7. CONCLUSIONS AND RECOMMENDATIONS

In *chapter 1* the framework for the integrated approach on road tunnel safety was presented and the question was raised whether this approach is applied in practise and if it actually has led to improvements in the tunnel system. The schematic representation of the approach is repeated in the *illustration* below, the focus of this report is highlighted in the figure with green lines.

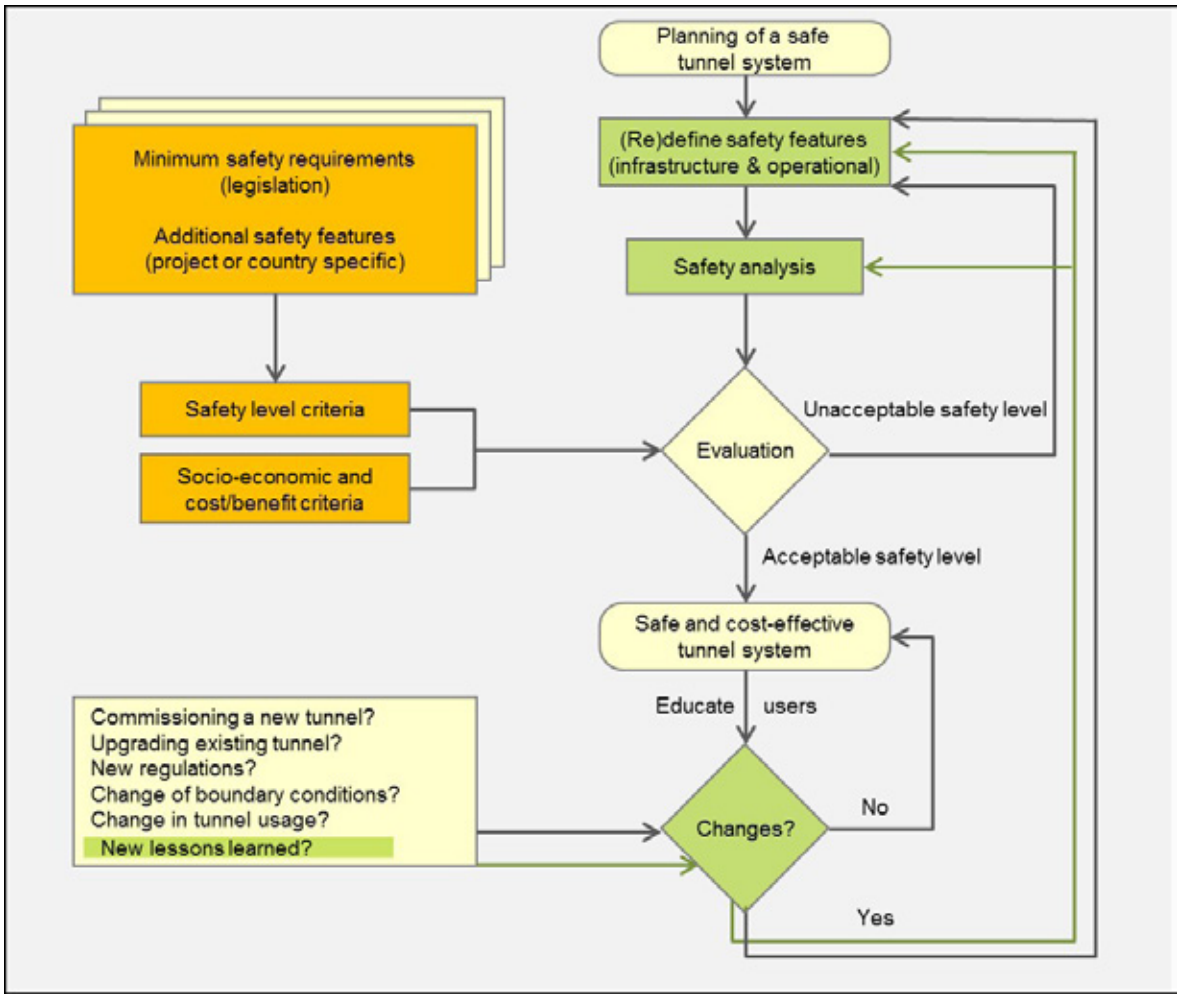

Illustration 11: main focus of the report

We can conclude that in many countries this approach is followed in one way or the other. In many countries data on incidents is collected and evaluated to identify specific shortcomings of an individual tunnel system. In specific cases this has led to changes in the particular tunnel system, improved procedures or better education. Some lessons learned on the basis of the evaluation of the 34 randomly selected real tunnel incidents which were collected and discussed with the responsible tunnel operators are compiled and discussed in *chapter 5.2*, such as:

