Risk assessment related tunnels

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Summary

Following the fire which occurred in March 1999 in the Mont Blanc tunnel located between France and Italy, an Appraisal Committee has been committed to assess the safety of 40 existing French road tunnels, with a length exceeding 1 km.

Later, a new regulatory document (circular) was issued (25/08/2000) about the safety of existing road tunnels. In this document, a new procedure is requested : a specific hazards study (SHS). A work is still under progress between different partners to define the methodology to be applied for these SHS. Every SHS will be submitted for acceptance to a National Evaluation Committee. New regulations are under preparation.

Such SHS are prepared only after achievements of preliminary studies (traffic studies, rules of operations, specific study for the transportation of dangerous goods if any...) from which a reference state if defined. The different steps of this SHS are : risks identification, definition of scenarios (standardised and customized) from which it is possible to describe a sequence of events, possible consequences and the validity of the system management of the system especially in emergency situations. The conclusion of the study is the evaluation of the safety level with possible use of severity/occurrence matrix. Proposals are then to be made by the contractor and operator to improve the safety level on weak points.

Among the difficult issues are : the need for preventive closure of a tunnel when a situation is incidental but without major consequences, the assessment of fire developments for different types of vehicles and the influence of the ventilation, the efficiency of fire fumes extraction, the definition and use of severity/occurrence matrix.

Introduction

Following the fire that occurred in the Mont Blanc tunnel on 24th March 1999, an Appraisal Committee was given the task of reviewing the safety of 40 French road tunnels exceeding 1 kilometre in length. Later a new interministerial Circular (No. 2000-63), covering the safety of all tunnels in the national road network[1], and including technical requirements (TR) was signed on 25.08.00 to replace that of 1981.

This Circular was a forerunner of a law - under preparation at the time - covering the special procedures applicable to all hazardous infrastructure, due to be submitted to the French parliament by the end of 2001, together with its decree of application to all road tunnels, including those outside the national network but being the responsibility of regional authorities. The Decree will apply to a total of nearly 200 tunnels.

Exceeding 300 metres in length, including motorways operated on a concessionary basis, but excluding cross-border systems

Annex 1 of the Circular establishes a new procedure that applies before tunnels are opened to traffic, including in particular the preparation of a Specific Hazards Study (SHS) for each facility in service, ways and means of monitoring their operation (enabling feedback of experience) supplemented by annual exercises. The procedure involves an appraisal by the Road Tunnel Safety Evaluation Committee (CESTR) issued from the initial appraisal committee.

1 Specific hazards studies

At the initiative of the French Ministry for Land-Use Planning and Environment, Annex 1 of the Circular includes the requirement that all the safety dossier for tunnels whether planned or in service should include a specific hazards study (SHS) referred to in very general terms: "... describing the accidents, of whatsoever origin, that might occur during operation as well as the nature and extent of their possible consequences; this study will specify, with proper justification, those measures likely to reduce the probability of occurrence of these accidents and their consequences."

As a guide to the preparation of such studies, the CETU[1], with the assistance of the Defence and Civil Safety Direction (French ministry of Interior) and INERIS, drew up an information note on SHS (Note No. 12). This note was submitted to the Assessment Committee and was then circulated in December 2000 by the Director for Roads to "owners" and design offices. However this was merely a provisional document, to be revised in the light of experience once a number of SHS wouldhave been produced.

On the basis of experience gained since that date, a methodology for producing these studies was worked out as a result of work done by representatives of CETU, INERIS, the Ecole Nationale Supérieure des Mines in Paris, design offices and operators.

The study may begin only when a number of prior investigations have been carried out to generate a frame of reference on which the SHS is based.

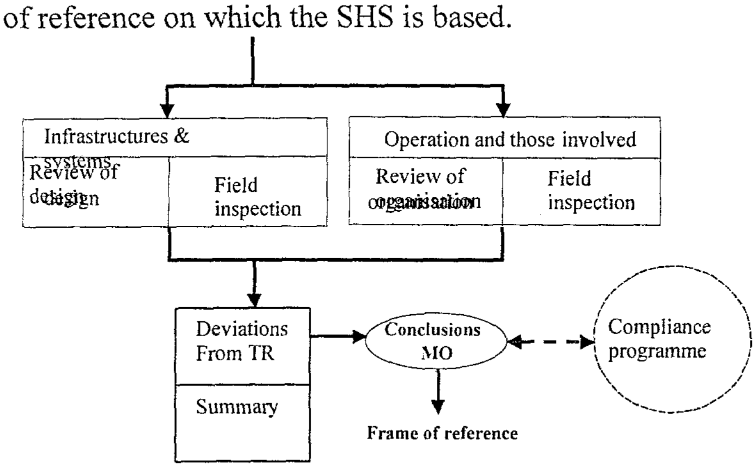

Figure 1: Principle of review, improvement, compliance programme

As regards the transport of hazardous goods, a Circular (No. 2000-82), replacing that dating from 1976, was published on 30.11.00 to supplement the Circular of 25.08.00. It introduces a

[2] CETU : Centre d'Etudes des Tunnels

specific procedure for the comparative review of risks due to hazardous materials between the tunnel route and alternative routes. This review must be quantitative in nature, as regards incident frequencies and severity levels (QRA approach) except for small non-urban tunnels[2].

