Statens vegvesen

Studies on Norwegian Road Tunnels II

An analysis on traffic accidents in road tunnels 2001-2006

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FOREWORD

Norway is one of the countries in Europe with the largest number of tunnels. They make up about 3% of the national road network. Constructing tunnels brings about many advantages, but operating costs are high and the consequences of accidents can be severe.

This road tunnel accident study intends to both analyze the accidents occurring in the tunnels and to investigate if there are characteristics with the tunnels that contribute in an increase in the number and severity of accidents. This is the second major study of road tunnel traffic accidents undertaken by the Norwegian Public Roads Administration. The first study was documented in 1997. The present study concerns tunnels of higher technical and safety standard and thus represents a follow-up of the previous one.

The study is based on tunnel information registered by the National Road Data Bank (NVDB) and person injury accidents reported to the police and registered in the Public Roads Administration accident data base. It is undertaken by Arild Engebretsen and Finn Harald Amundsen, both employed at the Traffic Safety Section of the Directorate of Public Roads.

Oslo 2009-06-09

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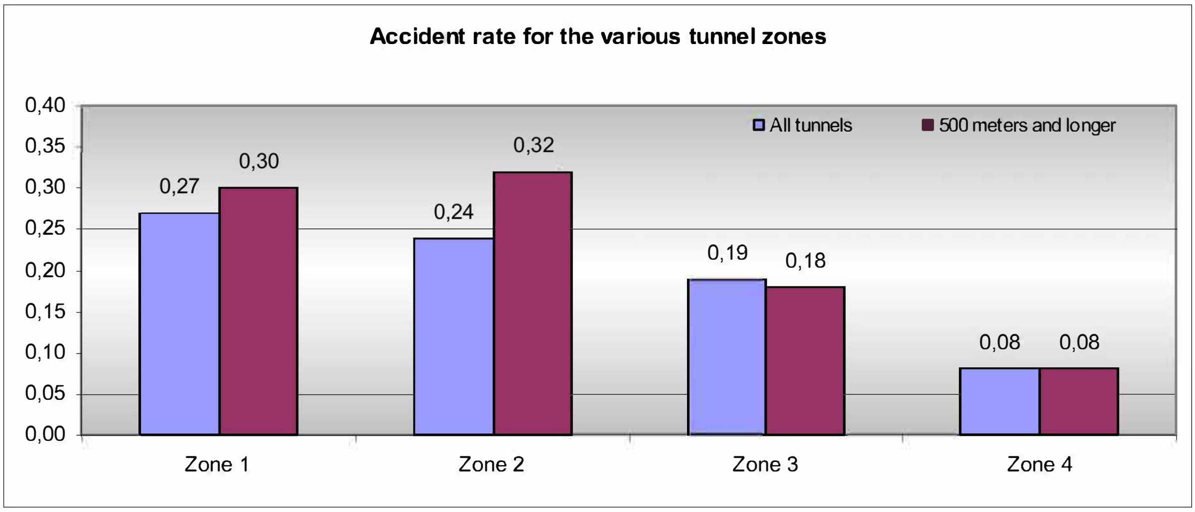
The study is based on 797 national road tunnels with a total length of about 778.5 km. Accidents were recorded in 250 of these tunnels during the study period. When including the last 50 meters before the tunnel entrance, there were recorded tunnel related accidents in 299 of the tunnels.

The 926 person injury accidents included in this study resulted in 1428 fatalities or personal injuries. A total of 739 of these accidents occurred within the tunnel itself and the remainder at the last 50 meters before the tunnel entrance. The 739 tunnel accidents involved a total of 1130 fatalities or personal injuries.

The three predominant tunnel accident types are same direction (rear end collision and lane change) with 43%, single accidents with 35% and head-on accidents with 15%. Single accidents are most common in single tube tunnels, while accidents involving vehicles in the same direction predominates in dual tube tunnels.

This study confirms previous study findings, which show that it is the entrance zones that have the highest accident rate and that the accidents rate declines with distance inwards.



Overall accident rate for tunnels is 0.12 and 0.10 for tunnels exceeding 500 meters. When zone 1 is included the overall accident rate is 0.13 and 0.12 for tunnels exceeding 500 meters.

A study of the correlation between tunnel length and accident rate supports corresponding findings from all previous studies. Findings show that accident rates vary between 0.22 for tunnels shorter than 100 meters and decline down to 0.08 for tunnels exceeding 3000 meters in length.

When considering the correlation between traffic volume and accident rate, it appears that the accident rate declines with increasing traffic. This may be related with the fact that tunnels with little traffic are of a lower standard than those with more traffic.

The study also shows a clear correlation between horizontal curvature and accident rate. The accident rate declines with increasing radius. The study does not find the same clear correlation between gradient and accident rate. This might be because accidents caused by a gradient might not always take place within the incline.

The study also groups the tunnels into four types: single tube, sub-sea, urban dual tube and rural dual tube. The results show a wide variation in accident rate for these tunnel types. The table below summarizes the main findings for the four tunnel types.

	Single tube	Sub-sea	Urban dual tube	Rural dual tube
Accident rate zones 2-4	0,10	0,09	0,14	0,04
Accident rate zones 1-4	0,12	0,10	0,16	0,06
Injury cost	0,52		0,22	0,31

Accident costs for all sub-sea tunnels have not been estimated, but for sub-sea tunnels longer than 300 meters accident costs are 0.34 NOK per vehicle kilometer.

The table shows that even if there is a major difference in accident costs for the two groups of dual tube tunnels, there is no similar large difference in injury costs. This means that the severity is relatively lower in urban tunnels even though there are a larger number of accidents.

1. The Problem

Norway is one of the countries in the World with the largest number of road tunnels. The national road network includes about 800 road tunnels with a total length of 800 km. Norwegian road tunnels are typically long with little traffic by European measure. They are also often of lower design standard due to significant less traffic than foreign tunnels. Experience obtained from other countries is thus not always representative under Norwegian conditions. Experience with road user behavior and traffic accidents is important when designing road tunnels and thus essential when revising road tunnel guidelines. Knowledge about how tunnels function contributes to the construction of tunnels with superior safety standards at modest construction costs. Tunnels can on this basis be built and equipped to a high level of safety without excessive equipment and a costly design standard that might not necessarily contribute to an improved level of safety.

