

**Jozef ŠTEFANAČ\*, Juraj SPALEK, Fedor KÁLLAY**

University of Žilina, Faculty of Electrical Engineering,  
Univerzitná 8251/1, 010 26 Žilina, Slovakia

\*Corresponding author. E-mail: jozef.stefanak@fel.uniza.sk

## ROAD TUNNELS SAFETY ACCORDING TO EUROPEAN LEGISLATION

**Summary.** The article deals with safety of European road tunnels in accordance with actual European legislation. Standards and recommendations of European Commission, PIARC and other professional bodies of the European Union define minimal technological requirements for equipment and operation of the tunnels in scope of Trans-European Road Network.

## BEZPIECZEŃSTWO TUNELI DROGOWYCH ZGODNIE Z USTAWODAWSTWEM EUROPEJSKIM

**Steszczenie.** Artykuł zajmuje się bezpieczeństwem europejskich tuneli drogowych zgodnie z aktualnie obowiązującym prawem europejskim. Standardy i rekomendacje Komisji Europejskiej, PIARC i innych ważnych organów Unii Europejskiej określają minimalne wymagania technologiczne w zakresie wyposażenia i eksploatacji tuneli w ramach europejskiej sieci drogowej.

### 1. PROGRESSION OF TRANS-EUROPEAN TRAFFIC NETWORK AND CONTEMPORARY SITUATION IN SLOVAK AND CZECH REPUBLIC

One of the first big traffic-operational concepts of the development of Europe at supranational level was „Blue Banana“ project, when besides EU member states Great Britain was also involved into the concept. The arch was including strategic nodes – London, industrial intersection Belgium – north France – Holland, it was cumulating in west part of Germany – in Purina, where continually crossed into the Bavaria (Munich), Switzerland and through the west Austria. It finished in industrial agglomeration of north Italy (region of Turin and Milan).

Political changes – admission of new member states into the EU in May of 2005 proposed theme of shifting the hub and connection of new agglomerations. It results in new concept under the name of „Red Octopus“, which central part lies in the area of Germany and from there branches into several arms:

- South - west branch: Turin – Barcelona – Madrid,
- South branch: region Trento – Treviso – Raven – Rome,
- North branch: Hamburg – Copenhagen – Stockholm,
- North – east branch: Poznan – Warsaw – Vilnius.

Both concepts, Banana and Octopus, are shown in Figure 1.

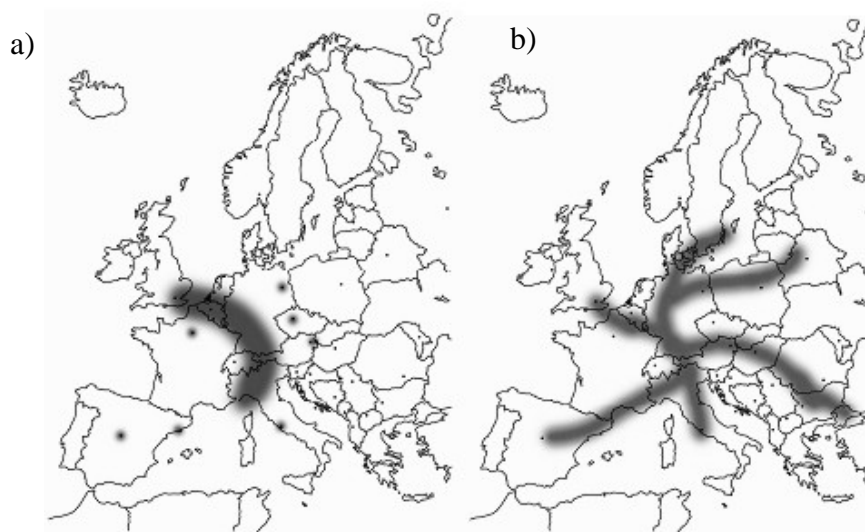


Fig. 1. Concepts a) Banana, b) Octopus  
 Rys. 1. Koncepcje a) Banana (Banan), b) Octopus (Ośmiornica)

The construction of road infrastructure ergo also construction of tunnels in Slovak Republic, the Czech Republic and in Poland is apparently related with the concept. At the arterial road south-north and east-west the construction of 23 tunnels is planned in Slovakia, over 30 in the Czech Republic and 10 tunnels in Poland, which has to comply with requirements of European legislation.

