The AA Motoring Trust

April 2003

EUROTEST 2003
TUNNEL TESTS
Safety of Road Tunnels in Europe

Results of the 2003 Pan-European Tunnel Testing Programme

Eurotest 2003 is a consortium of motoring organisations in Europe: The AA Motoring Trust (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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1 - Key points summary

* Twenty five 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 five years, the AA joined the consortium in 2000
* The tests were carried out between 3 February and 5 March 2003
* Overall winners were the Weserauen Tunnel near Porta, Westfalica in Germany and the Somport Tunnel that links France and Spain. Both tunnels achieved a 'very good' grade
* Overall loser was the Soller Tunnel on the island of Majorca in Spain, which rated 'very poor'
* The Rotherhithe Tunnel, despite being the best rated of the UK tunnels, was still rated 'poor'
* Blackwall Tunnel northbound was the worst rated UK tunnel, rated 'very poor'.

2 - Overall UK results

	European rankings	risk potential	per cent score	grade awarded
Rotherhithe	16	low	64.7	poor
Blackwall South	17	medium	64.0	poor
Tyne	18	medium	62.5	poor
Blackwall North	22	medium	59.8	very poor

The European rankings were calculated from a checklist of 8 categories with points allocated in each and weighted in importance (please see pages 21 to 23 for scoring schedule).

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*

(The way in which the level of risk was calculated is described on pages 24 and 25.)

3 - UK vs European ratings

	Number of tunnels given this rating	Number of UK tunnels given this rating
Very Good	3	0
Good	4	0
Acceptable	7	0
Poor	7	3
Very Poor	4	1
Total	25	4

4 - Overall European results – distribution by country

	Austria	Belgium	France	Germany	Italy	Nether lands	Norway	Spain	Switzer land	UK
Very Good			1**	1				(1**)	1	
Good			1	2					1	
Acceptable	4*				1		2			
Poor			1			1			2	3
Very Poor		1				1		1		1
Total	4	1	3	3	1	2	2	1	4	4

* Including one from Austria to Slovenia
** France to Spain

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; mechanical barriers for closing the tunnel.
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; prevention of smoke from entering external escape routes; external access for rescue personnel.
Fire	Fire protection equipment; fire alarm system (automatic and manual); fire extinguishers; drain-pipe system in traffic 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	Emergency response plans; 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	Weserauen	Germany	102.6	very good	low
2	Somport	France/Spain	97.0	very good	low
3	Pomy	Switzerland	90.8	very good	medium
4	Prado Carenage	France	86.6	good	low
5	4th tube of Elb	Germany	86.0	good	high
6	Petuelring	Germany	81.7	good	high
7	de Gorgier	Switzerland	80.5	good	medium
8	Ekeberg	Norway	79.9	acceptable	high
9	Gleinalm	Austria	76.6	acceptable	high
10	Franzensfeste	Italy	76.2	acceptable	medium
11	Karawanken	Austria/Slovenia	74.7	acceptable	medium
12	Perjen	Austria	73.9	acceptable	medium
13	Pfänder	Austria	72.6	acceptable	high
14	Festnings	Norway	70.1	acceptable	high
15	Ij	Netherlands	68.2	poor	medium
16	Rotherhithe	UK	64.7	poor	low
17	Blackwall South	UK	64.0	poor	medium
18	Tyne	UK	62.5	poor	medium
19	Piumogna	Switzerland	62.1	poor	medium
20	Nogent-sur-Marne	France	60.3	Poor	high
21	Milchbuck	Switzerland	60.3	Poor	high
22	Blackwell North	UK	59.8	very poor	medium
23	Maas	Netherlands	55.2	very poor	medium
24	Waasland	Belgium	50.0	very poor	low
25	Soller	Spain	39.1	very poor	medium

7 - Strengths and weaknesses of Blackwall Northbound Tunnel, London - Rating: Very poor

Location:	London
	City tunnel
Year built:	1897
Length:	1,350m
Portal height level:	0
Number of tubes:	One tube – 2 lanes one-way
Speed limit:	48 kph
Vehicles per day:	50,000
Share of HGVs:	5 per cent
Breakdowns in 2002:	173
Accidents in 2002:	6
Fires in 2002:	0
Risk:	Medium

Strengths:

- No hazardous goods transported through the tunnel
- Loudspeakers at the portals
- Well lit, bright tunnel walls due to enamel panelling
- Full video surveillance with cameras provided every 80 metres
- Emergency phones provided every 50 metres
- When an emergency call is made and as soon as a fire extinguisher is removed, a video camera is automatically activated
- Fire extinguishers provided every 50 metres
- Special ventilation programmes in the event of a fire that consider the longitudinal flow, fire ventilation is of sufficient dimensions
- Access for rescue teams from outside the traffic tubes
- Pressurized water pipe throughout and hydrants provided every 50 metres
- Fire brigade is well-trained and well-equipped
- Regular emergency drills
- Up-to-date emergency response plan

Weaknesses

- ☹ Heavy traffic, daily congestion
- ☹ Traffic lane is relatively narrow, measuring 2.9 metres in width
- ☹ Traffic radio cannot be received throughout the tunnel
- ☹ No automatic traffic detection system, but manually controlled traffic signals on the tunnel approaches
- ☹ No lay-bys, no emergency lane provided
- ☹ Emergency phones are neither clearly identified nor are they adequately protected against noise to the high standards now considered necessary
- ☹ No additional escape or rescue routes
- ☹ The escape route in the tunnel is not identified ie no signs
- ☹ No automatic fire alarm system but 24 hour manned surveylance
- ☹ When a fire is reported fire ventilation and closure of the tunnel is not automatically activated
- ☹ The cables in the traffic area are not designed to resist fire

Note:

- ◆ A study is currently underway that is looking into improving the safety standards of this tunnel.