Current knowledge on road tunnel safety in Norway is based on a number of older studies from the 1980s as well as an accident study covering the 1992-1996 period. Results from these studies are largely in reasonably good agreement with results obtained from foreign countries. All studies undertake on road tunnel safety show that tunnels generally are as safe as motorways. In spite of this, tunnel safely is often questioned. Lately there has been a special focus on fire prevention. Traffic safety is often questioned in connection with specific road tunnel accidents with serious person injury accidents. Driving in tunnels represents a special challenge for many drivers because it generally involves driving inside a mountain, often in darkness, frequently resulting in insecurity and anxiety. Moreover, many sub-sea tunnels have a very special vertical alignment.

The objective of this study is to acquire improved knowledge on traffic accidents in tunnels in general and in sub-sea tunnels and dual tube tunnels in particular. Of interest is also whether there are special conditions associated with the accidents in question that can be mitigated in order to improve traffic safety. Conditions associated with transition zones, entrance zones and the tunnel proper are also of interest as well as accident types, weather and driving conditions, traffic volume and tunnel length. Moreover, it will be useful to review individual tunnels with an accident frequency well above those of similarly designed tunnels. Such tunnels should be subject to individual detailed studies.

2. Earlier Norwegian Studies

Previously there have been undertaken three major accident studies on Norwegian road tunnels. **The first** one was undertaken by Magne Mo in 1979/80 as a thesis at NTH (now NTNU). The data was later processed at SINTEF Vegteknikk (Asbjørn Hovd 1981). The study covered 361 road tunnels on the national road network in 16 counties. The tunnels are relatively short (72% are shorter than 500m) and narrow (35% narrower than 6m) and with little traffic (85% with AADT lower than 1500). Nearly 80% of the tunnels are without illumination. A total of 221 person injury accidents in these tunnels were reported to the police during the ten years of the 1970-79 period. Traffic counts from 1974 were used to establish current and future AADT estimates. All tunnels had been open to traffic for more than three years in that period. Accidents within 100m of the tunnel entrance and within the tunnel itself were included in the study. Accidents were then subdivided according to whether they occurred in the transition zone or mid-zone. Of the 221 accidents, 72 took place beyond the transition zone (i.e. on the approaching road 50-100m from the entrance), 100 in the transition zone and 49 in the mid-zone.

Additional findings from this study included the following:

- single vehicle accidents (off-the-road) made up about 52% of the accidents
- accidents with vehicles in opposing directions stood for about 20% of the accidents
- accidents with vehicles in the same direction comprised about 13% of the accidents
- other types accidents constituted about 15%

The widest tunnels and those with the most traffic had the relatively largest number of rear end collisions, while the narrowest had the largest number of front-to-front accidents. Regular two lane tunnels (roadway width of 6-7m) had the largest number of such head-on collisions.

Accident rate (Ar) expressed as annual person injury accidents per million vehicle kilometers was estimated based on length and AADT:

- entire study area (the tunnel and 100m beyond)	Ar = 0,52
- transition zone (50m before and 50m into the tunnel)	Ar = 0,86
- mid-zone	Ar = 0,17

The accident rate in the transition zone is five times that of the mid-zone. A corresponding difference is also documented in a number of foreign studies.

The same report also documents an additional study undertaken to find out how the tunnel accident rates compare to those of the approaching roads. This study encompassed 772km of the national road network of which 58km was in tunnel. This study revealed a similar accident rate, i.e. about 0.50 on roads in the open and 0.52 in road tunnels (including transition zones).

The second study was undertaken in 1988 at Hordaland District Road Office (Hvoslef 1988). The study covered four road sections with a total of 35 road tunnels with a combined length of 31.45 km. The average tunnel length was 875m and most (23) of the tunnels were in the 100-700 m length group. The transition zone was in this study assumed to extend from 50m outside the tunnel to 50m within. During the 1980-86 period a total of 57 person injury accidents were reported in these tunnels. The accident rate of the transition zone was estimated at 0.78 (annual person injury accidents per million vehicle kilometers), while the accident rate in the mid-zone was 0.14. The accident rate in the transition zone was more than six times that of the mid-zone; a somewhat larger difference than that of the study previously referred to. The discrepancy is probably caused by the fact that the Hordaland study included only tunnels where accidents had been observed. The study revealed a clear overrepresentation of accidents with wet road surface (38%) and snowy/icy (35%) conditions in the transition zones when compared to Hordaland roads in general (28% on wet road surface and 24% on snow and ice).

The third study was conducted in 1997 by Finn H Amundsen and Guro Ranes. This study included 587 road tunnels opened to traffic in 1992 or earlier. A total of 499 person injury accidents were reported in one third of the tunnels. The study reveals that the accident rate of the entrance zone is three times that of the tunnel mid-zone. When comparing accident rates with those of earlier studies (about 15 years) the reduction has been larger for the entrance zone than for the tunnel proper. The accident rate declines with increasing tunnel length, tunnel width and AADT. Accidents between vehicles in the same direction are relatively more prevalent in road tunnels than on the open road. This is particularly the case in tunnels with one-way traffic (dual tube). In tunnels with two-way traffic, however, frontal accidents predominate.

When tunnels are divided into zones according to distance from the entrance, there is a clear decline in the accident rate with distance away from the entrance:

zone	accident rate
zone 1	0,30
zone 2	0,23
zone 3	0,16
zone 4, mid-zone	0,10

The fourth study was undertaken by Arild Engebretsen and Finn Harald Amundsen in 2004 and concerns tunnel incidents.

This study involved the evaluation of about 3000 reported road tunnel incidents. The number of incidents recorded annually is estimated at around 1300. Most recorded incidents were from the Oslo area. It is also there that the tunnel traffic is heaviest. More than half of the incidents were caused by technical malfunction, 20% by fuel shortage, 11% from collision/accident and just below 1% from fire or fire attempt in vehicles.

