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Risk Analysis in Road Tunnels

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Abstract

Safe operation of road tunnels is very important, therefore we make risk analysis already in project developing. In Slovak Republic, the risk analysis is carried out according to technical conditions [1]. It allows make assessment of safety of road tunnels and calculate the specific level of risk, which reflects possible (statistically expected) number of deaths for a specific period. Than we know to compare tunnels with the reference tunnel and also we classify individual tunnels into hazard classes, which provides an overview about absolute risk level of tunnels.

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Keywords: tunnel; road; risk analysis; safety; accident

1. Introduction

Safe operation of tunnel is very important, because tunnels are specific engineering structures, which are constructed in order to shorten transport routes and improve road safety. Road (highway) tunnels under consideration of the safety documentation require the risk analysis. In Slovak Republic the assessment method is utilized according to the Austrian experiences. Risk analysis methodology is important for a safety in road tunnels, because in Slovakia there will be 33 or 34 road (highway) tunnels in the future. Also transport of dangerous goods through the tunnel affects the overall safety of the tunnel.

2. Risk analysis

Risk analysis methodology has a great importance for safety in road tunnels. Risk analysis is done according to technical specification TP 02/2011, [1]. Tunnel safety is defined like a safety and protection of persons, property, and surround of structure, which is given by result of risk evaluation, solution reasoning in point of risks, fire-safety structure solution and solution of structure influence on environment, protection of monuments, nature and countryside. Risk model has been developed on the base of Austrian model TuRisMo (RVS 09.03.11).

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2.1. Method of risk analysis

Risk analysis and risk assessment includes quantitative application of risk model and possible realization further steps of risk analysis to review special questions like transport of dangerous goods. For studying the transport of dangerous goods is suitable specific risk model DG-QRAM (Dangerous Goods – Quantitative Risk Assessment Model). Model of tunnel risk analysis explores personal risk of tunnel users, what means that all parameters are used only to accidents with personal injury. It detects the statistical value of risk for risk groups of users of the tunnel, namely the value statistically expected number of fatal casualties pre year. Effects of dangerous goods are considered only a simplified model [1].

In Fig. 1 the risk analysis model consists of two main elements:

- quantitative analysis of frequency,
- quantitative analysis of accident consequences.
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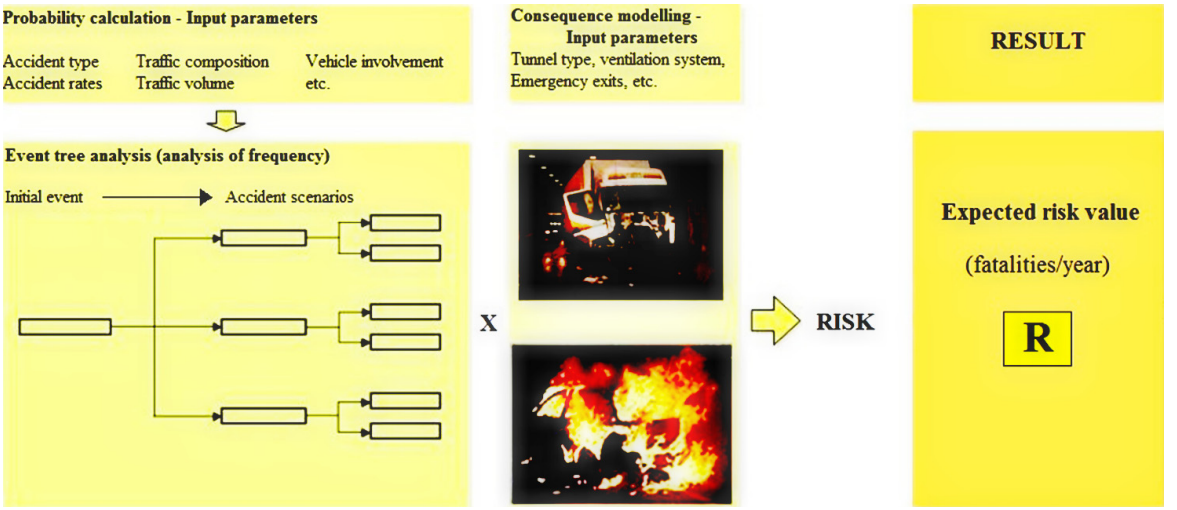

Fig. 1. Risk analysis structure of road tunnels.

2.2. Relative risk evaluation

Relative risk evaluation consists in axiom that the tunnel with its all specific safety-technical relevant characteristic cannot allocate higher risk as a similar reference tunnel which satisfies in all points and authoritative parameters to minimal requirements of government regulation. This approach enables achieve that through the medium of prescriptive measures is possible to keep minimal safety level also by respecting of specific curiosities of individual tunnel. The principle of relative evaluation can be shown with follow diagram in Fig. 2 [1].

