autostrada del brennero s.p.a.

UPgrading of existing TUNnels

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Causes and Frequency of Incidents in Tunnels

Prof. Ing. Konrad Bergmeister
Dr. Ing. Sandro Francesconi

Autostrada del Brennero SpA

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1. INTRODUCTION

With a series of recent accidents in the major European alpine road tunnels – Mont Blanc between France and Italy, Tauern in Austria and St. Gotthard in Switzerland – in which some 62 persons died, traffic safety in tunnels has become a burning issue for the public, politicians and experts.

Tunnels and underground transport facilities are important means of communication, not only in terms of shorter journeys, but also increasingly out of consideration for the local population and the environment. Generally speaking, important underground transport links are expected to be available without any restrictions and to operate smoothly round the clock. Interruptions due to accidents, technical malfunctions or maintenance work quickly cause traffic jams and delays, and figure in transport policy statistics as economic looses.

Rising traffic densities and the growing demand for underground communication links result in a higher probability of accidents, injuries and damage. Added to this are other factors increasing the potential hazards of traffic tunnels:

- the increasing length of modern tunnels
- the transport of hazardous materials
- two – way traffic (with undivided carriageways)
- higher fire loads due to growing traffic volumes and higher loading capacities
- mechanical defects in motor vehicles.

Road traffic and especially heavy goods traffic in tunnels has continually increased over the last years. In addition, with improving construction techniques, tunnels are an increasingly cost-effective engineering solution in many countries, not simply to cross difficult geographic features, but also to traverse urban areas with minimum local environment impact.

A serious incident involving dangerous goods in a tunnel can be very costly in terms of human lives, the environment, tunnel damage and transport disruption. On the other hand, needlessly banning dangerous goods from tunnels may create unjustified economic costs. The rules and regulations for the transport of dangerous goods in tunnels vary considerably among countries and even within countries. For the most part, there are no general rules or regulations that are applicable to all road tunnels at the european level.

2. ACCIDENTS IN TUNNELS

Fires in tunnels are a major hazard to human life and cause costly damage to the infrastructure. The considerable increase of the road traffic, together with the rising mobility of dangerous goods and the inadequacy of the structures resulted in the last three decades in a dramatic sequence of fires in tunnel with great damage in terms of human lives, structures and economy.

In the next pages, the following Tables are shown:

Table 1 shows a list of the largest fire accidents in the world's road tunnels, with identification of the causes, the vehicles involved, the duration of the fire and the consequences on people, vehicles and structures

Table 2 shows a list of fires in tunnels. The data have been collected for the FIT project and describe, for each accident, the tunnel, its type and length, the country, involved vehicles and the consequences on people.

