OECD Studies in Risk Management
Norway
TUNNEL SAFETY

Looking back on the disasters of recent years alone (the Indian Ocean tsunami disaster, Hurricane Katrina, terrorist attacks in New York, Madrid and London, avian flu, the 2003 heat wave in Europe), one could be forgiven for thinking that we live in an increasingly dangerous world. A variety of forces are helping to shape the risks that affect us, from demographic evolutions to climate change, through the development of mega-cities and the rise of information technology. These changes are clearly a major challenge for risk management systems in OECD countries, which have occasionally proved unable to protect the life and welfare of citizens or the continuity of economic activity.

The OECD Futures Project on Risk Management Policies was launched in 2003 in order to assist OECD countries in identifying the challenges of managing risks in the 21st century, and help them reflect on how best to address those challenges. The focus is on the consistency of risk management policies and on their ability to deal with the challenges, present and future, created by systemic risks. The Project covers a range of risk management issues which were proposed by the participating countries and together form three thematic clusters: natural disasters, risks to critical infrastructures, and the protection of vulnerable population groups. In the first phase of the Project, the OECD Secretariat prepared a case study for each issue. The studies cover both recent international developments of interest and the national policy context, and come with a tool for self-assessment to be used later in the Project in order to review the national policies in question.

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Norway

TUNNEL SAFETY
Foreword

The OECD Futures Project on Risk Management Policies aims to assist OECD countries in identifying the challenges of managing risks in the 21st century, and contributing to their reflection on how best to address those challenges. Its focus is placed on the consistency of risk management policies and on their ability to deal with the challenges, present and future, created by systemic risks. It is designed in two phases. In Phase 1, the countries participating in the project propose specific themes as case studies of their risk management policies. For each proposal, the OECD Secretariat prepares an overview of the issue covering both recent international developments of interest and the national policy context. In addition, the Secretariat elaborates a tool for self-assessment and review, consisting of one or several questionnaires following the methodological framework of the project. This prepares the ground for Phase 2 in which an in-depth review of the risk management issues will be conducted by a team of experts for those countries that wish it. Self-assessments will be used as the basis of these reviews. At the end of phase 2, a cross-country report will bring together the lessons learned from the project, and identify opportunities for sharing best practices and improving risk management.

In the framework of the OECD Futures Project on Risk Management Policies, the Norwegian Ministry of Justice and the Police has proposed a Phase 1 case study on “Risk management in connection with the prevention of and response to fires, and to accidents involving dangerous goods in underground traffic systems”. The study would lay the ground for self-assessment and review of Norway’s risk management policies concerning fires in tunnels, with the objective, in the Ministry’s words, of “identify[ing] and address[ing] current problems related to the balancing between risk (reduction) in the form of preventive, preparedness and response measures against fires and accidents involving dangerous goods on the one hand, and the desire to optimise the transportation of humans as well as goods in such traffic.” Tunnel safety has become a matter of concern and policy reform after a series of serious accidents in Europe, and although Norway has so far been spared from a large-scale accident, the number of tunnels in the country and its topographic specificities make tunnel risk management particularly challenging.

This study has been prepared by Reza Lahidji and Marit Undseth, from the OECD International Futures Programme. The authors have benefited from the support of Hilde Bostrom Lindland and Terje Olav Austerheim, at the Norwegian Directorate for Civil Protection and Emergency Preparedness, and from the guidance of the Steering Group to the OECD Futures Project (list of members in Annex 6). The study is issued under the responsibility of the Secretary General of the OECD.
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Introduction

In the framework of the OECD Futures Project on Risk Management Policies, the Norwegian Ministry of Justice and the Police has proposed a Phase 1 case study on large-scale accidents in underground traffic systems. The issue of tunnel safety is of particular importance to Norway due to the country’s topography and the specificities of its road and railway networks, not least in light of the implications for Norway of the adoption of a new European Directive on minimum safety requirements for road tunnels.

The aim of the case study is to prepare the ground for self-assessment and a review of the policy framework applied to tunnel safety. Policy decision-making regarding tunnels has to take account of a myriad of factors, including risks, technical solutions, human, societal and economic costs and benefits, trade-offs and linkages between prevention and preparedness, consideration of alternative means of transport and routes, and the standpoints of the various stakeholders. It also involves a range of national and local actors, and is implemented in part through a set of laws and regulations. The review of tunnel safety policies will have to consider the way and extent to which all these elements are integrated in the decision-making process; the institutional setting, in particular the sharing of roles and responsibilities between the various centres of decision-making; and the consistency of the legal and regulatory framework.

This Phase 1 study provides a general overview of recent developments in road and railway tunnel accidents and safety, analyses the Norwegian context against this background and elaborates a tool for self-assessment and review in the second phase of the Project. The first part of the study reviews the lessons learnt from some important accidents that have occurred in tunnels and other underground transport systems in recent years. Safety management at the international level is analysed in the second part, and the third part examines the Norwegian situation and policy context, and the major challenges the country faces in the field of tunnel safety. Annexes 1 and 2 complement the study with a more thorough presentation of recent accidents (annex 1) and risk-based methodology for tunnel safety (annex 2). Annexes 3 and 4 describe the relevant safety management authorities and regulations following the project’s methodological framework. Annex 5 proposes the main lines of five questionnaires, designed as a tool for self-assessment and review.
Safety issues in tunnels: lessons learned from recent accidents and disasters

The risks related to road and rail tunnels and underground traffic systems have been tragically illustrated by a succession of large-scale accidents, or sometimes even disasters, in the past years: the King’s Cross underground station fire in London (1987), the successive fire disasters in the Mont Blanc (March 1999), the Tauern (May 1999), and the Saint Gotthard (October 2001) tunnels, and most recently the deliberately caused or triggered disasters of Daegu (February 2003), Madrid (March 2004) and London (July 2005).\(^1\)

Notwithstanding their specific causes and circumstances (which, in certain cases, are still to be determined), such events shed light on a number of key facts regarding tunnel safety, which are developed hereafter: (1) the risks related to road tunnels belong to the low probability/large consequence type; (2) inadequate tunnel structures, freight vehicles and safety procedures remain important factors of vulnerability; (3) railway tunnels are relatively safer, but the market share of rail in total freight has been steadily decreasing; (4) human responses to emergency situations are of utmost importance in tunnel safety; and (5) malevolent acts have to be factored in safety design and management.

\((1)\) Transport through road tunnels entails risks which can be characterised by a low probability of occurrence and potentially catastrophic consequences.

The main threats to safety inside tunnels are fire, smoke, spillage of hazardous substances, and explosions, which can be caused by accidents, defects in the tunnel structure or in vehicles, human error.

Available studies and statistics show that road accidents are relatively infrequent in tunnels.\(^2\) An analysis of accidents on Switzerland’s national road network between 1992 and 1999 reveals that the average accident rate in tunnels is 0.35 per million vehicle-km, compared to 0.47 on open roads.\(^3\) In graph 1 below, it can also be seen that the frequency of road accident in tunnels in Norway is comparable to that of high-speed national roads in sparsely populated areas (on which many of the longest Norwegian road tunnels are situated), and half of the average road accident frequency.

The reduced likelihood of accidents in tunnels can be explained by the absence of a range of external risk factors (intersections, ‘soft’ road users such as pedestrians or bicycles, rockslides, bad weather, etc.), by

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\(^1\) See Annex 1 for a brief description of these events.

\(^2\) Accidents in this respect (although subject to some national variation) refer to incidents which have led to personal injury or fatality, are reported to the police, and include at least one moving vehicle (EU CARE database).

\(^3\) Salvisberg \textit{et al.}, 2004.
better roads (less curves and lower inclination), and by lower speed limit in tunnels and more concentrated drivers (unusual surroundings, high subjective awareness of danger). There is less available data on other sources of hazards, such as deficiencies in tunnel structures or in vehicles, which seem to be the origin of a majority of harmful events.

Figure 1 – Number of accidents per annum per 1 000 000 vehicle kilometres in Norway

As a consequence, risk management in all tunnel systems has been often based on the assumption of very low probability of fire. In particular, the scenario of a large-scale accident was considered as too unlikely in all of the disasters reviewed in annex 1. In fact, tunnel safety management schemes have traditionally focused their attention on the transport of dangerous goods, which have been subjected to stringent regulations (see box 1). Indeed, in the presence of flammable liquids or toxic materials inside a tunnel, minor technical failures which would not represent a threat in normal conditions can have severe consequences.

The Mont-Blanc, Tauern and Saint-Gotthard accidents show, however, that even more banal loadings can cause devastating accidents in a tunnel. In the Mont Blanc tunnel, for instance, the fire was initially caused by a truck carrying flour and margarine. Because of a succession of failures, it continued for 53 hours and reached temperatures to which the shelters and tunnel structure did not resist. This conclusion is supported by recent tests in the Norwegian Runehamar tunnel, within the framework of the European

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4 Elvik et al., 2000.
5 Salvisberg et al., 2004, op. cit.
6 In Norway, for instance, only 10% of vehicle fires in tunnels are caused by an accident (Amundsen et al, 2001).
research project UPTUN.⁷ Four large-scale tests with different semi-trailer fire loads where carried out, all containing cellulose (wood pallets or furniture) and plastics (polyethylene/polystyrene). The tunnel fire test obtained the highest peak heat release rate ever measured – more than 200 MW with gas temperatures in the vicinity of the fire above 1350°C.⁸

The recent accidents therefore showed that:

- tunnel safety management was not based on an adequate assessment of the likelihood of occurrence and the potential consequences of a large-scale accident;

- the trend increase in freight transport seems to constitute an important factor of risk per se, which needs to go hand in hand with sustained efforts to promote road tunnel safety;

- the increasing length of tunnels poses specific challenges, in particular as rescue operations become more complex.

### Box 1 – The transport of dangerous goods

The potential scale of an accident involving explosive, flammable or particularly toxic substances justifies that all necessary measures be taken to prevent its advent. The transport of such goods therefore falls under specific regulations, such as the European Agreement concerning the international carriage of dangerous goods by road (ADR, signed in Geneva in 1957 – see also section 2). The ADR agreement has been incorporated into the legislative framework of the European Union (directive 94/55/EEC). It is based on the following classification of dangerous goods:

- Class 1 Explosive substances and articles
- Class 2 Gases
- Class 3 Flammable liquids
- Class 4.1 Flammable solids, self-reactive substances and solid desensitised explosives
- Class 4.2 Substances liable to spontaneous combustion
- Class 4.3 Substances which, in contact with water, emit flammable gases
- Class 5.1 Oxidizing substances
- Class 5.2 Organic peroxides
- Class 6.1 Toxic substances

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⁷ Cost-effective, Sustainable and Innovative Upgrading Methods for Fire Safety in Existing Tunnels (UPTUN), a European Research and Technological Development project. See [http://www.uptun.net/](http://www.uptun.net/).

⁸ SP Swedish National Testing and Research Institute.
Class 6.2 Infectious substances
Class 7 Radioactive material
Class 8 Corrosive substances
Class 9 Miscellaneous dangerous substances and articles

Such products, according to European statistics, represent about 5 percent of all goods transported on roads – more than half of this share being attributable to flammable liquids. This share varies according to country specificities, from a minimum of 2.2 percent in the Netherlands to a maximum of 7.7 percent in Ireland. In Norway, it is estimated that dangerous goods account for about 5.5 percent of all transported products if all modes of transport are considered, of which 75 percent are petroleum products.

(2) Inadequate tunnel structures, freight vehicles and safety procedures remain important factors of vulnerability.

Since 1970, the risk of road accidents has dramatically decreased, as witnessed by the reduction in the number of fatalities at a time when the transport of passengers and goods was rising steadily in all OECD countries.