8 - Strengths and weaknesses of Blackwall Southbound Tunnel, London - Rating: Poor

Location:	London
	City tunnel
Year built:	1967
Length:	1,174m
Portal height level:	0
Number of tubes:	One tube – two lanes one-way
Speed limit:	65kph
Vehicles per day:	50,000
Share of HGVs:	10 per cent
Breakdowns in 2002:	16
Accidents in 2002:	3
Fires in 2002:	0
Risk:	Medium

Strengths:

- Traffic management in front of the tunnel
- No hazardous goods transported through the tunnel
- Well lit, bright tunnel walls due to enamel panelling
- Full video surveillance with cameras provided every 120 metres
- Emergency phones provided every 50 metres
- When an emergency call is made or as soon as a fire extinguisher is removed, a video camera is automatically activated
- Fire extinguishers provided every 50 metres
- Automatic fire alarm system
- Special ventilation programmes in the event of a fire that consider the longitudinal flow, fire ventilation is of sufficient dimensions
- Access for rescue teams from outside the traffic tubes
- Pressurized water pipe throughout and hydrants provided every 50 metres
- Fire brigade is well-trained and well-equipped
- Regular emergency drills
- Up-to-date emergency response plan

Weaknesses

- ☹ Heavy traffic, daily congestion
- ☹ Traffic radio cannot be received throughout the tunnel
- ☹ No lay-bys, no emergency lane provided
- ☹ Emergency phones are neither clearly visible nor are they adequately protected against noise to the high standards now considered necessary
- ☹ No loudspeakers
- ☹ No additional escape or rescue routes
- ☹ The escape route direction in the tunnel is not identified ie no signs
- ☹ When a fire is reported, neither fire ventilation is automatically activated nor is the tunnel closed automatically
- ☹ The cables in the traffic area are not designed to resist fire

Note:

- ◆ Many of the deficiencies listed above should be rectified as part of the £15M refurbishment programme currently being undertaken in the southbound tunnel. The works are due for completion early next year.

9 - Strength and weakness of Rotherhithe Tunnel, London - Rating: Poor

Location:	London
	City tunnel
Year built:	1905
Length:	1,483m
Portal height level:	10m above sea level
Number of tubes:	One tube - 2 lanes two-way traffic
Speed limit:	32kph
Vehicles per day:	33,000
Share of HGVs:	0
Breakdowns in 2002:	27
Accidents in 2002:	6
Fires in 2002:	0
Risk:	Low

Strengths:

- Ban on HGVs and the transport of hazardous goods
- Speed limit is monitored
- Full video surveillance with cameras provided every 100 metres
- Emergency phones provided every 50 metres
- Walkways for pedestrians used as emergency walkways, sufficiently wide
- Fire extinguishers provided every 50 metres
- Automatic fire alarm system
- Special ventilation programmes in the event of a fire that consider the longitudinal flow, fire ventilation is of sufficient dimensions
- Access for rescue teams from outside the traffic tubes
- Pressurized water pipe throughout and hydrants provided every 50 metres
- Fire brigade is well-trained and well-equipped
- Regular emergency drills
- Up-to-date emergency response plan

Weaknesses

- One tube with two-way traffic
- Heavy traffic, daily congestion, but no heavy goods vehicles
- Traffic lane is relatively narrow, measuring 2.45 metres in width
- Road edges and centre line are poorly marked
- Traffic radio cannot be received throughout the tunnel
- No automatic traffic detection system
- No lay-bys, no emergency lane provided
- Emergency phones are not adequately protected against noise to the high standards now considered necessary
- No loudspeakers
- When an emergency call is made or a fire extinguisher is removed, no video cameras are automatically activated
- No additional escape or rescue routes
- No signs showing the escape route direction in the tunnel, nor is emergency lighting provided
- The tunnel is not closed automatically when a fire is reported
- Details of the proper functioning of fire ventilation, fire trials or through flow measurements could not be provided (please see below)
- The cables in the traffic area are not designed to resist fire

Note:

- A study is currently underway that is looking into improving the safety of the Rotherhithe Tunnel.
- The tunnel was taken over by Transport for London last year and details of the fire ventilation system had not been passed on to the authority. Proving trials of the system are being arranged.

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

Location:	Great Britain / in Newcastle City tunnel
Year built:	1967
Length:	1,692m
Portal height level:	12m above sea level
Number of tubes:	1 tube - two-way traffic
Speed limit:	48kph
Vehicles per day:	38,000
Share of HGVs:	8 per cent
Breakdowns in 2002:	194
Accidents in 2002:	10
Fires in 2002:	0
Risk:	Medium

Strengths:

- ☺ Hazardous goods must be reported to the tunnel control centre, an escort vehicle is provided for certain classes of hazardous goods, ban on certain hazardous goods
- ☺ Loudspeakers at the portals
- ☺ Traffic radio throughout the tunnel that can be interrupted for additional messages
- ☺ Full video surveillance with cameras provided every 80 metres
- ☺ Emergency phones provided every 47 metres
- ☺ Fire extinguishers provided every 47 metres
- ☺ Automatic fire alarm system via CO sensors
- ☺ Special ventilation programmes in the event of a fire, fire ventilation is of sufficient dimensions, correct functioning of fire ventilation confirmed in fire trial
- ☺ Pressurized water pipe throughout and hydrants provided every 47 metres
- ☺ Dedicated rescue teams available 24 hours a day in the event of an emergency
- ☺ Fire brigade is well-trained and well-equipped
- ☺ Regular emergency drills
- ☺ Up-to-date emergency response plan

Weaknesses

- ☹ One tube with two-way traffic
- ☹ Heavy traffic, daily congestion
- ☹ No traffic management in front of the tunnel
- ☹ No lay-bys, no emergency lane provided
- ☹ Emergency phones are not protected against noise
- ☹ Emergency walkways are relatively narrow, measuring only 50 centimetres in width
- ☹ No automatic traffic detection system
- ☹ When an emergency call is made or a fire extinguisher is removed, no video cameras are automatically activated
- ☹ No additional escape or rescue routes
- ☹ No signs showing the escape route direction in the tunnel, nor is emergency lighting provided
- ☹ The tunnel is not closed automatically when a fire is reported

Plans for the future:

- ◆ A proposal for a second tunnel is currently under scrutiny at a Public Inquiry.
- ◆ Extensive refurbishment of the existing tunnel is proposed.