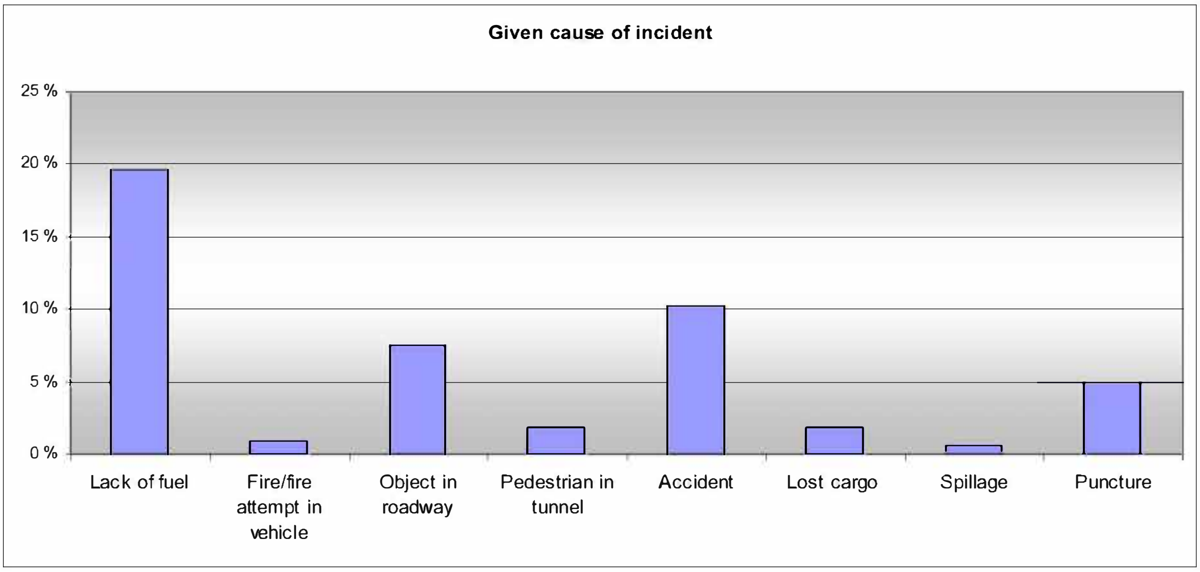


Figure 2.1 Causes of vehicle stoppage in tunnels

The fifth study concerns traffic accidents in sub-sea road tunnels undertaken by Finn H. Amundsen, Per Ola Roald, Arild Ragnøy and Arild Engebretsen.

The study is based on police reported person injury accidents. A total of 70 accidents are included in the study. Seven of these occurred on the last 50m outside the tunnels, three within the first 150m inside the tunnel and 60 in the remainder of the tunnels, i.e. in the mid-zone. This means that the accident risk (expressed as annual number of person injury accidents per million vehicle kilometers) is four times higher on the last 50m before the tunnel and twice as high in the entrance zone when compared to that of the mid-zone. In spite of relatively steep grades, the relative risk in the various zones is about the same as for regular road tunnels.

Passenger cars were involved in 85% of the accidents, motorcycles in 10% and heavy vehicles in 10%. Overall accident rate appears to be higher at nighttime than during the day.

Regression analysis made on the data reveals the following correlations:

* The risk declines or levels out with increasing tunnel length
* The risk increases with steepness of grade
* The risk declines or levels out with increasing AADT
* The risk is somewhat higher with the older tunnels

This study indicates that an accident reduction can be attained by raised standards such as for example by improved illumination. New tunnels should not be built to gradient over 8% (or preferably 7%).

3. Data Basis

All accident data in this study was provided by NVDB. All accident data from 1977 to the present was available, but in conjunction with this study only data for the six-year period from 2001 to 2006 were used.

The study was based on data from 797 national road tunnels representing a total length of about 778.5km. Not all tunnels were open to traffic during the entire study period. The table below shows how many tunnels were included for the various study years.

Number of tunnels in the study						
	2001	2002	2003	2004	2005	2006
Under 500 meters	412	424	425	434	437	437
500 meters and longer	314	329	336	348	356	360
Total	726	753	761	782	793	797

Table 3.1 Number of tunnels.

The total length of these tunnels is shown in the table below.

Total length of tunnels in the study in km						
	2001	2002	2003	2004	2005	2006
Under 500 meters	81,7	84,9	85,0	87,0	87,5	87,5
500 meters and longer	603,4	631,3	642,8	661,7	681,6	690,9
Total	685,1	716,2	727,8	748,7	769,2	778,5

Table 3.2 Total length of tunnels.

In this report the tunnels are divided into the following four groups: Dual tube urban and rural tunnels, sub-sea tunnels and other single tube tunnels. The numbers are shown in the table.

	Number of tunnels		Tunnel length in km	
	500 m and longer	Under 500 m	500 m and longer	Under 500 m
Single tube/Two-v	312	416	565,8	648,5
Urban dual tube	14	8	19,0	20,5
Rural dual tube	12	13	16,7	20,0
Sub-sea	22	0	89,4	89,4
Total	360	437	690,9	778,5

Table 3.3 Tunnels by type and length.

Accidents had occurred in 250 of these tunnels. When the last 50m before the tunnel was included there were person injury accidents in 299 of the 797 tunnels. This means there were no person injury accidents recorded in 498 of the tunnels or in zone 1. The table below shows the number recorded accidents for tunnels shorter and longer than 500 meters.

	Number of tunnels with accidents	
	Zones 2 - 4	Zones 1 - 4
Tunnels shorter than 500 m	83	115
Tunnels500 m and longer	167	184
Total	250	299

Table 3.4 Number of tunnels with accidents during the study period.

Throughout the report the notion zone 1 to 4 will be used with the following meaning:

- Zone 1 – Last 50 meters before the tunnel opening
- Zone 2 – First 50 meters within the tunnel
- Zone 3 – Next 100 meters into the tunnel
- Zone 4 – Mid-zone (rest of the tunnel),
- Zone 2 – 4 – Inside the tunnel

4. Results

4.1. Person injury accidents

In this report the term accident always refers to person injury accidents registered by the police and accessed the national road accident data base.

The 926 person injury accidents covered by the study resulted in 1428 injuries, some of which were fatal. Absolute and relative numbers of severity of the injuries sustained in these accidents are summarized in Table 4.1 below. The table gives numbers for all tunnels with those for tunnels exceeding 500m in length shown in parenthesis.

Numbers killed and injured in tunnels by zone (Numbers in parenthesis are for tunnels 500 meters and longer)						
Severity	Zone				Total	Within tunnel
	1	2	3	4		
Killed	6 (2)	6 (5)	9 (9)	25 (25)	46 (41)	40 (39)
Severely injured	20 (10)	16 (3)	21 (10)	48 (48)	105 (71)	85 (61)
Lightly injured	272 (132)	210 (115)	274 (149)	521 (505)	1277 (901)	1005 (769)
Sum killed and injured	298 (144)	232 (123)	304 (168)	594 (578)	1428 (1013)	1130 (869)
Sum killed and severely injured	26 (12)	22 (8)	30 (19)	73 (73)	151 (112)	125 (100)
Person injury accidents	187 (87)	172 (90)	187 (102)	380 (369)	926 (648)	739 (561)

Table 4.1 Numbers killed or injured according to tunnel zone.

