The AA Motoring Trust

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EUROTEST 2002
TUNNEL TESTS

Safety of Road Tunnels in Europe

Results of the 2002 Pan-European Tunnel Testing Programme

Eurotest 2002 is a consortium of motoring organisations in Europe: AA (UK), ACI (Italy), ADAC (Germany), AL (Finland), AMZS (Slovenia), ANWB (Netherlands), FDM (Denmark), FFAC (France), NAF (Norway), ÖAMTC (Austria), RACE (Spain), RACC (Spain), TCB (Belgium) and TCS (Switzerland)

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EuroTest 2002
Safety of Road Tunnels in Europe
The 30 tunnels inspected
++ = very good
+ = good
o = acceptable
- = poor
-- = very poor
Løvstakken
Bergen
Nordkapp
Mersey Kingsway
Mersey Queensway
Tyne
Glasgow
Newcastle
Dublin
Liverpool
NORDSEE
Kopenhagen
OSTSEE
Dartford
Wijker
Hamburg
Amsterdam
London
Piet Hein
Berlin
Blackwall Nord
Blackwall Süd
Rheinufer
Brüssel
Britz
Leopold II
Düsseldorf
Cointe
Strahov
Paris
Luxemburg
Prag
La Défense
Nancy
Stuttgart
Kappelberg
Maurice Lemaire
Wien
Bözberg
Zürich
Lainberg
Bosruck
El Folgoso
Lyon
Katschberg
Ljubljana
Loibl
Montblanc
Mailand
St. Gotthard
San Salvatore
Andorra
Monaco
Parpers
Lissabon
Madrid
Barcelona
Korsika
Elba
El Castellot
Rom
BALEAREN
Menorca
Sardinien
Ibiza
Mallorca
Alicante
San Juan
500 km
ADAC Infogramm

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TUNNEL TESTS 2002

1 - Key points

* Thirty tunnels were tested across twelve European countries, selected on the basis of volume of traffic and the tunnel length
* The tests are designed to examine the safety standards of a selection of major European road tunnels (over 900m)
* The project was managed by the ADAC (the German AA) and funded by the EuroTest consortium of motoring organisations
* The tests were carried out by Deutsche Montan Technologie GmbH (DMT)
* The ADAC have undertaken tunnel tests for four years, the AA joined the consortium in 2000
* The tests were carried out between 20 January and 5 March 2002
* Overall winners were the Cointe Tunnel near Lüttich in Belgium and the Montblanc Tunnel near Chamonix that links France and Italy. Both tunnels achieved a 'very good' grade
* Overall losers were the Loibl Tunnel near Klagenfurt, which runs from Austria to Slovenia, and the two London Blackwall Tunnels, rated 'very poor'

2 - Overall UK results

	European rankings	risk potential	per cent score	grade awarded
Mersey Kingsway	7	medium	82.3	good
Dartford	18	medium	73.9	acceptable
Mersey Queensway	21	medium	70.4	acceptable
Tyne	24	medium	66.0	poor
Blackwall South	28	medium	52.6	very poor
Blackwall North	29	medium	51.6	very poor

The European rankings were calculated from a checklist of 8 categories with points allocated in each and weighted in importance.

Very good	at least 90 per cent of the total points
Good	at least 80 per cent of the total points
Acceptable	at least 70 per cent of the total points
Poor	at least 60 per cent of the total points
Very poor	less than 60 per cent of the total points

The assessment of risk potential is based on the following factors:

* Traffic volumes
* Proportion of heavy goods vehicles
* Tunnel gradients
* One or two way traffic and traffic density
* Hazardous material on lorries

3 - UK vs European ratings

	Number of **European** Tunnels given this rating	Number of **UK** Tunnels given this rating
Very Good	3	0
Good	6	1
Acceptable	13	2
Poor	3	1
Very Poor	5	2
Total	30	6

4 - Overall European results – distribution by country

	Austria	Belgium	Czech Republic	France	Germany	Nether lands	Norway	Spain	Switzer land	UK
Very Good		1		1**		1				
Good	2		1		1			1	2	1
Acceptable	1	1		2	1		2	2		2
Poor					1				1	1
Very Poor	1*						1	1		2
Total	4	2	1	3	3	1	3	4	3	6

* Austria to Slovenia
** France to Italy

5 - EuroTest: tunnel assessment categories

Tunnel system	The number of tubes; the tunnel route; the width of the traffic lanes; the layout of emergancy lanes and breakdown bays.
Conditions	Lighting; signs; road surface and markings.
Traffic and traffic surveillance	One way or two way traffic; congestion in the tunnel and congestion detection devices; restrictions on vehicles carrying hazadous materials and hazardous material detection devices; special measures for HGVs; Speed limits and surveillance of safety distance between vehicles; traffic management; video surveillance; height checks; diversion information when the tunnel is closed.
Communication	Loudspeakers, radio traffic information; emergency telephones.
Escape and rescue routes	Provision and signposting of additional ecape routes and chambers with distances; emergancy lighting; use of fire resistant materials and ventilation; external access for rescue personnel.
Fire	Fire protection equipment; fire alarm system (automatic and manual); fire extinguishers; drain-pipe system in trafic lanes for fluid drainage; distance and time taken for fire brigade to arrive; fire brigade training and equipment.
Fire ventilation	Special fire programmes; control of air flow and extraction.
Crisis management	Alarm and rescue operations; automatic limkings of the systems; regular fire drills; regular inspection of safety equipment.

6 - Results in order of ranking

	Tunnel	Country	Per cent score	Grade awarded	Risk potential
1	Cointe	Belgium	96.2	very good	medium
2	Mont Blanc	France/Italy	96.2	very good	medium
3	Wijker	Netherlands	95.4	very good	medium
4	Britz	Germany	86.3	good	medium
5	El Castellot	Spain	84.3	good	low
6	Bosruck	Austria	83.8	good	medium
7	Mersey Kingsway	UK	82.3	good	medium
8	Bözberg	Switzerland	81.8	good	medium
9	Strahov	Czech Republic	80.4	good	medium
10	Pet Hein	Netherlands	79.2	acceptable	low
11	Rheinufer	Germany	78.4	acceptable	medium
12	Katschberg	Austria	78.9	acceptable	medium
13	Gotthard	Switzerland	78.1	acceptable	very high
14	Parpers	Spain	77.6	acceptable	low
15	Maurice Lemaire	France	77.2	acceptable	very low
16	Leopold II	Belgium	76.4	acceptable	medium
17	La Défense	France	75.2	acceptable	high
18	Dartford	UK	73.9	acceptable	medium
19	Lainberg	Austria	72.4	acceptable	medium
20	El Folgoso	Spain	70.9	acceptable	low
21	Mersey Queensway	UK	70.4	acceptable	medium
22	Nordkapp	Norway	70.3	acceptable	low
23	Kappelberg	Germany	68.1	poor	high
24	Tyne	UK	66.0	poor	medium
25	San Salvatore	Switzerland	65.5	poor	medium
26	San Juan	Spain	58.0	very poor	medium
27	Løvstakken	Norway	52.6	very poor	medium
28	Blackwall North	UK	52.6	very poor	medium
29	Blackwall South	UK	51.6	very poor	medium
30	Loibl	Austria/Slovenia	50.4	very poor	very low