11 - Results: analysis and evaluation

This winner of the 2003 Tunnel Test was a German tunnel: Weserauen Tunnel near Porta Westfalica/ Minden, which first went into operation in 2002, was given a clear rating of "Very good" and based on the current state of the art, this tunnel comes pretty close to the ideal concept for a safe tunnel. In addition to this, the risk of having an accident while driving through this tunnel is low. The two runners up were also rated as "Very good". Somport Tunnel came second – a transboundary tunnel linking Zaragoza in Spain and Pau in France - this tunnel was completed early 2003, and also has a low risk. Third place was achieved by Pomy Tunnel near Yverdon in Switzerland - this tunnel was opened in 2001, and yet the risk potential for this tunnel was classified as "medium".

Four of the 25 European test tunnels were rated as "Good". Seven tunnels were located mid-field and given a rating of "Acceptable". Six tunnels did badly and were rated as "Poor" and five tunnels were rated as "Very poor". Lagging far behind and coming last in this year's test is Spain's Sóller Tunnel between Palma and Sóller on the island of Majorca.

The risk potential was classified as "High" for eight tunnels, as "Medium" for twelve tunnels (including Sóller Tunnel which came last) and as "Low" for five tunnels. This meant that none of the tunnels in this year's test were found to have either a "Very high" or "Very low" risk potential.

Evaluation of specific categories: Tunnel system

The tunnel system was found to be "Very good" in six of the tunnels: Weserauen Tunnel, the 4th tube of Elb Tunnel, the Gleinalm, Ekeberg, Somport and Pomy tunnels. Blackwall Tunnel, northbound and southbound, the Rotherhithe, Tyne, Ij, Maas, Milchbuck, Waasland and Franzensfeste tunnels were classified as "Very poor".

Fourteen of the tunnels inspected have two tubes and Elb Tunnel has four. In the same number of tunnels, the traffic lanes were found to be sufficiently wide, measuring more than 3.5 metres in width. In Blackwall Tunnel, northbound, the lane is only around 2.90 metres wide, and in Rotherhithe Tunnel only around 2.45 metres wide.

Only two tubes have emergency lanes throughout, 13 tunnels have lay-bys. Neither lay-bys nor emergency lanes are provided in the following tunnels: Blackwall Tunnel, northbound and southbound, the Rotherhithe, Tyne, Ij, Maas, Milchbuck, Waasland and Franzensfeste tunnels.

20 tunnels feature emergency walkways on both sides. These walkways are provided on one side only in Blackwall Tunnel, northbound, and in the Ij, Maas and Waasland tunnels. Nogent-sur-Marne tunnel has no separate emergency walkway, but at least an emergency lane is provided. In the 4th tube of Elb Tunnel, as well as in the Sóller, Tyne, Maas and Franzensfeste tunnels, the emergency walkways are less than 70 centimetres wide.

Condition:

The condition was found to be "Very good" in ten tunnels and "Good" in eight tunnels. The Sóller and Piumogna tunnels were found to be "Poor" in this category, above all, due to the relatively poor lighting for traffic lanes and the lack of markings for the right shoulder.

All of the tunnels inspected are illuminated throughout and feature adaptation zones at entrances and exits which enable motorists to become accustomed to the changing lighting conditions. The lighting equipment as well as the traffic and information signs are usually clean. In Nogent-sur-Marne Tunnel, several signs for emergency phones and emergency exits are either defective or destroyed.

The lane markings in most tunnels were found to be in a good condition, some improvements were found to be necessary in this respect in the Gleinalm and Karawanken tunnels. No serious shortcomings in road surface were found in any of the tunnels. The right shoulder and the centre line, in particular, in tunnels with two-way traffic, ie the Gleinalm, Karawanken, Perjen, Pfänder, Somport and Milchbuck tunnels, were well-marked with cats' eyes, LEDs, etc; only the Sóller and Rotherhithe tunnels were found to be lacking here.

Evaluation of specific categories: Traffic and traffic surveillance

Traffic and traffic surveillance was found to be "Very good" in the Weserauen, Somport and Prado Carénage tunnels. On the other hand, "Very poor" was awarded eight times: to the Pfänder, Festnings, Sóller, Tyne, Milchbuck, Piumogna, Gorgier and Waasland tunnels.

The two-tube tunnels, including Blackwall Tunnel, have one-way traffic, the tunnels with one tube have two-way traffic. Fourteen of the tunnels tested are located in city areas. Most of these tunnels are congested most days.

In the Elb, Gleinalm, Pfänder and Nogent-sur-Marne tunnels, HGV mileage totals more than 10,000 km per day and tube. HGVs over 3.5 tonnes have no access to the Rotherhithe, Prado Carénage and Waasland tunnels. In Somport tunnel, all HGVs undergo visual inspection at the Spanish end and no more than two buses are permitted to drive through the tunnel at any one time.

The transport of hazardous goods through the tunnels is handled in different ways. Eight of the tunnels have a general ban on the transport of hazardous goods: the Weserauen, Somport, Blackwall, northbound and southbound, Rotherhithe, Maas, Prado Carénage and Waasland tunnels. The Tyne, Ij and Nogent-sur-Marne tunnels have bans on certain hazardous goods, in the Gleinalm, Karawanken, Pfänder, Tyne and Franzensfeste tunnels, hazardous goods transports that have been approved must be escorted. Hazardous goods can only be transported through the Elb, Ekeberg and Festnings tunnels at certain times. In four tunnels, the transport of hazardous materials must be reported to the tunnel control centre. In the Petuel, Perjen, Milchbuck, Piumogna, Gorgier and Pomy tunnels, there are no restrictions whatsoever on the transport of hazardous goods.

The speed limits differ in the tunnels tested. These range from 32 kph in Rotherhithe Tunnel and 100 kph in Switzerland's Piumogna, Gorgier and Pomy tunnels. Only a few tunnels have equipment for monitoring speed. Instructions concerning the safety distance to be kept to the vehicle ahead or especially between HGVs both in front of the portals and at times in the tunnel are only provided in the Gleinalm and Somport tunnels.

Except for Waasland tunnel, all the tunnels have control centres that are manned around the clock. In Blackwall Tunnel, northbound and southbound, as well as in Rotherhithe Tunnel, this task is carried out by the police. Weserauen Tunnel is monitored by a traffic control centre. In some cases, the tunnels are monitored parallel by both the tunnel operator and the police.

Nine tunnels are able to influence traffic in front of the tunnel entrances. This is partially computerised, by adjusting speed using variable traffic signs or by controlling traffic at the tolls by dispatching vehicles in batches.