Figure 2 – Road fatalities and passenger car performance, 1970-2001
In fatalities per year and billion person kilometres


10 Ibid.
Still, transport systems of OECD countries have shown a number of factors of vulnerability.

Firstly, road tunnels are still of variable quality. In Europe, this can be traced back to different national regulatory differences linked to traffic concentration, traditions in construction and topography, and age and length of tunnels. According to tests carried out by road drivers’ associations, safety levels are low in many tunnels: among the 25 tunnels tested in 2003, 11 were found to have poor or very poor safety (ADAC, 2003). Safety issues generally concern old tunnels, which were built to specifications that have become outdated. The updating of such tunnels may come at a very high cost and is sometimes physically impossible.

Second, technological progress has made it possible to build ever faster vehicles, infrastructure with higher physical acceptance levels, and longer tunnels. These constructions have normally been constructed with safety in mind, but this does not necessarily apply to the other components in the transport system. 30-year old tunnels are no longer adapted to the height and length of modern heavy goods vehicles, for instance. Speed limits have also risen the last 30 years, but it is limited to which extent old infrastructure can be modified to assure the same levels of safety as new roads and tunnels.

With the increasing levels of trade within the enlarged European Union, notably via road freight, the highly differing technical standards of road freight vehicles in Europe are also a source of concern. Technical failure of a vehicle is often the cause of accident or car fire, a risk that should become more prevalent as the vehicle ages. In a tunnel fire review carried out by the OECD and PIARC studying 33 tunnel fires in OECD countries and South Africa, in 20 cases, the fire started in a road freight vehicle, and in 18 cases the fire was caused by a “vehicle related problem”. A recent study by Eurostat shows that both in terms of goods transported and distance covered, the share of relatively new vehicles (1 to 6 years) has increased in the European Union, while the share of vehicles aged between 7 and 14 has decreased. Since 1999, the proportion of vehicle-kilometres (vkm) covered by freight vehicles over 6 years old has fallen from over a quarter to nearly a fifth. This average, however, hides significant national differences. Whereas for Germany, France and the United Kingdom more than half of total road freight in 2003 was carried out by vehicles under 4 years of age and less than 10 percent by vehicles aged 10 years or more, in Spain less than half of the transport was carried out by vehicles aged less than four years, and 18 percent by vehicles aged 10 or more. This latter trend is even more pronounced in the new Member States of the European Union.

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For Cyprus, Lithuania and Latvia, the share of the older vehicles is 33, 39 and 29 percent respectively (see figure 3 below). It is in these countries that transport is expected to increase fastest in the next decades.

Figure 3 – Distribution of total transport by reporting country and age of vehicle, in vkm loaded, 2003

(3) Railway tunnels are relatively safer, but the market share of rail in total freight has been steadily decreasing.

Railway tunnels are generally considered safe. No serious accident involving human losses has been recorded in recent years, and Munich Re estimates it about 20 times more likely that fire breaks out in a road tunnel than in a railway tunnel. The only notable railway tunnel fire experienced in OECD countries in the past ten years occurred in the Eurotunnel between France and the UK, on 18 November 1996. This positive record, however, concerns conventional railway tunnels. When other underground rail systems such as subways and underground railway stations are considered, several very serious accidents have occurred in recent years (see annex 1). It must be mentioned that the legal framework governing tunnel rail safety usually extends to such systems, as is the case for instance in Norway, where the railway legislation concerns trains, metros, trams and other light railways.

In any case, the market share of rail in total transport has been steadily decreasing to the benefit of road over the past 30 years. Road transport, as measured by the total distance travelled in motor vehicles in the OECD area has increased by 72% between 1980 and 1998, and is expected to experience an

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14 Ibid., p. 3.
additional 40% rise by 2020. This trend is in large part attributable to the development of road freight transport, which has been boosted over the past decades by economic growth, trade liberalisation, falling transport costs, and lesser needs of infrastructure investments than rail, water or air transport (see figure 4). Figures for the Mont Blanc tunnel indicate that in 1998, commercial transport accounted for about 40% of total traffic in the tunnel.

Figure 4 – Trends in freight transport (tonne-kilometres), Western Europe, 1970=100

In Western Europe, the total volume of goods transported is three times higher today than in the early 1970s, due – among other things – to a dramatic increase in the relative share of road freight. Sustained growth is likely to continue in the coming years, not least due to increased intra-regional trade with Central and Eastern European Countries (CEECs), where the Gross Domestic Product is expected to increase by 300% in volume by 2030. From Norway’s perspective, an important factor will be the expected development of trade in the Baltic area.

Whereas 75% of all transported goods are nowadays conveyed on roads, the market share of rail is close to 8% (down from 21.1% in 1970). The volume of goods transported on railways has indeed decreased from 283 billion tonne-kilometres (tkm) in 1970 to 241 tkm in 1998. Current rail transport levels in Europe are

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17 European Commission, 2003b.
very low compared to other industrialised regions such as the United States. According to the European Commission’s projections, the rail’s market share will fall further to 7 percent in 2010, if nothing is done.

(4) **Human responses to emergency situations are of utmost importance in tunnel safety.**

It is important to note the significance of human behaviour on tunnel safety. The final outcome of some incidents may depend more on the quick and right reaction of individuals than on the technical safety level in the tunnel. This is a specific research topic in the UPTUN project and has also been subject to earlier research, both in tunnels and in related situations (fires, evacuation of buildings, etc.).\(^{19}\) **Findings imply that people have difficulties interpreting danger signals such as smoke, and that the reaction time is long.**

(5) **Malevolent acts have to be factored in safety design and management.**

Finally, the **possibility that an accident in a transport system could be deliberately caused by a malevolent action cannot be ignored in risk and vulnerability analyses**, in the context of increased terrorist activity in parts of the world. The attack at the Atocha train station in Madrid on 11 March 2004 was not directly related to tunnel fires, but it underlined that transport nodes with high concentrations of persons and inherent infrastructure vulnerabilities can become very attractive targets for terrorists. This was tragically confirmed in the attacks of 7 July 2005 in London.

The consequences and magnitude of such an accident may also attract the interest of malicious actors and increase the probability of sabotage or terrorism.

\(^{19}\) Stene et al, 2003; Netherlands Organisation for Applied Scientific Research TNO, n.a.
Selected developments in safety management

The recent large-scale accidents prompted several national and some concerted international efforts to improve the management of safety in road and railway tunnels. At the international level, tunnel safety has become subject to regulation both in the UN and most prominently in the EU, as well as important international R&D programmes. At national level, reforms have been introduced either in reaction to accidents, or to implement long-term Vision Zero programmes.

International initiatives in road tunnel safety

The major international forum regarding tunnel safety is the United Nations Economic Commission for Europe (UNECE). 55 international agreements and conventions have been elaborated under the auspices of the UNECE’s Inland Transport Committee, which provide the legal and technical framework for the development of road, rail, inland waterways and combined transport in Europe. These include the European Agreement concerning the international carriage of dangerous goods by road (ADR, signed in Geneva in 1957), and the less stringent UN Convention on Road Traffic (Geneva, 1949). Some conventions have been adopted by non-UNECE countries, and therefore apply to other regions than Europe. The ADR agreement has also been incorporated into the legislative framework of the European Union (directive 94/55/EEC).

A notable initiative to improve existing regulations was taken in 1999 by the UNECE Working Party on Road Traffic Safety, which gathered a group of experts to develop “recommendations for minimum requirements concerning safety in tunnels of various types and lengths”. In December 2001, the group presented 43 recommendations concerning road users, tunnel operation, infrastructure and vehicles.20 In particular, the recommendations propose to include specific questions concerning tunnel behaviour in driving tests (this exists already in Switzerland and Australia, and is under consideration in Germany and Austria21); as well as specific training and tests for professional drivers, especially drivers of dangerous goods. Another important contribution is the study by the OECD and PIARC (World Road Association) produced in 2001 on the transport of dangerous goods through road tunnels, reviewing past tunnel accidents and national legislations, and proposing three tools for a better management of risks: harmonised groupings of dangerous good loadings, a risk quantification model, and a decision support model (OECD, 2001).

21 SINTEF, 2003, p. 29.
In April 2004, after more than two years of discussions, the European Union adopted a new directive on minimum safety requirements for road tunnels. The directive, which incorporates many of the aforementioned recommendations, applies to tunnels of more than 500 meters, located in the trans-European network. The directive creates a comprehensive regulatory framework addressing both administrative practices and infrastructure and technical standards.

The text aims at identifying different levels of responsibility through the designation of a central supervisory authority, responsible for all aspects of safety in a tunnel; a tunnel manager; and a safety officer, designated by the tunnel manager and responsible for the coordination of all safety measures and contact with emergency and rescue services. A control unit is responsible for carrying out regular controls and evaluations. The directive promotes a risk approach to safety regulations, where the introduction of measures has to take into consideration infrastructure, operations, users and vehicles. Minimum safety measures regarding infrastructures and operations are introduced, in order to ensure a homogenous safety level and harmonised installations for external users. Requirements concern in particular tunnel geometry (number of tubes and lanes, gradient, etc); structural issues (emergency exits, fire resistance, etc); equipment (lighting, ventilation, detection and communication systems, etc.); personnel training; preparedness and emergency plans; and accident management. Finally, the directive introduces a harmonised tunnel signing system. Concerning the ‘human factor’, the directive prescribes the regular organisation of information campaigns concerning correct behaviour of road users when approaching and driving through tunnels.

**512 tunnels will be affected in the European Union, mostly in Austria and Italy.** In most countries, the new standards must be met within ten years (with at least half of the tunnels complying within six years). Countries with many tunnels have 5 more years than the others to conform to the standards. For existing tunnels, many of the safety requirements may be replaced by alternative measures offering the same level of safety. The European Commission envisages a total cost of the proposal to about EUR 2.6 to EUR 6.3 billion, depending on whether existing tunnels are modified according to the provisions for new tunnels, or to alternative measures.  

Finally, as safety breaches are often found in old tunnels where possibilities to integrate new safety features may be limited, the international research project UPTUN (Cost-effective, Sustainable and Innovative Upgrading Methods for Fire Safety in Existing Tunnels) aims at finding cost-efficient ways to improve fire safety in existing tunnels. The 4-year project is carried out under the Fifth Framework

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22European Commission, n.a., p. 7.
Programme, Competitive and Sustainable Growth, of the European Union, and has 41 members from 16 different EU Member States and one EEA Member State (Norway). Its budget is about EUR 12 million. The objective is two-fold: first, to develop technologies in the areas of detection and monitoring, mitigating measures, influencing human response, and protection against structural damage; with the main output being a set of innovative cost-effective technologies; second, to develop, demonstrate and promote procedures for rational safety level evaluation, including decision support models, and knowledge transfer.

*International initiatives in rail tunnel safety*

The international work on road tunnel safety had a spin-off effect on railway tunnel safety activity. In 2003, the Inland Transport Committee of the UNECE developed a series of recommendations and minimum standards for the construction of tunnels longer than 1 000 metres and up to 15 000 metres. These comprise measures related to infrastructure, rolling stock and operations, at four different levels of effectiveness:

- **Prevention of accidents:** installation of a speed monitoring and signalling system, regular inspection of tunnel condition, and fire protection measures;

- **Mitigation of the consequences of accidents:** derailment containment measures, fire protection requirements for structures, train radio, emergency brake neutralisation and maintaining movement, taking the train out of the tunnel and stopping following or passing trains in case of incident;

- **Facilitation of escape:** escape walkways, handrails in tunnels, tunnel markings and emergency lighting, training of railway staff

- **Facilitation of rescue:** water supply for fire-fighting and rescue services, radio installation for rescue services, reliability of electrical installations, emergency and rescue plans, exercises with rescue services and information on transport of dangerous goods

In addition, measures aimed at minimising risks in existing tunnels have been developed. Standards should be applied to all tunnels, but exceptions from any of the standards are possible, as long as the safety level can be reached by a combination of other measures. Recommendations should be applied to specific tunnels, according to local conditions.