7 - Strengths and weaknesses of Mersey Kingsway Tunnel, Liverpool - Result: Good

Year built	1971 (first tube)/ 1974 (second tube)
Length	2,244 m
Portal height level	0 m above mean sea level
Number of tubes	2/ one-direction traffic
Speed limit	40 mph
Vehicles per day	48,000
Share of HGVs	8 per cent
Breakdowns in 2001	204
Accidents in 2001	26
Fires in 2001	3
Hazardous materials in tunnel	With some restrictions
Risk potential	Medium

Strengths:

+ Two tubes with connecting passageways as additional escape or emergency routes
+ No access for most vehicles carrying hazardous materials; those with access must register with the tunnel safety post; escort vehicles for certain categories of hazardous goods and/or certain times specified for transporting these goods
+ Video surveillance throughout with cameras at around every 200 metres
+ Traffic management via traffic lights and barriers at the portals
+ Loudspeakers installed at the portals
+ Radio traffic service reception throughout, with the additional option of transmitting messages
+ Emergency lighting for escape route, escape direction indicated and distance to next exit displayed
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 50 metres)
+ Sufficient number of fire extinguishers (every 50 metres)
+ Fire brigade is well trained and well equipped
+ The tunnel has its own rescue services for emergencies (accidents, fire) stationed around the clock at both portals
+ Special ventilation programmes in the event of fire that take longitudinal flow into consideration
+ Functionality of the fire ventilation system demonstrated in fire trials
+ Fire ventilation system is sufficiently dimensioned
+ Regular emergency drills
+ Latest alarm and rescue operations plan provided

Weaknesses:

- No emergency lanes or lay-bys
- No automatic detection of traffic congestion
- Emergency phones are not sound-proofed
- Distance between emergency exits is relatively long (600 metres)
- In the event of fire, the fire ventilation system is not automatically activated nor is the tunnel automatically closed, ie this is done manually

Plans for the future:

➢ To build more connecting passageways in order to reduce the distance between emergency exits to 330 metres (2002)
➢ Installation of electronic signs

8 - Strengths and weaknesses of Dartford Tunnel - Result: Acceptable

Part of the M25 London orbital motorway

Year built	1963 (first tube)/ 1980 (second tube)
Length	1,430 m
Portal height level	5 m below mean sea level
Number of tubes	2/ one-direction traffic
Speed limit	50 mph
Vehicles per day	75,000
Share of HGVs	11 per cent
Breakdowns in 2001	203
Accidents in 2001	4
Fires in 2001	0
Hazardous materials transport	With some restrictions
Risk potential	Medium

Strengths:

+ Two tubes with connecting passageways as additional escape or emergency routes (every 250 to 450 metres)
+ No access for most vehicles carrying hazardous materials; those with access must register with the tunnel safety post; escort vehicles for certain categories of hazardous goods
+ Video surveillance throughout with cameras at around every 350 metres
+ Automatic detection of congestion and accidents
+ Traffic management via traffic lights and barriers at the portals
+ Sufficient number of emergency telephones (every 50 metres)
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 50 metres)
+ Sufficient number of fire extinguishers (every 50 metres)
+ Fire brigade well equipped and well trained
+ Special ventilation programmes in the event of fire
+ Functionality of the fire ventilation system demonstrated using flow measurements
+ Fire ventilation system is sufficiently dimensioned
+ Latest alarm and rescue operations plan provided
+ Radio traffic service provided throughout

Weaknesses:

- No emergency lanes or lay-bys
- No loudspeakers
- Emergency phones are not sound-proofed
- In the event of fire, the fire ventilation system is not automatically activated, nor is the tunnel automatically closed, ie this is done manually

Plans for the future:

- ➢ Emergency lighting for escape routes (2002)
- ➢ Pictograms to identify escape routes
- ➢ Installation of loudspeakers

9 - Strengths and weaknesses of Mersey Queensway Tunnel, Liverpool - Result: Acceptable

Year built	1934
Length	3,600 m
Portal height level	5 m above mean sea level
Number of tubes	1/ on-coming traffic
Speed limit	30 mph
Vehicles per day	40,000
Share of HGVs	0
Breakdowns in 2001	168
Accidents in 2001	18
Fires in 2001	0
Hazardous materials transport	With some restrictions
Risk potential	Medium

Strengths:

+ No access for heavy goods vehicles (shifted to the Mersey Kingsway Tunnel)
+ No access for most vehicles carrying hazardous materials, the remaining categories must register with the tunnel safety post; escort vehicles for certain categories of hazardous goods and/or certain times specified for transporting these goods
+ Video surveillance throughout with cameras at around every 180 metres
+ Traffic management via traffic lights and barriers in front of the portals
+ Loudspeakers installed at the portals
+ Radio traffic service reception throughout, with the additional option of transmitting messages
+ Emergency lighting for escape route, escape direction indicated and distance to next exit displayed
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 50 metres)
+ Sufficient number of fire extinguishers (every 50 metres)
+ Fire brigade is well trained and well equipped
+ The tunnel has its own rescue services for emergencies (accidents, fire) stationed around the clock at both portals
+ Special ventilation programmes in the event of fire
+ Functionality of the fire ventilation system demonstrated using flow measurements
+ Fire ventilation system is sufficiently dimensioned
+ Regular emergency drills
+ Latest alarm and rescue operations plan provided

Weaknesses:

- Only one tube with oncoming traffic
- No emergency lanes or lay-bys
- Traffic lanes are only 2.75 metres wide (however, no HGVs), emergency walkways are only 0.60 metres wide
- No automatic detection of traffic congestion
- Emergency phones are not sound-proofed
- Distance between emergency exits is relatively long (1500 metres)
- The functionality of the fire ventilation systems has not been demonstrated in fire trials or using flow measurements.
- No monitoring of the longitudinal flow in the tunnel
- In the event of fire, the fire ventilation system is not automatically activated nor is the tunnel automatically closed, ie this is done manually

Plans for the future:

➢ Installation of pressurised escape chambers (around 2004)
➢ Installation of electronic signs

