

# SafeT

## Work package 7 Harmonised European Guidelines for Tunnel Safety



### WP7.0 SafeT Project Outline

**Version:** 7 May 2006

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## EXECUTIVE SUMMARY

SafeT is the culmination of seven projects funded by the European Union as part of the “5th Framework Programme” to address the problems of tunnel design and safety [1,2]. It is described as a “Thematic Network” and as such does not normally involve research and development but the judicial collection and analysis of existing data leading to recommendations thereof that form part of Best Practice European Guidelines. Nevertheless, it was decided from the outset that SafeT should follow a philosophy for the project. Furthermore, the first author proposed that SafeT should develop a “Global Approach” to tunnel safety that encompasses specific approached and general approaches from different specific areas of the subject and from wider approaches from different organisations and countries. In this respect, the *global approach is an original development* within SafeT that goes beyond the requirements of a thematic network. The subjects incorporated in SafeT start with data collection followed by analysis of the data and then the drafting of recommendations for the European Harmonised Guidelines.

While a global approach is developed which includes both prevention and mitigation of the consequences of an incident (e.g. accidents, fire), SafeT focuses on the important issue of preventive measures, management and cross-border issues. SafeT was a three year project initiated in 2003 and completed in 2006. It is co-ordinated by TNO (NL) and is organised in three stages (I – III), each covering one or more work packages (7 in total). These are:

- Stage I: *Inventory*  
WP1 Current State of Practice
- Stage II: *Integrated Tunnel Safety*  
WP2 Accident/incident Detection and Traffic Management  
WP3 Evacuation Intervention Management  
WP4 Post-accident investigation/Evaluation  
WP5 Harmonised Risk Assessment  
WP6 Integrated Tunnel Safety Management Systems
- Stage III: *Best Practice Guidelines*  
WP7 Global Approach and Best Practice European Guidelines

The main objectives of the SafeT project are to:

- a) Produce *Best Practice Guidelines* ([Report 7.2](#)) focusing on six specific issues (relating to Work Packages 2-6 of the Project). The Guidelines comprise the executive summaries of the 6 Work Packages in stand alone sections. The full six reports are in appendices for further reference. The text of the Guidelines is drafted by experts but is written to be easily readable by the non-expert.
- b) Develop a holistic *Global Approach* ([Report 7.1](#)) to tunnel safety accommodating both incident prevention and mitigation. Addresses the issue at the highest level is distilled into one flow chart with subset information placed in other pages or as “pop up” on PowerPoint presentations or as additional pages in this report.. It is user friendly at a conceptual level and aimed at general understanding of the overall holistic picture. The Global Approach is inclusive, non-restrictive, flexible thus incorporating both performance based and prescriptive approaches and is applicable



to all EU Member States. It should be noted that a safety assessment alone is not enough to achieve a safe tunnel.

These aim to help with the deployment of the existing EU Directive (e.g. in data collection and risk assessment); provide guidance towards any potential future development of the EU Directive; provide guidance to decision makers, operators etc.; provide a reference list that will assist non-experts to locate experts; provide contact details of tunnel operators who are employing certain risk assessment methods; help improve tunnel safety. The target audiences includes, EU as the client; tunnel managers and safety officers; tunnel owners/operators; engineers; consultants; industry; local, national and international authorities and bodies; students and academics; research organisations.

## 1. INTRODUCTION

This report is the first of three reports that form part of Work Package 7 of the Thematic Network “SafeT” funded by the European Union (EU). These are:

Report 7.0: *Outline of the SafeT project;*

Report 7.1: *Global Approach to Tunnel Safety;*

Report 7.2: *Best Practice European Guidelines to Tunnel Safety*

EU thematic networks are essentially glorified data collection exercises, albeit extremely useful to industry and government as a source of valuable information. In SafeT, effort was not only made to collect data, but also to carefully analyse this data and to present well considered recommendations along with their limitations. This report goes even further in that it also includes original innovative development. The essence of the three WP7 reports can be summarised as follows:

### 1.1 Contents of Report 7.0

Report 7.0 presents an outline of the SafeT project, its objectives and structure. It also places the project into perspective in terms of (a) Historical Appropriateness, (b) Tunnel Safety; (c) European perspective and last but not least into technical Perspective.