## 2. EUROPEAN LEGISLATION

European Commission in its White Paper of 12 September 2001 announced a proposition of minimum safety requirements for tunnels belonging to the Trans-European road network. The objective of the proposed action should be the achievement of a uniform, constant and high level of protection for all European citizens in road tunnels.

Safety in tunnels requires a number of measures relating, amongst other things, to the geometry of the tunnel and its design, safety equipment, including road signs, traffic management, training of the emergency services, incident management, the provision of information to users on how best to behave in tunnels, and better communication between the authorities in charge and emergency services such as the police, fire-brigades and rescue teams. The conduct of road users is a decisive aspect of tunnel safety.

Safety measures should enable people involved in incidents to rescue themselves, allow road users to act immediately so as to prevent more serious consequences, ensure that emergency services can act effectively and protect the environment as well as limit material damage.

Therefore with regard to the proposal from the Commission, the European Parliament and the Council of the European Union have adopted the *Directive 2004/54/EC*. This directive aims at ensuring a minimum level of safety for road users in tunnels in the trans-European road network. *It shall apply to all tunnels in the trans-European road network with lengths of over 500 metres*, whether they are in operation, under construction or at the design stage. In order to implement a balanced approach and due to the high cost of the measures, minimum safety equipment should be defined taking into account the type and the expected traffic volume of each tunnel.

### 3. COMMITMENTS AND DEADLINES FOR EU MEMBER STATES FOLLOWING FROM THE DIRECTIVE 2004/54/EC

Member states shall designate an *administrative authority*, which shall have responsibility for ensuring that all aspects of the safety of a tunnel are assured and which shall take the necessary steps to ensure compliance with the directive. The administrative authority may be set up at national, regional or local level.

For each tunnel, whether it is in the design, construction or operating stage, the administrative authority shall identify as *tunnel manager* a public or private body responsible for the management of the tunnel at the stage in question. The administrative authority itself may perform this function.

For each tunnel, the tunnel manager shall, with the prior approval of the administrative authority, nominate one *safety officer* who shall coordinate all preventive and safeguards measures to ensure the safety of users and operational staff.

Member states had to notify the Commission within 24 months after directive came into force (which was on 1<sup>st</sup> May 2006) of name and address of the administrative authority.

Every tunnel whose *design has not been approved* by the responsible authority by 1<sup>st</sup> of May 2006 shall be subject to the requirements of this Directive. In the case of tunnels which *design has been approved* but which *have not been opened to public traffic* by 1<sup>st</sup> of May 2006, the administrative authority shall assess their compliance with the requirements of this Directive. In the case of tunnels which were already *open to public traffic* by 30<sup>th</sup> of April 2006, the administrative authority had within 30 months (until 30<sup>th</sup> of October 2006) to assess their compliance with the requirements of this Directive.

Member States had 36 months after directive came into force (which was on 30 April 2007) to submit a report to the Commission on how they plan to meet the requirements of this Directive, on planned measures, and where appropriate, on the consequences of opening or closing the main access roads to the tunnels.

The refurbishment of tunnels shall be carried out according to a schedule and shall be finished within 10 years after the directive came into force which will be on 30 April 2014.

### 4. SAFETY REQUIREMENTS FOLLOWING THE DIRECTIVE

Member States shall ensure that tunnels in their territory meet the minimum safety requirements. Where the structural requirements needed for ensuring minimal safety level cannot be achieved or can be achieved only at disproportionate cost, the administrative authority may accept the implementation of risk reduction measures as an alternative to application of those requirements, provided that the alternative measures will result in equivalent or improved protection. The efficiency of these measures shall be demonstrated through a risk analysis.

Risk analyses shall be carried out by a body which is functionally independent from the Tunnel Manager. The content and the results of the risk analysis shall be included in the safety documentation submitted to the administrative authority.

A risk analysis is an analysis of risks for a given tunnel, taking into account all design factors and traffic conditions that affect safety, notably traffic characteristics and type, tunnel length and tunnel geometry, as well as the forecast number of heavy goods vehicles per day. Member States shall ensure that, at national level, a detailed and well-defined methodology, corresponding to the best available practices, is used and shall inform the Commission of the methodology applied.