10 - Strengths and weaknesses of Tyne Tunnel, Newcastle - Result: Poor

Year built	1967
Length	1,692 m
Portal height level	12 m above mean sea level
Number of tubes	1/ on-coming traffic
Speed limit	30 mph
Vehicles per day	34,000
Share of HGVs	8 per cent
Breakdowns in 2001	200
Accidents in 2001	7
Fires in 2001	1
Hazardous materials transport	With some restrictions
Risk potential	Medium

Strengths:

+ No access for most vehicles carrying hazardous materials, others must register
+ Escort vehicles for certain categories of hazardous goods
+ Video surveillance throughout with cameras at around every 85 metres
+ Traffic management via traffic lights, variable traffic signs and barriers at the tunnel entrance
+ Loudspeakers installed at the portals
+ Radio traffic service reception throughout, additional option of transmitting messages
+ Sufficient number of emergency telephones (every 56 metres)
+ When an emergency call is made, a video camera is automatically activated
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 56 metres)
+ Sufficient number of fire extinguishers (every 56 metres)
+ Fire brigade is well trained and well equipped
+ The tunnel has its own rescue services for emergencies (accident, fire) stationed around the clock
+ Special ventilation programmes in the event of fire
+ Functionality of the fire ventilation system demonstrated in fire trials
+ Fire ventilation system is sufficiently dimensioned
+ Regular emergency drills
+ Latest alarm and rescue operations plan provided

Weaknesses:

- Only one tube with oncoming traffic and heavy traffic
- No emergency lanes or lay-bys
- No automatic detection of traffic congestion, no traffic management in order to avoid congestion
- Emergency phones are not sound-proofed
- No additional possibilities for escape or rescue routes
- In the event of fire, the fire ventilation system is not automatically activated nor is the tunnel automatically closed, ie this is done manually

11 - Strengths and weaknesses of Blackwall North Tunnel, London - Result: Very poor

Year built	1897
Length	1,350 m
Portal height level	No information available
Number of tubes	1/ one-direction traffic
Speed limit	30 mph
Vehicles per day	50,000
Share of HGVs	8 per cent
Breakdowns in 2001	No information available
Accidents in 2001	3
Fires in 2001	0
Hazardous materials transport	With some restrictions
Risk potential	Medium

Strengths:

+ No access for many vehicles carrying hazardous materials; those with access must register with the tunnel safety post
+ Video surveillance throughout with cameras at around every 80 metres
+ Transport management via traffic lights and barriers in front of the portals
+ Loudspeakers installed at the portals
+ Emergency lighting for escape route, escape direction indicated and distance to next exit displayed
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 50 metres)
+ Sufficient number of fire extinguishers (every 50 metres)
+ Fire brigade is well trained and well equipped
+ Special ventilation programmes in the event of fire
+ Fire ventilation system is sufficiently dimensioned
+ Regular emergency drills
+ Latest alarm and rescue operations plan provided

Weaknesses:

- No emergency lanes or lay-bys
- Traffic lanes only 2.24 metres in width
- No automatic detection of traffic congestion, no traffic management in order to avoid congestion
- No information on observing the minimum distance
- No monitoring of speed limit
- Radio traffic service not provided throughout
- Emergency phones are not sound-proofed
- No additional possibilities for escape or rescue routes
- Ventilation equipment is not heat-resistant
- The functionality of the fire ventilation systems has not been demonstrated in fire trials or using flow measurements.
- In the event of fire, neither the fire ventilation system is automatically activated nor is the tunnel automatically closed, ie this is done manually

12 - Strengths and weaknesses of Blackwall South Tunnel, London - Result: Very poor

Year built	1967
Length	1,375 m
Portal height level	No information available
Number of tubes	1/ one-direction traffic
Speed limit	30 mph
Vehicles per day	50,000
Share of HGVs	8 per cent
Breakdowns in 2001	No information available
Accidents in 2001	7
Fires in 2001	1
Hazardous materials transport	With some restrictions
Risk potential	Medium

Strengths:

+ No access for many vehicles carrying hazardous materials; those with access must register with the tunnel safety post
+ Video surveillance throughout with cameras at around every 200 metres
+ Traffic management via traffic lights and barriers in front of the portals
+ Loudspeakers installed at the portals
+ Sufficient number of emergency telephones (every 50 metres)
+ When an emergency call is made, a video camera is automatically activated
+ Automatic fire alarm system via CO detectors
+ Pressurised water pipe throughout tunnel and sufficient number of hydrants (every 50 metres)
+ Fire brigade is well trained and well equipped
+ Special ventilation programmes in the event of fire
+ Fire ventilation system is sufficiently dimensioned
+ Regular emergency drills
+ Latest alarm and rescue operations plan provided

Weaknesses:

- No emergency lanes or lay-bys
- No information on observing the minimum distance
- No monitoring of speed limit
- No automatic detection of traffic congestion, and no traffic management in order to avoid congestion
- Radio traffic service not provided throughout
- Emergency phones are not sound-proofed
- No additional possibilities for escape or rescue routes
- No fire extinguishers
- The functionality of the fire ventilation systems has not been demonstrated in fire trials or using flow measurements.
- In the event of fire, the fire ventilation system is not automatically activated nor is the tunnel automatically closed, ie this is done manually

Plans for the future:

➢ Installation of emergency lighting (2002)

13 - EuroTest: why we test tunnels

Tunnel tests have become a regular part of the annual EuroTest programme. Since the first tests in 1999 there have been considerable developments in Europe's road tunnels. Many operators have been prompted by the test results to make improvements. This costs money -in some cases a great deal - and for this reason investment to improve tunnel safety is also a political decision.

The risk of having an accident in a tunnel is much less than on the open road. There is statistical evidence that far fewer accidents occur in tunnels. Weather conditions have hardly any impact, lighting conditions remain constant, and speed restrictions or enforcement usually slow the traffic down.

However, when there is an accident in a tunnel, it is much more difficult to control events, even with smaller accidents. Motorists cannot simply get out of the way or escape, and it is harder for rescue teams to reach the site of the accident. A car catching fire can easily lead to a disaster. Toxic smoke and temperatures of up to 1200 degrees celsius can threaten the lives of motorists and rescue teams alike. The accidents in the Mont Blanc, Tauern and Gotthard tunnels are recent distressing and alarming examples.

Safety technology, which is designed to control emergencies, can almost always be improved. But of the 30 tunnels tested only nine were judged to be 'very good' or 'good', suggesting a need for substantial investment in many of Europe's tunnels.

But even a tunnel with the best equipment can never guarantee complete safety. The greatest hazard is the motorist. 95 per cent of general traffic accidents are caused by bad driving and in tunnels it is no different.