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In the case of existing tunnels, the minimum standards do not require structural or construction changes, and contain measures such as the installation of speed monitoring and signalling system, regular inspection of tunnels, emergency tunnel lighting and provision of rescue equipment. These standards and recommendations, issued in December 2003, have not been incorporated into any international legal framework.

In April 2004, at the same time as it introduced a new directive on road tunnels safety, the EU adopted a directive on the safety of the Community’s railways (directive 2004/49/EC). The directive aims at establishing a common regulatory framework for railway safety through the harmonisation of the content of safety rules, safety certification of railway undertakings, the tasks and roles of the safety authorities and the investigation of accidents. Its purpose is to harmonise the regulatory structure in the Member States; define responsibilities between actors; develop common safety targets and methods; require the establishment, in each Member State, of a safety authority and an accident and incident investigating body; define common principles for the management, regulation and supervision of railway safety.

It clearly states that the approach to safety has to be systemic, and identifies the basic elements of the safety management system: a safety policy; qualitative and quantitative targets for the maintenance and enhancement of safety; procedures and methods for carrying out risk evaluation and implementing risk control measures and arrangements for the provision of information within and between organisations.

Regarding dangerous goods, their transport on railways is regulated by the Convention concerning International Carriage by Rail (COTIF) and the Regulation concerning the International Carriage of Dangerous Goods by Rail (RID), developed in the UN system as a railway counterpart to the ARD. First only applicable to international carriage, the RID was then incorporated into the European framework as the directive 96/49/EC of 23 July 1996 (RID Framework Directive) to be applied also to domestic transport.

A number of European-level initiatives (public and private-driven) and national measures have been developed to try to reverse the trend increase in road transport at the expense of rail. One notable event is the establishment of a European Railway Agency in the EU, which should support the efforts to create a single European railway system by 2020. The agency should also contribute to the development of a common European safety approach, by developing common safety methods and targets.

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Country-level evolutions

Several countries are currently taking measures with the ambition to drastically reduce transport risks in the long-term, with the introduction of Vision Zero programmes, mainly in the road traffic sector. The main line of thought is that the fallibility of road users and error tolerance must be integrated into the transport systems, and an ethical standpoint is added that considers each fatality as ‘unacceptable’. Examples of such safety visions include the Sustainable Safety Programme of the Netherlands and the ‘Vision Zero’ programmes in Sweden. Other countries are also considering or have implemented similar programmes, including Norway and Switzerland.

The Netherlands, as part of its Vision on Safety in Road and Rail Tunnels, suggests a wide-reaching integration of tunnel safety principles into tunnel construction and operation. An independent group of experts on tunnel safety would be involved in the planning, design and building phase of new tunnels, and each tunnel would have a safety file to be supervised regularly by inspection entities. The safety file would include the registration of the safety process, the documents with the considerations leading to the safety decisions, and a list of the decisions (including the building licence, the decision on requirements for use and the decision to open the tunnel for use).27

Several countries have also reorganised their road tunnel management in order to improve the level of safety after the occurrence of a serious accident or a disaster.

In France, after the Mont Blanc accident in March 1999, an evaluation committee evaluated all tunnels more than 1000 metres long (39 tunnels in all). Its recommendations led to modifications of the existing legislation and regulatory regime. Bilateral agreements also ensured that the same standards were applied to tunnels shared between two countries. A road tunnel safety evaluation committee (comité d’évaluation de la sécurité de tunnels routières) was established in 2000, bringing together representatives from several ministries and sectoral experts with the task of examining the safety level of tunnels longer than 300 metres, whether they are planned, new or existing. The builder or tunnel operator prepares a safety file which is transmitted to the committee by the prefect, the regional head of defence and civil preparedness under the Ministry of the Interior. According to its 2003 activity report, the committee found that the communication was good between the different parties, but that too often the tunnel constructor operator

did not know sufficiently well the tunnel and proposed supplementary equipment whereas the existing equipment was either inadequately maintained or unreliable.\textsuperscript{28}

After the Tauern tunnel accident in 1999, Austria also established a commission to coordinate measures to improve tunnel safety. The tunnel commission, with a fixed-term mandate, had an inter-disciplinary composition and gave recommendations in close cooperation with the road operators and the regions.

Switzerland has adopted strong measures to control road freight, including the decision to reduce the number of trucks crossing the Swiss Alps on road from 1.4 million to 650 000 per year. The decision should enter into force at the latest two years after the completion of the Lötschberg railway tunnel, scheduled for 2007.\textsuperscript{29} The rail market share in Switzerland is already high, due to weight limits and night and week-end circulation bans for trucks.

Multilateral cooperation was further reinforced after the St. Gotthard accident in 2001. Ministers of the Alpine countries met shortly after the fire and signed a declaration pledging to improve safety. A working group chaired by Switzerland was also created to propose new safety measures.

\textsuperscript{28} Comité d’évaluation de la sécurité des tunnels routiers, 2004, p. 1.

\textsuperscript{29} International Union of Railways, 2004.
The challenges of tunnel safety in Norway

Norway has 91,450 km of public roads and 4,077 km railway network. The country has one of the highest averages of road tunnel kilometres per inhabitant in Europe, with 844 tunnels and a total length of 768 km. 390 of these tunnels are longer than 500 m, some of which are among the longest in the world (24.5 km for the Lærdal tunnel). In comparison, there are 702 railway tunnels. Population density is low with 4.5 million inhabitants living on 324,000 km². The majority of the population lives in the south-eastern part of the country, in the Oslo-region.

The general picture

The last 30 years has also seen an increase in the number of long road tunnels in Norway (the average length has increased by more than 20 percent since 1992, from 770 to 945 metres). This may be explained, on the demand side, by the higher mobility of persons and the increase in the number of cars, and on the supply side by higher public spending on road infrastructure and district-level political measures, as well as increased efforts to improve road traffic safety. Norwegian tunnels in rural areas replace narrow mountain roads, often exposed to rock slides or bad weather, or ferry connections, and are thus considered a much safer and less disruptive alternative to open roads. Norwegian road tunnel safety is deemed high relative to international standards, when it comes to accident and fatality risk.

Norway enjoys one of the highest levels of road safety in the world. Fatality figures have halved since 1970, despite increases in traffic concentration and car ownership, and have stabilised around 300 fatalities per year. Yet, the number of accidents has remained relatively stable (7.3 percent decline since 1970). As indicated above, accident rates are lower in tunnels than on open roads, and efforts are currently made to reduce accident risks on the road network even further.

Norwegian rail transport safety is comparable to the European level, but the sector has been marred by a series of accidents with fatalities in the last years, the most important of which being the Åsta accident in January 2000 with 19 deaths. Traffic safety in rail tunnels is probably lower than outside the tunnel, because most railway accidents take place at rail crossings and include road users. Figure 5 below shows the number of fatalities in road and rail transport in EU-15 between 1990 and 1999 per billion person kilometre. Fatalities in railway accidents, especially those limited to railway passengers, are considerably lower than the number of road traffic deaths. It should further be noted that the estimated Norwegian train passenger fatality risk (an average for the period 1990-2003) is above the EU-15 average, whereas the

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Norwegian figure for road accident fatalities, 4.6 deaths per billion person kilometre, numbers for 1988-93, is far below the European average. But it should be noted that railway accidents with fatalities are so rare, even at the European level, that fatality rates fluctuate considerably from year to year and are sensitive to single events.

**Figure 5 - Fatalities in transport accidents, road and rail, 1990-1999, EU-15**

Per billion person.kilometre

Source: Eurostat (2003), and the Norwegian Rail Administration and Norwegian Railway Safety Authority yearly statistics.

Norway has experienced similar trends in transport modes as other European countries since 1970 (figure 6).

**Figure 6 – National mainland goods transport, 1965-2003, million tonne-kilometres**

Source: Statistics Norway.

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In part because of the country’s geography, goods are to a very large extent transported on roads. According to figures from the Norwegian Statistical Agency, road goods transport accounted for 47 percent of all mainland transport in 2003 (in terms of tonne-kilometres), which compares to 5 percent for rail transport. As shown in figure 6, the market share of road transport has more than doubled since 1965, and the transport activity, as measured in tonne-kilometres, has increased six-fold. Only between 1985 and 2000, the goods transport doubled from 6.5 to 13 billion tonne-kilometres.

Risk and vulnerability factors

Parts of the tunnel infrastructure are clearly poorly adapted to today’s heavy goods traffic. About half of all road tunnels have a width of 6 meters or less, many of which have high traffic concentration with more than 5000 ADT (annual daily traffic). Most tunnels measure less than 4.6 metres in height, 18.5 percent measure less than 4 metres, which is the minimal height.32 There is anecdotal evidence of many heavy goods vehicles having to drive in the middle of the road in certain tunnels. Drivers of passenger cars also have a tendency to approach the centre of the lane in narrow tunnels, according to Dutch tunnel observations.33 Furthermore, Norwegian tunnels are not necessarily constructed to handle fires in heavy-goods vehicles. As described in section 1, the test fire carried out within the research project UPTUN reached very quickly 1 350 degrees Celsius with an effect of about 200 megawatt (MW). Tunnel equipment (construction and fans) in tunnels with high traffic (more than 10 000 ADT) are dimensioned to endure a fire of 20 MW, equipment in tunnels with less traffic should endure fires of 5 MW.34

Information about the transport of dangerous and flammable material on roads and rail is piecemeal. The second most serious Norwegian railway incident after the Åsta accident is the collision in Lillestrøm in 2000 involving a train transporting two containers each filled with 45 tonnes of propane. The investigation after the accident revealed that there was no up-to-date information available concerning the transport of dangerous goods on the Norwegian railway network, indicating transport volumes or distances travelled.35 A limited mapping was carried out for road and rail transport in 2002-2003, and it showed that the transport of dangerous goods is more substantial than earlier conceived in areas with a high density of road tunnels, more specifically the quantities of gases transported through the mountainous area separating the Eastern and Western part of Norway.36 This area contains the majority of road tunnels in Norway, some of

34 Opeide, 2003, p. 20.
which have a higher risk profile than other tunnels, because they are very long, including the 24.5 km long Lærdal tunnel, or in need of modernisation (narrower than 6 metres or lower than 4 metres). The report estimated annual quantities transported at about 1 100 000 tonnes,\textsuperscript{37} excluding classes 3, 6.2 and 7. In addition, it found a concentration of transport on several roads which are all included in the Trans-European Network (E6, E16, E18, E39, E134 and E136). The analysis\textsuperscript{38} also showed that the most commonly transported products, except for products of class 3, are gases and corrosive substances (classes 2 and 8), both of which are very dangerous. Today there are no restrictions on transport of dangerous goods in these tunnels.

This shows that even if traffic safety is high, Norwegian road and rail networks are exposed to a growing number of risk and vulnerability factors. One important issue is the widespread use of polyethylene (PE) foam to protect against frost and water leakages. Polyethylene is highly inflammable, and it is estimated that Norwegian road tunnels are covered with about 750 000 square metres of unprotected PE foam, a banned practice in new tunnels. In a study evaluating tunnel fires between 1990 and 2000, the PE foam caught fire in 6 of 67 reported fires.\textsuperscript{39} Work has been initiated to find a replacement material and to cover most of the unprotected foam in old tunnels by 2015. NOK 700 million was dedicated to upgrading old tunnels in the government transport plan 2002-2011, whereas NOK 1700 million is the budgetary frame for the plan covering 2006-2015.