The majority of the test tunnels have traffic lights installed, as well as variable traffic signs, both in front of the entrances and in the tunnel. Nineteen tunnels have barriers at the portals that are used to close the tunnel.

The majority of the tunnels have a sufficient number of video cameras, so that the entire tunnel can be monitored throughout. The video cameras are between 65m apart in the Maas Tunnel and around 350m apart in the Franzensfeste Tunnel. In the Petuel and Waasland tunnels, there are short stretches that cannot be monitored. There are no video surveillance systems at all in the Sóller and Piumogna tunnels. Fourteen tunnels have systems that automatically detect congestion in the tunnel using induction loops or video systems.

Evaluation of specific categories: Communication

Communication systems were found to be "Very good" in Weserauen Tunnel, the 4th tube of Elb Tunnel, Ij Tunnel and in Somport Tunnel. Eight tunnels were rated as "Very poor": Sóller Tunnel, Blackwall Tunnel, northbound and southbound, the Rotherhithe, Maas, Nogent-sur-Marne, Waasland and Franzensfeste tunnels.

With the exception of Sóller tunnel, Blackwall Tunnel, northbound and southbound, the Rotherhithe, Maas and Nogent-sur-Marne tunnels, traffic radio can be received throughout all the tunnels inspected. (The refurbishment programme for the Blackwall southbound Tunnel will rectify this.) In the majority of tunnels, it is also possible for the control centre to interrupt traffic radio in order to broadcast additional messages. This is not possible in the de Gorgier, Piumogna and Waasland tunnels.

With the exception of Franzensfeste tunnel, all the tunnels feature emergency phones with the shortest distance between these phones measuring 30 metres in Ij Tunnel and the longest distance measuring 600 metres in Petuel Tunnel. In the case of Franzensfeste Tunnel, emergency phones are provided in front of the portals. Signs for emergency phones are poor in Blackwall Tunnel, northbound and southbound, Maas Tunnel and Nogent-sur-Marne Tunnel, and emergency phones are protected against noise in twelve tunnels only.

In eighteen tunnels, as soon as an emergency phone is used, the nearest video camera is activated, so that the tunnel control room can immediately see what is happening. In Gleinalm Tunnel, the tunnel is also closed, in the Somport, Piumogna and Weserauen tunnels, the speed limit in the tunnel is reduced. In nine tunnels, the lighting is also switched to full power.

The provision of loudspeakers also differs considerably in the tunnels. The Pfänder, Ij, Petuel, the 4th tube of Elb Tunnel and Weserauen tunnels have loudspeakers installed throughout the tunnels. The Gleinalm and Somport tunnels have loudspeakers at least in lay-by areas. Blackwall Tunnel, northbound, Tyne Tunnel and Maas Tunnel have loudspeakers installed at the portals only, and fifteen tunnels have no loudspeakers at all.

Evaluation of specific categories: Escape and rescue routes

The escape and rescue facilities were found to be "Very good" in the Weserauen, Petuel, Somport, Gorgier, Pomy and Prado Carénage tunnels. On the other hand, "Very poor" was awarded to the Gleinalm, Karawanken, Perjen, Pfänder, Sóller tunnels, Blackwall Tunnel, northbound and southbound, as well as to the Rotherhithe, Tyne, Milchbuck, Piumogna and Waasland tunnels.

With the exception of Blackwall Tunnel, all the two-tube tunnels have cross-connections leading to the neighbouring tube or to an additional safety gallery. With the exception of Piumogna, these cross-connections can also be used as escape routes. The two tubes of Blackwall Tunnel that were separately evaluated in the test are not connected to each other. The Petuelring and Prado Carénage tunnels as well as Weserauen tunnel and the 4th tube of Elb Tunnel have additional emergency exits to the open. Of the one-tube tunnels, only Somport Tunnel has a parallel safety gallery, an old railway tunnel. The Gleinalm, Karawanken, Perjen, Pfänder, Sóller, Tyne, Milchbuck and Waasland tunnels have no additional escape and rescue routes.

Additional access for rescue services is guaranteed via cross-connections to the neighbouring tube or to the safety gallery. These routes can sometimes also be accessed by rescue vehicles. The existing cross-connections in the Piumogna Tunnel are at least used for rescue services. Separate access for rescue services is also provided in Blackwall Tunnel, northbound and southbound, as well as in Rotherhithe Tunnel.

The distance between emergency exits was found to be sufficient in nine tunnels, ie less than 300 metres. The distance in Petuel Tunnel is only 60 metres. On the other hand, the distance measured in Somport Tunnel and in the 4th tube of Elb Tunnel was relatively long, totalling 800 or 500 to 1,000 metres respectively.

The signs for emergency exits are poor in the Maas, Nogent-sur-Marne and Prado Carénage tunnels. Lighting indicating escape routes, ie lamps fitted at a height of around 1m on the tunnel wall, etc, is provided in fifteen tunnels.

Evaluation of specific categories: Fire

The measures in place for fire incidents were found to be "Very good" in Weserauen Tunnel, the 4th tube of Elb Tunnel, as well as in the Gleinalm, Karawanken, Perjen, Pomy and Franzensfeste tunnels. The Sóller, Ij, Maas and Nogent-sur-Marne tunnels were found to be "Very poor" in this respect.

Thirteen tunnels have sheathing that prevents large-scale flaking of concrete in the event of a fire. Power supply cables are usually safely fitted in a sand bed under emergency walkways or in special cable ducts. Cables that enter the traffic area, for example, that are connected to fans, usually have the required fire resistance class. In Sóller Tunnel, Blackwall Tunnel, northbound and southbound, the Rotherhithe, Milchbuck, Piumogna and Waasland tunnels, these cables do not have the required fire resistance or information concerning this was not available.

Fire extinguishers are installed in all the tunnels tested. These are also regularly serviced. The recesses for these fire extinguishers were no more than 150 metres apart in the case of 20 tunnels. The shortest distance of 30 metres was found in Ij Tunnel and the longest of 300 metres was measured in Sóller Tunnel.

In seventeen tunnels, as soon as a fire extinguisher is removed, the nearest video camera is automatically activated. This permits the tunnel control room to evaluate the situation. In the Gleinalm, Pfänder and Piumogna tunnels, the fire programme is also activated, ie the tunnel is closed and fire ventilation is triggered, all immediately and automatically.