The four years of tunnel tests in the EuroTest programme have raised awareness of tunnel safety and have exposed weaknesses. It is expected that this year the European Commission will issue guidelines for co-ordinated minimal safety standards applicable throughout Europe. In many countries improvements and renovations are taking place. However, further big efforts are required from all those involved in order to achieve the highest possible safety standards in Europe's tunnels.

14 - EuroTest methodology: how we tested

The criteria for selecting the 30 tunnels in twelve European countries were their length and traffic volumes. Two of the tunnels cross borders: the Loibl tunnel connects Austria and Slovenia, and the Mont Blanc tunnel connects France and Italy. In Germany, three city tunnels were inspected: the Britz (A 100 in Berlin), Rheinufer (B1 in Düsseldorf) and Kappelberg (B 14 in Fellbach near Stuttgart) tunnels. The following tunnels were inspected again this year: the Leopold II tunnel in Belgium, the Mersey Queensway, the Mersey Kingsway and Tyne in Great Britain, Bosruck and Katschberg in Austria, Gotthard in Switzerland, and San Salvatore in Spain. The Mont Blanc tunnel was also tested, before its reopening in March 2002.

The German Montan Technologie GmbH (DMT) was once again engaged in the execution of the Tunnel Test. The DMT is an international technology service provider in the areas of raw materials, safety and infrastructure, with 850 employees. One area which emerges from mining operations is safety in complex systems such as tunnels, and in particular protection against fire and explosions, ventilation, and rescue operations. DMT, together with its subsidiary Risc Ruhr, also operates a state-of-the-art training centre for fire services where firemen can be trained in fire fighting in tunnels and buildings under realistic conditions.

The experts from DMT inspected the 30 test tunnels on location between 20 January and 5 March 2002 according to a checklist. During these tests, safety-relevant questions for the tunnels in question were discussed on site with the respective operators. Additional details, for example special measures, updating, and changes in tunnels are for the most part listed under the individual tunnel descriptions, but they were not taken into consideration in the final evaluation. In advance of the test a list was sent to those responsible for carrying it out giving the most important technical data about the tunnels.

The ADAC and DMT-drafted checklist is based on the high standards of the regulations governing road tunnels in Germany and Austria, and the recommendations of the UNECE-Safety Commission. It offers a yardstick for tunnel safety, and is divided into the following eight areas:

➢ Tunnel system: Weighting 9 per cent

- Number of tubes
- Tunnel route
- Width of the traffic lanes/ emergency walkways
- Layout of emergency lanes/ breakdown bays

➢ Condition: Weighting 7 per cent

- Illumination
- Signs
- Road surface and markings

➢ Traffic and traffic surveillance: Weighting 18 per cent

- Type of traffic (one direction/ both directions)
- Congestion in the tunnel
- Restrictions for or registration of vehicles carrying hazardous material
- Special measures for HGV traffic
- Surveillance of the safety-distance between vehicles and observance of speed limit
- Speed limit
- Control rooms
- Traffic management
- Video surveillance
- Automatic detection of congestion
- Automatic detection of vehicles carrying hazardous materials
- Mechanical barriers to close the tunnel
- Height check
- Information about detours/bypasses when tunnel is closed

➢ Communication Weighting 9 per cent

- Loudspeakers, radio traffic information
- Language
- Emergency telephones

➢ Escape/rescue routes: Weighting 15 per cent

- Provision of additional escape routes and/or chambers, as well as distances
- Signposting of the emergency exits
- Emergency lighting and marking of escape routes

- Prevention of smoke intrusion
- Fire resistance/ ventilation
- External access for rescue personnel

Fire: Weighting 20 per cent

- Fire protection equipment
- Fire alarm systems (automatic/manual)
- Fire extinguishers
- Drain-pipe system in the traffic lanes for fluid drainage
- Distance to be covered and time needed for fire brigade
- Fire brigade training and equipment

➢ Fire ventilation: Weighting 13 per cent

- Special fire programmes
- Control of the longitudinal flow in the tunnel and consideration of this in ventilation control
- Temperature stability of facilities and equipment
- Proof of functioning by way of fire behaviour test and measurement of current flow
- Longitudinal ventilation:
  - Airflow rate
  - Length of ventilation sectors
  - Reversibility of ventilators

➢ Transverse/semi-transverse ventilation:
  - Volume flow of extraction
  - Influence of the longitudinal ventilation
  - Whether or not opening and closing of exhaust air outlets can be controlled

➢ Crisis management: Weighting 9 per cent

- Alarm and rescue operations
- Automatic linking of the systems
- Regular fire drills
- Regular inspection of safety equipment (internal/external)

The areas of the tunnel system, condition, traffic and traffic surveillance are essentially the preventative measures; escape routes and fire ventilation the self-rescue and rescue measures; and fire protection, crisis management and communication measures are for the control of an emergency situation. The **safety potential** is the sum of all these measures, architectural, technical and organisational, which prevent emergencies and should limit their extent.

Alongside the safety potential, however, the danger- or risk potential was also calculated. This describes on the one hand the statistical likelihood of emergencies (collisions, fires), and on the other the extent of the damage in the case of an accident. The risk potential indicates the likelihood of an accident in any given tunnel, and the consequences to be expected in the case of such an accident.

The calculation of risk potential was based on the following considerations:

- The likelihood of accidents and fires increases with the volume of traffic
- The higher the number of HGVs, the more likely a major fire becomes. Inappropriate behaviour on the part of tunnel users and incorrect decisions by safety personnel in the tunnel can then lead to major catastrophes, as seen for example at the Mont Blanc, Tauern and Gotthard tunnels.
- The longitudinal gradient of a tunnel influences the spreading of smoke. The steeper the gradient, the stronger the thermal lift and hence the larger the area where smoke spreads.
- Type of traffic (one direction or both directions) and traffic conditions (slow-moving traffic/ congestion in the tunnel, every day or rarely) influence the escape and rescue possibilities, and the choice of ventilation system. With traffic in one direction and with no congestion in the whole tunnel, longitudinal ventilation systems allow those vehicles positioned behind the fire to leave the tunnel without risk. The vehicles ahead of the fire can be protected by extracting the smoke in the same direction as the traffic. In the case of oncoming traffic or two-way traffic with congestion, there may be vehicles at both sides of the fire that cannot easily leave the tunnel. Moreover, oncoming traffic brings the risk of serious accidents (for example frontal collision), as occurred for example in 2001 in the Gleinalm and Amberg tunnel in Austria.
- If a vehicle transporting hazardous materials catches fire, the resultant fire and the extremely poisonous gases can lead to a catastrophe (Caldecott tunnel, California, 1982, seven dead; Nihonzaka tunnel, Japan, 1979, seven dead). Thus the unrestricted transport of hazardous substances, and high numbers of HGVs, increase the possibility of a large-scale fire.