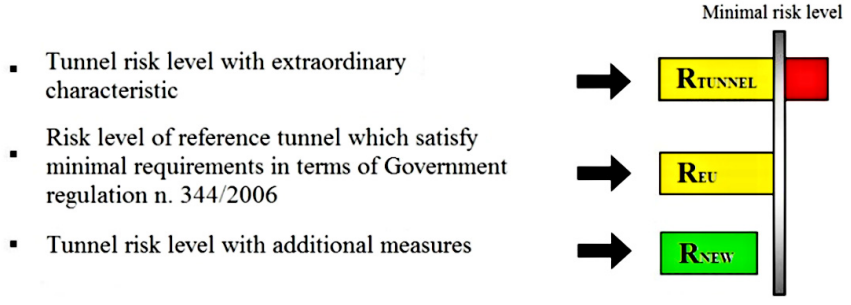

Fig. 2. Relative risk evaluation.

2.3. Absolutely risk evaluation

Absolutely risk evaluation complements the relative evaluation and its goal is to provide information about absolute risk margin. Based on the expected value of risk (specified risk analysis) the studied tunnel is assigned to risk (hazard) class according to [1] Table 1:

Table 1. Distribution of hazard classes.

Expected Risk Value		**Hazard Classifications**
Lower thresholds	Upper threshold	
-	0.02	I
> 0.02	0.1	II
> 0.10	0.5	III
> 0.50	-	IV

3. Exploration of ADR

University of Žilina made the exploration of proportion of dangerous goods in transport through the tunnel. This research was aimed mainly to be objective determination of how much of transport dangerous goods is in the section of the road network. Although it was found out how many of these vehicles use a detour of tunnel, because in Slovak republic there is transport of dangerous goods through tunnel forbidden, and how many these vehicles drive through the tunnel despite the entry ban. The research was carried out three days in the period from 5.3.2013 to 7.3.2013 from the place before the tunnel, where were two observers 24 hours a day. Result of the research showed that proportion of dangerous goods in this section is 2.19 % from the transport of HGVs. It was also found that approximately 26.32 % of these HGVs with dangerous goods (marked as ADR) go through the tunnel despite the entry ban the transport of dangerous goods in road tunnels in Slovakia and 76.68% use the detour [2].

4. Tunnel Traffic & Operation Simulator

Basic composition of Tunnel Traffic & Operation Simulator (hereinafter referred to Simulator):

- Central control system – part of automatic control of tunnel equipment,
- Manual control module – part of manual control (separated module),
- software for prediction of phenomenon's EMUT (evidence of tunnel incidents).

4.1. Central control system

Technological equipment of virtual tunnel is in accordance with the Government Regulation of the Slovak Republic on minimum safety requirements for tunnels in the road network and technical conditions. The principle of automatic control consists in the automatic control of tunnel equipment by Central control system which is divided into three basic levels:

- control - functional management of tunnel equipment,
- procedural - the lowest layer of management. Its mission is to transform the states of technological devices to electrical form, where, for example the temperature sensor converts the value of a physical quantity (temperature to an electrical signal 4 to 20 mA. Computers through visualization program display technological quantities and allow operators to perform interventions in technology,
- operational (visualisation) - the highest layer of the control system, which is primarily designed to ensure contact of human with technology management.

Simulation workstation (Simulator) from functional point of view is based on real control algorithms used for the managing of existing tunnels. Operators can verify the management philosophy and to simulate situations that occur

in real operation of the tunnel although rarely, but it is more important to well respond. Management of tunnel technology is identical to the real workplace management. Scheme of operator's workstation is shown in Fig. 3.