### 1.2 Contents of Report 7.1

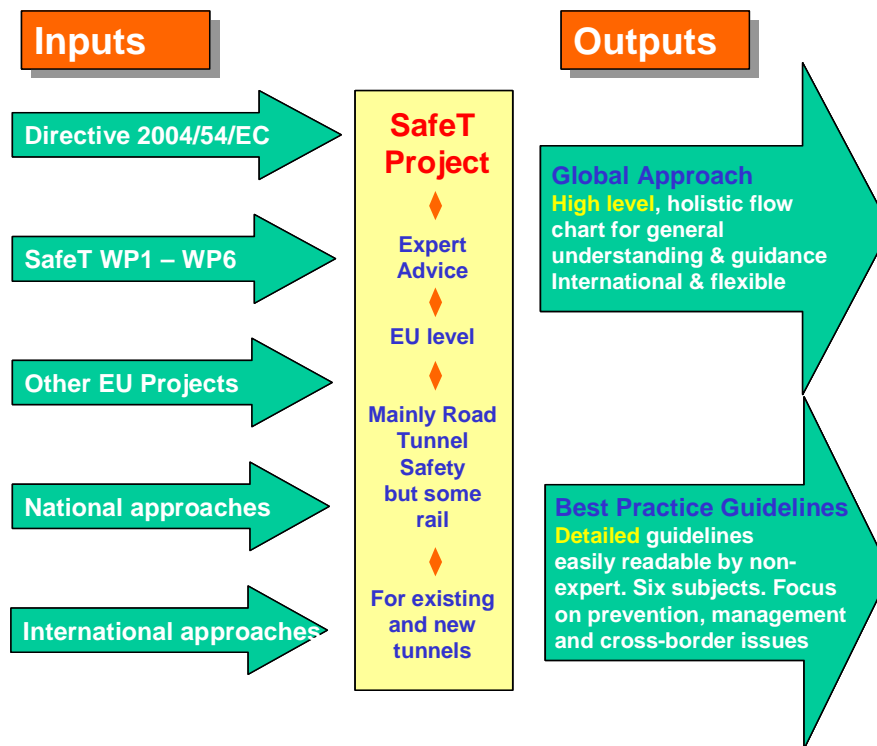
Report 7.1 presents a generalised global, albeit flexible, approach to tunnel safety that has been *developed* from the knowledge gained in the SafeT project, and from knowledge of tunnel safety approaches worldwide including the other 6 EU projects on tunnel design/safety. This report shows that “global” approaches are surprisingly few in the world. Even those that exist are partial and incomplete. The great majority of countries surveyed do not have a global approach to tunnel safety, only detailed manuals. So the global picture is necessary to (a) round up the other six EU projects on tunnel design/safety; (b) to provide a broad-brush wider basis for the specific Guidelines of Report 7.2 and (c) avoid the confusion that arises from the presence of multi-approaches.

### 1.3 Contents of Report 7.2

Report 7.2 focuses on issues that complement previous EU projects on tunnel/design safety. As such report 7.2 focuses on management issues for generalised tunnel safety, accident detection and preventive measures, mitigation, post accident investigation, and harmonised risk assessment. Fire issues feature as part of the overall wider picture that are addressed in detail in other EU funded projects such as FIT and UPTUN. Essentially, Report 7.2 distils the recommendations from the first five work-packages of SafeT to form the Best Practice *European Guidelines* to tunnel safety. The current EU Directive is taken as the starting point of the exercise leading to the Guidelines. The subject areas of the Guidelines can be viewed as part of the wider picture through the Global Approach of Report 7.1.

## 2. OUTLINE OF THE SAFET PROJECT

The SafeT project is a three year “Thematic Network” of 24 partners funded by the European Union and Co-ordinated by TNO. It was initiated in 2003 and completed in 2006. An outline of the project is given in Figure 1. The outputs of safeT comprise two reports:



**Figure 1.** General outline of the SafeT European project.

A holistic **Global Approach** (Report 7.1) to tunnel safety accommodating both incident prevention and mitigation. Addresses the issue at the highest level (see Report WP7.1) distilled into one flow chart (see Report WP7.1) with subset information placed in other pages or as “pop up” on PowerPoint presentations. It is user friendly at a conceptual level and aimed at general understanding of the overall holistic picture. The Global Approach is inclusive, non-restrictive, flexible thus incorporating both performance based and prescriptive approaches and is applicable to all EU Member States. It should be noted that a safety assessment alone is not enough to achieve a safe tunnel.

A Detailed Best Practice **Guidelines** (Report 7.2) on six specific issues (relating to Work Packages 2-6 of the Project - see Figure 2) and focusing on preventive measures, management and cross-border issues. The Guidelines comprise the executive summaries of the 6 Work Packages in stand alone sections. The full six reports are in appendices for further reference. The text of the Guidelines is drafted by experts but is written to be easily readable by the non-expert.

### 3. OBJECTIVES OF SAFET

The *objectives* of the SafeT project are to:

- develop a holistic “Global Approach” to tunnel safety (report 7.1);
- draft best practice harmonised “European Guidelines” on tunnel safety, focusing upon management and cross-border issues (Report 7.2);
- help with the deployment of the existing Directive (e.g. in data collection and risk assessment);
- provide guidance towards any potential future development of the EU Directive;
- provide guidance to decision makers, operators etc.;
- provide a reference list that will assist non-experts to locate experts;
- provide contact details of tunnel operators who are employing certain risk assessment methods;
- help improve tunnel safety.

*Achieved through:*

- building upon the European Directive 2004/54/EC on road tunnel safety [1];
- distilling the main outcomes of the 5<sup>th</sup> Framework EU projects on tunnel design/safety [ 2];
- sourcing information from different countries and organisations;
- taking valuable contributions from local authorities and fire brigades;
- draft the Guidelines to be easily readable by the non-expert with references to detailed SafeT work-package reports;
- presenting each of Work Packages 2-6 reports as stand alone section in the Guidelines comprising the executive summary of the report in question.

With the following *criteria*:

- Generic in approach;
- High level in the Global approach but specific details in the Guidelines;
- Importance of reliability of the sources of data and recommendations made thereof;
- Expert in advice;
- Global Approach to be inclusive, non-restrictive, flexible incorporating both performance based and prescriptive approaches;
- Applicable to all EU Member States and international in approach;
- Harmonising methodologies and not countries;
- Safety per tunnel and not per country;
- Applicable to new and existing tunnels;
- Non-political, though aware of political issues.

with the following *limitations*:

- While the Global Approach is holistic, the emphasis in the Guidelines is on prevention rather than incident mitigation;
- Applies primarily to road tunnels and only in part to rail tunnels.

aimed at the following *targets*:

- EU as the client
- tunnel managers and safety officers
- tunnel owners/operators
- engineers
- consultants
- industry
- local, national and international authorities and bodies
- students and academics
- research organisations.