The risk potential was quantitatively as well as qualitatively assessed. Fundamental to this were the relevant investigations of the DMT on behalf of the Federal Institute for Roads, and the experience of the three previous EuroTest Tunnel tests.

The following parameters were used in the assessment:

♦ Traffic performance per year(derived from traffic load and tunnel length):	maximum 10 points
♦ Number of HGVs per day and per tunnel tube:	maximum 10 points
♦ Type of traffic (one direction or both directions):	maximum 4 points
♦ Traffic volume (vehicles per hour and lane):	maximum 5 points
♦ Transport of hazardous goods:	maximum 5 points
♦ Maximum longitudinal gradient in the tunnel:	maximum 4 points
♦ Additional hazards, for example entrances and exits, intersections in the tunnel or in the area after it, long slopes before the tunnel:	maximum 3 points

These risk points were totalled and classified as follows:

♦ Very low risk:	4 to 10 points
♦ Low risk:	11 to 17 points
♦ Medium risk:	18 to 24 points
♦ High risk:	25 to 31 points
♦ Very high risk:	more than 31 points

In the overall evaluation of a tunnel, the safety and risk potentials were amalgamated. The evaluation of the safety potential (see above) with a points total of 100 per cent constitutes an objective measure for safety. This safety potential was multiplied by the relevant factors included in the risk potential calculated in each case. This means that the points total of a tunnel with a very low risk factor was credited as 30 per cent, that of a tunnel with low risk at 20 per cent, a tunnel with medium risk at 10 per cent, and with a high risk at 5 per cent. A tunnel with a very high risk factor was not credited with any extra points. In this way, the risk potential of a tunnel became a determining factor in its safety potential. A low risk potential improved the overall evaluation of a tunnel.

The overall evaluation was based on the following grade boundaries:

Very good (++):	at least 90 per cent of the total points
Good (+):	at least 80 per cent of the total points
Acceptable (o):	at least 70 per cent of the total points
Poor (-):	at least 60 per cent of the total points
Very poor (- -):	less than 60 per cent of the total points

15 - Results: analysis and evaluation

The results of the individual test categories are summarised as follows:

- Tunnel system:

  18 of the tested tunnels comprised two tubes, ten tunnels comprised one tube. The Blackwall North and South tunnels (built independently) were tested separately.

  Ten of the tunnels have a safety lane and a further ten tunnels have been equipped with breakdown bays. There are neither breakdown bays nor safety lanes in the following tunnels: Loibl, San Salvatore, Strahov, Piet Hein, Mersey Queensway, Mersey Kingsway, Blackwall North and South, Dartford and Tyne. In the majority of tunnels lanes are sufficiently wide (at least 3.5 meters). The Blackwall tunnel has lanes only 2.24 m wide and the Mersey Queensway 2.75 m wide.

  In 20 tunnels there are emergency walkways on both sides. They are available on only one side of the tunnel at San Salvatore, Løvstakken, Leopold II, Wijker, Piet Hein, El Folgoso, San Juan, Parpers, Blackwall North and Dartford. In three tunnels, Maurice Lemaire, Mersey Queensway and Mersey Kingsway, the emergency walkways are narrower than 0.7 metres. In the El Castellot tunnel there is no separate emergency walkway (only a safety lane).

- Condition:

All tunnels in the survey are lit throughout and, with the exception of the San Juan tunnel, they are equipped at the entrance and exit with so-called adaptation zones which enable the motorist to adapt to the transition from daylight to artificial lighting or the other way round. As a rule the lighting equipment, traffic signs and information boards are clean.

Lane markings in all tunnels are adequate. Deficiencies of road surface were only found in the Katschberg tunnel. The right-hand edge of the lane and the centre line are particularly well marked (cats eyes, luminous diodes or similar) in the following tunnels which carry traffic in both directions: Bosruck, Loibl, Katschberg, Lainberg, Maurice Lemaire, Mersey Queensway and Tyne.

- Traffic and traffic surveillance/control:

In two-tube tunnels, including the two Blackwall tunnels, traffic moves only in one direction; in one-tube tunnels it moves in both directions. There is a daily occurrence of tailbacks in the town tunnels Rheinufer, Løvstakken, Strahov, Piet Hein, La Défense, Blackwall North and South and Tyne.

There are differences in the way that transport of hazardous goods through the tunnels is regulated. In eight tunnels there is no restriction on hazardous goods. In nine tunnels the transportation of hazardous goods is completely prohibited: Rheinufer, Loibl, Cointe, Leopold II, Mont Blanc, Maurice Lemaire, La Défense, El Catellot and Parpers. In British tunnels the transportation of a number of hazardous goods is prohibited, whilst others may only be transported with an escort. The Wijker and Piet Hein tunnels are also closed to certain hazardous goods, but there is no obligation for any other goods to be escorted. The Gotthard tunnel is closed to the transportation of explosives and of inflammable materials, and other types of hazardous goods need to be escorted. In the Bosruck and Katschberg tunnels all transportation of hazardous goods is allowed, but for certain types of hazardous goods only if escorted. In nine tunnels any transport of hazardous goods has to be notified to the control room.

Four tunnels are closed to HGV traffic (over 3.5 tonnes): Loibl, Leopold II, Maurice Lemaire, and Mersey Queensway. In the Gotthard tunnel HGV traffic is only allowed in one direction at a time. This is one of the consequences of the fire of October 2001.

In eleven tunnels there are special signs at the entrance, and in some cases in the tunnel, requiring observance of safety distances either between all vehicles, or between HGVs. Speed is monitored only in a few tunnels. Maximum speed in tunnels is regulated in different ways. In the Loibl, Leopold II, Mersey Queensway, Blackwall North and South and Tyne tunnels there is a speed restriction of 50km/h; in the Wijker tunnel of 120km/h.

All tunnels have a control room which is manned round the clock. For the Britz, Kappelberg, Loibl, San Salvatore and Bözberg tunnels these are the nearest police stations, at the Rheinufer tunnel it is the fire station at Düsseldorf.

For 19 tunnels traffic is regulated at the approach of the tunnel. This is achieved partly by computer controlled speed limits (variable traffic signs), or by regulating traffic flow at toll booths (batch management). The majority of tunnels are equipped with traffic lights and variable traffic signs both at the portals and in the tunnel itself. Fourteen tunnels are equipped with barriers at both ends, which can be lowered when the tunnel is closed. In addition to this, in the Mont Blanc tunnel half-barriers have been erected at 600m intervals to prevent motorists from ignoring red traffic lights.