Year	TUNNEL Length	Location Country	Vehicle where fire occurred	Most possible cause of fire	Duration of fire	CONSEQUENCES		
						People	Vehicles	Structures Installations
1949	Holland 2 550 m	New York USA	Lorry with 11 tons of carbondisulfid	Load falling off lorry explosion	4 h	66 injured smoke inhalation	10 lorries 13 cars	Serious damage over 200 m
1974	Mont Blanc 11 600 m	France-Italy	Lorry	Motor	15 min	1 injured		
1976	Crossing BP - A6 430 m	Paris France	Lorry with 16 tons polyesterfilm	High speed	1 h	12 light injuries	1 lorry	Serious damage over 150 m
1978	Velsen 770 m	Velsen Nederland	4 lorries 2 cars	Front-rear-collision	1h 20	5 dead 5 injured	4 lorries 2 cars	Serious damage over 30 m
1979	Nihonzaka 2 045 m	Shitzuoka Japan	4 lorries 2 cars	Front-rear-collision	159 h	7 dead 1 injured	127 lorries 46 cars	Serious damage over 1 100 m
1980	Kajiwara 740 m	Japan	1 truck: 3600 litres of paint in 200 cans	Collision with side wall and overturning		1 dead	1 truck, 4t 1 truck, 10t	Serious damage over 280 m
1982	Caldecott 1 028 m	Oakland USA	1 car, 1 coach 1 lorry with 33000 l petrol	Front-rear-collision	2h 40	7 dead 2 injured	3 lorries 1 coach 4 cars	Serious damage over 580 m
1982	Salang 2 700 m	Mazar-e-Sharif - Kabul Afghanistan	Soviet military column. At least one petrol truck.	Unknown. Probably mine explosion		> 200 dead		
1983	Pecorila 662 m	Gênes Italy	Lorry with fish	Front-rear-collision		9 dead 22 injured	10 cars	Little damage
1986	L'Arme 1 105 m	Nice France	Lorry with trailer	Braking after high speed		3 dead 5 injured	1 lorry 4 cars	Some equipment destroyed
1987	Gumefens 343 m	Berne Switzerland	1 lorry	Front-rear-collision	2 h	2 dead	2 lorries 1 van	Slight damage
1990	Røldal 4 656 m	Røldal Norway	Car with trailer		50 min	1 injured		Little damage
1990	Mont Blanc 11 600 m	France-Italy	Lorry with 20 tons cotton	Motor		2 injured	1 lorry	Some equipment destroyed
1993	Serra Ripoli 442 m	Bologne-Florence, Italy	1 car + lorry rolls of paper	Collision	2h 30	4 dead 4 injured	5 lorries 11 cars	Little damage
1993	Hovden 1 290m	Høyanger Norway	Motor cycle 2 cars	Front-rear-collision	1h	5 injured	1 motorcycle 2 cars	111 m insulation material
1994	Huguenot 3 914 m	South-Afrika	Bus with 45 passengers	Electrical fault	1h	1 dead 28 injured	1 coach	Serious damage
1995	Pfander 6 719 m	Austria	Lorry with trailer	Collision	1h	3 dead 4 injured	1 lorry 1 van, 1 car	Serious damage
1996	Isola delle Femmine 148 m	Palermo Italy	1 tanker with liquid gas + 1 little bus	Front-rear-collision		5 dead 20 injured	1 tanker 1 bus 18 cars	Serious damage tunnel closed for 2.5 days
1999	Mont Blanc 11 600 m	France-Italy	Lorry with flour and margarine	Oil leakage Motor		39 dead	23 lorries 10 cars 1 motorcycle	Serious damage Tunnel reopens 22.12.2001
1999	Tauern 6 401 m	A10 Salzburg-Spittal Austria	Lorry with paint	Front-rear-collision 4 cars and 2 lorries		12 dead 49 injured	14 lorries 26 cars	Serious damage
2000	Seljestad 1 272 m	E 134 Drammen - Haugesund Norway	Trailer-truck with diesel fire in the engine room before the collision.	Front-rear-collision 1 truck, 4cars	45 min	6 injured	1 lorry 6 cars 1 MC	Serious damage. NOK 1 mill. Tunnel closed for 1 1/2 days.
2001	Prapontin 4 409 m	A 32 Torino - Bardonecchia Italy				19 injured by smoke		Closed til 6. June in direction Frejus
2001	Gleinalm 8 320 m	A 9 near Graz Austria	Car	Front collision lorry - car		5 dead 4 injured		
2001	St. Gotthard 16 918 m	A 2 Switzerland	Lorry	Front collision 2 lorries		11 dead		Serious damage. Closed 2 months

Table 1: Largest fire accidents in the world's road tunnels

Sources: CETU, PIARC, ADAC (@: home.no.net/lotsberg/index_it.html)

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
20/01/2004	Ring tunnel, Lubijana	Road	Slovenia	700 m	1 bus with 50 passengers	?
18/01/2004	Dullin tunnel	Road	France	1550 m	1 bus	none
10/11/2003	Floyfjell tunnel	Road	Norway	3100 m	1 car	none
25/09/2003	Mont-Blanc tunnel	Road	France	11,6 km	none	2 injured (CO intoxication ?)
24/07/2003	Prudential tunnel, Boston	Road	France	?	1 "empty" bus	none
06/08/2003	Guadarrama tunnel	Rail	Spain	4000	special rolling stock	no victims
30/06/2003	44 - France	Road	France	618 m	private car + motorcycle	2 deaths
15/05/2003	72 - France	Road	France	1591 m	HGV + car	1 slightly injured
02/05/2003	Mornay tunnel	Rail	France	2600 m	auctorial' vehicle	none
18/02/2003	Daegu Underground	Metro	South Korea	2200 m	two 6-carriages train	198 deaths
03/11/2002	Homer tunnel	Road	New Zealand	1200 m	bus	4 injured (smoke inhalation)
01/08/2002	Tunnel on line Ozieri Chilivani-Cagliari	Rail	Italy	?	freight train	no victims
07/06/2002	52 - Interior tube - France	Road	France	660 m		2 injured
02/06/2002	80 - North tube - France	Road	France	1836 m		no victims
20/05/2002	96 - France	Road	France	4100 m		1 slightly injured
19/05/2002	Ted Williams tunnel, Boston	Road	USA	1200 m	bus	no victims
03/05/2002	Tunnel on line Genova Nervi-Pisa	Rail	Italy	?	loco of passenger train	no victims
27/04/2002	Crêt d'eau tunnel	Rail	France	4000 m		no victims
29/03/2002	Tunnel on line Nodo di Napoli	Rail	Italy	?	passenger train	no victims
20/03/2002	Valderoy tunnel	Road	Norway	4200 m	bus	no victims
05/03/2002	A 86 tunnel	Road	France	1800 m	special rolling stock	no injured
18/01/2002	Tauern tunnel	Road	Austria	6400 m	1 lorry	no victims
24/10/2001	Saint Gotthard tunnel	Road	Switzerland	16,92 km	two HGVs (initial phase)	11 deaths