The Circular makes it clear that the review may *in particular* utilise a model developed under the auspices of the OECD and the World Roads Association by INERIS, the British contractor W.S. Atkins and the University of Waterloo in Canada. The CETU has arranged a presentation of this model together with training in its use for 2nd and 3rd October 2001.

In this way a frame of reference for the tunnel is defined; the principle of formulating the SHS is shown diagrammatically on figure 2. The frame of reference indicates, in a summarized manner, the systems and procedures, the tunnel environment, and gives a functional description of the installations, equipment and systems relating to operation and safety (including a summary of the review of incidents and accidents that have occurred in the tunnel and of the safety exercises).

We shall now give some details of the different steps shown schematically in figure 2. The chapter references given on the figure are those used in the CETU information note No. 12 (See paragraph 1).

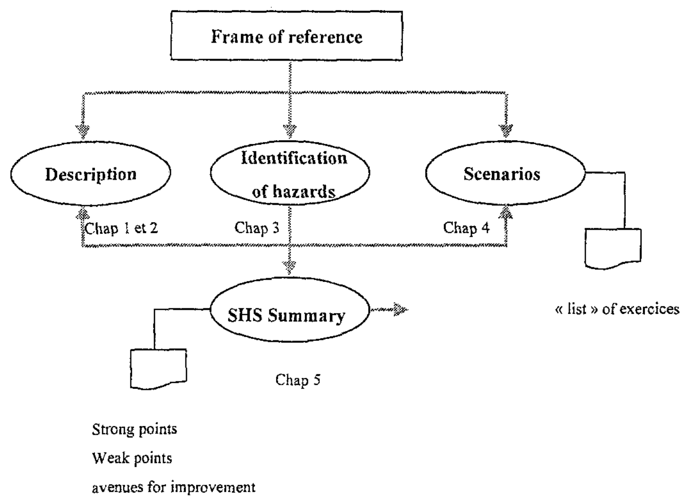

Figure 2 : Basis for producing a specific Hazards study (SHS)

1.1 Description

[2] Less than 500 metres in length if they are one-way tunnels, and less than 800 metres in length if they are two-way.

This stage generates a summary description of the tunnel geometrical and functional characteristics. It also gives the contractor in charge of the SHS an overall idea of the tunnel and enables it to highlight the points it perceives as essential for safety.

1.2 Identification of hazards and choice of scenarios

This process involves establishing:

- a list of hazards according to origin, by choosing a suitable method,
- the incidents and accidents likely to occur,
- the consequences, leading to a definition of scenarios and an evaluation of severity,
- a classification of the scenarios according to the estimated severity and frequency,
- the selection of certain scenarios to be examined with more details in a further step.

1.3 Study of scenarios

In defining scenarios, only the first 30 minutes of their development will be normally considered, so as to investigate their consequences and the steps to be taken as regards operating instructions and evacuation schemes. The hazardous factors (heat, toxic gases, poor visibility, pressure waves, projectiles, and so on) should be investigated from the standpoint of both the tunnel and the environment.

It must also be emphasised that certain scenarios (notably those concerning fire) are required, while others are optional.

The *standardised scenarios* (see figure 3) establish a minimum comparability between tunnels. They are based upon *standard incident events*, including also *standardisation of the parameters and modelling approaches* necessary for describing the development of events, actions and serial consequences caused by the initial event. The *optional scenarios* make it possible in particular to investigate the consequences of incident events tha highlight the particular features of the tunnel.