In the Festnings and Sóller tunnels, in Blackwall Tunnel, northbound, in the Ij, Maas and Waasland tunnels, automatic fire detection and reporting is not provided. Rather than using a line fire-alarm cable, Tyne Tunnel uses the existing CO sensors to detect fires, Nogent-sur-Marne uses visibility impairment measuring equipment, whilst local fire alarm devices are used in Piumogna Tunnel. In the

Ekeberg and Prado Carénage tunnels, the video surveillance system that can detect any vehicle that has come to a halt in the tunnel within a matter of seconds is also used to report fires.

The majority of the tunnels inspected have a pressurized water pipe and hydrants installed at sufficiently short intervals. This is not the case in Sóller Tunnel; here, the fire brigade carries its own extinguishing water. Nine tunnels have slot-gutter systems of sufficient dimensions that permit the quick draining of flammable liquid and hence the spatial restriction of the fire zone.

The distance which fire brigades have to cover ranges between 0.6 km in Elb Tunnel and 22 km in the Somport and Gorgier tunnels. In most of the tunnels, the time which fire brigades need to reach the tunnel is less than 15 minutes and only five to ten minutes in some tunnels. The only exception is Somport Tunnel where rescue services require 20 minutes according to the tunnel operator. Elb Tunnel has its own dedicated fire brigade, in this case stationed at the portals, as does Piumogna Tunnel. In this case, the fire brigade is stationed at the southern portal of the nearby Gotthard Tunnel. The Tyne and Somport tunnels have staff specifically at hand for first-aid.

The fire brigades carry out regular drills in most of the tunnels, at least once a year in eighteen tunnels and every 1.5 to two years in three of the tunnels. In the Ij and Waasland tunnels, no regular drills are carried out, and in Nogent-sur-Marne Tunnel, this takes place every three years. Almost all the fire brigades carry out training under simulated conditions, for example, using artificial smoke, but not under real "hot" conditions like those that would prevail in an emergency in the tunnel. The fire brigades are generally well-equipped. They all have suitable equipment for rescuing injured people from vehicles, respiratory protection and suitable extinguishing equipment. In some cases, however, respiratory protection failed to meet with the special requirements for fighting tunnel fires that demand at least 2 hours of use. More than half of the fire brigades have heat-picture cameras.

Evaluation of specific categories: Fire ventilation

Weserauen Tunnel, the 4th tube of Elb Tunnel, the Gleinalm, Karawanken, Perjen, Pfänder, Somport tunnels, Blackwall Tunnel, northbound and southbound, as well as the Rotherhithe, Tyne, Gorgier, Pomy and Franzensfeste tunnels were found to be "Very good". The Sóller, Ij, Maas, Piumogna, Nogent-sur-Marne and Waasland, on the other hand, were found to be only "Very poor".

All the tunnels in the test have mechanical ventilation. In most of the tunnels, ventilation is activated on the basis of a defined programme whilst the location of the fire zone is also usually taken into consideration. Only the Sóller and Waasland tunnels fail to meet with this criterion. In six tunnels, the longitudinal flow of air in the tunnel is not monitored and in seven tunnels, the proper functioning of fire ventilation was neither checked in fire trials, nor in smoke trials, nor using flow measurements.

Longitudinal ventilation is carried out in the event of fire in twelve tunnels, on the other hand, some tunnels use intermediate shafts to exchange air. With longitudinal ventilation, smoke and fumes in the traffic area of the tunnel are pushed to the exit or to the intermediate shafts. In order to control smoke spread, it is vital that the air flow speed in the longitudinal direction of the tunnel is high enough. All of these tunnels meet with this criterion. The length of the ventilation section in which smoke can spread was estimated to be too large, however, in the case of Sóller Tunnel. The fans can be reversed in all the tunnels.

In thirteen tunnels, smoke can be extracted from the tunnel tubes. The fans are usually strong enough, their performance, however, in the Somport, Ij and Nogent-sur-Marne tunnels is too weak. Smoke extraction is particularly effective when the vents that are normally located in the tunnel ceiling are opened fully near the fire zone and closed fully away from the fire. This is possible in the

Gleinalm, Karawanken, Perjen, Pfänder, Somport, Gorgier tunnels and in the 4th tube of Elb Tunnel. Particularly in older tunnels, the exhaust air vents can be neither automatically opened nor closed; this is the case in the Ij, Maas, Milchbuck, Nogent-sur-Marne, Prado Carénage and Waasland tunnels.

Evaluation of specific categories: Incident management

Incident management was found to be "Very good" in Weserauen Tunnel, in the 4th tube of Elb Tunnel, as well as in the Petuel, Somport, Gorgier and Pomy tunnels. This was found to be "Very poor", however, in the Sóller, Ij, Maas and Waasland tunnels.

In most tunnel control rooms, updated emergency response plans are in place to deal with incidents, ie congestion, accident, fire, etc. The negative exceptions to this are Waasland Tunnel which has no emergency response plan at all, and the Maas and Milchbuck tunnels where the plans are out of date.

In more than half of the tunnels, as soon as a fire is detected and/or reported, fire ventilation is activated and the tunnel is closed. In some tunnels, the fire brigade is also notified immediately. In order to avoid false alarms, the control centres sometimes intervene here.

In twenty-one of the tunnels tested, emergency drills are carried out regularly; this is not the case in the Ij, Maas, Milchbuck and Nogent-sur-Marne tunnels. Safety equipment is usually examined on a regular basis by internal and/or external specialists.

12 - EuroTest: why we test tunnels

EuroTest is the consumer testing programme funded and managed by Europe's motoring organisations, and the inspection of road tunnels has 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 major 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 or a lorry on 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 systems designed to control emergencies can almost always be improved. But of the 25 tunnels tested only seven were judged to be 'very good' or 'good', suggesting a continuing need for substantial investment in many of Europe's road tunnels.