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
17/10/2001	Guldborgsund tunnel	Road	Denmark	460 m		5 dead, 6 injured
03/09/2001	Gleinalm tunnel	Road	Austria	8300 m	1 touring coach	no victims
07/08/2001	Gleinalm tunnel	Road	Austria	8300 m		5 deaths, 4 injured
29/07/2001	Gleinalm tunnel	Road	Austria	8300 m	Swedish touring coach	no victims
18/07/2001	Baltimore tunnel (Howard st tunnel)	Rail	USA	2600 m		no victims
11/07/2001	Schipol airport tunnel	rail	The Netherlands	?		no victims
10/07/2001	Tauern tunnel	Road	Austria	6400 m	two private cars	no victims
07/07/2001	Kurt Schumacher Platz St (Berlin)	Metro	Germany	not pertinent	rear carriage of 100 m long train	no victims
28/05/2001	Prapontin tunnel	Road	Italy			14 intoxicated
27/11/2000	Laerdal tunnel	Road	Norway	24500 m		no casualties
11/11/2000	Kitzsteinhorn (Kaprun)	Rail (cable)	Austria	3400 m	passenger rail cabins	155 deaths
28/09/2000	Oslofjord	Road	Norway	7200 m	truck	no victims
24/08/2000	Saukhopf tunnel Weinham	Road	Germany	2700 m	car	no victims
14/07/2000	Seljestad tunnel	Road	Norway	1272 m		6 injured
08/07/2000	Berlin, Deutsche Oper Stat.	Metro	Germany	not pertinent		no victims
29/05/2000	Cross Harbor Tunnel	Road	Honk-Kong	2000 m		no victims
26/04/2000	L'Ems tunnel	Road	Germany	1000 m		no victims
04/03/2000	Lermoos tunnel	Road	Austria	3200 m		no victims
01/02/2000	Toulon tunnel	Road	France	2969 m		no victims
10/01/2000	Tauern tunnel	Road	Austria	6,4 km		no victims
30/08/1999	Munich Candid Tunnel	Road	Germany	252 m		no victims
12/07/1999	Amsterdam, Weesperplein ST	Metro	The Netherlands	not pertinent		no victim, evacuation needed

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
29/06/1999	Olso Fjord tunnel	Road	Norway	7200 m		2 deaths (firemen), 15 injured
23/05/1999	Salerno tunnel	Rail	Italy	10 km		4 deaths, 9 injured
29/03/1999	Tauern tunnel	Road	Austria	6,4 km		12 deaths
24/03/1999	Mont-Blanc tunnel	Road	France/Italy	11,6 km	23 HGVs, 1 van, 9 cars, 1 fire-engine vehicle, one emergency car, 1 motorcycle	39 deaths
02/03/1999	Leinebusch tunnel	Rail	Germany	1740 m	half of a freight train with 24 wagons	no victims
08/09/1998	Gleinhalm tunnel	Road	Austria	8300 m	1 double deck bus	
10/07/1998	Gueizhou tunnel	Rail	China	800 m		over 80 people killed
31/10/1997	Saint Gotthard tunnel	Road	Switzerland	16,92 km		no victims
17/09/1997	Saint Gotthard tunnel	Road	Switzerland	16,92 km		no victims
01/07/1997	Exilles tunnel	Rail	Italy	2100 m		no victims
18/11/1996	Channel tunnel	Rail	France/UK	50 km		minor intoxication
21/08/1996	Ekeberg tunnel	Road	Norway	1600 m	1 line bus	
18/03/1996	Isola delle femmine	Road	Italy	150 m	18 cars, 1 tank truck (LPG), 1 bus	5 deaths, 20 injured
20/12/1995	Simplon tunnel	Rail	Switzerland	19800 m		no victims
28/10/1995	Baku	Metro	Azerbaijan	not pertinent		289 deaths, 265 injured
10/04/1995	Pfänder tunnel	Road	Austria	6,7 km	1 lorry, 1 van, 1 car	3 deaths, 4 injured
24/01/1995	Hitra tunnel	Road	Denmark	5,6 km		no victims
15/10/1994	Kingsway tunnel (Mersey)	Road	United Kingdom	2000 m		no victims
05/07/1994	St Gotthard	Road	Switzerland	16,3 km	1 lorry + trailer	no victims