Norway has had no railway tunnel fires with human losses in recent years, but there has been a series of incidents, especially in the Oslo metro underground, with 54 small fires in 2002.\textsuperscript{40} The Norwegian Railway Inspectorate’s inspections of the Oslo metro system have revealed a number of breaches on safety regulations. This includes lacking routines for checking tunnel fire safety and evacuation of tunnels (the inspection was done in 2002), insufficient safety communication with employees, and incomplete risk analyses. It should be noted that the metro tunnels are at places very narrow (the distance between the train and the walls less than 60 cm), that not all trains have emergency exists at the ends,\textsuperscript{41} and that both trains and tunnels have flammable material. Some of the trains are more than 30 years old, with uncovered flammable insulation material,\textsuperscript{42} and the electricity cables in the tunnels are covered with PVC (polyvinylchloride), which develops highly poisonous gases if catching fire. The Accident Investigation

\textsuperscript{37} DSB, 2004, p. 17
\textsuperscript{38} ibid.
\textsuperscript{39} Norwegian National Norwegian Public Roads Administration, 2001, p. 17.
\textsuperscript{40} Haram, 2003.
\textsuperscript{41} Falck-Ytter, 1998.
\textsuperscript{42} Havarikommisjonen for Sivil Luftfart og Jernbane, 2004, p. 3.
Board has asked the infrastructure manager to replace the cables inside tunnels, a work which should be finalised in 2004.\textsuperscript{43} The public transport system in Oslo is at the moment undergoing major changes and reform, including renewal and modernisation of train equipment and rail network.\textsuperscript{44}

It may also be questioned whether existing fire safety measures are correctly implemented or adapted to the current traffic situation. A recent risk and vulnerability assessment released by the County Governor (\textit{Fylkesmannen}) in Hordaland has identified a series of safety issues related to the rail and road tunnels in the region. The region of Hordaland has among the highest concentrations of tunnels in Norway, with about one-fourth of all road tunnels, all in all 190 km, and 65 km rail tunnels.\textsuperscript{45} The County Governor has principal responsibility for the coordination of civil preparedness in the counties, and this study was developed in cooperation with, among others, the local fire brigade, the National Roads Administration and NSB, the national railway operator. \textbf{The report found that fire safety measures and standards for railway tunnels are poor,} and recommended the development of general requirements in this area, regarding marking, emergency lighting and emergency communication. Furthermore, urgent improvement of evacuation possibilities was needed.\textsuperscript{46} The report also suggested that current safety measures for the transport of dangerous goods in road tunnels be reinforced, through transport restrictions, the acceleration of planned measures (removal of flammable material and installation of fire extinguishers), and measures to increase the distance between vehicles in selected tunnels.\textsuperscript{47} It is certain that all road tunnels do not fulfil existing national fire safety requirements – for instance, 9 percent of tunnels do not have fire extinguishers according to the requirements.\textsuperscript{48} This should, however, be improved in the current and next transport plan period.

The above examples show the difficulty of incorporating and implementing different safety principles and cultures into a rapidly changing transport sector, which leave little time for organisational response and adaptation. The most important trends in this context seem to be the increase in good transport on roads, the rising number of long tunnels in Norway and the increases in speed, both on roads and on rail, while the structures are poorly adapted. Furthermore, the internationalisation of regulation, as described in the preceding section, has led to an increase in the number of institutional actors in the field.

\textsuperscript{43} Haram, op. cit.
\textsuperscript{44} ibid.
\textsuperscript{45} Fylkesmannen i Hordaland, 2004, p. 94.
\textsuperscript{46} ibid., p. 96.
\textsuperscript{47} ibid., p. 106.
\textsuperscript{48} Amundsen and Engebretsen, 2003, p. 9.
Evolutions in the safety management doctrine

Norwegian transport and tunnel safety policy has in the last years been influenced by large-scale national initiatives in traffic safety, preparedness and fire safety. It seems that the importance of risk management and preparedness was recognised at the government level in the second half of the 1990s with the 1998 Government White Paper No. 25 Main guidelines for the activities and development of civil preparedness for the time period 1999-2002 (St.meld. 25 (1997-1998): Hovedretninglinjer for det sivile beredskapsvirksomhet og utvikling for tiden 1999-2002). This white paper outlined the importance of risk and vulnerability assessments “within all important areas and levels of society”.49

Another important document was the investigation report ordered by the Ministry of Justice and the Police A Vulnerable Society (et sårbart samfunn), which undertook the first large-scale vulnerability analysis of critical infrastructures at the national level. The report identified tunnels and the transport of dangerous goods as areas with considerable accident potential and called for better preparedness levels. A series of recommendations were made which are currently being implemented and will be identified more specifically later on.

The most important development in relation to transport safety is the introduction of the Vision Zero for all transport modes. The programme for road safety, which was launched in 2001, is based on the principles of integrating the fallibility of the road user into the traffic system and of spreading accident responsibility among several actors (road users, the National Roads Administration, the Police and the Norwegian Council for Road Safety (Trygg Trafikk)).50

A series of measures have been implemented in the areas of transport planning, road user training and supervision, infrastructure, vehicle control and supervision, injury treatment and preparedness and local and regional cooperation. Measures of particular relevance to tunnel fire safety include those directed towards heavy goods transport (increased frequency of police control of competence certificates for drivers of dangerous goods, increased frequency of controls of heavy goods vehicles (brakes, driving and resting regulations)).51 Furthermore, the tunnel handbook which is the main reference for all road tunnel construction in Norway, was changed in 2002, involving a reinforcement of requirements to safety equipment and introducing the requirement to use twin-bored tunnels at a lower level of traffic

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51 Ibid., p. 21 (Annex).
concentration than before.\textsuperscript{52} Advances in digital technology will also enable the increased use of automatic traffic control (video surveillance) in tunnels.\textsuperscript{53}

The Vision Zero Programme for road traffic in Norway will prioritise the most lethal accidents – 81 percent of road traffic fatalities are caused by head-on accidents, single vehicle accidents and pedestrian accidents.\textsuperscript{54} Considering that tunnels are safer (in terms of road accident fatalities) than most open roads, tunnel safety is not a first priority area within the Vision Zero. Nevertheless, the Ministry of Transport and Communication in its most recent transport plan for 2006-2015 (Stortingsmelding nr. 24 (2003-2004): Nasjonal transportplan 2006-2015) underlines the importance of improving tunnel safety because of the consequences of a potential accident.\textsuperscript{55}

In railway transport, the Vision Zero programme is for the moment less clearly expressed. Nevertheless, in the proposed working programme for 2006-2015, the Norwegian Rail Administration emphasises that ‘individual error shall not lead to loss of life or serious personal injury.’\textsuperscript{56} Tunnel safety is listed as one of five priority areas in the planning period 2006-2015. The Administration is responsible for 21 railway tunnels longer 2 km and 50 longer than 1 km. Of the 21 longer tunnels, 11 shall be secured before 2006. For the remaining 10 longer tunnels, a safety package will be prepared involving emergency lighting and signs, securing of PE foam and basis measures for assisted evacuation.\textsuperscript{57}

It should be noted that the fire and accident prevention authorities in Norway also have their specific Vision Zero when it comes to tunnel fires, as presented in the Ministry of Labour and Government Administration White Paper on Fire and Explosion Protection (Stortingsmelding nr. 41 (2000-2001): Brann og eksplosjonsvern). \textit{This paper sets as national target to eliminate the occurrence of ‘fires, explosions or accidents involving the transport of dangerous goods with many fatalities’}.\textsuperscript{58} The wording ‘many’ is deliberately vague, but indicates in practice accidents with more than four fatalities.\textsuperscript{59} The White Paper underlines that all public fire safety activities (audit, regulation) shall be risk-based, with the development of different types of risk acceptance criteria, methods for risk classification of fire audit objects

\begin{footnotesize}
\begin{enumerate}
\item Ibid., p. 50.
\item Ibid., p. 46.
\item Ibid., p. 30.
\item Norwegian Ministry of Transport and Communications, 2004, p. 84.
\item Norwegian Railway Administration, 2005, p. 40.
\item Ibid.
\item Norwegian Ministry of Labour and Government Administration, 2001.
\item Ibid.
\end{enumerate}
\end{footnotesize}
[tilsynsobjekter] and for risk-based decision making (see Annex 2). Owners of particular fire audit objects [særskilte brannobjekter], which includes tunnels, are required to carry out risk analyses to determine the level of fire safety measures and to document this to the fire safety authorities.

**Implications of international regulations**

International regulation is increasingly influential in Norwegian transport policy, also when it comes to safety management. The most recent examples are the directives on road tunnel safety and on railway safety management.

The implications of the new EU directive on road safety for the management of road tunnels in Norway have yet to be clarified. In the context of the implementation of the new directive, the Ministry of Transport and Communication asked in January 2005 the National Roads Administration to elaborate a regulation for road tunnel safety in cooperation with the Directorate for Civil Preparedness. It was decided that all tunnels longer than 500 metres on the national road network, all in all 237 tunnels, shall meet the requirements of the directive. Among these, it is estimated that 22 tunnels will be particularly concerned by the new safety requirements.

The costs of adding required equipment (such as evacuation lighting, mechanical ventilation and longitudinal ventilation, radio network and video surveillance) will amount to about NOK 180 million (EUR 22 million), where video surveillance with incident detection functions accounts for more than half of the cost, as it will have to be installed in eight tunnels. If all existing tunnels had to be **rebuilt** according to the provisions for new tunnels, the costs would amount to about NOK 1600 million, or EUR 195 million (2005 value), according to Norwegian estimates. In comparison, the Lærdal tunnel project cost NOK 930 million (2000 value). Main problem areas for Norwegian tunnels are the inclination of tunnels and emergency exits; however, as noted earlier, the directive does open for the use of alternative measures. The National Public Roads Administration and the Directorate for Civil Preparedness are currently translating the directive provisions into national legislation.

It should also be noted that the directive is not always directly transferable to Norwegian conditions. Norwegian road tunnels distinguish themselves by having low rates of average annual daily traffic (ADT),

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60 Ibid.
61 Norwegian Directorate for Civil Protection (DSB), 2002, p. 49.
by their construction (in rock), and by needing frost protection. For instance, the problem of PE foam is not at all accounted for in the directive.

The new directive on railway safety should not entail immediate changes, as the recommended elements of a safety management system (such as a safety authority and an accident and incident investigating body for railways) already exist in Norway.

The organisation of tunnel safety management

Evolutions in the stance of safety policy and the international regulatory framework have had repercussions on the institutional setting. A main source of concern for road tunnel management in Norway, emphasised in the 2001 national vulnerability assessment report, is the institutional setting of tunnel construction, maintenance and control. The 2000 vulnerability report *A Vulnerable Society* (NOU 2000:24) recommended separating safety control functions from construction and maintenance.

The institutional situation is here quite different for road and railway tunnels. Whereas the Public Roads Administration controls the safety of its own construction and also investigates accidents, the railway sector has been subject to institutional reform, and has separated designated bodies for safety (Railway Inspectorate) and investigation (Investigation Board for Civil Aviation and Railway). Before 2002 there existed no permanent accident investigation authority for the railway sector. Instead, NSB BA, the public railway undertaking, and the National Rail Administration had investigation groups for internal use whose reports were not public. Under extraordinary circumstances, the government could create an independent investigation commission, as was the case after the Åsta railway accident in January 2000. It was argued that the occurrence of a number of serious accidents and incidents, most notably the Åsta accident, justified the creation of a permanent investigation board for railways.  

It is planned to add road accidents to its field of investigation in 2005.

Furthermore, the government suggested in its White Paper No. 17, 2002-2003, *Om statlige tilsyn* (government supervisory authorities), that safety and security supervision and the provision of services for certain modes of transport be separated at ministerial level. The reform would affect civil aviation, railways and sea transport. The main purpose is to strengthen the legitimacy and authority of the agencies.