The five years of tunnel tests in the EuroTest programme have raised awareness of tunnel safety and have exposed weaknesses. In response, the European Commission has issued guidelines for co-ordinated minimal safety standards applicable throughout Europe. In many countries improvements and renovations are taking place. In the UK, in response to last year's EuroTest tunnel survey, the Merseyside Passenger Transport Authority announced a £14 million scheme to provide a pedestrian escape route alongside the Liverpool/Birkenhead Tunnel. On Tyneside there is a Public Inquiry underway to build a second tunnel, to provide two one-way tubes. However, more investment is required at many of Europe's tunnels in order to achieve the highest possible safety standards.

14 - EuroTest methodology: how we tested

Twenty five tunnels were selected for inspection, located in eleven European countries: Austria, Switzerland, France, Italy, Belgium, the Netherlands, Spain, Great Britain, Norway, Slovenia and Germany. The Karawanken Tunnel (Austria / Slovenia) and Somport Tunnel (Spain / France) are two transboundary tunnels.

In Germany, two city tunnels, ie Petuelring Tunnel (B 2R in Munich) and the 4th tube of Elb Tunnel (A 7 in Hamburg) were inspected, and one above-ground tunnel, Weserauen Tunnel (B 61n near Porta Westfalica).

Follow-up tests to the inspections carried out in 2002 were performed in the Gleinalm, Perjen, Pfänder, Karawanken, Blackwall (northbound and southbound) and Tyne tunnels.

The German Montan Technologie GmbH (DMT) was once again engaged to conduct the tunnel tests. 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, and provision of ventilation and rescue plans. DMT, together with its subsidiary Risc Ruhr, also operates a state-of-the-art training centre for fire services where fire personnel can be trained in fire fighting in tunnels and buildings under realistic fire conditions.

The experts from DMT inspected the 25 test tunnels between 3 February and 5 March 2003 using a standard checklist. During these tests, safety-relevant questions for the tunnels in question were discussed on site with the respective operators. Additional information, for example special measures, updating, and changes in tunnels are listed under the individual tunnel descriptions, but they were not taken into consideration in the final evaluation. In advance of the test, a check list was sent to tunnel managers to obtain the most important technical data about the tunnels.

The check list provides an objective foundation for evaluating tunnel safety and is based on the high standards for road tunnels in Germany and Austria, and on the draft EU directive on minimum safety standards for tunnels in the Trans-European Transport Network.

This check list contains the most important safety related aspects and is broken down into the following eight key areas:

- **Tunnel system** — Weighting 10.3 per cent
  - Number of tubes
  - Tunnel route
  - Width of traffic lanes / emergency walkways
  - Layout of emergency lanes / lay-bys
- **Condition** — Weighting 9.3 per cent
  - Lighting
  - Signposting
  - Road surface and markings
- **Traffic and traffic surveillance** — Weighting 19.3 per cent
  - Type of traffic (unidirectional / bi-directional traffic)
  - Congestion in the tunnel
  - Restrictions for and/or registration of vehicles carrying hazardous goods
  - Special measures for HGV traffic
  - Monitoring the safety distance between vehicles as well as the driving speed
  - Speed limit
  - Safety post
  - Traffic control (traffic lights, variable message signs, signs, etc.)
  - Video surveillance
  - Automatic detection of congestion
  - Automatic detection of vehicles carrying hazardous goods
  - Mechanical barriers for closing the tunnel
  - Height check
  - Information for detours/bypasses when tunnel is closed
- **Communication** — Weighting 10.0 per cent
  - Loudspeakers, traffic radio
  - Language
  - Emergency phones (signs, functions, noise protection)
- **Escape routes** — Weighting 13.1 per cent
  - Distance between emergency exits
  - Signs for emergency exits

- Emergency lighting and escape route signs in the tunnel
- Prevention of smoke from entering the external escape routes
- Fire resistance / ventilation
- Special measures
- External access for fire and rescue services
- Access routes for fire and rescue services

➢ Fire protection Weighting 20.7 per cent

- Fire protection on the tunnel structure, fire resistance of cables
- Fire alarm systems (automatic / manual)
- Extinguishing systems (arrangement, signs, functions)
- Slot-gutter system
- Distance to be covered and time needed for fire service
- Fire service training and equipment

➢ Fire ventilation Weighting 10.0 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 correct functioning in fire trials and flow measurements
- Longitudinal ventilation
    - Airflow rate
    - Length of ventilation sectors
    - Reversible fans
- Transverse / semi-transverse ventilation
    - Volume flow of extraction
    - Capacity to control longitudinal flow
    - Opening / closing of the exhaust air outlets can be controlled

➢ Emergency management Weighting 7.3 per cent

- Emergency response plans
- Automatic linking of the systems
- Regular emergency drills
- Regular inspection of safety equipment (internal / external)

The resultant evaluation then provides a reference value for safety that is subsequently correlated with the existing **risk potential.**

The risk potential is evaluated in terms of quality and quantity on the basis of the related examinations by DMT on behalf of the Federal Highway Research Institute (BASt) as well as the experience gained in the previous tunnel tests. The following parameters are also taken into consideration with different weighting:

➢ Annual traffic performance (derived from traffic density and tunnel length)	10 risk points max.
➢ HGV traffic performance per day and tunnel tube	10 risk points max.
➢ Type of traffic (one-directional/two-directional traffic)	4 risk points max.
➢ Traffic volume (vehicles per hour and lane)	5 risk points max.
➢ Transport of hazardous goods	5 risk points max.
➢ Maximum longitudinal gradient in the tunnel	4 risk points max.
➢ Additional risks, such as entrances, exits and intersections in the tunnel or in the downstream area as well as long gradients in front of the tunnel	3 risk points max.

The risk points for the parameters above are added together and classified as follows:

➢ Very low risk	4 to 10 risk points
➢ Low risk	11 to 7 risk points
➢ Medium risk	18 to 24 risk points
➢ High risk	25 to 31 risk points
➢ Very high risk	more than 31 risk points

In the overall evaluation, safety is evaluated as follows: tunnels with a very high risk potential receive 100 per cent of the overall number of points calculated for safety potential, tunnels with a high risk potential receive 95 per cent, tunnels with a medium risk potential 90 per cent, tunnels with a low risk potential 80 per cent and tunnels with a very low risk potential 70 per cent.

This form of risk assessment is also based on the following considerations:

- The greater the traffic performance the higher the number of accidents and fires. The accident statistics analysed for the tunnels already inspected confirm this (see Fig 1). A very long period of time is required in order to statistically evaluate fires because such incidents are rare events in most tunnels.

