency facilities
- traffic situation e.g. characteristic traffic data, portion of heavy goods vehicles, traffic regulation
- transport of dangerous goods with an estimation of relevance of risk of hazardous goods transport
- safety organization and emergency response e.g. emergency response plan, coordination with the emergency services
- feedback of experience e.g. documentation on safety exercises carried out, implementation of findings from exercises

Collection and analysis of incidents are essential for the risk assessment of a tunnel and for the improvement of safety measures. The EU-Directive requires a report when a significant incident or accident occurs in a tunnel by the tunnel manager and every two years an information about the frequency and causes of significant incidents by the member states. Significant incident which have to be reported are incidents, accident or fires in tunnels which clearly affect the safety of road users in tunnels.

The collected data allow in particular, evaluating the frequency and the causes of significant incidents or accidents and provide information on the actual role and effectiveness of safety facilities and measures and on users behaviour.
In Austria a web-based data collection sheet for tunnel incidents is developed and used since the beginning of 2006.

Safety inspections of tunnels are another tool of safety management which is required by the European Directive. At least every 6 years periodic inspections are mandatory to make sure that the tunnel meets the safety requirements. The inspections shall be carried out by the inspection entity, which have to be independent from the tunnel manager. The administrative authority may execute the inspection entity or transmit it to a private entity. Considering a possible change of relevant parameters of tunnel safety, e.g. traffic density, status of safety equipment, the safety level of in service tunnel must be regularly assessed in order to

- secure the tunnel management team on its organisation and safety measures applied
- check that the initial safety level has not decreased regarding possible new conditions of operation

The safety inspection which is in progress in Austria since several years ensures the high level of safety of the operational and infrastructural measures.

5. CONCLUSIONS

The EU-Directive 2004/54/EC provides a tunnel management system for road tunnels considering all aspects for tunnel safety in a holistic way in order to gain uniform minimum standards for road tunnels in the European Union. Beside the requirements of safety measures regarding infrastructure, operation and tunnel user additionally the use of a risk analysis considering the particular risk relevant influence parameter for a specific tunnel is provided. A new element in the EU-Directive is the definition of several levels of responsibilities and compulsory procedures ensuring the minimum safety level in the planning stage and when opened for traffic and for existing tunnels, with regular inspections of the infrastructure and operation. A systematic collection and analysis of incident data in tunnels should enable the efficiency of the various safety measures and improve the data for risk estimation and risk evaluation.