## 4. STRUCTURE OF SAFET

SafeT was a three year project organised in three stages (I – III), each covering one or more work packages (Figure 2). The three stages were as follows:

### Stage I: Inventory

WP1 Current State of Practice

### Stage II: Integrated Tunnel Safety

WP2 Accident/incident Detection and Traffic Management

WP3 Evacuation Intervention Management

WP4 Post-accident investigation/Evaluation

WP5 Harmonised Risk Assessment

WP6 Integrated Tunnel Safety Management Systems

### Stage III: Best Practice Guidelines

WP7 Global Approach and Comprehensive Guidelines

Encompassing all these was one overall activity devoted to Network co-ordination (Work Package 8) as indicated in Figure 2.

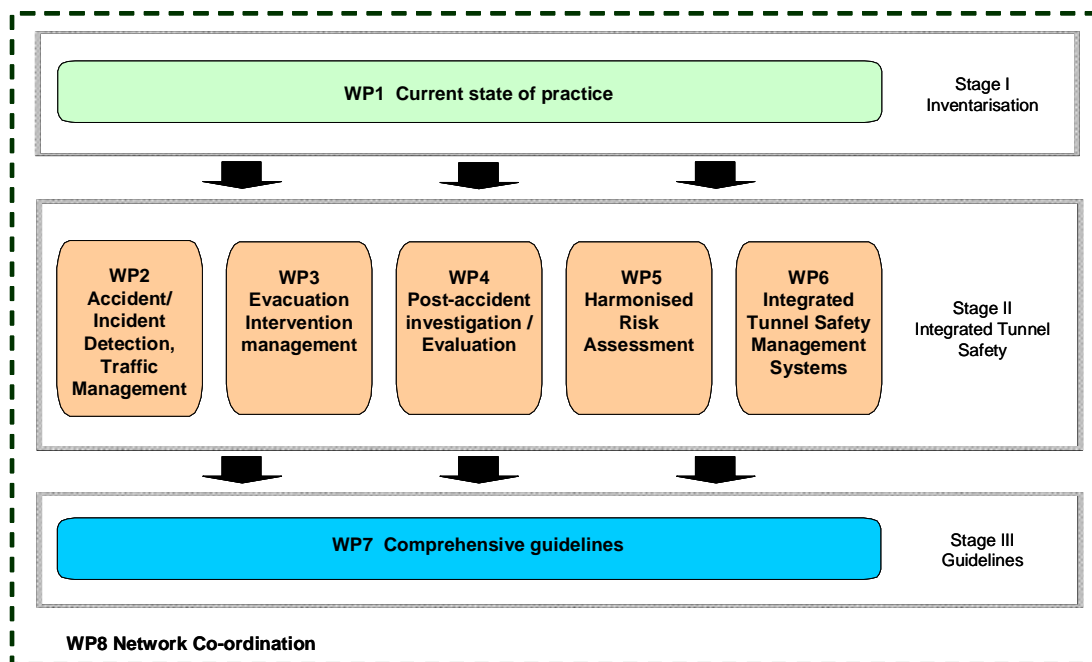
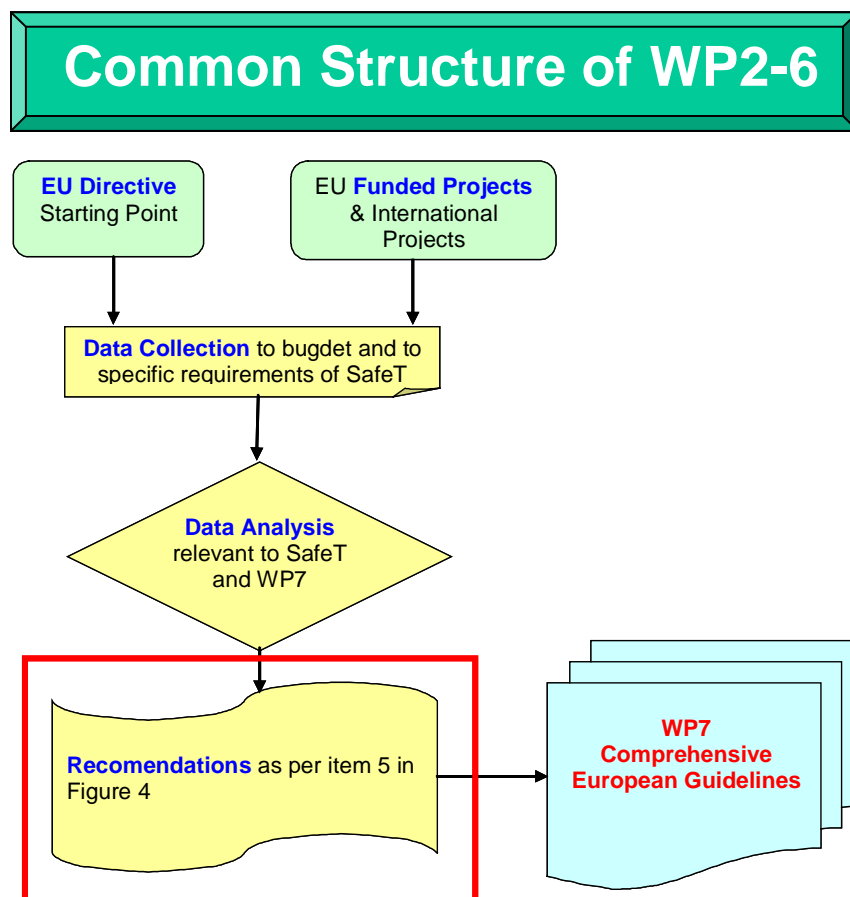


Figure 2. Structure of the SafeT project: Work Packages 1-6 feed into the WP 7 .