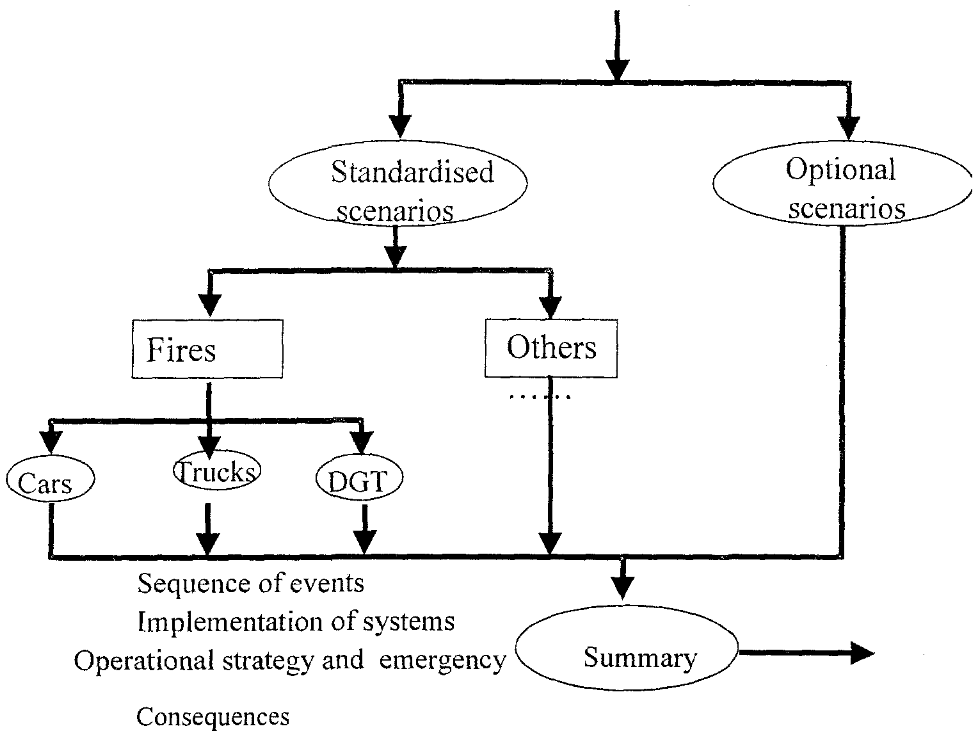

Figure 3 : Definition of scenarios

1.4 Summary of SHS

On completion of these different stages the total of the information gathered should make it possible to evaluate the level of safety of the facility. Mention should be made of the strong points and shortcomings (along with proposals for improving prevention and protection). It is then up to the "owner" to indicate what he intends to do.

1.5 "Owner's" report

When this work has been completed, an expert may be brought in (the Circular makes explicit provision for this). The expert should not have been involved in the previous phases. His/her role is to provide an external view of the entire approach and the proposed conclusions.

It is then up to the "owner" to set out in a report the chosen protective and preventive measures and the schedule for improvement works if any.

Note: an expert may also be brought in for the preliminary projects and for inspecting facilities already in service.

1.6 Expert opinion on the entire safety dossier

After this owner's report, an expert[3] has to write a global appraisal on the entire safety dossier.

[3] Or a competent organisation as regards the safety of road tunnels

It is requested in the circular :

- For the project (POA or APOA), " *appraisal of the safety by an expert* "
- before operation , " *expert appraisal about the relevancy as regards safety requirements and other requirements included in the dossier* "
- when examining the premises in operation " *a diagnosis by an expert of the premises safety and of the operation safety* "

The Assessment Committee then makes the final appraisal after being made aware of all appropriate information by one of its members acting as rapporteur.

2 Some current problems not fully resolved.

2.1The decision on preventive closure

Since the accident in the Mont Blanc tunnel, the operating instructions have become a little more precise in this connection, but they are still fairly sketchy. Although in general there is provision for closure if some of the smoke extraction systems (used in the event of a fire) are lost, or if the atmosphere is too polluted or visibility is nil, the actions to be taken in case of other kinds of event, such as a lasting loss of electricity supplies, are still often poorly defined.

This being said it is nevertheless difficult to plan everything in advance since decisions have to be taken on a case-by-case basis, faced with the need to keep traffic flowing, bringing forth the need for alternative routes, with all that that entails. It then becomes necessary to highlight certain instructions to be applied automatically by the operator, subsequently modifiedin real time if necessary according to the emergency.

2.2 Predicting the development of a fire and adjusting the ventilation system

Since passed significant accidents have proved that the first 30 minutes have generally a crucial importance, the modelling of fire scenarios considered for the evacuation and sheltering of road users are based on total heat power evolutions within the first 30 minutes.

The 30 MW fire used in the Technical Instructions as regards the standards to be observed, is a rating basis for trucks (HGVs), excluding the transport of hazardous materials, and has been the subject of considerable research. However it is known that 100 MW fires are plausible, even excluding hazardous material transport, and that if these hazardous materials involve flammable liquids, 200 MW or even more can be reached. Even so, these circumstances are even more difficult to describe. As regards cars and vans, the power can range from a few MW to over 15 MW, if the fire spreads to several vehicles.

Note : the duration of fire scenarios can extend beyond 30 minutes and extinguishing can occur before 30 minutes. These aspects are also essential.

It is therefore of primary importance to describe the first 15 to 30 minutes, which are crucial for moving people into shelter. The subsequent bringing under control of the fire, using techniques that vary according to circumstances, does not really form part of the scenario to be developed. However the case of people in shelters, awaiting the arrival of the emergency services for evacuation, may deserve particular attention.