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
11/06/1994	Great Belt East Tunnel	Rail	Denmark	8000 m		no victims
14/04/1994	Castellar tunnel (Nice)	Road	France	570 m		no victims
27/02/1994	Huguenot tunnel	Road	South Africa	3910 m	bus	1 death, 28 injured
01/02/1994	Eole transit line	Metro	France	?		no victims
01/06/1993	Vardo tunnel	Road	Norway	?		?
01/06/1993	Hovden tunnel	Road	Norway	1300 m		5 injured (in collision)
01/02/1993	Serra Ripoli tunnel	Road	Italy	442 m	4 lorries, 11 cars	4 deaths, 4 injured
01/08/1991	Unnamed tunnel	Rail	China			15 passengers killed ?
16/04/1991	Hirschen Graben tunnel	Rail	Switzerland	1300		no victims
28/12/1990	N-Y subway tunnel	Metro	USA	not pertinent		2 dead, 200 injured
13/07/1990	Los Angeles Red Line	Metro	USA	?		no victims
11/01/1990	Mont-Blanc tunnel	Road	France/Italy	11,6 km		no victims
18/05/1989	Brenner tunnel	Road	Switzerland	1236 m		2 deaths, 9 injured (tox)
18/11/1987	King's Cross Station, London	Metro	United Kingdom	not pertinent		31 killed, about 100 injured
02/07/1987	Tanzenberg Tunnel	Road	Austria	?		1 injured
15/05/1987	Münden tunnel	Road	Germany	> 1200 m		no victims
18/02/1987	Gumefens tunnel	Road	Switzerland	340 m	2 lorries + 1 van	2 deaths, 5 injured
30/12/1986	Herzogberg	Road	Austria	?		no victims
09/09/1986	L'Arme tunnel	Road	France	1105 m		3 deaths, 5 injured
23/12/1984	San Benedetto tunnel	Rail	Italy	18,5 km		17 dead, 120 injured
20/12/1984	Summit tunnel	Rail	United Kingdom	not pertinent		no victims
23/11/1984	Oxford Circus Tube, London	Metro	United Kingdom	not pertinent		15 injured