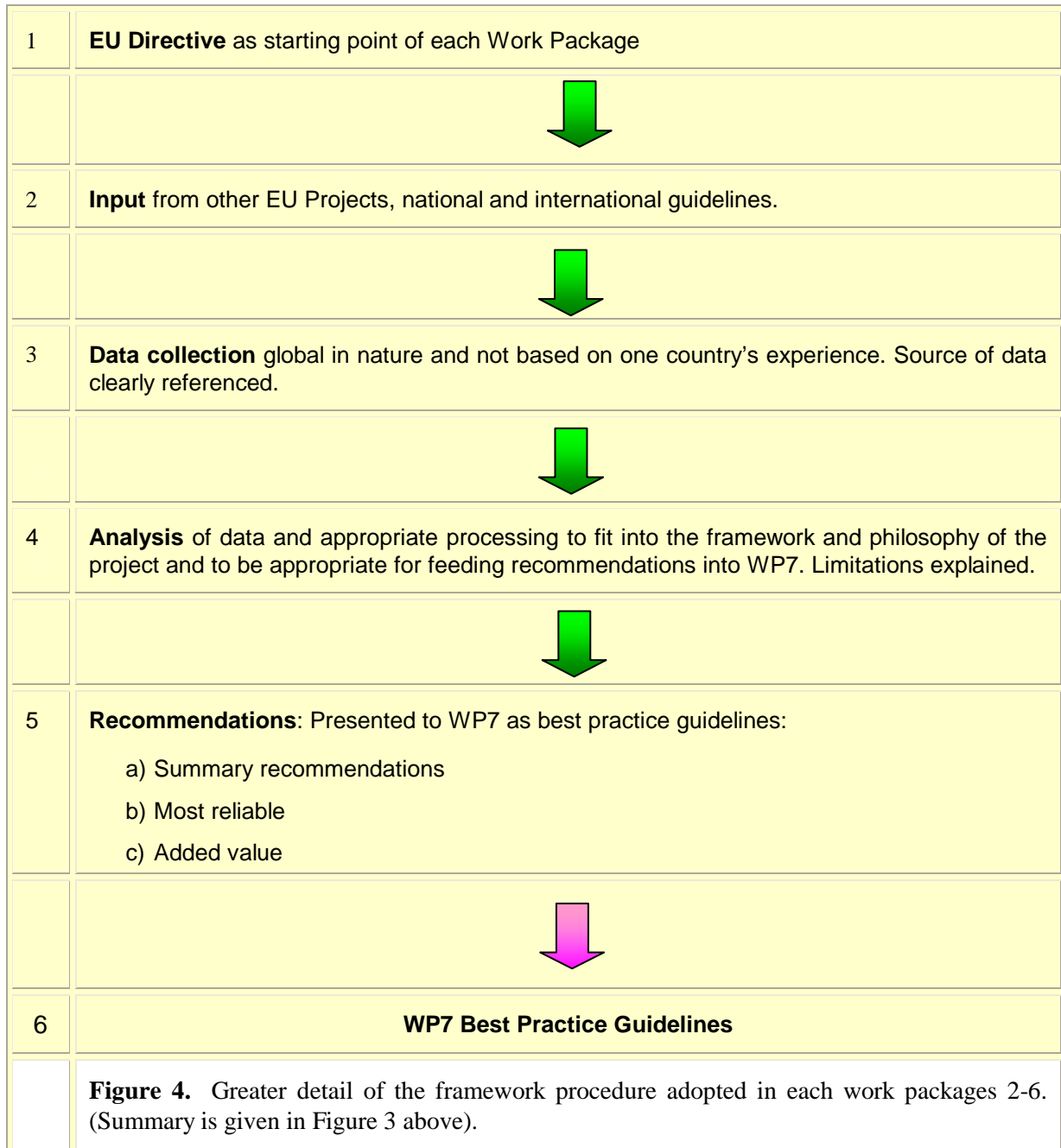
The key function of Work Packages 1-6 is to feed into the Best Practice Guidelines of Work Package 7. They cover 6 subject areas focused on preventive measures, management and cross-border issues. While each report examines its specific subject in detail, summary recommendations are presented in each report for the guidelines of WP7. The Guidelines, therefore, comprise the executive summaries of the 6 Work Packages in stand alone sections, but it starts with the Global approach that provides the wider conceptual framework within which the six Work Packages fit. The full six reports are then placed in appendices for further reference. The text of the Guidelines (Report WP7) is drafted by experts but is written to be easily readable by the non-expert.

Care was taken to ensure that the reports of work package 2-6 followed the same procedure (See Figures 3-4) in order to be:

- consistent within the project;
- fit within its framework;
- contribute optimally to Work package 7.



**Figure 3.** Consistent overall structure of each SafeT Work Package (2-6) feeding into WP7.



## 5. SAFET PROJECT IN PERSPECTIVE

The SafeT project should be viewed within the wider perspective of tunnel safety at several levels:

- **Historic Appropriateness**
- **Tunnel Safety** in relation to improving tunnel safety;
- **EU (and international)** in relation to the EU Directive and six other 5<sup>th</sup> Framework projects on tunnel design/safety;
- **Technical** in terms of subject matter;

These will be discussed briefly in the following sections.