*Within 5 years after the directive came into force (which will be on 30<sup>th</sup> of April 2009) the Commission shall publish a report on the practice followed in the Members States.*

## 5. THE COMPARISON OF TUNNELS CATEGORISATION ACCORDING TO DIRECTIVE 2004/54/EC AND TECHNICAL REGULATION-TP98

Directive 2004/54/EC [1] classifies road tunnels by two parameters:

- traffic volume - the number of cars per one lane in a day,
- and tunnel length.

Based on these two parameters tunnels can be divided according to directive as follows: tunnels with traffic volume up to or equal 2000 vehicles per one lane and a day. Due to this traffic volume the tunnels are divided into tunnels with length of 500 – 1000 m and above 1000 m. If the traffic volume is bigger than 2000 vehicles per one lane and a day, tunnels are divided into three groups of 500 – 1000 m, 1000 – 3000 m and above 3000 m.

Thus the directive 2004/54/ES divides tunnels in to 5 types. Every type of tunnel shall be equipped with technological equipment defined in the directive.

As the minimum of mandatory equipment for all types of tunnels which is required by the directive are following: normal, safety and evacuation lighting, water supply at least every 250 m, road signs, automatic incident and fire detection, emergency radio messages for tunnel users with loudspeakers in shelters and exits, emergency power supply and fire resistance of equipment. The directive defines except for mandatory also mandatory with exceptions, not mandatory and recommended equipment. These minimum requirements are exactly defined in document [1].

Technical regulation TP 98 [2] classifies road tunnels from the view of safety equipment as follows:

- by tunnel length,
- and by traffic character on land intersections.

A tunnel has to comply with the safety standard, which is designated on the basis of tunnel division by identical safety category. These categories are given by approximately equal safety factor given by portion of the number of accidents in number of cars and passed distance, which is verified in the long term statistic measures.

The tunnel length and traffic volume determine the type of safety technological equipment to be used. From the safety view tunnels are divided into three categories - TA, TB and TC. This categorisation applies to the tunnel tube with one or two lanes in a traffic line and relevant traffic volume. Tunnels with three or more lanes in one line are always suggested for TA category.

For the traffic volume less than 1000 vehicles per day tunnels are categorised only by the length. Tunnels with length of 100 – 500 m belong to the TC category, with length of 500 – 3000 m to TB and from 3000 to 10 000 m into TA category. For traffic volume range of 1000 - 4000 vehicles per day the tunnel categorisation is adjusted by the given length in dependence on the traffic volume. Boundary lines express non-linear dependency of power function with the negative coefficient B of the form:

$$q = A \cdot l^{-B} \quad (1)$$

Where:

- q - traffic volume,
- l - tunnel length,
- A, B - regression indexes of power series.

As far as the traffic volume is expected to be higher than 15 000 vehicles per day the tunnels are suggested for TA category.

Technical regulation TP 98 from the point of view of identical safety also defines short tunnels which start at length of 100 meters and do not exceed 200 m.

Comparison of tunnel categorisation according to European directive 2004/54/EC and technical regulation TP 98 is represented in Figure 2. Categorisation according to the European directive is demonstrated by colour rectangles. Black lines and marks TA, TB and TC represent categorisation according to TP 98.