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65 Road transport is exempted from this reform because of the slightly different role of the Road and Transportation Directorate. Unlike the Railway agency, it supplies a service directly to road users, not to transport companies.
and limit the possibilities of political intervention. In consequence, the ministries would still be charged with deciding budgetary frameworks, priorities and general safety standards and levels, but they would no longer be legally allowed to influence specific agency decisions or instruct agency actions. The agencies would then have more freedom of action within their economic and legal framework. A new independent body would be created to evaluate agency complaints. Until now, this was the task of the Ministry, whose objectivity could be questioned, because of its mixed responsibilities of manager and supervisor of its own activities. This reform does not concern the road sector.

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Conclusion and proposal regarding the second phase of the Project

The report has reviewed recent accidents and legal and policy developments both at the national and international level in recent years. It shows that road tunnel safety is receiving increasing attention at the international level, where many measures have been taken to increase safety. When it comes to tunnels with a lower risk of accident, such as railway and metro tunnels, fewer efforts have been made. When reviewing future trends in the transport sector, a few developments stand out: traffic concentration, technological progress and modal shifts in transport have increased very rapidly. This may be specific to the last 30 years, but it still means that current transport infrastructure is not perfectly adapted to the vehicles or users that make use of it, something which makes it vulnerable to accidents. Second, the risk of terrorism is more pronounced than it used to be, and must be considered in risk analyses and preparedness plans. More generally, decision-makers and infrastructure operators need to use a more forward-looking and pro-active approach to risk management in order to keep up with societal and technological trends.

The question of tunnel safety in Norway reflects this problem. Many tunnels were not constructed with the current transport situation in mind, and supplementary safety measures come at a very high price, if they are at all possible. At the same time, accident rates are low in tunnels, and it is difficult to justify the extra costs with traditional cost-benefit analysis methods. Yet, the analysis has shown that there is a considerable risk potential in Norwegian road, rail and metro tunnels. Transport authorities are making sincere efforts to improve risk management policies, both through new safety and risk routines and institutional reorganisation, but it may be questioned whether the efforts are counterproductive or give a false sense of safety. Will the Vision Zero programme take away or liberate funds from ‘safe’ road tunnels? Will the carrying out of risk analyses become routine operations based on dated material? With the number of new actors, national and international, and policies which have been introduced in the transport sector and for tunnels in the last years, it is important to ensure that policy measures are coherent.

The questionnaire will be based on the Project’s methodology, scrutinizing separately each functional layer with regard to the coherence of its organisation (definition of roles and responsibilities, communication and co-ordination between the major players, links with other pertinent layers, etc.), effectiveness in achieving its objectives (adequate consideration of all tasks, use of relevant tools, etc.), and openness on external sources (communication with stakeholders, international cooperation).

67 This means that in practice, a specific part of the questionnaire will be developed for each layer (assessment, decision-making, etc.), and addressed to all the major actors involved in that layer. For actors intervening in more than one layer, the various parts can naturally be joined in a single document.
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Annex 1. An overview of recent accidents and disasters in tunnels and underground transport systems

Road tunnels and systems

The most costly of these accidents, both in terms of human and economic losses, was the fire in the Mont Blanc tunnel between France and Italy on 24 March 1999. The accident was caused by a fire in the engine of a truck carrying flour and margarine. The driver stopped the truck, mid-way in the tunnel, and tried to extinguish the fire, but it intensified and spread to the rest of the trailer. The ventilation system then carried the combustion gases to the French end of the tunnel, where a thick mass of smoke and unburnt gases formed. The emergency services had no information of the size of the fire or the number of vehicles involved, and failed in their attempts to access the burning truck. The shelters did not resist the heat of the fire, there was no service tunnel, and cars continued to enter the tunnel after the fire was detected. The fire went on for 53 hours, reaching temperatures of almost 1000°C, melting the asphalt and causing the concrete structures to collapse. All in all 39 persons died, mostly from asphyxiation, and direct damage was estimated at about EUR 200 million.68 The tunnel did not reopen for traffic until March 2002. The trial to determine responsibilities in the disaster was conducted between January and April 2005, with 16 defendants, including the truck driver, the manufacturer of the heavy goods vehicle, the Italian and French tunnel managing companies, safety regulators, and the mayor of the nearby town of Chamonix, in principle responsible for emergency response. The Italian operating company, SITMB, agreed in the beginning of 2005 to pay the families of the victims a total of EUR 13.5 million, if 80 percent of the relatives accepted, while underlining that it did not accept liability for the disaster. The court’s verdict is expected by end July 2005.

On 29 May 1999, two months after the Mont-Blanc accident, in the Tauern tunnel in Austria, a fire broke out after a truck rammed into vehicles waiting at traffic lights, including a lorry loaded with spray cans which exploded. 24 vehicles subsequently caught fire. The smoke created by the fire lay initially along the ceiling, allowing people to exit the tunnel, but several explosions then generated so much heat and smoke that it was impossible to keep the carriageway free of smoke. Eight people died as a direct consequence of the collision, whereas four other died in the fire following the accident. Insured losses alone amounted to EUR 36 million.69

68 Swiss Re, 2000.
69 ibid.
Two years later, on 24 October 2001, a major accident occurred in the St. Gotthard tunnel in Switzerland, one of the longest road tunnels in the world (16 km long), with a very high traffic concentration (21 000 vehicles/day in 1999). The accident was triggered by the collision of two road trucks, one of which was carrying tyres and tarpaulins which caught fire. Fire-fighters were unable to enter the tunnel afterwards due to the strong heat and thick smoke. However, well-functioning safety measures limited the casualties. The inclusion of a service tunnel saved many lives, automatic barriers stopped additional cars from entering the tunnel, ventilation systems switched to emergency settings and rescue workers were rapidly alerted. Still, 11 persons died, mostly from asphyxiation. The only available cost estimation concern the costs of repair and insured losses for vehicles, which amounted to EUR 12 million.70

Rail tunnels and systems

A fire was detected in a heavy goods vehicle shuttle, about 19 km from the French portal. The fire produced large quantities of smoke, which made the evacuation of 31 passengers and two crew members difficult. The insured damage of the accident was estimated at FRF 1.9 billion (EUR 290 million – more than the Mont-Blanc? Isn’t there a problem with units here?).71 In the inquiry after the accident, a series of security breaches were identified, most notably in the emergency procedures, which proved to be too complex for an understaffed and insufficiently trained Control Centre staff to handle. Consequently, the Control Centre operators did not have time to implement all the required actions, including halting the following and preceding trains. In addition, the ventilation system was not operated soon enough, and the fire detection system, although functioning correctly, did not give an immediate warning of the fire.

One example is the King’s Cross underground station fire in London, 18 November 1987. The fire started behind wooden escalators inside the station, in rubbish probably ignited by a discarded match. The fire spread rapidly to the booking hall, some witness reports referred to a ‘jet of flame’.72 The decision was made to prevent trains from stopping at the station, meaning that people could not escape onto trains. Thus the trains continued through and acted like pistons forcing an air draft up the escalator shaft, fanning the fire further.73 31 people died in the accident. The official inquiry resulted in the introduction of the Fire Precautions Regulations of 1989 for Sub-surface Railway Stations, which ban the use of combustible material in underground railway stations and require the presence of fire equipment and the training of personnel.

70 Bieler Tagblatt, 2002.
71 Swiss Re, 1997.
The most recent serious railway tunnel accident took place in the Daegu metro underground in Korea on 18 February 2003. During an arson attack, flammable liquid was set alight in a carriage. The fire spread quickly to the other five carriages and a second, six-carriage train that arrived at the station after the fire began. The power system automatically shut down when the fire began, leaving those trying to escape in the dark. Furthermore, although arriving several minutes afterwards, the second train was not stopped outside the station. 198 persons died, and total damage was estimated at about USD 500 million.\(^{74}\)

A special case is the tunnel fire in Kaprun, Austria, on 11 November 2000, in a funicular train transporting ski tourists to the Kitzsteinhorn glacier. The fire probably started when an illegally installed heater at the back of the train ignited spilled oil from the hydraulic brake system and spread rapidly to the plastic-covered floor. As the blaze developed, the falling hydraulic oil pressure led the train to a halt half-way through the tunnel. The train had no emergency equipment such as fire extinguisher and hammer, and no emergency button to alert neither the driver, physically separated from the travellers, nor the operation centre.\(^{75}\) Furthermore, the tunnel was not lit, there were no escape signs and the only escape route was a narrow service stairway.\(^{76}\) Finally, the door from the tunnel to the summit station did not close properly, causing three fatalities from suffocation as toxic fumes from the burning train were drawn into the station. Only 12 persons in the train survived the accident by escaping through a broken window located at the back. 155 persons died, and insured losses, excluding liability, amounted to USD 14 million.\(^{77}\) In February 2004, in the court trial following the accident, the 16 defendants (train operators, suppliers and inspectors) were acquitted. But separate court trials, seeking compensation for relatives of the victims, are under way in Germany and the USA. After the accident in Kaprun, a group of experts in fire safety and railways from Alpine countries (France, Italy, Austria, Germany and Switzerland) was gathered to scrutinise the security measures for funicular trains tunnels. They concluded that safety measures for road and ordinary railway tunnels are only to a limited extent transferable to funicular trains. The risk of fire for funicular trains are much lower, as the trains have no engines, there is no meeting traffic, travel times are short, and goods and persons are not transported at the same time.\(^{78}\) The expert group maintained that safety standards were high and generally very similar in all affected countries, but that the vulnerabilities in case of a fire of this magnitude had not been taken into consideration – a common theme in most if not all accidents reviewed in this study.

\(^{74}\) Swiss Re, 2004.

\(^{75}\) Bahnaktuell, 2001.

\(^{76}\) BBC online news, 2004.

\(^{77}\) Swiss Re, 2001.

The attack, which took place in the morning hours, involved four different trains, in which a total of 10 bombs went off. In addition, the police found three other bombs at the station. All in all, 191 people were killed. It was probably planned that the bombs of two of the trains detonate inside the train station and cause a collapse of the building construction, in which case the consequences would have been even more catastrophic.
Annex 2. Risk-based methodologies for the management of tunnel safety

Road tunnels

Within the framework of Vision Zero, risk analyses shall be increasingly used as a basis for priorities in the road transport sector. This should not have any direct consequences for road tunnel fire safety, where risk analyses have been obligatory since the beginning of the 1990s. For tunnels under construction, the questions of risk and safety are treated at different stages in the construction process. The first preparatory analysis takes place in the so-called ‘consequence assessment’ which is carried out to make sure that “concerns related to the environment, natural resources and society have been taken into account. The consequence assessment determines if, and under which conditions, plans or measures can be carried out.” The assessment is preceded by a range of preparatory efforts to look into strategic analyses, limit the area of planning and impact area, evaluation of the transport system and transport analyses, the development of alternatives, and preparedness- and risk issues. The main bulk of the consequence assessment consists of a cost-benefit analysis. For tunnels under construction and when updating tunnels, the requirements are the following (excerpt taken from the handbook for consequence assessments):

Risk analyses shall be carried out for new road tunnels longer than 500 metres and when upgrading existing tunnels, and to show that public requirements to fire safety are fulfilled according to national guidelines and standards (standard 3901, with guideline for road tunnels). The analysis shall take as a starting point the tunnel project and if possible the preparedness plan. The analysis shall include personal safety, risk for damage on tunnel and equipment, as well as risk for environmental damage. Both the construction phase and the operation phase shall be taken into consideration.