### 5.1 Historic appropriateness

The SafeT project is appropriate at this point in history following the completion in the year 2006 of seven 5<sup>th</sup> Framework projects on tunnel design/safety funded by the European Union (Figure 5), and the introduction of the European Directive during this period. Particularly in the wake of a series of some 10 tunnel fires/incidents with serious human and economic consequences, several countries (including Austria, France, Germany and Switzerland) have been revising their design guidelines in an attempt to improve the safety in their tunnels.

### 5.2 Tunnel Safety Perspective

The recent tunnel fires have highlighted a number of important safety issues that require attention including:

- increased traffic flow especially the number of lorries carrying dangerous goods;
- inappropriate user behaviour;
- poor management;
- inappropriate tunnel layout with escape routes;
- inadequate ventilation systems;
- spalling of concrete;
- fatalities/injuries and material damage due to cross border issues.

The whole multinational European movement for improved tunnel safety started with a survey of 25 European tunnels by European automobile clubs (ADAC) carried out in 1999-2000. The survey indicated that a third of the tunnels were assessed as “critical” (6 tunnels) or “sub-standard” (2 tunnels), 9 were assessed as “good”. No tunnel received the “very good” rating [3]. The results and the manner in which the survey was carried out led to considerable discussion. Operators found it hard to accept that the ADAC, as an outsider, should examine its structures. In neighbouring countries, the tunnel survey by the German automobile club was, in some cases, entirely rejected [3] and the

methodology criticised on the basis that its is “additive” rather than “holistic”. Safety features were given ratings and weightings to produce an overall assessment of “safety” but this did not take into consideration the dynamic interaction between the different safety features following a critical path from accident development to the response of people and structure whereby the failure of just one critical feature could result in serious fatalities. This shortcoming has been addressed by the UPTUN project (see below).

### 5.2.1 Human and Material loss in accidents

Although the issue of fire in tunnels has gained high profile in recent years it should be emphasised that in Norway, for example, over the last 15 years 3 persons died in fires in tunnels and about 100 died in accidents [4]. Naturally, the statistics vary from country to country. SafeT focuses on accident/incident prevention and is, therefore, wider than just for fire events. However, it was in particular the human casualties in Mont Blanc, Tauern, Kaprun and Gotthard tunnel fires (221 lives lost in 4 fires over a period of just 2 years - Table 1) that have provided the impetus for a major re-appraisal of fire safety in European road and rail tunnels. These incidents have changed perceptions of road tunnel fires worldwide and increased the death toll statistics in two-way tunnels relative to one-way tunnels. Added to this human tragedy, is the damage to the tunnel structures and installations.

**Table 1.** Examples of human and material Consequences of 6 European tunnel fires [5].

Tunnel	Type	Year	Length (m)	Fire Duration	Deaths	Material Loss
Great Belt Denmark	Rail	1994	8,000	7 hrs	None	16 segment rings (1.65m long) damaged in crown during construction.
Channel UK-France	Rail	1996	50,500	9 hrs	None	500m of structural damage, rolling stock damaged and major repair and operational losses.
Mont Blanc France-Italy	Road	1999	11,600	50 hrs	39	900m of tunnel structure severely damaged. 23 lorries and 10 cars burnt.
Tauern Austria	Road	1999	6,400	17 hrs	12	16 lorries & 24 cars destroyed, Concrete spalled 10-15 cm. Toll losses 6.5m Euro/month
Kaprun Austria	Rail	2000	3,300	1-2 hrs	159	Train's base all that remained after 1,000°C fire
Gotthard Switzerland	Road	2001	17,000	24 hrs	11	200m false ceiling damaged

### 5.2.2 Socio-Economic Loss

It should be highlighted that the tunnel incidents mentioned above have had serious socio-economic losses, but that assessment at the macro-economic level has not been considered in any tunnel safety evaluation. Socio-economic impacts on the wider regional economy (e.g. Italy and France from the closure of the Mont Blanc tunnel) should be better appreciated and quantified in the future as part of an overall tunnel safety evaluation. The financial cost alone (excluding socio-economic impact) from direct damage and lost revenue of the Channel Tunnel fire has been estimated at £200M. The cost to the Italian economy from the 3 year closure of the Mont Blanc tunnel has been estimated to be 2.5bn Euros. The cost of upgrading itself was 300M Euros. Despite this, it is still a common practice in engineering circles to assess the impact of a scheme only in micro-economic terms (capital-maintenance-operating costs, internal rates of return, user benefits-costs etc.). However, there is a growing understanding of the importance of economic analysis that goes beyond the limited traditional microeconomic cost benefit analysis [6]. Although economic impact does not form part of the SafeT guidelines, it is necessary to include socio-economic impact as part of the wider Global Approach which is holistic and all encompassing.

## 5.3 European Perspective

### 5.3.1 Fifth Framework EU Projects

SafeT is the last of seven projects funded by the European Union (Figure 5) as part of the “5th Framework Programme” to address the problems of tunnel design and safety. It is described as a “Thematic Network” and as such does not involve research and development but the judicial collection and analysis of existing data leading to recommendations thereof. Its focus is on preventive measures, management and cross-border issues. In fact the first of the seven projects is also a thematic network called Fire in Tunnels (FIT) dedicated primarily to a similar exercise but focusing instead on fire issues.