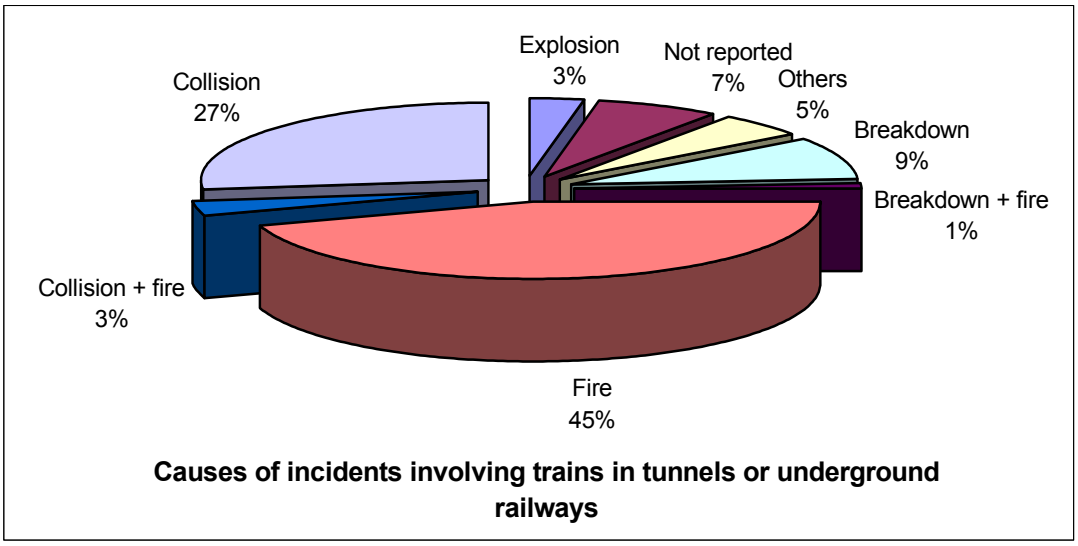
Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
01/07/1984	Felbertauern tunnel	Road	Austria	5130 m	1 bus	no victims
02/04/1984	St Gotthard	Road	Switzerland	16,3 km	1 lorry	no victims
05/09/1983	München	Metro	Germany	not pertinent		7 injured by smoke
03/02/1983	Frejus tunnel	Road	France/Italy	12,87 km	1 truck	1 slightly injured
01/02/1983	Pecorile tunnel	Road	Italy	600 m		8 dead, 22 injured
02/11/1982	Salang tunnel	Road	Afghanistan	2600 m	petrol tankers ? Military vehicles	over 400 deaths ?
02/06/1982	N-Y subway tunnel	Metro	USA	not pertinent		10 injured, over 1000 evacuated
07/04/1982	Caldecott tunnel	Road	USA	1028 m	3 trucks + 4 cars + 1 bus	7 dead, 2 injured (tox)
13/01/1982	Washington DC	Metro	USA	not pertinent		no victim, 1200 evacuated
01/06/1981	Moscow, Oktyabrskaya st.	Metro	Russia	not pertinent		7 dead, > 2000 evacuated
15/07/1980	Sakai tunnel	Road	Japan	459 m		5 dead, 5 injured
17/04/1980	Kajiwara tunnel	Road	Japan	740 m	1light truck (4t)+ 1 HGV (10t)	1 dead
08/04/1980	Hamburg U-Bahn	Metro	Germany	not pertinent		no victim, 3 injured
11/07/1979	Nihonzaka tunnel	Road	Japan	2045 m	127 trucks + 46 cars	7 dead, 2 injured
17/01/1979	Bart system San Francisco	Metro	USA	5,9 km		1 dead, 58 injured
11/08/1978	Velsen tunnel	Road	Netherlands	770 m	2 trucks, 4 cars	5 dead, 5 injured
23/03/1978	Baltimore Harbor tunnel	Road	USA	unknown		no victims
02/10/1976	Christie Station, Toronto	Metro	Canada	not pertinent	3 H4-class cars	unknown
21/09/1976	San Bernadino	Road	Switzerland	6600 m		no victim
11/08/1976	B 6 motorway tunnel	Road	France	430 m	1 truck	12 intoxicated
25/05/1976	Lisbon Metro	Metro	Portugal	not pertinent		no fatalities, users evacuated

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
01/09/1975	Mexico	Metro	Mexico	not pertinent		50 dead, 30 injured
14/08/1975	Guadarrama	Road	Spain	3330 m	1 truck	no victims
02/08/1975	Boston subway	Metro	USA	not pertinent		no fatalities, 34 injured
03/05/1974	Chesapeake Bay Bridge tunnel	Road	USA	?		no victims
23/01/1974	Montreal	Metro	Canada	not pertinent	24 cars fully destroyed	1 death ; > 1000 evacuated
27/03/1973	Paris, line 7, near Porte d'Italie	Metro	France	not pertinent		2 killed by smoke
06/11/1972	Hokuriku tunnel	Rail	Japan	13,9 km		30 dead, 690 injured
01/02/1972	Lötschberg tunnel	Rail	Switzerland	?		3 injured
24/06/1971	Sylmar tunnel, (Cal)	Water ?	USA	not known		17 dead (explosion)
20/03/1971	Crozet tunnel	Rail	France	226 m		2 dead, 200 injured
14/02/1971	Wranduk tunnel	Rail	Yugoslavia	1600 m		34 dead
01/10/1970	Wallace tunnel	Road	USA (Alabama I-10)	1000 m		no victims
08/11/1969	Simplon tunnel	Rail	Switzerland	19800 m		no victims
31/08/1968	Moorflet tunnel	Road	Germany	243 m	1 truck +trailer	no victims
01/01/1965	Blue Moutain, PA, Turnpike	Road	USA	?		no victims
02/03/1963	Union Station, Toronto	Metro	Canada	not pertinent	six cars train, fully involved	?
23/11/1960	Stockholm	Metro	Sweden	not pertinent		no victims
11/08/1960	Moorgate St Station, London	Metro	United Kingdom	not pertinent		39 injured
28/07/1958	London Tube station	Metro	United Kingdom	not pertinent		1 dead, 47 injured by smoke
23/06/1949	Penmanshield	Rail	United Kingdom	?		no victims
13/05/1949	Holland tunnel	Road	USA	2250 m	10 trucks + 13 cars	66 people intoxicated