Most tunnels have been equipped with a sufficient number of video cameras to ensure that they can be fully monitored. In the Bözberg tunnel there are several 50m stretches which cannot be monitored. There is no close-circuit television monitoring system in six tunnels: Kappelberg, Loibl, San Salvatore, Løvstakken, Nordkapp and San Juan. 19 tunnels have been equipped with systems that automatically monitor tailbacks (induction loop, close circuit television).

- Communication:

With the exception of the Loibl, Løvstakken, Maurice Lemaire, El Folgoso, El Castellot, San Juan, Parpers, Blackwall North and South tunnels, radio traffic news can be received throughout all tunnels. In most cases there is also the possibility to feed additional announcements directly from the control room into the radio broadcast. This is, however, not possible in the case of the Britz, Kappelberg, Bözberg, Cointe and Wijker tunnels.

Emergency telephones are available in all tunnels, mostly at adequate intervals (200m at most), in some tunnels on both sides of the carriageway. Only in the Nordkapp tunnel is there a distance of 500m between telephones. The emergency telephones are always adequately signposted and lit. Only in ten tunnels, however, are they sufficiently insulated against noise. In twelve tunnels the use of the emergency phone automatically triggers emergency measures: first the nearest video camera is activated to give the control room an immediate picture of the situation. The Bosruck and Katschberg tunnels are closed immediately; in the Lainberg, San Salvatore, Bözberg and Parpers tunnels, the speed limit is reduced; in the Mont Blanc tunnel an early warning is triggered to activate the ventilation systems.

The equipment with loudspeakers is however adequate in only a few tunnels. Only the Bosruck, Lainberg, Katschberg, Wijker and Piet Hein tunnels have loudspeakers at both ends as well as in the areas around the breakdown bays and escape routes. In 18 tunnels no loudspeakers have been installed at all.

- Escape and rescue routes:

All two-tube tunnels that were tested have direct connecting passageways to the neighbouring tube or to an additional escape tube, which can be used as escape routes. The Britz, Rheinufer and Leopold II tunnels also possess additional escape exits into the open. The two tubes of the Blackwall tunnel, which were tested separately, are not connected.

Of the one-tube tunnels, the Gotthard and Bosruck tunnels have a parallel escape gallery. In the Lainberg tunnel, sections of escape gallery are available; in the Mont Blanc tunnel a parallel ventilation shaft is available; in the Mersey Kingsway tunnel there are escape routes into the open. In the Gotthard and Bosruck tunnels the links to the escape galleries, and in the Mont Blanc to the ventilation gallery, have been converted into escape spaces.

The distance between emergency exits in tunnels has been assessed as acceptable (300m at most) in 15 tunnels. In four tunnels the distances are even less than 100m : Kappelberg (60m), Rheinufer (80m in places), Wijker (80m) and Piet Hein (90m). In three tunnels the distances are relatively great: Mersey Queensway (1500m), Lainberg (1000m), and Mersey Kingsway (600m).

In four tunnels the escape routes are not, or insufficiently, signposted: Kappelberg, San Salvatore, Piet Hein and San Juan tunnels. Only half of the tunnels have emergency lighting of escape routes in the tube (lights on the wall at a height of about one metre).

Direct links to the neighbouring tube or to the escape tunnel ensure external access for emergency teams. Some of these routes can also be used by rescue vehicles. Six tunnels are equipped with such access routes for vehicles at acceptable intervals (900m at most): San Salvatore, Bözberg, Leopold II, Piet Hein, La Défense and El Castellot.

Eight tunnels have no additional escape or rescue routes: Katschberg, Loibl, Løvstakken, Nordkapp, Maurice Lemaire, Blackwall North and South, and Tyne.

- In case of fire:

All tunnels have sufficient fireproof lining. The power cables are usually safely laid below the emergency walkways in a sand bed or in special cable conduits. When installed in areas used by traffic, for example for the blast ventilators, cables with suitable fire resistance are used. For eight tunnels, duration of fire resistance was insufficient or unavailable: at the Lainberg, Loibl, Gotthard, El Folgoso, El Castellot, San Juan, and Blackwall North and South.

With the exception of the Blackwall South, fire extinguishers have been installed in all tunnels, and they are regularly serviced (safety check stickers), except in the case of La Défense tunnel. The distance between fire extinguisher bays is in most cases acceptable at 200m or less. In the Parpers tunnel however the distance is 350m. In twelve tunnels the nearest video camera is automatically activated so that staff at the control room can assess the situation. In the case of the Bosruck, Lainberg, Katschberg and Bözberg tunnels the full fire safety drill is triggered (closure of the tunnel, fire ventilation). The Nordkapp tunnel too is closed automatically. In the Mont Blanc tunnel a warning is sounded to activate the fire ventilation; in the Gotthard tunnel emergency lighting of the escape routes is switched on; in the San Salvatore tunnel the speed limit is reduced.

In the case of the Loibl, Løvstakken, Wijker, Piet Hein, Maurice Lemaire and La Défense tunnels there is no possibility of automatically identifying a fire. Instead of linear fire notification cables, the existent CO-sensors are used to recognise a fire in the Nordkapp, El Catellot, Mersey Queensway, Mersey Kingsway, Blackwall North and South, Dartford and Tyne tunnels; in the San Juan tunnel spot ionisation alarms are used.

Most tunnels have a pressurised water pipe throughout and hydrants spaced at reasonable intervals. But these are missing in the Loibl, Løvstakken, Nordkapp, El Folgoso, San Juan and Parpers tunnels. In these cases the fire engines bring their own water. Six tunnels have a suitable drain-pipe system via which flammable fluids that have leaked can be quickly collected so that the seat of the fire can be restricted. 18 tunnels have not been equipped with a system of this kind.

The distances to be covered by fire brigades to reach an individual tunnel vary between 0.2 and 25 km. In most cases fire brigades are able to reach a tunnel in less than 15 minutes. Only for the El Folgoso tunnel are 25 minutes needed. The Gotthard, Mont Blanc and Maurice Lemaire tunnels have their own fire brigade stationed at the tunnel portals. In the Mont Blanc tunnel there is an additional detachment in the middle of the tunnel. The Mersey Queensway, Mersey Kingsway and Tyne tunnels have their own emergency staff.

In most tunnels the fire brigades undertake regular fire drills: in 15 tunnels at least once a year, and in ten tunnels about once every one and a half to two years. In the case of the Loibl, Piet Hein, El Folgoso, and Parpers tunnels, however, no such exercises have yet been undertaken or only at irregularly and long intervals. Only half of the fire brigades undertake training in realistic conditions at appropriate temperatures and with smoke.