Coordination problems have been observed in the past between the tunnel constructor and local fire authorities, in particular concerning the incorporation of safety measures in the planning and building process of new tunnels. An alleviating measure was the preparation of a guideline for the administrative handling of fire safety in road tunnels, which prescribes the participation of local fire authorities early in the planning process of new tunnels and gives more detailed instructions for the carrying out of risk analyses. According to the guideline, the risk analysis for new tunnels shall be carried out and shared with local fire authorities as soon as detailed planning documents exist, so that changes can be made before the

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80 Norwegian Public Roads Administration, 2005a, p. 10.
81 Ibid., p. 43.
end of construction period. If the analysis shows that the safety measures does not fulfil the accept criteria, risk reduction measures must be taken, according to the following prioritisation:\footnote{The information is taken from op.cit.}

- Measures reducing the probability of an incident
- Measures enabling road users to put out an eventual fire
- Measures enabling quick alerting, closing and communication with alert terminal
- Measures ensuring safe and efficient evacuation of persons
- Measures facilitating fire fighter operations in the tunnel
- Measures strengthening the local fire safety preparedness

The risk analysis methodology is described in the national standard NS 3901, and its guideline to risk analysis of fire in road tunnels. The methodology foresees the use risk acceptance criteria and sets as overall safety objective that “the safety against personal injury shall not be worse per km road in the tunnel compared to the open road outside the tunnel.”\footnote{Aven et al., 2003, p. 40.} The second accept criterion is related to protection against large-scale fires. There should not be more than one fire with five fatalities or more in every 50 years in all road tunnels in Norway, something which gives an annual probability per km tunnel of $3 \times 10^{-5}$.\footnote{Norwegian Public Roads Administration, 2005b, p. 14.} The probability of unwanted events are then determined quantitatively, and the consequences are determined qualitatively. The standard further contains estimated measurements for different vehicle fire effects.

According to Amundsen et al. (2001) the Public Roads Administration has since 1987 used a tool, TUSI, to estimate the probability of tunnel fires according to the tunnel’s design and ADT (average annual daily traffic). The model is based on international records of tunnel fires, traffic concentration and tunnel design. Preliminary analysis showed that fires depended primarily on traffic concentration and tunnel length, but later results have proven that road inclination may negatively the probability of fires in heavy goods vehicles. All these variables are now integrated into the model.\footnote{Amundsen et al., 2001, p. 10.}

\textit{Railway tunnels}

Risk assessments have been given high priority in the railway sector’s safety programme, launched in the late 1990s and reinforced after the Åsta and Lillestrøm accidents in 2000. Risk assessments are
furthermore required by law in the Requirement Regulation (Kravforskriften). The regulation lays down as primary traffic safety principles the continuous improvement of traffic safety, reduction of risk as low as reasonably practicable (ALARP) and the establishment of barriers against serious consequences of singular errors.\(^\text{87}\) The regulation requires the infrastructure manager or railway operator to carry out risk analyses at acquisitions, constructions and modifications of infrastructure or equipment, establish follow-up systems and establish criteria for acceptable risk. These criteria shall take into account the probability of the unwanted event as well as the consequence of the event.\(^\text{88}\) Preparedness plans must also be established. The preparedness plan must be based on the result of risk analyses.\(^\text{89}\)

The implementation of these safety provisions by the infrastructure manager has so far been incomplete, as identified in recent safety audits and accident investigation reports:

The accident report from the most serious transport accident in Norway in the last decade, the Åsta train collision in 2000, found that the railway safety management suffered from the transition process between the traditional railway safety management based on the evaluation of experiences and incidents and the creation of safety rules, and the new risk-based security management system with increased emphasis on risk analysis, introduced in 1996 by the rail operator NSB BA..\(^\text{90}\) The old system was incapable of integrating new, rapidly changing trends, whereas the new system was still too unfamiliar. This still remains a problem. Findings from the Norwegian Railway Inspectorate reveal that risk analyses are not yet systematically carried out. Inspections conducted in 2000 in two of the most heavily trafficked tunnels in the Oslo area, found that risk analyses had not been used as a basis for preparedness plans. This implies that important aspects such as traffic concentration and transport of dangerous goods had not been taken into account.\(^\text{91}\) Furthermore, specific recommendations for safety measures derived from risk analyses had not been implemented, including quite simple measures such as emergency lighting and signs.\(^\text{92}\) In a recent report from the Railway Inspectorate, which took account of the general use and management of risk mapping and evaluation by railway authorities, it was found that the railway operator,

\(^{87}\) Ministry of Transport and Communication, 2001, chapter 2.

\(^{88}\) Ibid., chapter 5.

\(^{89}\) Ibid., chapter 9.

\(^{90}\) NOU 2000:30.

\(^{91}\) Norwegian Railway Inspectorate, 2000.

\(^{92}\) Ibid., p. 12.
the National Rail Administration, had no standardised procedure for the systematic use and treatment of risk analyses.⁹³

The Railway Inspectorate nevertheless finds that the routines for carrying out risk analyses have improved in the last years, and that the main challenges are to be found in the follow-up process; in updating the safety management system in the entire organisation.⁹⁴

**Methodological issues**

Is tunnel safety sufficiently integrated into evaluation models for road and rail? It is a difficult question to answer. First of all, it must be asked if the current risk analyses are performed correctly. The above review has shown that much of the data on which are calculated the probabilities for unwanted incidents are incomplete or lacking. This applies in particular to unreported car incidents in tunnels, or undetected technical incidents in the tunnel construction. Furthermore, some of the material may not be updated frequently enough. Examples are the geographic mapping of the transport of dangerous goods, or, possibly, the fire effect of fires in various vehicles. How of often is this information updated, and at which pace are the new results incorporated into standards for risk analyses and tunnels? The introduction of procedures and routines for carrying out risk analyses is primarily a safety-enhancing measure, but it must be made sure that the underlying criteria are relevant and up-to-date. This is especially important when acceptance criteria are used in the analysis.

A second question is whether the right model is used. RISIT (Risk and Safety in Transport) is a Norwegian research project that looks at risk factors and risk management in the transport sector. One of the reports issued within the framework of this project is very critical to what it calls the ‘technical/natural science perspective to risk’. It claims that this perspective “bases its evaluations on models with no holding the real world, that it is difficult to handle the aspect of uncertainty in risk estimates in a professional way, and that it contributes to maintaining a system of power where experts are given more authority than what is justified,”⁹⁵ [author’s translation]. It further notes that “the use of average probability estimates are to crude to reflect the interplay between people, technology and organisation […],” that the perspective “does not take into account the significance of organisational errors and weaknesses […],” that probability and risk estimates are not objective, and that “risk cannot be managed entirely by principles of calculated risk –

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⁹⁴ Ibid., p. 2.
⁹⁵ Aven et al., 2003, p. 12.
other principles such as justice and flexibility needs to be accounted for, something which implies the inclusion of interest groups or affected groups in the risk assessment.\textsuperscript{96}

One third possibility is to valuate fatalities tunnel fires higher in cost-benefit analyses than what is actually the case. It must be asked if accidents inside a tunnel are any different from those happening outside. The current method for calculating costs of accidents include both direct costs, as well as lost quality of life, estimated in willing to pay to prevent the accident. The direct costs comprise lost productivity as well as medical, material and administrative costs. In Norway, direct costs and costs of lost quality of life amount to NOK 25 000 000 or app. EUR 3 million for fatalities and NOK 17 000 000 or EUR 2 million for seriously injured (2004 value).\textsuperscript{97} There are indications that the public is willing to pay more to prevent large-scale accidents, more prone in railways and aviation than in road transport, \textit{i.e.} that 100 lives lost in one large accident are rated higher than one life lost 100 times.\textsuperscript{98} It has also been argued that WTP levels are higher in situations where persons are not in control (difference between tolerance levels of road accidents compared to rail and aviation, or inside and outside tunnels). To which extent are and should considerations of this kind be included into cost-benefit analyses in transport projects?

\textsuperscript{96} All citations from Aven \textit{et al.}, 2003, p. 13.

\textsuperscript{97} Norwegian Public Roads Administration, 2005a, p. 83.

Annex 3. The policy context in Norway

The following section briefly describes the layers of the safety management system that are involved in defining and applying an overall policy regarding tunnel accident risks, first for road and then for railway tunnels. It follows the project’s methodology (described in OECD, 2004) for analysing risk management systems. The principal actors and laws are indicated in bold.

Road

Assessment: The **Road Directorate, the head office of the Public Roads Administration** systematically assess risks and safety needs for new tunnels, in accordance with the fire legislation, the methodology displayed in the guideline *Risk Analysis of Fire in Road Tunnels*, and the conditions defined in the *Tunnel Handbook*. The new Administrative Handling Guideline requires that **Fire authorities** participate in the evaluation of safety measures.

Regulation on consequence analysis makes the Public Roads Administration responsible for a broad evaluation of consequences of building road tunnels, including direct and indirect societal consequences, preparedness, risk of accident and interaction between these.

In addition, since the Government’s White Paper No. 17 to the Storting, the Public Road Directorate is responsible for an analysis of risk in existing tunnels of more than 500 meters (which is then reported to the local fire authorities). Fire authorities participate in the establishment of consequence scenarios, including, when appropriate, indirect effects such as secondary fires.

The **Public Roads Administration** is responsible for possible restrictions on transport of dangerous goods in road tunnels.

Finally, the **Directorate for Civil Defence and Emergency Planning** has the authority to perform safety assessments on an ad-hoc basis.

Policy decision-making: The State, via the Ministry of Transport and Communications, is the legal owner of tunnels on the national network. The Regional offices of the Public Roads Administration are operators and represent the owner of state roads. The County Councils are the legal owners of the regional road
networks. Safety decisions regarding the design, building, operation and maintenance of tunnels all fall within its responsibilities.

The allocation of resources for tunnel construction, maintenance and upgrading is part of the National Transport Plan (elaborated by the Ministry of Transport and Communication).

Framework conditions: The Road Directorate enforces and controls the application of safety policy decisions.

The Municipal Councils and local Fire Brigades have the duty of inspecting tunnels within their territory (at least once every second year), and can obtain financial contributions to improve their preparedness capacity from the tunnel owner.

Traffic restrictions and regulations are enforced by the Police Department (Ministry of Justice and the Police).

It should be noted that the issue of safety in road tunnels is at the intersection of several major laws, namely the fire protection legislation, the planning and building legislation, and the road legislation. The definition of the roles and responsibilities of various central and local administrations in ensuring safety in road tunnels by these various legislations does not always seem consistent.

The Directorate for Civil Defence and Emergency Planning is responsible for the Norwegian regulation of dangerous goods on road.

Rail

Assessment: The Norwegian Rail Administration systematically assesses risks and safety needs for new railway tunnels, in accordance with the fire legislation and explosion act, whereas Oslo T-banedrift is responsible for the metro underground network in Oslo.

The safety level of existing rail and metro tunnels is assessed by the Norwegian Railway Inspectorate.

Regulation on consequence analysis makes the Rail Administration responsible for a broad evaluation of consequences of building railway tunnels, including direct and indirect societal consequences, preparedness, risk of accident and interaction between these.
It is unclear whether the local **Fire Authorities** have been accorded the same access to develop *ex ante* safety measures for rail tunnels as is now the case for road tunnels.

Finally, the **Directorate for Civil Defence and Emergency Planning** has the authority to perform safety assessments on an ad-hoc basis.

**Policy decision-making:**

The **Rail Administration** is the legal owner of tunnels on the national rail network. Safety decisions regarding the design, building, operation and maintenance of tunnels all fall within its responsibilities. The allocation of resources for tunnel construction, maintenance and upgrading is part of the National Transport Plan (elaborated by the **Ministry of Transport and Communication**). In addition, the Oslo City Council allocates resources to the Oslo metro, sometimes in cooperation with regional and central transport authorities.

**Framework conditions:**

The **Norwegian Railway Inspectorate** enforces and controls the application of safety policy decisions.

The **Municipal Councils** and local **Fire Brigades** have the duty of inspecting tunnels within their territory (at least once every second year), and can obtain financial contributions to improve their preparedness capacity from the tunnel owner.