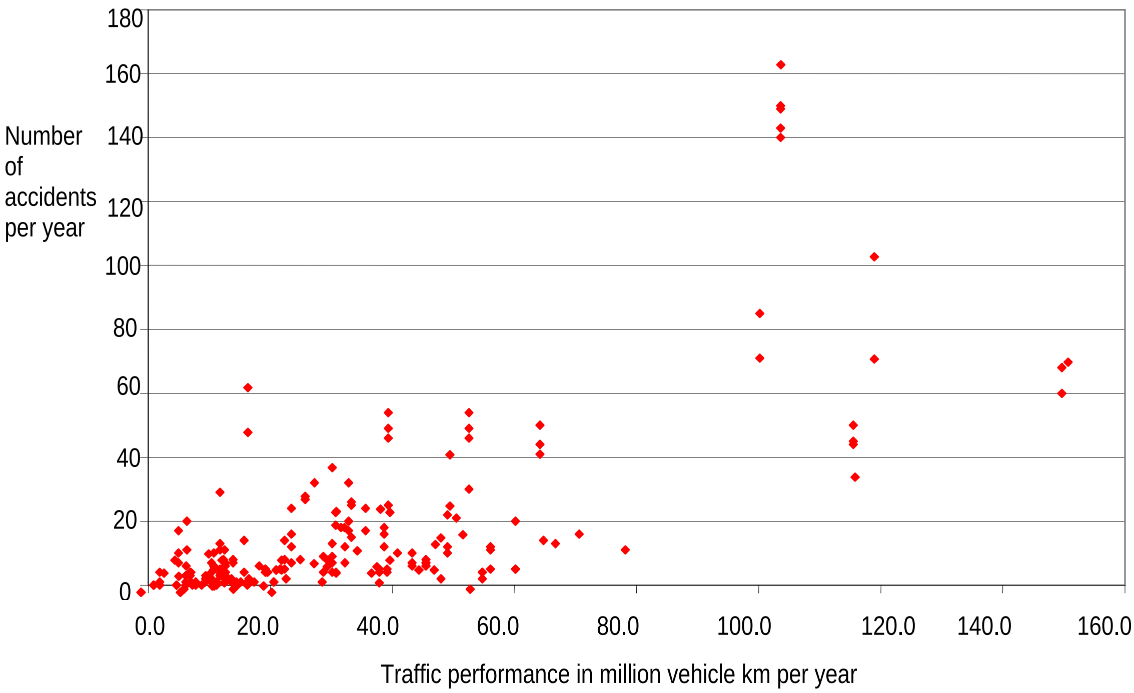

Fig 1: The number of accidents in relation to traffic performance for the 1999 to 2003 tunnel tests

- The greater the proportion of HGVs or the higher the number of HGVs, the greater the likelihood of a major fire. Combined with human error on the part of tunnel users and incorrect decisions by safety personnel in the tunnel, this can lead to major disasters (as seen with the Montblanc Tunnel, the Tauern Tunnel and the Gotthard Tunnel).

- The longitudinal gradient of a tunnel influences the spreading of smoke. The greater the gradient, the stronger the thermal lift and hence the more smoke can spread, particularly until fire ventilation becomes effective.

Furthermore, longer tunnel stretches with gradients can lead to brakes and engines overheating, particularly in the case of HGVs, and hence to the greater likelihood of a fire breaking out.

- Type of traffic (one-way or two-way traffic) and traffic conditions (slow-moving traffic/congestion in the tunnel, every day or rarely) influence the escape and rescue situation as well as the choice of ventilation system. With one-way traffic, no congestion throughout the tunnel, and with longitudinal ventilation systems, those vehicles located behind the fire zone can leave the tunnel without any risk. The vehicles in front of the fire zone can be protected by extracting the smoke in a single direction, in the direction of existing traffic.

  In the case of two-way traffic, or one-way traffic with congestion, vehicles may be located at both sides of the fire zone and unable to easily leave the tunnel. This places high demands on the ventilation system (suitable smoke extraction) and escape routes.

  Furthermore, the risk of serious accidents (eg head-on crash) is greater in the case of two-way traffic as took place in 2001, particularly in the Gleinalm and Amberg tunnels in Austria.

- When a vehicle carrying hazardous goods is involved in a fire, this can lead to a disaster due to high calorific values and the formation of an extremely toxic atmosphere (for example, in 1982 in Caldecott Tunnel in California with seven fatalities; in 1979 in Nihonzaka Tunnel in Japan with seven fatalities). This means that the unrestricted transport of hazardous goods as well as a high number of HGVs are likely to boost the likelihood of a major fire (disaster).

Risk is generally described by a probability statement that considers the expected frequency of events that lead to an incident (accident, fire) and the extent of damage expected when such incident takes place.

The safety potential evaluated in the test includes the sum of all safety-relevant measures (structural, technical, organisational) that both prevent (preventive measures) and stem the extent of such incidents.

Testing

As in previous years, a data list was sent to tunnel operators in advance, listing the most important technical parameters of a tunnel.

Between 3 February 2003 and 5 March 2003, three experts from DMT made pre-planned visits to 25 tunnels and inspected them, in cooperation with tunnel managers. Apart from the visual impression, the random checking of safety equipment (eg emergency equipment, hydrants, fire extinguishers), the experts spoke with the tunnel operators on site and discussed safety relevant issues for the respective tunnels. Additional data, in particular, measures to be adopted by the operator, retrofitting and planned changes in the tunnel are largely included in the presentation of individual results,. However, these aspects were not taken into consideration in the safety evaluation of the individual tunnels, ie the safety evaluations are those at the time of the inspections.

Evaluation

The tunnel test protocols were evaluated by Deutsche Montan Technologie GmbH and the results were compiled in table form. All the data was carefully checked and the three experts compared the individual data.

The areas of the tunnel system, the condition, the traffic and traffic surveillance are essentially the preventative measures; escape routes and fire ventilation are the self-rescue and rescue measures; fire protection, crisis management and communication measures are 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 in recent years, 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-way or two-way) and traffic conditions (slow-moving traffic/congestion in the tunnel, every day or rarely) influence the escape and rescue opportunities, 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 head-on 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 German 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, 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

16 - International co-operation with other automobile clubs

The test of 25 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). 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
12.9 million members
website: www.AAtrust.com

In Germany

ADAC
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

RACCatelonia
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.