The fire brigades are generally well equipped. All have equipment for rescuing injured passengers from their vehicles, respiratory equipment and suitable fire fighting equipment. Respiratory protection is not in all cases equal to the special challenges of fire fighting in a tunnel during least two hours. About half of the fire brigades have heat-imaging cameras.

- **Fire ventilation:**

The Loibl tunnel is the only one not equipped with mechanical ventilation. In most tunnels ventilation is activated according to a set procedure where the location of the seat of the fire is also taken into consideration. Only in the Løvstakken and Nordkapp tunnels has this aspect been ignored. In ten tunnels the linear airflow is not monitored. In eleven tunnels the functioning of the fire ventilation has not been tested either by fire or smoke tests or by measurements of the airflow.

In the event of fire, 19 tunnels have longitudinal ventilation. In some of these cases there is an exchange of air via intermediate shafts. In longitudinal ventilation fumes in the traffic area of the tunnel are conducted to the exit portal or to intermediate shafts. A sufficient airflow rate in the longitudinal direction of the tunnel is vital when it comes to preventing smoke from spreading. All the tunnels fulfil this criterion. The length of the ventilation sectors where smoke can spread is assessed as too large in the Nordkapp tunnel. In the Leopold II, El Castellot, Parpers and Blackwall South tunnels the ventilators cannot be reversed.

In ten tunnels smoke can be extracted from the tube. In most cases the ventilators are strong enough, but in the Katschberg, San Salvatore and La Défense tunnels they appear to be of insufficient strength. Smoke extraction is particularly effective when the flaps, which are usually situated in the ceiling of the tunnel, can be opened fully near the seat of the fire and closed completely in the areas far from the fire. This is only the case in the Bosruck, Katschberg, Gotthard (after completion of building works), Cointe and Mont Blanc tunnels. In the older tunnels of San Salvatore and La Défense the flaps cannot be opened or closed automatically.

- **Crisis management:**

In cases of emergency (congestion, accident, fire etc.) most control rooms have emergency plans which are updated continually. Negative exceptions are the Loibl, Leopold II and El Folgoso tunnels.

In most tunnels the fire alarm automatically triggers off fire ventilation and closure of the tunnel. In some tunnels the fire brigade is also immediately notified. In order to avoid false alarms, the control rooms are sometimes notified first. In 21 of the tested tunnels fire and emergency drills take place at regular intervals. In most cases safety equipment is tested regularly by external and/or internal experts.

- **Risk assessment:**

The risk potential has been assessed as “very high” for the Gotthard tunnel, “high” for the La Défense and Kappelberg tunnels, “low” for the six tunnels Nordkapp, Wijker, Piet Hein, El Folgoso, El Castellot and Parpers, and “very low” for the two tunnels Loibl and Maurice Lemaire. The risk potential of the remaining 19 tunnels was assessed as “medium”.

- **Note:**

In some tunnels measures are currently being taken to increase safety, which have been taken into account in the assessment above. For the Gotthard tunnel the alteration to the ventilation system (installation of remote control flaps for effective smoke extraction) which was underway at the time of the test and which is expected to be completed by the time the results are published, has been taken into account. Further measures, such as the determination of ventilation control in case of fire and the validation of the effectiveness of the ventilation system in case of fire, have not been included in the assessment. However, it is expected that the tunnel will then achieve a rating as ‘good’.

16 - International co-operation with other automobile clubs

The test of 30 European tunnels took place within the framework of the international "EuroTest" programme, a consortium of 14 motoring organisations from 13 European countries under the auspices of AIT & FIA (Alliance Internationale de Tourisme & Fédération Internationale de l'Automobile). They were supported in this by the European Commission in Brussels and the FIA foundation in London. As in previous years, the German AA (ADAC) undertook the management of the test. The results of the test will be published in all the countries represented by the partner organisations. These partner organisations are:

in Great Britain

AA
12 million members
website: www.theaa.com

In Germany

ADAC (Project Leader)
14.3 million members
website: www.adac.de

in Belgium

TCB
0.6 million members
website: www.touring.be

in Denmark

FDM
0.2 million members
website: www.fdm.dk

in Finland

AL
0.07 million members
website: www.autolitto.fi

in France

FFAC
0,15 million members
website: www.automobileclub.org

in Italy

ACI
1.1 million members
website: www.aci.it

in the Netherlands

ANWB
3.7 million members
website: www.anwb.nl

in Norway

NAF
0.4 million members
website: www.naf.no

in Austria

ÖAMTC
1.4 million members
website: www.oeamtc.at

in Switzerland

TCS
1.4 million members
website: www.tcs.ch

in Slovenia

AMZS
0.09 million members
website: www.amzs.si

in Spain

RACE
0.3 million members
website: www.race.net

also in Spain

RACC
0.6 million members
website: www.racc.es

17 - Chronology: tunnel disasters since 1970

14 February 1971 in Bosnia
The Zepce-Zenica early train derailed in the tunnel near Vranduk. 34 people suffocated in the subsequent fire.

6 November 1972 in Japan
In the 13-kilometre long train tunnel near Fukui, the Kitaguni night express caught fire. This was caused by a fire in the dining car. 29 travellers suffocated.

1975 in England
In London's Moorgate underground station a train full of passengers rammed into the tunnel wall. Human error on the part of the train driver caused this accident. 43 people died, 55 were injured.

11 July 1979 in Japan
In a collision between several lorries and cars in the Nihonzaka tunnel seven people lost their lives.

7 April 1982 in the US
In the Caldecott tunnel near Oakland, California, seven people died in a pile-up.

3 November 1982 in Afghanistan
In the Salang tunnel north of Kabul, a Soviet army convoy truck collided with a tank lorry. The explosion triggered an inferno. 700 to 2000 people suffocated and were burned.

18 November 1987 in England
In a smouldering fire at London's Kings Cross underground station 31 people died.
This disaster was caused by a discarded match.

10 April 1995 in Austria
In a pile-up in the Pfänder tunnel near Bregenz, four cars caught fire. Three people died. A motorist driving into incoming traffic caused this accident.

28 October 1995 in Azerbaijan
289 people suffocated and were burned in a metro tunnel in Baku. A short-circuit in the electrical equipment of a metro car was suspected to have caused this disaster.

10 February 1996 in Japan
On the island of Hokkaido, a huge boulder weighing 50,000 tonnes crashed onto a tunnel tube. It took rescue services a number of days to reach the accident site. 20 passengers died.

18 March 1996 in Italy
After a rear-end collision a tank lorry exploded in a tunnel near Palermo. 19 cars caught fire. Five people died, 26 people were injured.