The seven projects fall within a time framework of 5 years starting in the year 2001 and ending in the year 2006. Three of these projects are devoted to fire issues: FiT, Virtual Fires and UPTUN (Upgrading Tunnels), given that fire has been a dominant problem experienced in European tunnels over the past decade. However, other tunnel safety issues feature in the EU projects including design (e.g. DARTS Project) and management/preventive issues (e.g. Safe Tunnel, Sirtaki and SafeT). Hence, the seven projects are complementary culminating in SafeT with the development of the Global Approach to tunnel safety and the presentation of the Best Practice Guidelines.

The other six projects are described briefly as follows:

#### (1) FIT - (Fire in Tunnels)

Fire in Tunnels (FIT), launched in March 2001, is a 4 year “Thematic Network” of 33 partners from 12 European countries coordinated by BBRI (Belgium), and aims to establish and develop European networking and to optimise efforts on fire safety in tunnels. FIT forms an important first stage in the European wider action with the *gathering of existing information* and comprises of 4 work-packages related to 6 *consultable databases*.

The work packages include a state-of-the-art on design fires, guidelines on fire safe design and definition of best practises for fire response management.

The 6 consultable databases on tunnel and fire are available on line. FIT members, and the registered corresponding members, are invited to consult - and provide input to - the databases on research projects, test sites, numerical models, equipment, fire accidents and tunnel upgrade activities.








Project	Logo	2001	2002	2003	2004	2005	2006
FIT		Consultable Databases & Guidelines					
DARTS		Cost-optimal & durable new design					
Safe Tunnel		Preventive safety measures					
Sirtaki		Advanced tunnel management					
Virtual Fires		Tunnel fire simulator					
UPTUN		Upgrading of existing tunnels - Innovation					
SafeT ?		Harmonised European Guidelines					

Figure 5. Seven tunnel related project funded by the EU’s 5th framework programme [2].

(II) DARTS - (Durable and Reliable Tunnel Structures)

DARTS (Durable and Reliable Tunnel Structures) is a 3 year project, also launched in March 2001, undertaken by 8 European partners co-ordinated by COWI (Denmark) through six technical work-packages. It was prompted by the serious cost overruns, often exceeding 100%, and construction delays of recent tunnels combined by the lack of supportive tools for life cycle tunnel optimisation including durability, environmental aspects, sustainability, safety and hazards. DARTS aims at developing, for each individual case, operational methods and **supporting tools for the choice of cost-optimal tunnel type and construction procedures** regarding environmental conditions, technical qualities, safety precautions and long service life. It is a cradle-to-grave approach ensuring up-front decision making. However, DARTS is primarily concerned with new tunnels but develops decision procedures directly usable for upgrading of existing tunnels. Fire issues (12% of total effort) are



directly co-ordinated with the achievements of FIT and represent a key element of the hazards considered, which to a lesser extent includes also explosions, water inundation and earthquakes.  
Safe Tunnel

### (III) SAFE TUNNEL

(Innovative systems and frameworks for enhancing of traffic safety in road tunnels) is a 3-year project of 9 partners initiated in September 2001 and co-ordinated by Centro Ricerche FIAT (Italy) Its main objective is to contribute to the reduction of the number of accidents in road tunnels by *preventive safety measures*. The main focus is to achieve a dramatic decrease of the "fire accidents". The basic ideas are to avoid the access into the tunnel to those vehicles with detected or imminent on-board anomalies and to introduce measures to achieve the control of the speed of the vehicles inside tunnel.

### (IV) SIRTAKI

SIRTAKI stands for Safety Improvement in Road & rail Tunnels using Advanced information technologies and Knowledge Intensive decision support models. The 3-year project, initiated in September 2001, is undertaken by a consortium of 12 European partners, including local authorities, from 8 countries co-ordinated by ETRA (Spain). It aims at developing and assessing an *advanced tunnel management system* that specifically tackles safety issues and emergencies and is fully integrated in the overall network management. The proposed system will be evaluated in several road and rail tunnel sites. SIRTAKI plans to provide innovations in four main aspects of tunnel management and emergency situations: the prevention of conflictive situations and emergencies, supporting tunnel managers, integrated management within the transport network and improvements to sensors and surveillance. The Decision Support System (DSS) is one of the main components of SIRTAKI. Basically, the DSS provides a smart aid between, on the one hand, the crisis manager and the real time information needed to analyse the situation and, on the other, between the crisis manager and the emergency response means.

### (V) VIRTUAL FIRES

Virtual Fires (Virtual Real Time Emergency Simulator) is a 3-year project with 8 partners from 5 European countries initiated in November 2001 and co-ordinated by the Institute for Structural Analysis (Austria). The aim of the project is to develop a *simulator* that allows the training of fire fighters in the efficient mitigation of fires in a tunnel, using a computer generated virtual environment. This will be a low-cost and environmentally friendly alternative to real fire fighting exercises involving burning fuel in a disused tunnel. The simulator can also be used to test the fire safety of a tunnel and the influence of mitigating measures (ventilation, fire suppression etc.) on its fire safety level. End users will include tunnel operators, designers and government regulatory authorities.