The total numbers killed or injured per tunnel accident is given in the following table. The numbers shown in parenthesis are for tunnels exceeding 500m in length.

Numbers killed and injured per accident in tunnels by zone (Numbers in parenthesis are for tunnels 500 meters and longer)							Killed and injured per accident for all accidents 01-06
	Sone						
Severity	1	2	3	4	Total	Within tunnel	
Killed	0,03 (0,02)	0,06 (0,03)	0,09 (0,05)	0,07 (0,07)	0,06 (0,05)	0,07 (0,05)	0,03
Severely injured	0,11 (0,11)	0,03 (0,09)	0,1 (0,11)	0,13 (0,13)	0,11 (0,11)	0,11 (0,12)	0,13
Lightly injured	1,45 (1,52)	1,28 (1,22)	1,46 (1,47)	1,37 (1,37)	1,39 (1,38)	1,37 (1,36)	1,26
Sum killed and injured	1,59 (1,66)	1,37 (1,35)	1,65 (1,63)	1,57 (1,56)	1,56 (1,54)	1,55 (1,53)	1,42
Sum killed and severely injured	0,14 (0,14)	0,09 (0,13)	0,19 (0,16)	0,2 (0,19)	0,17 (0,16)	0,18 (0,17)	0,16

Table 4.2 Numbers killed or injured per accident by to tunnel zone.

From the table above it appears that the numbers killed per accident increases with distance from the opening. The same tendency is found with severely injured, while this was not the case with slightly injured. This indicates that although the probability of an accident declines with distance from the opening the severity will increase.
It also appears that the result of tunnel accidents will be more severe than for those taking place on the open road.

The same pattern that was found for all tunnels was also found for tunnels exceeding 500m. It appears that accidents are slightly more severe with tunnels exceeding 500m than with shorter tunnels. This reflects the impression that the severity increases with tunnel length and the distance from the tunnel opening. This might be caused by an increasing driving speed with distance from the opening.

4.2. Accident types

All accidents registered in NVDB are classified according to accident type.

All tunnels (Tunnels 500 meters and longer)							All national roads
Accident type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Within tunnel**	**Tunnel plus zone 1**	
Other accidents	5,3% (5,7%)	3,5% (5,6%)	3,2% (3,9%)	5% (4,6%)	4,2% (4,6%)	4,4% (4,8%)	4,1 %
Same direction	44,4% (39,1%)	37,8% (42,2%)	42,2% (41,2%)	44,7% (45,3%)	42,5% (44%)	42,9% (43,4%)	24,4 %
Opposite direction	15% (17,2%)	14% (10%)	15% (12,7%)	16,3% (15,7%)	15,4% (14,3%)	15,3% (14,7%)	14,8 %
Crossing and turning	2,7% (3,4%)	2,3% (1,1%)	0% (0%)	1,3% (1,4%)	1,2% (1,1%)	1,5% (1,4%)	18,4 %
Pedestrians involved	2,1% (1,1%)	1,7% (2,2%)	1,1% (0%)	0,3% (0,3%)	0,8% (0,5%)	1,1% (0,6%)	6,1 %
Single off-the-road	30,5% (33,3%)	40,7% (38,9%)	38,5% (42,2%)	32,4% (32,8%)	35,9% (35,5%)	34,8% (35,2%)	32,3 %
Sum accidents	**187 (87)**	**172 (90)**	**187 (102)**	**380 (369)**	**739 (561)**	**926 (648)**	

Table 4.3 Accident types by tunnel zone.

Obviously there are very few pedestrian accidents or accidents involving turning/intersection in the tunnels. Pedestrian traffic is prohibited in most tunnels. Frontal collisions and single accidents differ very little from accidents on the road network as a whole. This is also the case for other types accidents including those caused by objects in the roadway. Accidents between vehicles in the same direction, such as rear end collision and lane change (side swipe), however, are more prevalent in road tunnels than elsewhere. There are, relatively speaking, more than twice as many such accidents in tunnels than on the road network as a whole. There is little difference between the various tunnel zones.

It is worth noting that the longer tunnels have the relatively largest number of person injury accidents involving vehicles in the same direction, while the shorter tunnels not surprisingly experience the largest accident involvement of pedestrians. The shorter tunnels also have the relatively largest number of frontal collisions indicating a somewhat higher severity for accidents in shorter tunnels than those in the longer ones.

Subdividing into the four different study tunnel types gives the following tables:

Single tube tunnels (Tunnels 500 meters and longer						
Accident type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Within tunnel**	**Tunnel plus zone 1**
Other accidents	5,4% (2,6%)	1,9% (4,1%)	2,7% (1,8%)	7,9% (7,1%)	4,8% (5,4%)	4,9% (5,1%)
Same direction	33,9% (25,6%)	36,4% (40,8%)	30,1% (26,3%)	26,4% (27,6%)	30,2% (29,7%)	31% (29,2%)
Opposite direction	24,1% (35,9%)	20,6% (14,3%)	24,8% (22,8%)	27,5% (26,5%)	24,9% (23,6%)	24,7% (25,1%)
Crossing and turning	1,8% (2,6%)	2,8% (0%)	0% (0%)	2,2% (2,4%)	1,8% (1,4%)	1,8% (1,6%)
Pedestrians involved	2,7% (2,6%)	2,8% (4,1%)	1,8% (0%)	0% (0%)	1,3% (0,7%)	1,6% (1%)
Single off-the-road	32,1% (30,8%)	35,5% (36,7%)	40,7% (49,1%)	36% (36,5%)	37,2% (39,1%)	36,1% (38,1%)
Sum accidents	**112 (39)**	**107 (49)**	**113 (57)**	**178 (170)**	**398 (276)**	**510 (315)**

Table 4.3.a Accident types by tunnel zone in single tube tunnels

The table shows the distribution of accident types by zone for all single tube tunnels. Accidents between vehicles in the same direction, frontal accidents and single vehicle accidents are most prevalent. These represent 92.3% of accidents within the tunnel. Rear end collisions occur most frequently around the entrances, while single accidents take place most frequently inside the tunnels.