As far as safety is concerned the power developed in a fire is related – quite apart from obvious matters of the fire resistance of systems and temperature in the shelters[4] – primarily to the smoke extraction methods adapted to the energy levels encountered, the important point being the toxicity of smoke and the extent to which it spreads.

- *with semi-transverse or transverse ventilation* the modelling of the performance of smoke extraction systems is still little developed,

- *with longitudinal ventilation in an uncongested one-way tunnel it is possible to use 1-dimensional modelling* in the steady state which is fairly easy to handle and can be done using charts or EXCEL spreadsheets. However this type of modelling assumes that all the physical parameters are constant along the stretch of tunnel represented, and cannot therefore represent 2-D or even 3-D phenomena such as the stratification of smoke. *Accordingly they are valid only above the critical air speed which ensures that there is no stratification or "backlayering".*

Of course the air velocity during the fire depends, amongst other things, on ventilation, the amount of traffic in the tunnel and the backpressures at the tunnel portals resulting from the weather. This type of model is unable to describe what happens for lower air speeds or – this is an important point – the transient phases at the beginning of the event. Transient 1-D simulations can be carried out to overcome this drawback but they too cannot take into account any phenomena of stratification and backlayering. The results provided must therefore be interpreted using qualitative evaluations based upon experience or various 3-D simulations.

- I*n the other cases considered (*congested, one-way, with longitudinal ventilation; longitudinal ventilation in a 2-way tunnel, and above all where ventilation is semi-transverse or transverse) *safety is strongly related to the stratification of the smoke which can only be reproduced by 3-D simulations.*

It is true that beside 1D and 3D modes zone models exist that are capable of allowing for stratification, but these are used only by their authors and have not been completely validated. A more pragmatic solution is to begin with a 1-D model to evaluate the overall air movements in the tunnel, and then to produce a qualitative description of the phenomena using this estimate of the air flow together with experience on how fire and smoke behave as a function of the air flow.

[4] This should remain below 40° until they are evacuated, even for a 200 MW fire in the most unfavourable circumstances.

There is still a considerable need for research on this general topic in order to produce tools that can cope with these complex phenomena.

2.3 Using severity/probability matrices

For the purposes of comparing hazards between different tunnels, it is proposed to utilise standardised matrices covering severity and probability of occurrence. For frequencies it is suggested that 6 classes should be used, ranging from very frequent to extremely rare. Table 1 shows how a few French tunnels would rank because of reported cases during last years.

Typical tunnels – truck fires	"Occurrence interval"
A	< 1 year "very frequent"
B Fréjus, Landy, Chamoise	< 10 years "frequent"
C Fourvière, Las Planas	10 to 100 years "occasional"
D Terregaye, Saorge, TC St Germain	100 to 1000 years "rare"
E	1000 to 10,000 years "very rare"
F	> 10,000 years "extremely rare"

Table 1: Class distribution for potential frequency of occurrence of truck (HGVs) fires

It is possible to identify subsequent damages in the five classes normally used : table 2.

Severity	**Damage**
I "Minor or nil"	Material damage
II "Significant"	Light injuries
III "Critical"	Serious injuries or < 5 fatalities
IV "Catastrophic"	> 5 fatalities, < 50 fatalities
V "Major disaster"	> 50 fatalities

Table 2: Severity/damage relationship

It is also possible to utilise indicators of the potential severity of consequences relating to the one-way or two-way character of a tunnel, the number of tunnel tubes and their intersections, the frequency of congestion and the presence of hazardous materials; this then leads to a classification which may be for instance the shown hereunder in order of decreasing potential consequences.

- 2-way urban,
- 2-way non-urban.
- 1-way, non-urban, single tube,
- 1-way urban with two tubes,
- 1-way non-urban with two tubes.

Logically, in each case, a heavier traffic and a less suited ventilation system lead to more severe consequences.

The consequences, starting from the incident event, themselves depend on factors for which probabilities could also be worked out beforehand (congestion, weather, etc.), or even the probabilities of which depend upon actions taken (failure of a system, human errors, emergency services not intervening before a certain time, etc.). Among parameters crucial when assessing consequences are unmistakably :

- premovement time for the road users
- time to activate emergency ventilation
- time to stop incoming traffic entering the tunnel
- times needed for the different emergency services to arrive,

which are highly specific to each tunnel.

The first three parameters are mainly to be dealt with by designers and operators.

The fourth parameter should in no way constitute a kind of commitment on the part of the emergency services, but should for example simply be the « best possible realistic » times.

Generating a severity-probability matrix would become particularly complex if the intention was to probabilise not only the incident event but also the entire scenario. It is therefore suggested at present that the matrices should be used only for a kind of initial "prescreening" approach, using the probability of the incident events alone and only the "potential" severity.