Date	Name of tunnel	Type of tunnel	Country	Tunnel length	Involved vehicles	Casualties
03/01/1944	Torre tunnel	Rail	Spain	?		91 dead
05/10/1921	Batignolles tunnel	Rail	France	?		> 28 dead
10/08/1903	Couronnes Station, Paris	metro	France	not pertinent		80 dead
06/1866	Welwyn North Tunnel	Rail	United Kingdom	?		3 trains fully destroyed
10/1842	Mendon	Rail	France	?		150 dead

Table 2: Fire accidents in tunnels: brief overview of real cases
Sources: FIT Database (@: www.etnfit.net, update: 30/01/2004)

Not only road tunnels are interested by fire accidents. The study of the UNECE (United Nations Economic Commission for Europe) entitled "Risk Analysis of Accidents in Tunnels" analysed 176 cases of accidents involving trains in tunnels or underground railways. Of these, 49% involved fires.



Causes of incidents involving trains in tunnels or underground railways

Source: UNECE, United Nations Economic Commission for Europe

A detailed examination of certain cases of accidents made it possible to demonstrate similarities in their mechanisms:

- the key events of the accident were limited
- there was a cause and effect relationship common to the key events of the accidents studied
- the consequences of the accidents were largely determined by the parallel occurrence of events (e. g. progress of the fire and the evacuation of the passengers during the fire)

Conclusions were finally drown:

- Travellers have to be informed on the conditions inside the tunnel
- The access on the place of the accident must be possible
- Safety measures have to be adapted to the tunnels in order to be efficient
- Travellers self rescue must be improved in order to increase the chances of survival immediately after the accident, and before rescue services arrive on the scene
- All people involved need better information, communication and training

Of the 5.590 km of the AISCAT highways, only 25,4 km are in tunnels. It corresponds to a percentage of 0,45%. Nevertheless, 4,60% of the total number of incidents happened in the tunnels. This disproportion is indicative of the higher danger of these stretches of roads.

Road incidents on the AISCAT highways (2001)	
Incidents in tunnel	1.902
Total incidents on the highways	41.251
Percentage of incidents in tunnel	**4,60%**
Incidents in tunnel with victims	11
Incidents on the highways with victims	516
Percentage of victims in tunnel	2,13%
Incidents in tunnel with injured	492

Source: Aiscat

The Table below shows the incidents in the 17 tunnels of the Brenner highway in the years 1995-2003. It is clear how the most frequent causes are crashes due to insufficient security distance and distraction of the drivers. However, there is a significant “percentage” difference between incidents in tunnels on the AISCAT highways and on the Brenner highway.

Incidents in tunnels of the Brenner Highway (1995-2003)		
Causes	**Number of incidents**	**Percentage**
Nose-to-tail crash	177	59,2%
Collision against fixed structures	51	17,1%
Material lost from other vehicle	18	6,0%
Material detached from the tunnel	16	5,4%
Lateral collision	14	4,7%
Upsetting	9	3,0%
Collision against signs	5	1,7%
Personal behaviour	4	1,3%
Loss of the cargo	3	1,0%
Frontal collision	1	0,3%
Road defect	1	0,3%
TOTAL incidents in tunnels	**299**	**100,0%**
Incidents with injured persons	69	23,1%

Total incidents on the highway	**15744**
% of incidents in tunnels	**1,90%**

Source: Autostrada del Brennero S.p.A.

A summary of the number of the tunnels in the UNECE countries is listed in the Table. The tunnels are categorised depending on their length.