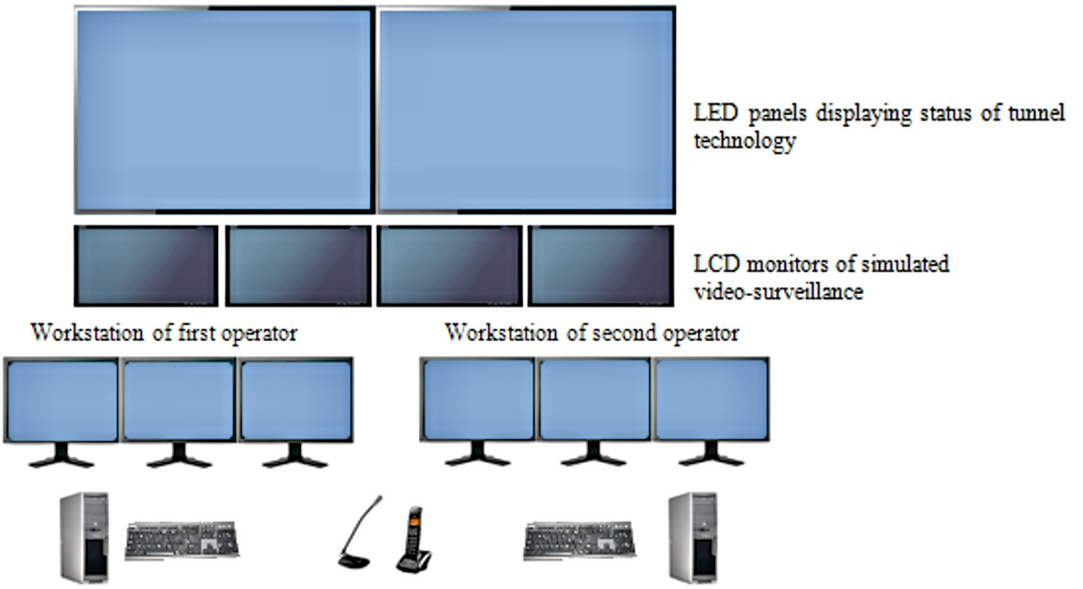

Fig. 3. Scheme of operator's Workstation.

This workstation is carried out as a workplace for the operator of the tunnel by two operators - operator of technology management and tunnel operator for traffic management. This focus on a specific area of organizational management is only a matter of momental reallocation of labour. Typical equipment for real operator workstation of tunnel technology management is available to operators:

- tunnel loudspeakers (in case of evacuation),
- radio re-broadcasting with possibility to interrupt broadcasting in case of emergency,
- phone connection of internal network to simulate the connection with emergency services and emergency stations.

4.2. Manual control module

Manual control module (MCM), see Fig. 4, allows manually performing operations related to the management of the tunnel, which carries out the Central control system (CCS) in emergency situations, which would not occur in tunnels (accident, fire, incident).

4.3. Evidence of tunnel incidents

Evidence is carried out in order to increase operational safety of tunnels based on registration of incidents in accordance with tunnel's sheets that contain a detailed description of the event, way of dealing with emergency event and timeline, especially, the date of event's origin, type of emergency event, method of detection, the arrival of emergency services and police, the closure period, data about stricken users and material damages etc. [3]

According to the evidence, it is possible to sort the data and create graphs of event frequencies. Example of one year tunnel operation assessment is shown in Fig. 5. There were restrictions of various kinds in the range of about 230 h/year (from real time 8760 h of tunnel operation).

Fig. 4. Manual control module.

It is used a configuration management systems, which occurs in the management of real tunnels and highways. Simulation workstation, in addition to engineering station, is located in a separate free-standing distribution box according to Fig. 4.

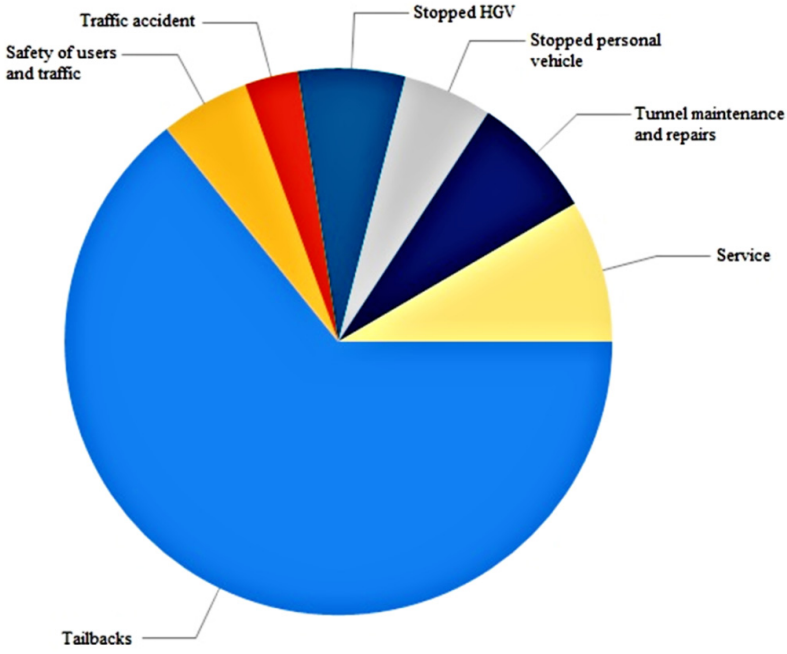

Fig. 5. Sectorial graph of events in a one tube tunnel, year 2007.

5. Conclusions

Tunnel Traffic & Operation Simulator, Manual control module and risk analysis with the evidence of emergency events allow simulations of various operational statuses which can occur in the tunnel and that are taken into account in risk analysis (accident, fire, etc.).

However it is not possible to exclude the human factor. Therefore, it is beneficial - especially for tunnel's operators – to check possible operational statuses on the Simulator or MCM, so that in the event of an emergency event were unnecessary loss of human life. Expected value of risk is the result of risk analysis for road tunnels and is defined as a statistically expected value of number of fatal casualties per year.

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