Sub-sea tunnels (Tunnels 500 meters and longer).						
Accident type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Within tunnel**	**Tunnel plus zone 1**
Other accidents	0% (0%)	33,3% (33,3%)	0% (0%)	2,5% (2,5%)	4,3% (4,3%)	4,2% (4,2%)
Same direction	50% (50%)	0% (0%)	0% (0%)	27,5% (27,5%)	23,9% (23,9%)	25% (25%)
Opposite direction	0% (0%)	0% (0%)	0% (0%)	27,5% (27,5%)	23,9% (23,9%)	22,9% (22,9%)
Crossing and turning	50% (50%)	33,3% (33,3%)	0% (0%)	0% (0%)	2,2% (2,2%)	4,2% (4,2%)
Pedestrians involved	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
Single off-the-road	0% (0%)	33,3% (33,3%)	100% (100%)	42,5% (42,5%)	45,7% (45,7%)	43,8% (43,8%)
Sum accidents	**2 (2)**	**3 (3)**	**3 (3)**	**40 (40)**	**46 (46)**	**48 (48)**

Table 4.3.b Accident type by tunnel zone in sub-sea tunnels

The table shows the distribution of accident types in sub-sea tunnels. Accidents in zones 1-3 are too infrequent to provide a meaningful pattern. As many as 97.5% of the accidents in the mid-zone are of the same type as those most prevalent in single tube tunnels. Single vehicle accidents appear to be the main problem with sub-sea tunnels.

Urban dual tube tunnels (Tunnels 500 meters and longer)						
Accident type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Within tunnel**	**Tunnel plus zone 1**
Other accidents	8% (12,1%)	6,1% (5,7%)	5,7% (8,3%)	2,1% (2,1%)	3,7% (3,7%)	4,4% (4,8%)
Same direction	64% (51,5%)	44,9% (45,7%)	66% (63,9%)	68,8% (68,8%)	63,4% (64,2%)	63,5% (62,5%)
Opposite direction	2% (3%)	2% (2,9%)	0% (0%)	1,4% (1,4%)	1,2% (1,4%)	1,4% (1,6%)
Crossing and turning	0% (0%)	0% (0%)	0% (0%)	0,7% (0,7%)	0,4% (0,5%)	0,3% (0,4%)
Pedestrians involved	0% (0%)	0% (0%)	0% (0%)	0,7% (0,7%)	0,4% (0,5%)	0,3% (0,4%)
Single off-the-road	26% (33,3%)	46,9% (45,7%)	28,3% (27,8%)	26,4% (26,4%)	30,9% (29,8%)	30,1% (30,2%)
Sum accidents	**50 (33)**	**49 (35)**	**53 (36)**	**144 (144)**	**246 (215)**	**296 (248)**

Table 4.3.c Accident types by tunnel zone in urban dual tube tunnels

The table shows the distribution of accident types in urban dual tube tunnels. These are tunnels with high traffic volumes and rush hour congestion. The main problems are rear end collisions and lane change conflicts. The share of accidents is highest in the mid-zone. Single accidents are most frequent in zones 2 and 3, but more rare in the mid-zone.

Rural dual tube tunnels (Tunnels 500 meters and longer).						
Accident type	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Within tunnel**	**Tunnel plus zone 1**
Other accidents	0% (0%)	0% (0%)	0% (0%)	5,6% (6,7%)	2% (4,2%)	1,4% (2,7%)
Same direction	52,2% (46,2%)	30,8% (66,7%)	55,6% (66,7%)	72,2% (66,7%)	55,1% (66,7%)	54,2% (59,5%)
Opposite direction	0% (0%)	7,7% (33,3%)	0% (0%)	0% (0%)	2% (4,2%)	1,4% (2,7%)
Crossing and turning	8,7% (7,7%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	2,8% (2,7%)
Pedestrians involved	4,3% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	1,4% (0%)
Single off-the-road	34,8% (46,2%)	61,5% (0%)	44,4% (33,3%)	22,2% (26,7%)	40,8% (25%)	38,9% (32,4%)
Sum accidents	**23 (13)**	**13 (3)**	**18 (6)**	**18 (15)**	**49 (24)**	**72 (37)**

Table 4.3.d Accident types by tunnel zone in rural dual tube tunnels

The table shows the distribution of accident types in rural dual tube tunnels. Here, single vehicle accidents occur more frequently than in urban tunnels.

4.3. Traffic accident temporal occurrence.

The following tables show the distribution of personal injury tunnel accidents by month, day of the week and hourly.

Traffic volumes are estimated based on counts at level 1 points available inside some of the study tunnels. These counts will represent a good indication of traffic distribution also for tunnels lacking counts provided traffic in these tunnels have a similar distribution to those with count data.

Figure 4.1 shows the number of accidents by month. It reveals that more accidents occur during summer and that August is the month with the highest number of accidents. For tunnels as a whole, 11.8% of accidents take place in August. Corresponding number for tunnels longer than 500 meters is 12.5%.

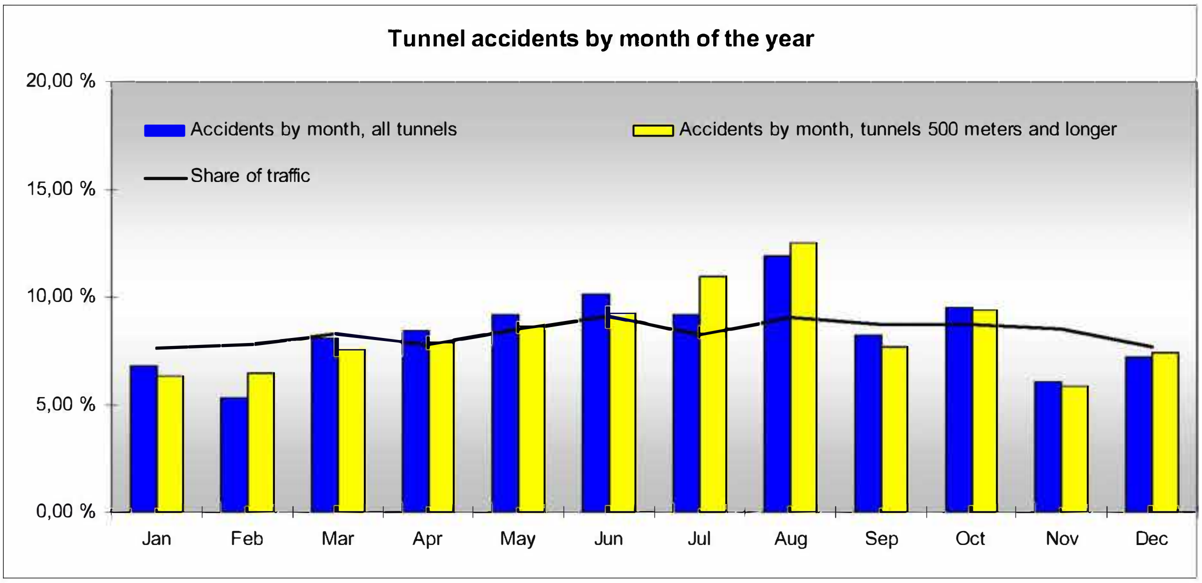


Figure 4.1Tunnel accidents by month.