COUNTRY	I.S.O. CODE	Number of Tunnels >1000 m	of which ≥1.000 m & <2.000 m	of which ≥2.000 m & <3.000 m	of which ≥3.000 m & <6.000 m	of which ≥6.000 m & <10.000 m	of which ≥10.000 m
Andorra	AD	**1**	1				
Armenia	AM	**1**	1				
Austria	AT	**55**	22	16	10	6	1
Belgium	BE	**7**	6	1			
Bosnia Herzegovina	BA	**2**	2				
Croatia	HR	**9**	5	1	3		
Denmark	DK	**1**			1		
France	FR	**46**	27	4	10	2	3
Germany	DE	**38**	28	7	2	1	
Iceland	IS	**3**			2	1	
Italy	IT	**180**	133	27	17		3
Monaco	MC	**1**	1				
Netherlands	NL	**4**	2	1			
Norway	NO	**203**	107	45	39	10	2
Portugal	PT	**3**	3				
Russian Federation	RU	**5**	2	1	2		
Slovak Republic	SK	**1**			1		
Spain	ES	**25**	16	3	5	1	
Sweden	SE	**3**	1	2			
Switzerland	CH	**67**	41	12	11	2	1
Turkey	TR	**8**	5	1	2		
United Kingdom	UK	**8**	6	1	1		
TOTAL		**664**	**406**	**122**	**105**	**23**	**8**

Source: UNECE, United Nations Economic Commission for Europe (28 December 2001)

3. INCIDENTS IN TUNNELS OF THE BRENNER HIGHWAY

The aim of this chapter is to analyse the influence of the length of the tunnels on the probability of incidents. Moreover, the time-distribution of incidents during the day has been considered.

The Brenner highway presents on its route 17 tunnels, all shorter than 1000 m. 13 of them have a length < 500 meter and will be therefore classified as short tunnels in the next pages. The other 4 are considered as long tunnels (800 m < length < 1000 m). These 4 long tunnels together cover 3455 m, which represent the **48,9%** of the total length of road in tunnels (7067 m).

In the 9 years between 1995 and 2003, 299 incidents happened in the 17 tunnels. Among them, **59,9%** (179) occurred in the 4 long tunnels. These data are collected in the table on the next page. The following graph clearly shows how the frequency of casualties is connected with the length of the tunnels.

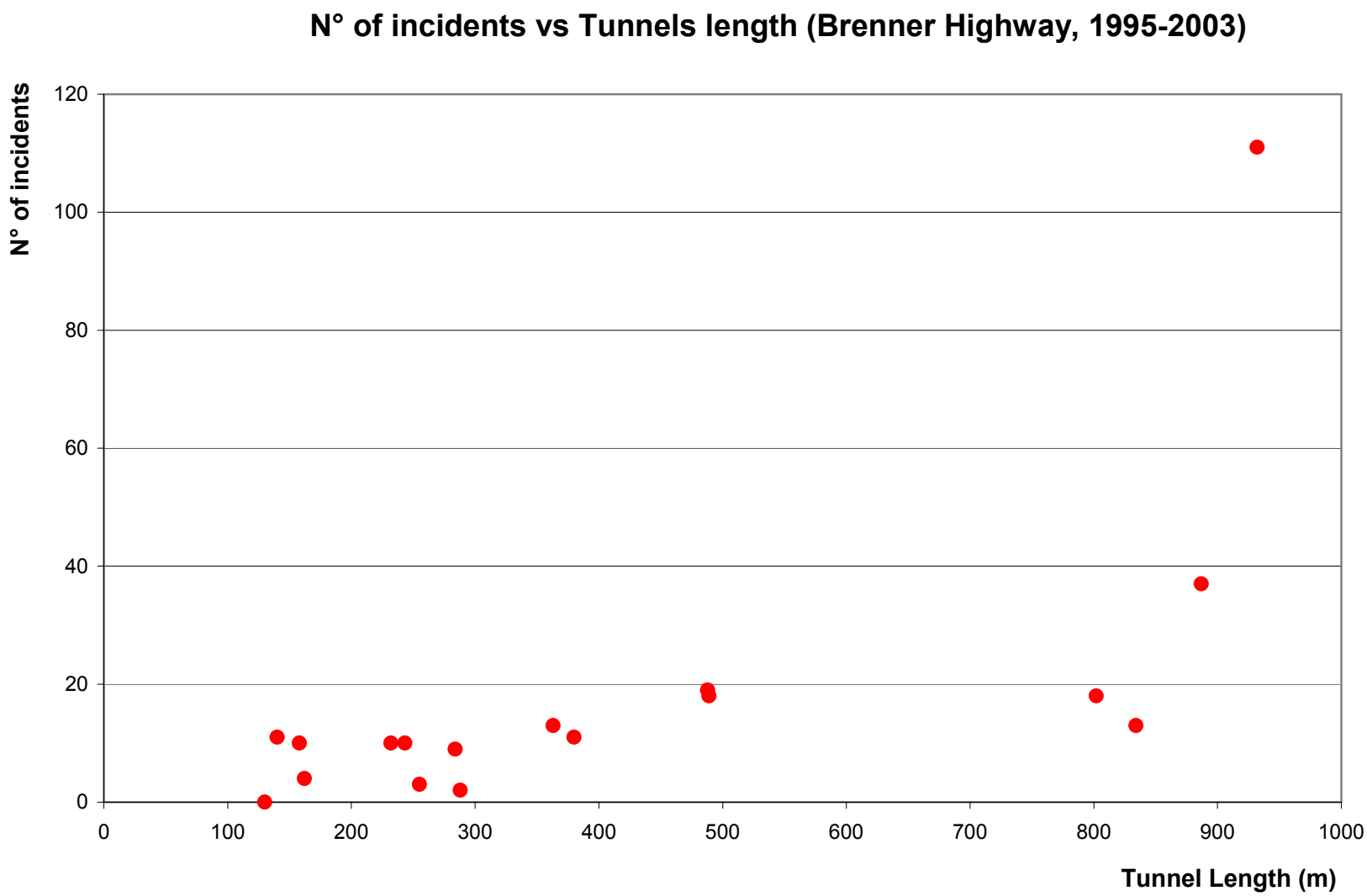
The table on the next page shows the number of casualties occurred in each tunnel in the daily hours (h. 7-19) and in the night hours (h. 19-7). **80,6%** (241) of them happened in the daily hours, when **72,1%** of the traffic is on the highway. This indicates that the frequency of incidents is higher during the day, when the traffic level is higher.