18 November 1996 in the Channel
In the Eurotunnel, a lorry on a freight train caught fire. It took five hours to get the fire under control. Around 30 train passengers suffered serious smoke poisoning.

2 March 1999 in Germany:
In a tunnel near Göttingen on the ICE route Hanover-Würzburg a railway car caught fire. It took twelve hours to extinguish the fire, which was fed by pulp and paper.

24 March 1999 in France/ Italy:
A Belgian lorry loaded with flour and margarine caught fire in the Mont Blanc tunnel. A lighted cigarette end caused this fire. The fire quickly spread and was not extinguished until 24 hours later. 39 people lost their lives in this fire.

29 May 1999 in Austria:
After a rear-end collision in the Tauern tunnel fire broke out. A lorry carrying paint exploded. 24 vehicles subsequently caught fire, turning the tube into a furnace in which twelve people died. It took 16 hours to get the fire under control.

10 January 2000 in Austria:
Another fire in the Tauern tunnel is less destructive: one lorry catches fire, but the drivers and passengers of all affected cars were nonetheless able to save themselves.

11 November 2000 in Austria:
At Kitzsteinhorn near Kaprun a fire broke out in one carriage of a cable car running through a tunnel in the Gletscher skiing area. This was caused by a smouldering fire in the heating system. 155 lives were lost, including many children and young people.

12 April 2001 in Austria:
In the Helbersberg tunnel on the Taunern route a rear-end collision led to a huge pile-up. A fire did not break out. Two people died and ten people were injured.

10 July 2001 in Austria:
After a frontal collision in the Tauern tunnel disaster was avoided due to the swift reactions of a car driver. He is able to extinguish the fire which was burning in a car.

6 August 2001 in Austria:
Two cars collided head-on in the Gleinalm tunnel on the Pyhrn motorway (A9) north of Graz. They caught fire immediately. Five people, including a young child, died. The five injured people, who were saved, included a child who sustained 70 per cent burns, and two children of three and five years who suffered head injuries and gas fume poisoning.
On 29th July the engine of a Swedish touring coach caught fire in the Gleinalm tunnel. The driver was able to manoeuvre the vehicle out of the tunnel, and thus avert a catastrophe.

8 August 2001 in Austria
In the Amberg tunnel on the Rhein valley motorway (A 14) between Frastanz and Feldkirch, an Austrian touring coach and an Austrian van collided. Several approaching vehicles were caught in the pile-up. Three people died.

13 August 2001 in Austria
Near Klagenfurt in Kärnten an Italian touring coach carrying 30 Polish pilgrims crashed into the portal of the Reigersdorf tunnel. 24 people were injured, some of them seriously.

26 August 2001 in Switzerland
A frontal collision occurred in the Gotthard tunnel on the A2 between Göschenen and Airolo. Six people were injured, one of them seriously.

31 August 2001 in Austria
Two dead and nine injured – this was the sad outcome of three tunnel accidents in one day. One woman was seriously injured as her vehicle crashed into the portal of the Sonnstein tunnel. In the Lainberg tunnel on the A 9 near Windischgarsten in Austria two Austrians were killed and two Germans injured in a frontal collision. In the Katschberg tunnel on the A 10 near St. Michael in Lungau six people were injured in a collision.

3 September 2001:
In the Gleinalm tunnel on the Pyhrn motorway (A9) North of Graz a touring coach caught fire. The tunnel was closed and nobody was injured.

17 October 2001 in Denmark:
In the Danish Guldborgsund tunnel between Copenhagen and the ferryport of Rödby a lorry drove into a car in thick fog, causing a massive crash. Five people died and nine were seriously injured.

24 October 2001 in Switzerland:
A fire was started by a frontal collision of two HGVs in the Gotthard tunnel on the A2 between Göschenen and Airolo. Eleven people lost their lives in this catastrophe. In addition, eight fires occurred in the Gotthart tunnel in 2000. None of them were fatal.

18 January 2002 in Austria
A lorry with a damaged engine caught fire in the Tauern tunnel, producing a great deal of smoke. The rescue services were however quickly able to bring the fire under control. There were no injuries.

Accidents and fires in the test tunnels:
In 2001 the most accidents happened in the town tunnels in La Défense (72 accidents) and Britz (39 accidents), and in the Gotthard tunnel (45 accidents). In sixteen tunnels there were fewer than 10 accidents. In 2001 there were fires in eight of the tested tunnels: three in the Mersey Kingsway, and one each in the Gotthard (see above), Lainberg, Katschberg, Løvstakken, La Défense, Blackwall South and Tyne tunnels.

18 - Recommendations: how tunnel operators can ensure safety

Short term measures:

- Provide better information for users about safety and conduct in the tunnel in general, and about existing safety facilities in the tunnel in question (escape exits, emergency telephones, fire extinguishers, breakdown bays etc.)
- Enforce the keeping of safe distances between all vehicles travelling through the tunnel
- Avoid stationary traffic (construction sites, congestion) in the tunnel by suitable traffic management
- Improve communication facilities. It must become standard practice to channel new reports into radio traffic broadcasts using pre-recorded announcements in several languages for a range of situations (accidents, closures, fire). Loudspeakers should be installed in prominent places such as breakdown bays and connecting passages between neighbouring tubes
- Motorists should be informed of the reason why a tunnel is closed, for instance using variable traffic signs or signboards
- Indicate clearly escape routes and emergency exits
- Only allow vehicles transporting hazardous materials to use the tunnel after notification and when escorted, with a sufficient safety distance or during times of low-density traffic (for instance at night)
- Order thorough checks of tunnel safety by independent experts

Medium term measures, to be implemented within two to four years:

- Improve traffic management in order to avoid tailbacks in the tunnel, particularly in tunnels with high traffic density
- Agree and introduce internationally accepted pictograms for specific situations (e.g. maintenance/building works, accident, fire)
- Introduce and continually update synchronised plans for alarms and emergencies
- Ensure provision of optimum equipment and training under realistic circumstances for fire services
- Conduct regular practices for all emergency services in disaster procedures
- Check ventilation systems and ensure that they comply with modern standards
- Equip all tunnels longer than 1000 m with automatic fire warning systems; improve fire detection, for instance using combined systems (heat detectors along the tunnel and visibility measurements installed at particular points)
- Install break-down/emergency bays at sufficiently short intervals in all tunnels which do not have emergency lanes
- Install escape chambers or rescue areas in all long tunnels which do not offer additional escape routes (for instance by converting existing ventilation channels into escape routes)

Long term measures, to be implemented within ten years:

- Create escape and rescue routes: construct additional tunnels and links to an existing second tunnel at sufficiently small intervals
- Link existing escape chambers to external escape routes
- Add a second tube to single tube tunnels