A general characteristic appears to be that tunnel accidents are overrepresented during the summer months in relationship to traffic volumes.

Figure 4.1b shows traffic accidents by month for the four tunnel types used in this study.

With single tube tunnels the number of summer accidents are higher than traffic gives ground for. With sub-sea tunnels traffic and accidents follow a similar pattern. The tendency is also here that accidents are more frequent in summer than should be expected from its share of traffic.

With dual tube rural tunnels there is no clear correlation, but it appears that November and December have more accidents than should be expected considering the level of traffic.

With dual tube urban tunnels it appears that summer/fall are the periods when the number of accidents exceeds what should expected considering the level of traffic.

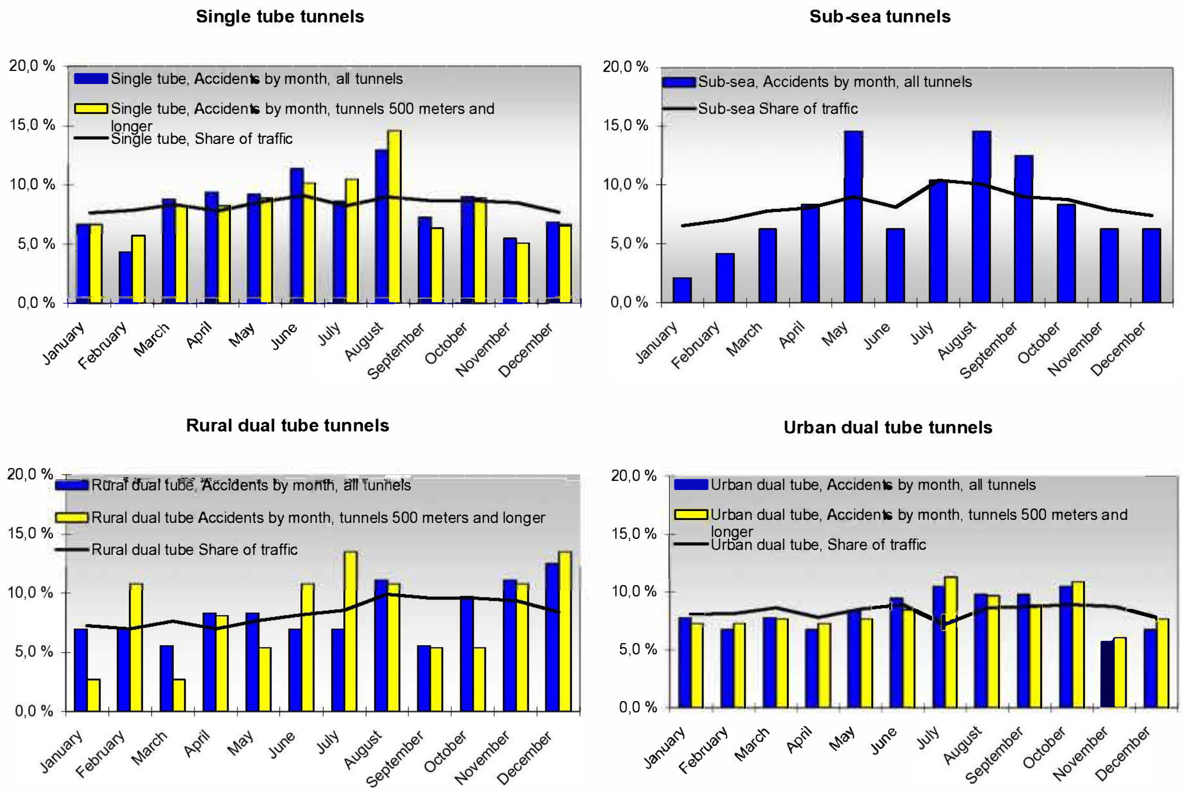


Figure 4.1b Tunnel accidents by month for the various tunnel types

Figure 4.2 below shows tunnel accidents by day of the week. As shown, most person injury tunnel accidents occur on Fridays (17.5%), when its share of the weekly traffic is estimated at 16.3%. With tunnels exceeding 500m no similar clear discrepancy is found for the other days of the week. The figure also shows fewer accidents on Saturdays and Sundays, probably due to less traffic on these days. There appears to be a good correlation between accidents and weekly traffic variations.