Restrictions and regulations on the transport of dangerous goods are enforced by the **Directorate for Civil Defence and Emergency Planning**.
Table 1 – Principal institutional actors in the area of road tunnel safety

<table>
<thead>
<tr>
<th>Functional layers</th>
<th>Actions</th>
<th>Authorities</th>
</tr>
</thead>
</table>
| **Assessment**    | Risk and safety assessments for new tunnels | • Public Roads Administration  
• Directorate of Roads  
• Local fire brigades |
|                   | Risk and safety assessments for existing tunnels | • Public Roads Administration  
• (Local fire brigades) + DSB |
|                   | Dangerous goods | • Public Roads Administration |
|                   | Development and promotion of risk assessment tools | • Public Roads Administration  
• DSB |
| **Policy advising and recommendation** | Resource allocation (and cost-benefit considerations) | • Ministry of Transport and Communication  
• Ministry of Justice and the Police |
|                   | Strategic co-ordination and supervision | • Ministry of Transport and Communication  
• Ministry of Justice and the Police |
| **Framework conditions** | Legal and regulatory framework | • Ministry of Transport and Communication  
• Ministry of Justice and the Police |
|                   | Supervision of road tunnel safety | • Public Roads Administration (through its five regional offices)  
• Local fire brigades |
|                   | Regulation of the transport of dangerous goods | • DSB |
Table 2– Principal institutional actors in the area of railway tunnel safety

<table>
<thead>
<tr>
<th>Functional layers</th>
<th>Actions</th>
<th>Authorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
<td>Risk and safety assessments for new tunnels</td>
<td>• Norwegian Rail Administration (railway)</td>
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<td></td>
<td></td>
<td>• Oslo T-banedrift (metro)</td>
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<td></td>
<td></td>
<td>• Norwegian Railway Inspectorate</td>
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<td></td>
<td></td>
<td>• Local fire brigades?</td>
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<td></td>
<td>Risk and safety assessments for existing tunnels</td>
<td>• Norwegian Rail Administration</td>
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<td></td>
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<td>• Norwegian Railway Inspectorate</td>
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<td></td>
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<td>• (Local fire brigades) + DSB</td>
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<td></td>
<td>Dangerous goods</td>
<td>• Norwegian Rail Administration</td>
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<td></td>
<td>Development and promotion of risk assessment tools</td>
<td>• Norwegian Rail Administration</td>
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<tr>
<td>Policy advising and</td>
<td>Resource allocation (and cost-benefit considerations)</td>
<td>• Ministry of Transport and Communication</td>
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<td>recommendation</td>
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<td>• Ministry of Justice and the Police</td>
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<td></td>
<td>Strategic co-ordination and supervision</td>
<td>• Ministry of Transport and Communication</td>
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<td>• Ministry of Justice and the Police</td>
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<td>Framework conditions</td>
<td>Legal and regulatory framework</td>
<td>• Ministry of Transport and Communication</td>
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<td>• Ministry of Justice and the Police</td>
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<td></td>
<td>Supervision of road tunnel safety</td>
<td>• Norwegian Railway Inspectorate</td>
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<td></td>
<td></td>
<td>• Local fire brigades</td>
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<tr>
<td></td>
<td>Regulation of the transport of dangerous goods</td>
<td>• DSB</td>
</tr>
</tbody>
</table>
Annex 4: Legal and regulatory framework

Tunnels (road and rail)

<table>
<thead>
<tr>
<th>Legislative framework</th>
<th>Enforcement authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act relating to the Prevention of Fire, Explosion and Accidents involving Hazardous</td>
<td>DSB</td>
</tr>
<tr>
<td>Substances and the Fire Services</td>
<td></td>
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<tr>
<td>The Norwegian Road Act</td>
<td></td>
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<tr>
<td>The Norwegian Railways Act and related regulations:</td>
<td>Norwegian Railway Inspectorate</td>
</tr>
<tr>
<td>- Authorisation Regulations (tillatelsesforskriften)</td>
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<tr>
<td>Regulations on Authorisation to Operate Railways, including Tramways, Underground</td>
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<tr>
<td>Railways and Suburban Railways, etc., and Access to the National Railway Network</td>
<td></td>
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<tr>
<td>- Allocation Regulations (fordelingsforskriften)</td>
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<tr>
<td>Regulations on the Allocation of Railway Infrastructure Capacity and the Levying of</td>
<td></td>
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<tr>
<td>Charges for the Use of the National Railway Network</td>
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<tr>
<td>- Requirement Regulations</td>
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<tr>
<td>Regulations on the Requirements to Railway Infrastructure manager and railway</td>
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<tr>
<td>operators.</td>
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<tr>
<td>Plan- og bygningsloven (Planning and Building Act)</td>
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<td>Plan- og bygningsloven (Planning and Building Act)</td>
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<tr>
<td>Plan- og bygningsloven (Planning and Building Act)</td>
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<tr>
<td>Teknisk forskrift til plan- og bygningsloven (Technical Regulations Pursuant of the</td>
<td>Technical supervisory authority in the respective</td>
</tr>
<tr>
<td>Planning and Building Act)</td>
<td>administrations (mainly municipal level)</td>
</tr>
<tr>
<td>Regulations relating to Systematic Health, Environmental and Safety Activities at</td>
<td>Norwegian Labour Inspection Authority</td>
</tr>
<tr>
<td>Enterprises (Internal Control Regulation)</td>
<td></td>
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<tr>
<td>Regulations of 5 July 1990 No. 546 relating to fire-preventive measures and fire</td>
<td></td>
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<tr>
<td>inspection</td>
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<tr>
<td>Legislative framework</td>
<td>Enforcement authority</td>
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<tr>
<td>Forskrift om transport av farlig gods på veg og jernbane med veiledning (er trykt i ADR/RID 2003) (Regulations on the transport on dangerous goods on road and rail, with guidelines)</td>
<td>DSB</td>
</tr>
<tr>
<td>Regulations restricting transport of dangerous goods on roads (Oslo and Aalesund)</td>
<td>Directorate of Roads</td>
</tr>
</tbody>
</table>
Annex 5: Self-assessment and review questionnaires

Three sets of questionnaires for road, rail and metro are proposed for the concerned Norwegian public administration or private operator to self-assess and take stock of their practices in the management of risk management for tunnel fire. The questionnaires are organised in three parts, one for each layer of security management:

A. Risk and vulnerability assessment, covering risk and safety assessment for old and new tunnels, the transport of dangerous goods where relevant, and the development and promotion of risk assessment tools

B. Policy decision-making, covering strategy co-ordination and supervision, and resource allocation for risk management options

C. Framework conditions, covering the legal and regulatory framework, the supervision of tunnel safety, and the regulation of the transport of dangerous goods where relevant.

In each case, the principal actors involved in risk management for tunnel fire are listed, in accordance with the description of the management system in Annex 3. Naturally, any other relevant actors should be added to those lists.
ROAD

A. Risk and safety assessment

Main actors: Public Roads Administration, Directorate of Roads, local fire brigades.

A.1. Risk and safety assessment for new tunnels

a. Describe the sharing of roles and responsibilities between and within the central authorities in risk and safety assessment (Road Directorate, the DSB) and regional/local authorities (regional offices of Public Roads Administration and municipal fire authorities)

b. Are there any legal provisions related to safety assessment?

c. Describe the co-operation in practice

d. Are there dispute mechanisms between the various entities?

e. Which are the underlying criteria and principles for safety assessment?

f. Which methods are used in the assessment? Please describe.

g. Which external factors are taken into account in the assessment (traffic concentration, heavy goods…) Are these factors reviewed and updated regularly and systematically?

h. How do you evaluate the quality of existing quantitative data (accident statistics, etc.)? Which measures are taken to improve quality of and access to data?

i. How often are assessment methods updated, and to which extent are state-of-the-art methods and practices taken into account?

j. How have past tunnel accidents, national reports and international co-operation affected risk and safety assessment work in Norway? Please give examples.

- EU directive on tunnel safety
- UNECE recommendations
- White Paper No. 17….
- European tunnel accidents, Seljestad tunnel fire, other incidents.

k. Does your organisation participate in any international co-operation on tunnel safety assessment (UPTUN, etc.)? Please describe.

A.2. Risk and safety assessment for existing tunnels

Main actors: Public Roads Administration, municipal fire brigades, DSB.

a. Which are the underlying criteria and principles for safety assessment of existing tunnels compared to new tunnels?
b. How often are risk and safety assessments carried out for existing tunnels? Which external factors are taken into account in the assessment (traffic concentration, heavy goods…) Are these factors reviewed and updated regularly and systematically?

c. How do you evaluate the quality of existing quantitative data (accident statistics, etc.) for carrying out risk and safety assessments? Which measures are taken to improve quality of and access to data?

d. Which control and reporting mechanisms exist for existing tunnels? Please describe.

e. Please give a detailed description of cooperation in practice between tunnel operator and fire safety authorities (DSB and municipal fire brigades) for safety assessment of existing tunnels.

A.3. Dangerous goods

Main actors: Public Roads Administration

a. Which are the legal provisions related to safety assessment?

b. Which are the underlying criteria and principles for risk assessment of transport of dangerous goods in tunnels?

c. To which extent are local stakeholders (municipal fire brigades) and sectoral expertise (DSB) consulted in the assessment process?

d. Which methods are used in the assessment? Please describe.

e. How often are risk assessments updated? Which external factors are taken into account in the assessment (traffic concentration, heavy goods…) Are these factors reviewed and updated regularly and systematically?

f. How do you evaluate the quality of existing quantitative data (accident statistics, etc.) for carrying out risk and safety assessments? Which measures are taken to improve quality of and access to data?

A.4. Development and promotion of risk assessment tools

Main actors: Public Roads Administration, DSB

a. Which are the underlying criteria and principles for safety assessment?

b. Which methods are used in the assessment? Please describe.

c. Which external factors are taken into account in the assessment (traffic concentration, heavy goods…) Are these factors reviewed and updated regularly and systematically?

d. How do you evaluate the quality of existing quantitative data (accident statistics, etc.)? Which measures are taken to improve quality of and access to data?
e. How often are assessment methods updated, and to which extent are state-of-the-art methods and practices taken into account?

f. How have past tunnel accidents, national reports and international co-operation affected risk and safety assessment work in Norway? Please give examples.
   - EU directive on tunnel safety
   - UNECE recommendations
   - White Paper No. 17....
   - European tunnel accidents, Seljestad tunnel fire, other incidents.

g. Does your organisation participate in any international co-operation on tunnel safety assessment? Please describe.
B. Policy decision-making

B.1. Resource allocation (and cost-benefit considerations)

Main actors: Ministry of Transport and Communication, Ministry of Justice and the Police, Roads Directorate

a. Which is the budgetary frame for road tunnel safety measures?

b. Please give a tentative budget breakdown according to type of safety measures (prevention, damage mitigation, and facilitation of rescue). Is supplementary funding to affected municipal fire brigades, i.e. emergency response, included in these figures?

c. At what stage are the costs, benefits and risks of alternative solutions considered, and how? Please describe.

d. Which is the budgetary frame for fire safety supervision, in particular related to road tunnels? Please give a budget breakdown according to type of activity (supervision, awareness-raising, development of risk assessment tools, international cooperation…)

B.2. Strategic coordination and supervision

Main actors: Ministry of Transport and Communication, Ministry of Justice and the Police

a. How are roles and responsibilities shared between and within central authorities (Road Directorate, Public Roads Administration)

b. How and where are decisions concerning tunnel safety met and circulated and coordinated in the central and local administrations?

c. Which are the main coordination and supervision tools of the Ministry?

d. Which reporting and conflict resolution mechanisms exist? Please describe.
C. Framework conditions

C.1. Legal and regulatory framework
Main actors: Ministry of Transport and Communications, Ministry of Justice and the Police

a. Please describe the expected effect of recent and future legal and regulatory developments
   - Government White Paper 17 (2001-2002) and the increased use of risk analysis
   - The new European Directive on road tunnel safety (management and budget consequences for new and existing tunnels)
   - The Vision Zero for transport accidents
   - Account equally for changes engendered by the Administrative Handling Guideline and the modification of the Fire and Explosion Act concerning tunnel fire and accident preparedness, and the inclusion of road accidents in the accident investigation board

C.2. Supervision of road tunnel safety
Main actors: Public Roads Administration (through its five regional offices), local fire brigades

a. Which procedures exist for the supervision of road tunnel safety?
b. How are roles and responsibilities shared between and within central and regional authorities (within the Public Roads Administration)
c. Are there any legal provisions related to safety supervision?
d. Supervisions are carried out at which frequency?
e. Which conflict resolution mechanisms exist?