- misbehaviour of car drivers seems to be the most common cause of tunnel incidents and may also cause problems in incident management (like impeding access of emergency services to the site of incident)
- in case of a fire drivers sometimes try to pass by the vehicle on fire to continue their ride, despite the potential danger caused by fire and smoke
- traffic management measures – such as closing of a lane (eg. by red crosses) or closing of the tunnel (by traffic lights), are often neglected if not enforced by additional means (eg. like

barriers for tunnel closure)
- problems of communication between the different stakeholders involved, which may be caused by various reasons, are a key issue in incident management
- the systematic evaluation of individual incidents often contributes to the optimisation of emergency response procedures and cooperation and training of all organisations involved in incident management

These are only examples, more information is given in *chapter 5.2*; however, it is not possible to give generally applicable recommendations on the basis of these findings because these may be different in dependence of the specific conditions of an individual country and an individual tunnel.

These examples also show how useful such information collected at international level can be for the various stakeholders involved in tunnel safety, especially to improve operational procedures, installation of equipment (radio, barriers, etc.) and the way they are used. It is obvious that it would be interesting to continue the collection of real incident information reported in *appendix 5.1*, so as to continuely, into the future, enrich the set of findings that can be derived from the analysis of such incidents.

Data from incidents is also evaluated on the level of road networks or national level with statistical tools, in order to produce statistical records. These statistical records are used to establish characteristic reference values for tunnel safety or to provide information and input data for an improved application of risk assessment tools. Results are given in *chapter 3* and *4*. It can be concluded, that although the amount and quality of data on collision and fire statistics has increased considerably in the past years, there are still many influencing factors which are difficult to quantify. Therefore, it is important that reliable data shall be collected in future for a large number of tunnels, so that the statistical basis can be improved in the coming years. As fires and severe collisions are rare events, it is of particular importance to report all indicators which are relevant for a proper evaluation of this type of incidents – a checklist containing required detailed information on fires is presented in *chapter 4.4*. In *chapter 3* a comprehensive list of all relevant data concerning collisions is provided.

When the collision and fire frequency of a given tunnel estimated, it is also necessary to evaluate which basic rates will be applicable and to take into account the influence of the special characteristics of this tunnel on the collision and fire rate.

The collision and fire rates shall be used with care, and evaluation of the applicability and modification of the rates for an application for a given tunnel shall be done by experts with experience in tunnel safety. When the above conditions are fulfilled, the incident rates can be applied in order to achieve safety systems for the tunnels which are balanced in relation to the incident risk at hand.

Chapter 2 focuses on the process of data collection. It has been noted that in practise collecting all necessary data for a good evaluation leading to improving safety procedures or incident statistics that can be used in risk analysis, is not easy and can be very time consuming. There can be a conflict in available and required resources for data collection. It is therefore recommended to clearly define the data collection chain and identify all parties involved. All stakeholders should define their feedback objectives, whilst taking into account the difficulties to obtain and

correct data and the resources needed. Based on the objectives and available resources the required data should be clearly identified, as well as in which time period the data should be collected (immediately after/during the incident or at a later stage) and which parties are involved in the data collection. To keep parties involved motivated to give their contribution, the purpose of data collection has to be made clear to them and feedback on lessons learned and benefits such as improved procedures and systems have to be provided.

In the past five to ten years the use of risk-based methodologies in tunnel projects has increased considerably. Risk analysis methods were formalised and incorporated in national legislation. The expanded use and increasing experience also led to a better understanding and acceptance of risk analysis as a reliable tool and improved the decision making process for new tunnel projects and refurbishment projects. In some countries like in the Netherlands, Austria and Switzerland the prescribed risk analysis methods were updated in the recent years, based on the experiences made in the first years of application, in order to improve the inherent models and to extend their applicability.

Experiences in the past years have shown that risk assessment is a valuable tool in decision making – for instance to decide on the most cost-efficient measures for the upgrading of existing tunnels – but has to be applied with care. It is therefore recommended that the risk analysis is performed by experts for a proper application of methods and interpretation of the results. Expertise is also necessary to identify the best suitable risk assessment approach depending on the purpose of the investigation and the data available.

Observations and findings from real incidents – as addressed in *chapter 5* – may contribute to the continuous improvement of risk models as well as of the input data required for their proper application as well as for a correct quantitative representation of the effectiveness of risk mitigation measures.

It is also noted that risk analysis is applied in combination with prescriptive guidelines. Risk analysis can be used to identify the necessary and/or best suitable safety measures, but technical details have to be worked out in guidelines.

The experiences shared in this report and incident data as described in this report show that the integrated safety approach is applied and leads to further improvements of tunnel safety as well as risk assessment methods.