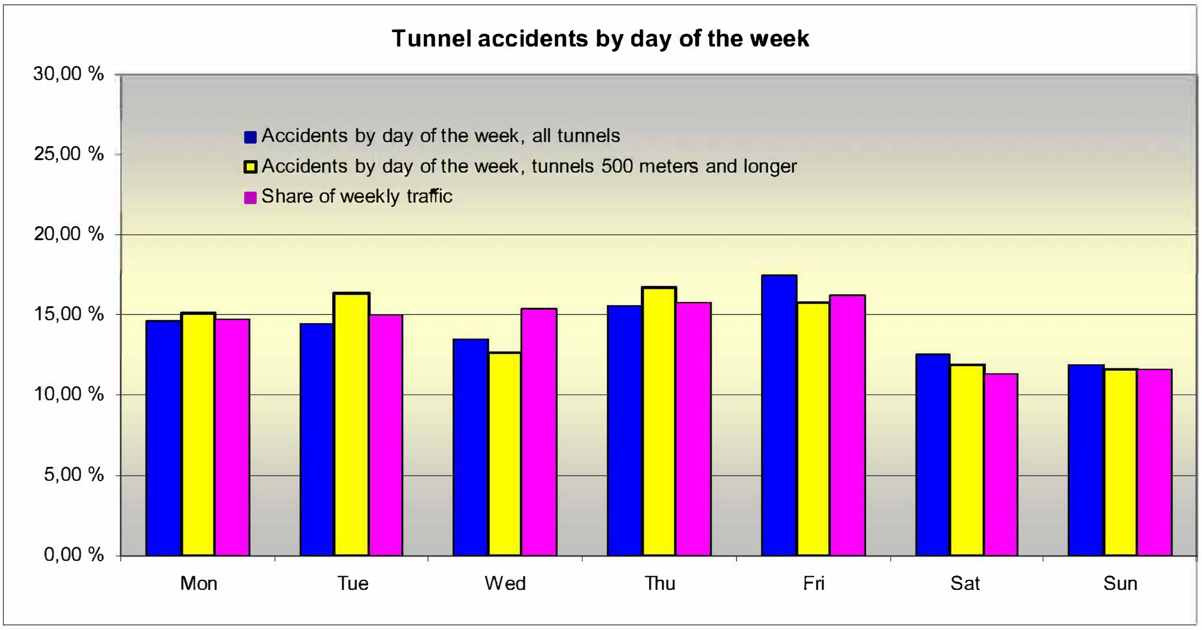


Figure 4.2 Tunnel accidents by day of the week.

The hourly accident distribution shows a minor peak between 0700 and 0900 AM. A total of 9.8% of accidents take place during this period. However, most accidents occur in the afternoon and in particular in the period from 0300 to 0500 PM (23%). Accidents are overrepresented relative to traffic from midnight until 0500 AM and during the two hours during the middle of the day.

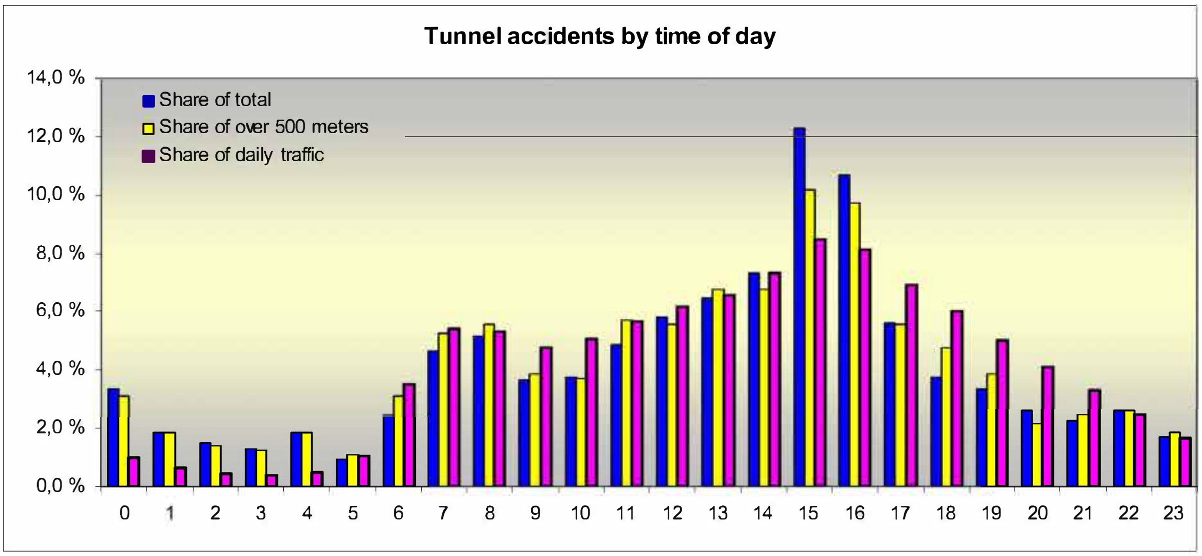


Figure 4.3 Tunnel accidents by time of day.

4.4. Traffic accidents in tunnel zones

Figure 4.4 below gives accident rates for the various tunnel zones.

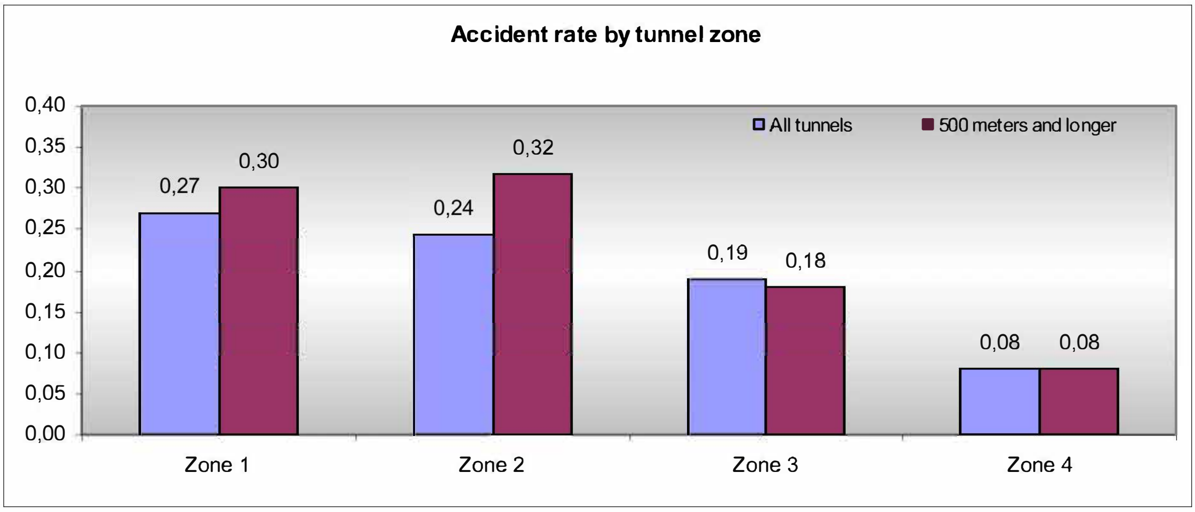


Figure 4.4 Accident rate by tunnel zone.

This study confirms earlier study findings that entrance zones experience the highest accident rate, and that the accident rate declines with distance from the opening. With tunnels exceeding 500 meters, zone 2 has a somewhat higher rate than zone 1, while with tunnels exceeding 500 meters it is zone 1 that experiences the highest accident rate. Why tunnels shorter than 500 meters has a lower accident rate could be attributed to improved visibility throughout the tunnel due to less variation in light conditions than in longer tunnels.

The overall accident rate for all tunnels is 0.12 and it is 0.10 for tunnels longer than 500 meters. When zone 1 is included the accident rate is 0.13 for all tunnels and 0.12 for those longer than 500 meters.