18 - Recommendations: how tunnel operators can ensure safety

The recommendations below include short-term, medium-term and long-term measures.

Short-term

- Traffic standstills (construction sites, congestion) in the tunnel must be avoided using suitable traffic management measures.
- A ban on the transport of hazardous goods is not a general solution to the problem. In the case of tunnels with two-way traffic and tunnels with heavy traffic loads, special measures, such as escort vehicles in order to ensure sufficient safety distance, or permitting transports during off-peak times, are useful. Staff in the tunnel control rooms should be informed when hazardous goods are being transported through the tunnel in question.
- Users must be given more information, ie general information on safety and correct behaviour in tunnels and specific information on the safety equipment and facilities provided (emergency phones, fire extinguishers, emergency lanes, etc.) (This is a task for tunnel operators in co-operation automobile clubs and driving schools).
- Communication must be improved; the feeding of messages into traffic radio should be a standard feature with standardised messages in several languages used for different situations (accident, closure, fire). Loudspeakers should be installed at readily visible points, eg in emergency lanes and cross-connections between neighbouring tubes.
- Escape routes and emergency exits should be clearly marked.
- Orientation in the tunnel must be improved. This means that lighting should be designed, taking the tunnel walls into consideration, when necessary, in conjunction with the respective paint or panelling on the tunnel walls. The hard shoulder should also be clearly marked (eg using LEDs). Furthermore, sufficiently large markings (eg on emergency telephone recesses or emergency doors) should inform tunnel users of their location within the tunnel.
- When a tunnel is closed, tunnel users should be informed of the reason for the closure (eg using variable traffic signs or variable message signs). This should create greater acceptance for these measures. Furthermore, traffic management should be designed in such a manner that suitable detour routes can be displayed immediately.
- Tunnel safety should be regularly examined by independent experts.

Medium-term (within 2 to 4 years)

- Improving traffic-management measures, particularly in tunnels with heavy traffic in order to avoid congestion in the tunnel
- Ventilation systems must be checked and brought in line with today's standard for ventilation and fire ventilation.
- All longer tunnels (1,000 metres and longer) should be equipped with automatic fire alarm systems; detection of fires should be improved, eg using combined systems (thermal line detectors and visibility impairment equipment installed at certain points).
- Video surveillance should be improved by reducing the distance between cameras, incident-controlled activation of cameras on an alarm screen and automatic recording and storage of incident data.
- Equipment for fire brigades must be optimised and training should be carried out under realistic conditions.
- Regular emergency drills should be carried out with all emergency services.
- Co-ordinated emergency response plans must be prepared for all tunnels and continuously updated.
- Escape chambers or rescue rooms must be set up in all long tunnels that have no additional escape routes, and existing possibilities must be used to create additional escape routes. Escape routes in tunnels must be marked in such a manner that users can orientate themselves even in the event of a fire with heavy smoke. Once again, LEDs along the emergency walkway can be useful here.
- Lay-bys / emergency bays must be set up in all tunnels where no emergency lane is provided.
- Internationally valid pictograms should be agreed to for certain situations (eg, accident, fire, maintenance/construction work).

Long-term measures (10 years)

- Escape and rescue routes must be created (eg by building a 2nd tube)

Recommendations for tunnel users

According to an OECD study, most road accidents are due in part to incorrect behaviour by road users. Specific attention should be paid to the "enclosed" conditions that exist in tunnels, and also to the safety equipment that is usually provided (lay-bys, emergency telephones, fire extinguishers, emergency exits, etc.). If the following instructions are observed, tunnel users can make their own contribution towards reducing the risk in tunnels.

General instructions

- Switch on the radio and tune to the traffic station (the frequencies are usually indicated at the portal of the tunnel)
- Switch on dipped headlights
- Take off your sunglasses
- Observe traffic signs and traffic lights
- Maintain a safe following distance
- Take note of emergency exits, lay-bys and other safety equipment

How to behave in the case of traffic congestion

- Position vehicle close to the hard shoulder and at a sufficient distance from the vehicle in front of you (at least 50m)
- If traffic comes to a complete halt, turn off the engine and switch on your hazard warning flasher
- Do not leave your vehicle
- Follow the instructions on traffic radio, on the information displayed or on the message signs

What to do if you have a breakdown

- Drive your vehicle if possible to the lay-by or the emergency lane (if provided), otherwise, stop as near as possible to the hard shoulder/lane-edge
- Turn the engine off and switch on your hazard warning flasher
- Find the next emergency telephone and contact the tunnel control room. Do not use a mobile phone; when the emergency call is placed, other protective measures are often automatically activated, for example, video cameras are switched on, speed limit is reduced, the tunnel is closed, etc.

How to behave if you are involved in an accident

- Position vehicle close to the hard shoulder/lane-edge and at a sufficient distance from the vehicle in front of you (at least 50m)
- Switch on your hazard warning flasher
- Find the next emergency telephone and contact the tunnel control room. Do not use a mobile phone; when the emergency call is placed, other protective measures are often automatically activated, for example, video cameras are switched on, speed is reduced, the tunnel is closed, etc.

How to behave if an accident occurs in which you are not involved

- Reduce speed and observe any variable traffic signs which may be displayed
- Watch for any lane closures
- If necessary, give first-aid treatment

How to behave if you are involved in a fire

- If possible, drive out of the tunnel and only then should you stop at an emergency lane
- If it is not possible to drive out of the tunnel, then position your vehicle either in an emergency lane, a lay-by, on the hard shoulder, or close to the nearside
- Switch on your hazard warning flasher, leave the key in the ignition, initiate a fire alarm, and proceed immediately to the nearest emergency exit

How to behave if a fire occurs in which you are not involved

- Position your vehicle close to the nearside as possible and at a sufficient distance from the vehicle in front of you (at least 50m)
- Follow the instructions on traffic radio, on the information displayed or on the message signs
- If smoke and fire are visible, switch on your hazard warning flasher, leave the key in the ignition, and moving away from the fire, proceed immediately to the next emergency exit or portal
- In the case of heavy smoke, look for light signals (emergency route lighting) or feel your way along the tunnel wall