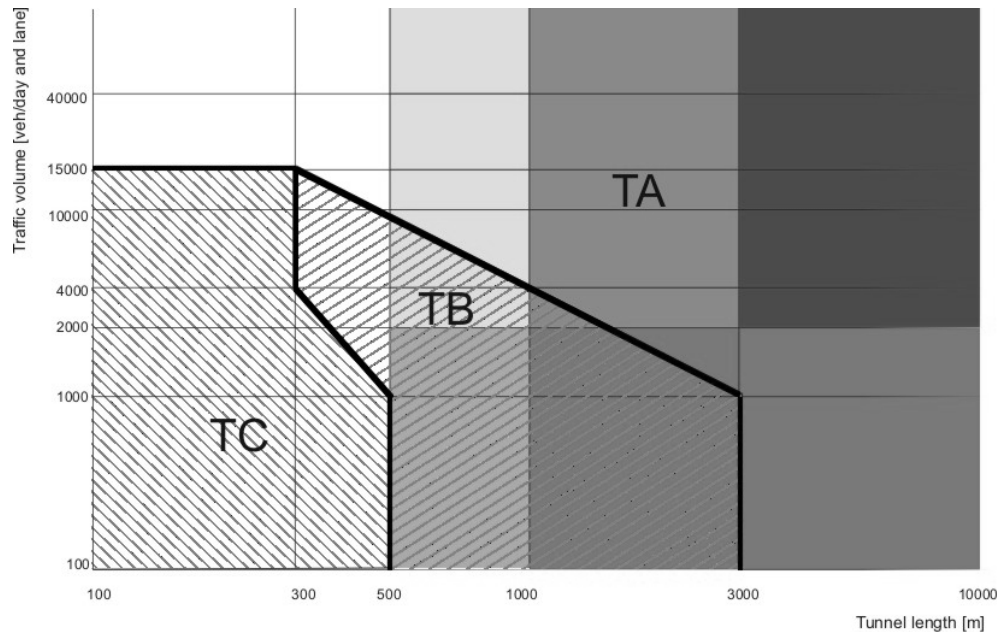


Fig. 2. Tunnel categorisation according to directive 2004/54/ES and TP98

Rys. 2. Klasyfikacja tunelu zgodnie z dyrektywą 2004/54/ES i TP98

## 6. CONCLUSION

As it was mentioned earlier, assurance of minimum safety level is possible by achieving implementation of risk reduction measures, which can be demonstrated through the risk analysis.

This risk analysis shall take into account 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.

At present the member states use for risk analysis various qualitative methods for risk identification and description, and quantitative methods for calculation of its probability and possible consequences.

Until present published works were dealing with quantitative risk assessment just at the municipal level. As an example the Dutch program TUNPRIM and the Austrian directive RVS 09. 03. 11 can be mentioned. The Austrian directive is dealing with the problem of incident origin but hardly ever considers the consequences.

According to [3], with regard to requirements of directive 2004/54/EC, the tree diagram methods namely FTA – Fault Tree Analysis method for event frequency assessment and ETA – Event Tree Analysis for event consequences assessment are considered the most advantageous methods for risk assessment.

Fault Tree Analysis is a method based on the event logical development which affects system errors and human faults. The output is represented as a tree diagram composed of nodes and description of relations between events frequencies and their causes.

Event Tree Analysis is a method based on the inductive logic which assesses possible event consequences. It follows a process progress from event initialisation through the event sequence of

technical equipment functions assessment and safety functions of the system always at the base of two choices: convenient – inconvenient. The result is qualitative but after failure occurrence probabilities replenishment it is quantitative.

By the use of these two methods it is possible to control entire risk analysis process well. However, there is a problem of nodes selection influencing users self-rescue in ETA method and the way of their assessment.

In the newly proposed model the most important nodes influencing the users self rescue in a tunnel are suggested:

- smoke presence in first five minutes,
- automatic ventilation start-up,
- users evacuation possibilities, which are affected by emergency exits distance, information campaigns in case of emergency...

Nodes assessment problem needs to be solved by the model which removes uncertainties by the use of an expert system. As the expert system fuzzy system will be used, which will help us to assess the events (convenient – inconvenient) thus the assessment will correspond to expert assessment. The method is based on the creation of fuzzy inference system which will decide on the successful identification probability of event acquired from individual detectors.

The course of research activities of the authors of the paper is heading toward these ideas. Some of the results are mentioned in [3, 4].

This work has been supported by the Grant Agency VEGA of the Slovak Republic, grant No. 1/0023/08 “Theoretical apparatus for risk analysis and risk evaluation of transport telematic systems”.

## Bibliography

1. Directive 2004/54/EC of the European parliament and of the Council On Minimum Safety Requierements For Tunnels In The Trans\_European Road Network, Brussels, 29 April 2004.
2. Technological equipment of road tunnels, Technical regulation TP98, ELTODO EG a.s., MD ČR, 2003 and revision in 2006 (in Czech).
3. Příbyl P., Heissinger J.: Research report 259-I/07-EEG, Eltodo EG a.s., 2007 (in Czech).
4. Příbyl P., Janota A., Spalek J.: Analysis and control of the risk in transport, Monograph. BEN, Praha. ISBN 80-7300-214-0, october 2007 (in Czech).
5. Štefaňák J., Spalek J.: Risk analysis of road tunnels – approaches and methods, Collection of abstracts of international conference Cybernetics and Informatics, 10 – 14. 2. 2008, Ždiar, P. 76-78, (in Slovak).

Received 24.03.2008; accepted in revised form 13.10.2008