Finally, the 299 incidents have been classified depending on the hour of happening. The results are shown in the last graph of the paper, where the number of incidents, as well as the normalised traffic amounts are displayed for each hour of the day. It is interesting to note the discrepancy between those two indices. In particular, between 10 and 17 o'clock, incidents are more likely to occur than it could be supposed by looking at the traffic evolution. On the other hand, they are less likely to occur between 17 and 23 o'clock. This could be explained by the presence of the sun, which acts as a dazzling light for the drivers.

Incidents in the Tunnels of the Brenner highway (1995-2003)

N°	Name	Max Length (m)	N° of incidents	Total	%	Day Incidents h. 7-19	Night Incidents h. 19-7
Short Tunnels (l < 500 m)							
1	ARTIFICIALE PONTICOLO	130	0			0	0
2	GARDENA NORD (GRÖDNER-TUNNEL)	140	11			9	2
3	ROSA (KOFLER-TUNNEL)	158	10			9	1
4	ARTIFICIALE S. OSVALDO (ST. OSWALD-TUNNEL)	162	4			3	1
5	CARDANO (KARDAUNER-TUNNEL)	232	10			8	2
6	CHIUSALTA (HOCHKLAUSNER-TUNNEL)	243	10			6	4
7	BRESSANONE (BRIXNER-TUNNEL)	255	3	**120**	**40,1%**	1	2
8	TASCH (TUSCH-TUNNEL)	284	9			6	3
9	ARTIFICIALE FORTEZZA	288	2			1	1
10	FUNES (MATSCHOLER-TUNNEL)	363	13			8	5
11	GARDENA SUD (TROSTBURGER-TUNNEL)	380	11			5	6
12	MICHELETTI - FIE' (VÖLSER-TUNNEL)	488	19			16	3
13	CASTELROTTO (KASTELRUTHER-TUNNEL)	489	18			15	3
	Total	**3612**					
	%	**51,1%**	of the total length of road in tunnels				
Long Tunnels (800 m < l < 1000 m)							
14	BRENNERO (BRENNER-TUNNEL)	802	18			12	6
15	FORTEZZA (FRANZENSFESTER-TUNNEL)	834	13	**179**	**59,9%**	12	1
16	VIRGOLO (VIRGL-TUNNEL)	887	37			31	6
17	PIEDICASTELLO	932	111			99	12
	Total	**3455**		**299**		**241**	**58**
	%	**48,9%**	of the total length of road in tunnels		**%**	**80,6%**	**19,4%**

	Day h. 7-19	Night h. 19-7
Traffic %	**72,1%**	**27,9%**
Incidents %	**80,6%**	**19,4%**


N° of incidents vs Tunnels length (Brenner Highway, 1995-2003)
N° of incidents
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000
Tunnel Length (m)

Time distribution of tunnels incidents and traffic (Brenner Highway, 1995-2003)