C.3. Regulation of the transport of dangerous goods
Main actors: DSB

a. Which are the underlying principles and criteria for the regulation of transport of dangerous goods?
b. Which are the communication channels to other stakeholders (transport interest organisations, road operators, local fire brigades)
c. Do any procedures of supervision exist for the transport of dangerous goods?
d. Describe to which extent international developments influence the national regulation of transport of dangerous goods (ARD, OECD/PIARC, other).
A. Risk and safety assessment

Main actors: Norwegian Rail Administration, Norwegian Railway Inspectorate, local fire brigades(?)

A.1. Risk and safety assessment for new tunnels

a. Describe the sharing of roles and responsibilities between and within the central authorities in risk
   and safety assessment (Norwegian Rail Administration, Norwegian Railway Inspectorate) and
   regional/local authorities (municipal fire authorities)

b. Are there any legal provisions related to safety assessment?

c. Describe the co-operation in practice

d. To which extent are local fire brigades involved in the safety assessment work?

e. Are there dispute mechanisms between the various entities?

f. Which are the underlying criteria and principles for safety assessment?

g. Which methods are used in the assessment? Please describe.

h. Which external factors are taken into account in the assessment (transport of heavy goods…) Are
   these factors reviewed and updated regularly and systematically?

i. How often are assessment methods updated, and to which extent are state-of-the-art methods and
   practices taken into account?

j. How have past tunnel accidents, national reports and international co-operation affected risk and
   safety assessment work in Norway? Please give examples.
   - Eurotunnel accident
   - Metro tunnel fires in Norway and abroad
   - EU directive on the safety of the Community’s railways (directive 2004/49/EC)
   - Deregulation of railway operation in Norway

k. Does your organisation participate in any international co-operation on tunnel safety assessment?
   Please describe.

A.2. Risk and safety assessment for existing tunnels

Main actors: Norwegian Rail Administration, Norwegian Railway Inspectorate, DSB (+ local fire
brigades).

a. Which are the underlying criteria and principles for safety assessment of existing tunnels compared
   to new tunnels?
b. How often are risk and safety assessments carried out for existing tunnels? Which external factors are taken into account in the assessment? Are these factors reviewed and updated regularly and systematically?

c. Which control and reporting mechanisms exist for existing tunnels? Please describe.

d. Please give a detailed description of cooperation in practice between tunnel operator and fire safety authorities (DSB and municipal fire brigades) for safety assessment of existing tunnels.

A.3. Dangerous goods

Main actors: Norwegian Rail Administration

a. Which are the legal provisions related to safety assessment?

b. Which are the underlying criteria and principles for risk assessment of transport of dangerous goods in tunnels?

c. To which extent are local stakeholders (municipal fire brigades) and sectoral expertise (DSB, Norwegian Railway Inspectorate) consulted in the assessment process?

d. Which methods are used in the assessment? Please describe.

e. How often are risk assessments updated? Which external factors are taken into account in the assessment? Are these factors reviewed and updated regularly and systematically?

A.4. Development and promotion of risk assessment tools

Main actors: Norwegian Rail Administration

a. Which are the underlying criteria and principles for safety assessment?

b. Which methods are used in the assessment? Please describe.

c. Which external factors are taken into account in the assessment? Are these factors reviewed and updated regularly and systematically?

d. How often are assessment methods updated, and to which extent are state-of-the-art methods and practices taken into account?

e. How do you evaluate the quality of existing quantitative data (accident statistics, etc.) for carrying out risk and safety assessments? Which measures are taken to improve quality of and access to data?

f. How have past tunnel accidents, national reports and international co-operation affected risk and safety assessment work in Norway? Please give examples.

- Metro tunnel fires in Norway and abroad
- EU directive on the safety of the Community’s railways (directive 2004/49/EC)
• Deregulation of railway operation in Norway

g. Does your organisation participate in any international co-operation on tunnel safety assessment? Please describe.
**B. Policy decision-making**

**B.1. Resource allocation (and cost-benefit considerations)**

Main actors: Ministry of Transport and Communication, Ministry of Justice and the Police, National Rail Administration

- e. Which is the budgetary frame for railway tunnel safety measures?
- f. Please give a tentative budget breakdown according to type of safety measures (prevention, damage mitigation, and facilitation of rescue). Is supplementary funding to affected municipal fire brigades, i.e. emergency response, included in these figures?
- g. At what stage are the costs, benefits and risks of alternative solutions considered, and how? Please describe.
- h. Which is the budgetary frame for fire safety supervision, in particular related to railway tunnels? Please give a budget breakdown according to type of activity (supervision, awareness-raising, development of risk assessment tools, international cooperation…)

**B.2. Strategic coordination and supervision**

Main actors: Ministry of Transport and Communication, Ministry of Justice and the Police

- e. How are roles and responsibilities shared between and within central authorities (Rail Administration, Railway Inspectorate)?
- f. How and where are decisions concerning tunnel safety met and circulated and coordinated in the central and local administrations?
- g. Which are the main coordination and supervision tools of the Ministry?
- h. Which reporting and conflict resolution mechanisms exist? Please describe.
C. Framework conditions

C.1. Legal and regulatory framework

Main actors: Ministry of Transport and Communications, Ministry of Justice and the Police

a. Please describe the expected effect of recent and future legal and regulatory developments
   • Government White Paper 17 (2001-2002) and the increased use of risk analysis
   • The new European Directive on road tunnel safety (management and budget consequences for new and existing tunnels)
   • The Vision Zero for transport accidents
   • Fire and Explosion Act concerning tunnel fire and accident preparedness
   • Deregulation of railway operation in Norway

b. Does an Administrative Handling Guideline for railway tunnels exist?
c. What has been the effect of including railway accidents in the accident investigation board

C.2. Supervision of railway tunnel safety

Main actors: Norwegian Railway Inspectorate, local fire brigades

a. Which procedures exist for the supervision of railway tunnel safety?
b. Are there any legal provisions related to safety supervision?
c. Supervisions are carried out at which frequency?
d. Which conflict resolution mechanisms exist?

C.3. Regulation of the transport of dangerous goods

Main actors: DSB

e. Which are the underlying principles and criteria for the regulation of transport of dangerous goods?
f. Which are the communication channels to other stakeholders (transport interest organisations, railway operators, Norwegian Railway Inspectorate, local fire brigades)
g. Do any procedures of supervision exist for the transport of dangerous goods?
h. Describe to which extent international developments influence the national regulation of transport of dangerous goods (RID, other).
**METRO**

*A. Risk and safety assessment*

Main actors: Norwegian Railway Inspectorate, Oslo T-banedrift, local fire brigades(?)

A.1. Risk and safety assessment for new tunnels

a. Describe the sharing of roles and responsibilities between the authorities in risk and safety assessment and local authorities (municipal fire authorities)

b. Are there any legal provisions related to safety assessment?

c. Describe the co-operation in practice

d. To which extent are local fire brigades involved in the safety assessment work?

e. Are there dispute mechanisms between the various entities?

f. Which are the underlying criteria and principles for safety assessment?

g. Which methods are used in the assessment? Please describe.

h. Which external factors are taken into account in the assessment (malicious acts, traffic concentration…) Are these factors reviewed and updated regularly and systematically?

i. To which extent are malicious acts accounted for in the risk assessment process?

j. How often are assessment methods updated, and to which extent are state-of-the-art methods and practices taken into account?

k. How have past tunnel incidents and accidents (metro and rail), national reports and international co-operation affected risk and safety assessment work in Norway? Please give examples.
   - Eurotunnel accident
   - Metro tunnel fires in Norway and abroad

l. Does your organisation participate in any international co-operation on tunnel safety assessment? Please describe.

A.2. Risk and safety assessment for existing tunnels

Main actors: Oslo T-banedrift, Norwegian Railway Inspectorate, local fire brigades)

e. Which are the underlying criteria and principles for safety assessment of existing tunnels compared to new tunnels?

f. How often are risk and safety assessments carried out for existing tunnels? Which external factors are taken into account in the assessment? Are these factors reviewed and updated regularly and systematically?

g. Which control and reporting mechanisms exist for existing tunnels? Please describe.
h. Please give a detailed description of cooperation in practice between tunnel operator and fire safety authorities (DSB and municipal fire brigades) for safety assessment of existing tunnels.

A.3. Development and promotion of risk assessment tools

Main actors: Oslo T-banedrift

h. Which are the underlying criteria and principles for safety assessment?
   i. Which methods are used in the assessment? Please describe.
   j. Which external factors are taken into account in the assessment? Are these factors reviewed and updated regularly and systematically?
   k. How often are assessment methods updated, and to which extent are state-of-the-art methods and practices taken into account?
   l. How do you evaluate the quality of existing quantitative data (accident statistics, etc.) for carrying out risk and safety assessments? Which measures are taken to improve quality of and access to data?

B. Policy decision-making

B.1. Resource allocation (and cost-benefit considerations)

Main actors: Oslo city council, Oslo T-banedrift

a. Which is the budgetary frame for railway tunnel safety measures?
   b. Please give a tentative budget breakdown according to type of safety measures (prevention, damage mitigation, and facilitation of rescue). Is supplementary funding to affected municipal fire brigades, i.e. emergency response, included in these figures?
   c. At what stage are the costs, benefits and risks of alternative solutions considered, and how? Please describe.
   d. Which is the budgetary frame for fire safety supervision, in particular related to metro tunnels? Please give a budget breakdown according to type of activity (supervision, awareness-raising, development of risk assessment tools…)

C. Framework conditions

C.1. Supervision of metro tunnel safety

Main actors: Norwegian Railway Inspectorate, local fire brigades

a. Which procedures exist for the supervision of railway tunnel safety?
   b. Are there any legal provisions related to safety supervision?
   c. Supervisions are carried out at which frequency?
   d. Which conflict resolution mechanisms exist?
Annex 6: Members of the Steering Group

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Looking back on the disasters of recent years alone (the Indian Ocean tsunami disaster, Hurricane Katrina, terrorist attacks in New York, Madrid and London, avian flu, the 2003 heat wave in Europe), one could be forgiven for thinking that we live in an increasingly dangerous world. A variety of forces are helping to shape the risks that affect us, from demographic evolutions to climate change, through the development of mega-cities and the rise of information technology. These changes are clearly a major challenge for risk management systems in OECD countries, which have occasionally proved unable to protect the life and welfare of citizens or the continuity of economic activity.

The OECD Futures Project on Risk Management Policies was launched in 2003 in order to assist OECD countries in identifying the challenges of managing risks in the 21st century, and help them reflect on how best to address these challenges. The focus is on the consistency of risk management policies and on their ability to deal with the challenges, present and future, created by systemic risks. The Project covers a range of risk management issues which were proposed by the participating countries and together form three thematic clusters: natural disasters, risks to critical infrastructures, and the protection of vulnerable population groups. In the first phase of the Project, the OECD Secretariat prepared a case study for each issue. The studies cover both recent international developments of interest and the national policy context, and come with a tool for self-assessment to be used later in the Project in order to review the national policies in question.

This work is now published as the OECD Studies in Risk Management.