### (VI) UPTUN (Upgrading existing Tunnels)

UPTUN (UPgrading TUNnels) stands for "Cost-effective, sustainable and innovative upgrading methods for fire safety in existing tunnels". It is a 4-year *research and development* project with 41 partners from 13 different EU Member States and from 3 associated countries. Additional organisations are involved in an Advisory Board headed by CETU (France). UPTUN is by far the



largest of the tunnel safety projects funded by the EU under the 5<sup>th</sup> Framework Programme. It was initiated in September 2002 and is co-ordinated by TNO (Netherlands) and ENEA (Italy). UPTUN's primary objectives are, (a) to develop, validate and promote innovative, sustainable and low-cost (preventive, detecting, monitoring and mitigating) measures, where appropriate, to limit the probability and consequences of fires in existing tunnels; and (b) to develop and promote a holistic evaluating and upgrading procedure for *existing tunnels*, based on the innovative measures developed in objective "a" to allow owners, stakeholders, designers and emergency teams to evaluate and upgrade human and structural safety levels. The work is divided into 7 technical work-packages:

- WP 1: Prevention, detection and monitoring;
- WP 2: Fire development and mitigation measures;
- WP 3: Human response;
- WP 4: Fire effect & tunnel performance: system structural response;
- WP 5: Evaluation of safety levels and upgrading of existing tunnels;
- WP 6: Fire effects and tunnel performance: system response;
- WP 7: Promotion, dissemination, education/training.

The first four work-packages aim to develop new measures to reduce the probabilities, and to mitigate the consequences, of fires in tunnels. The fifth and sixth work-packages mainly focus on the development and verification of the innovative holistic upgrading procedure. The last work-package is devoted to the promotion and dissemination of the results.

The innovations considered in UPTUN include fire suppression by means of the use of water mist technology and isolation of the fire (i.e. compartmentation) by means of inflatable tunnel plugs to starve the fire from oxygen and separate smoke from people. Work package 5 involves the development of the holistic evaluation and upgrading model (see Report WP7.2) employing artificial intelligence, heat & mass flow simulation, human behavioural modelling, structural response modelling, and socio-economic impact assessment, using Nobel Prize winning methodology.

#### (VII) SafeT (Safe Tunnels)

The final 7<sup>th</sup> project. A thematic network complementing the other six projects with a Global Approach to tunnel safety, and Best Practice Guidelines focusing on prevention, management and cross-border issues.

### 5.3.2 European Directive

Following a White Paper on European Transport Policy for 2010 published in September 2001, the European Commission published a proposal in December 2002 for a Directive of the European Parliament and the Council 2004/45/EC [1] on minimum safety requirements for tunnels in the Trans-European Road Network. It notes that the main causes of road accidents are incorrect behaviour of road users, inadequate installations on the road network, vehicles with technical defects and other faults as well as problems with loads. It sets two main objectives for optimal level of safety in road tunnels:

- (a) The primary objective is the **prevention of critical events** that endanger human life, the environment and tunnel installations;
- (b) the secondary objective is the **reduction of possible consequences** of events such as accidents and fires to enable people to rescue themselves, allow immediate intervention of road users, ensure efficient action by emergency services, protect the environment and limit material damage. It points out that the first 10-15 minutes of an event are crucial in terms of self-rescue and limiting damage.

The Directive applies to tunnels longer than 500m in the Trans-European Road Network. The proposal notes that users can usually escape from tunnels shorter than 500m on their own in approximately 5-10 minutes, and that within this time, hot smoke emitted by the fire is naturally stratified, which makes escape possible. It adds that tunnels shorter than 500m do not generally need to be equipped with mechanical ventilation systems. It considers 4 main factors influencing the level of safety: Infrastructure, operation, vehicles and road users. Requirements aimed at reinforcing safety in road tunnels will be established for each group. A cost/benefit study was carried out by ICF Consulting Ltd. The three main costs - to be borne by Member States - are:

- Refurbishment (majority of costs),
- costs of traffic delay caused by the refurbishment (quarter of costs) and operational costs.

The total cost of the proposal is estimated to range from 2.6 billion Euro (where certain modifications in the tunnel structure are replaced by alternative measures, such as traffic restrictions) to 6.3 billion Euro (assuming all existing tunnels will be adapted to meet the provision of new tunnels). The estimated benefits include:

- (a) Direct benefits of accidents avoided or contained (direct cost now running at about 210 million Euro per year);
- (b) Indirect benefits to the economy from avoidance of tunnel closures (about 300-450 million Euro per year for Italy alone);
- (c) Indirect potential economic benefits (e.g. transport, competitiveness).

A two-stage approach is considered. In the short to medium term the proposed legislation will set minimum standards to rapidly guarantee a high level of safety for road users of road tunnels. Medium and long term solutions are also suggested that include a shift in transport modes. Another European Directive is being prepared for rail tunnels. This proposal raises a number of concerns. It could be too prescriptive and thus may be unable to incorporate developments such as those that arise from the 5<sup>th</sup>

and 6<sup>th</sup> Framework projects. In addition, it appears that the evaluation of the overall safety level of a tunnel could be conducted in the manner of the ADAC approach, rather than holistically as proposed by UPTUN.

### 5.4 Technical Perspective

The fourth important perspective that needs to be considered is that of where the SafeT project fits within the overall scheme of tunnel safety. Of the seven factors influencing tunnel safety considered in Figure 6, SafeT addresses the following four factors:

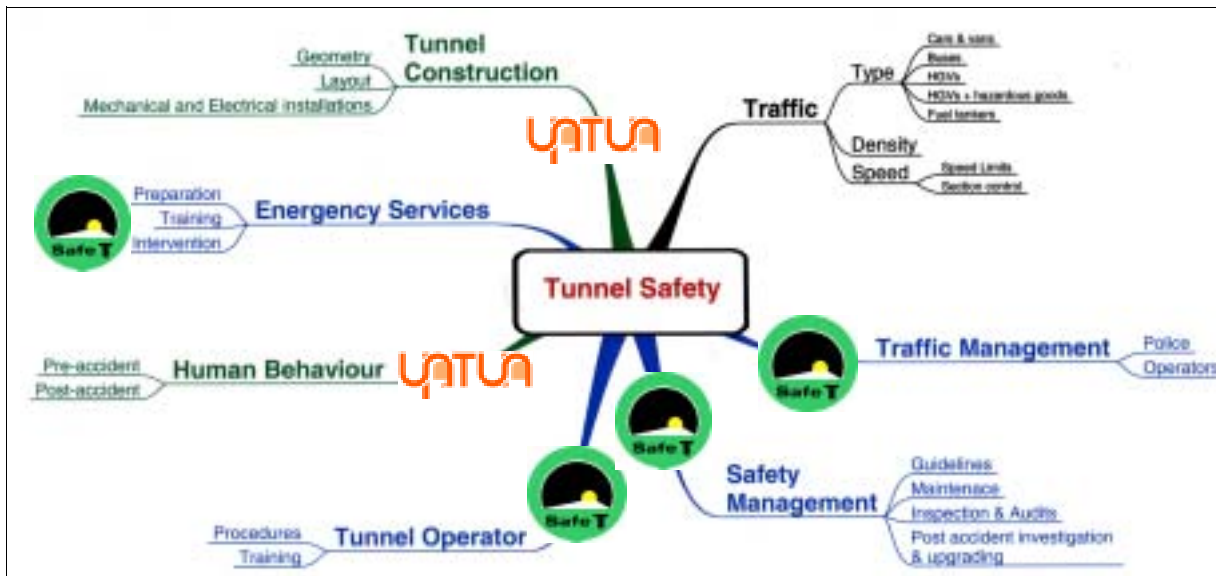
- Safety Management
- Traffic Management
- Emergency services
- Tunnel operator

Along with their subsets shown in Figure 6.

The UPTUN project relates more to post-fire mitigation and addresses factors such as:

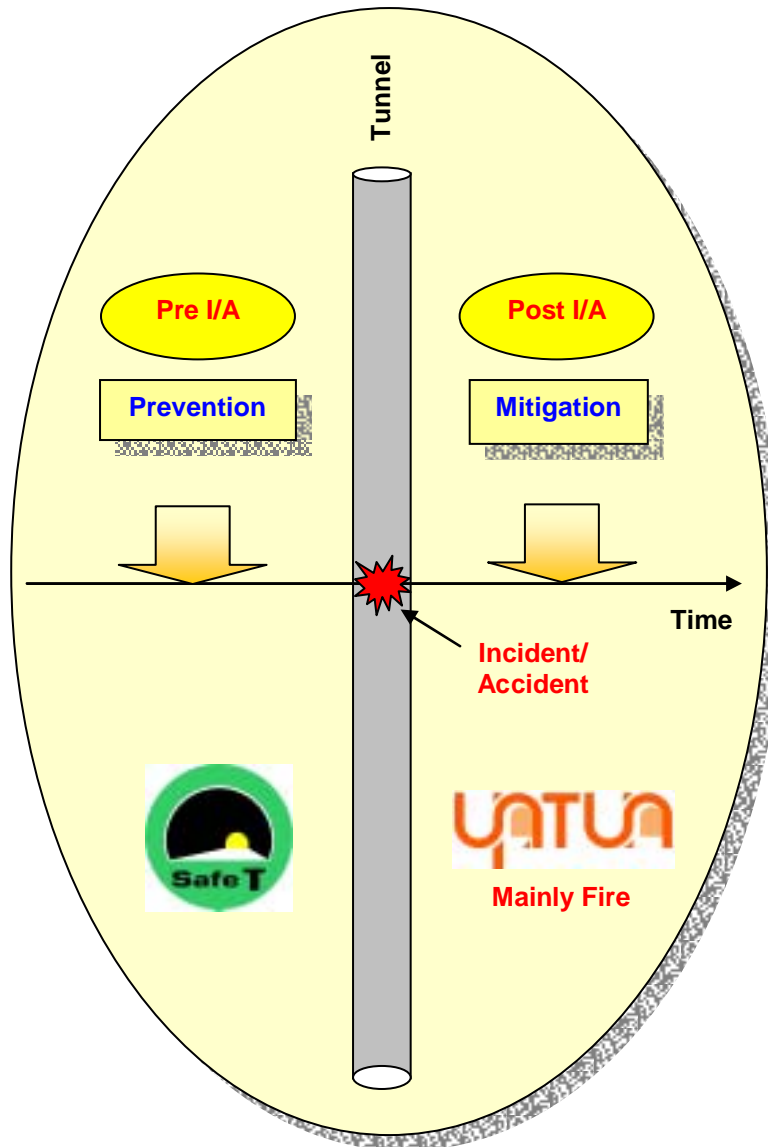
- Tunnel construction
- Human behaviour

This list is not exhaustive but gives an indication of how the EU projects complement each other and which issues each addresses.



**Figure 6.** Factors influencing road tunnel safety.  
 Notes: Blue items mainly in SafeT project  
 Green items mainly in UPTUN

Another technical angle of the two projects would be viewed in terms of prevention prior to an incident/accident (e.g. primarily SafeT) and in terms of investigation and mitigation after a incident/accident (in this case fire as in UPTUN) - Figure 7. The Global approach of SafeT developed in the next report encompasses both prevention and mitigation – not just related to fire.



**Figure 7.** SafeT Guidelines focuses primarily in accident/incident preventive measures, while UPTUN focuses on post-fire investigations/mitigation. The *Global approach developed in the next SafeT report (WP7-1) encompasses both prevention and mitigation in general, not just fire.*

## 6. REFERENCES

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