The figure below shows accident rates by zone for the various tunnel types.

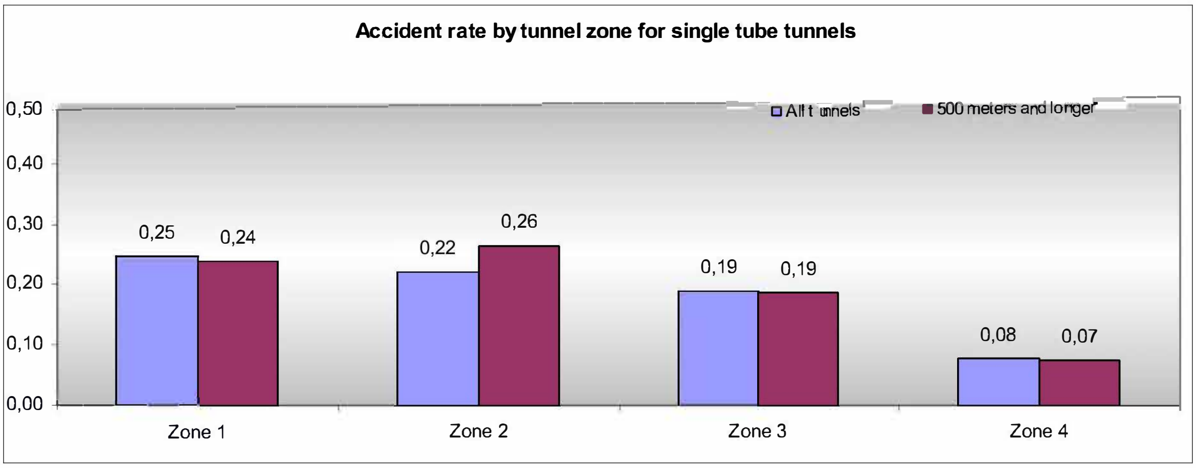


Figure 4.5 Accident rates by zone with single tube tunnels/two-way traffic.

There is little difference in single tube tunnel accident rates between zone 1 and zone 2. The rate is still lower in zone 3 and remains low inside the tunnel.

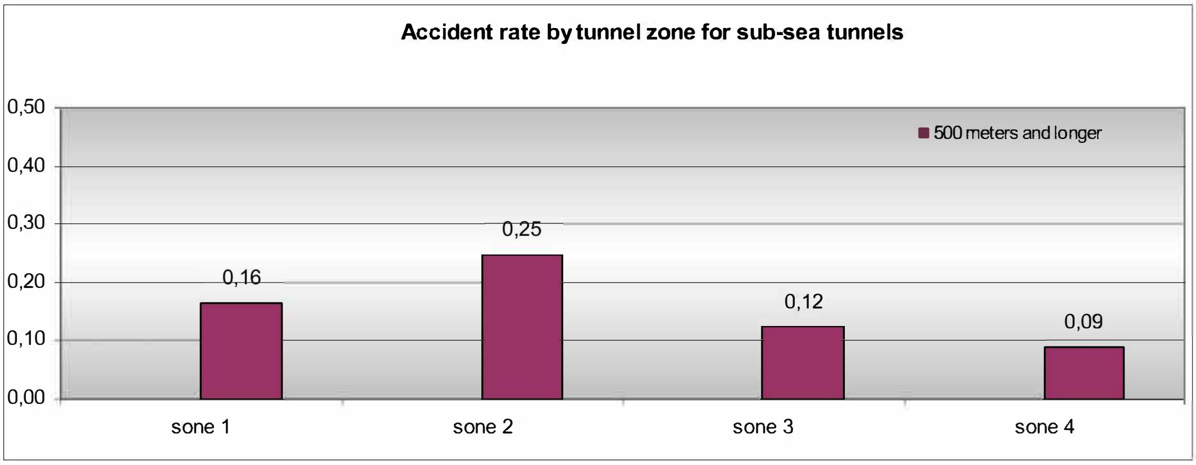


Figure 4.6 Accident rates by zone with sub-sea tunnels.

In sub-sea tunnels the accident rate is highest on the first 50 meters into the tunnel. Accident rates within these tunnels differ little from regular single tube tunnels. This might be an indication that drivers are more cautious when entering sub-sea tunnels than elsewhere.

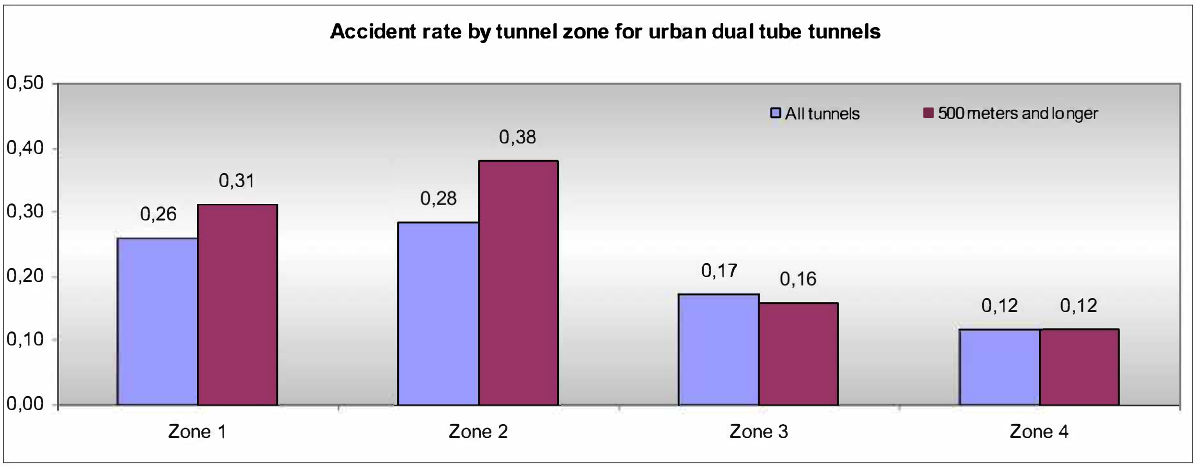


Figure 4.7 Accident rate by zone with urban dual tube tunnels.

Urban dual tube tunnels experience a somewhat higher accident rate on the first 50 meters inside the tunnel than outside. This might be caused by queuing. The accident rate is, however, generally slightly higher than what should be expected. This might be the result of high traffic volumes and occasional congestion.

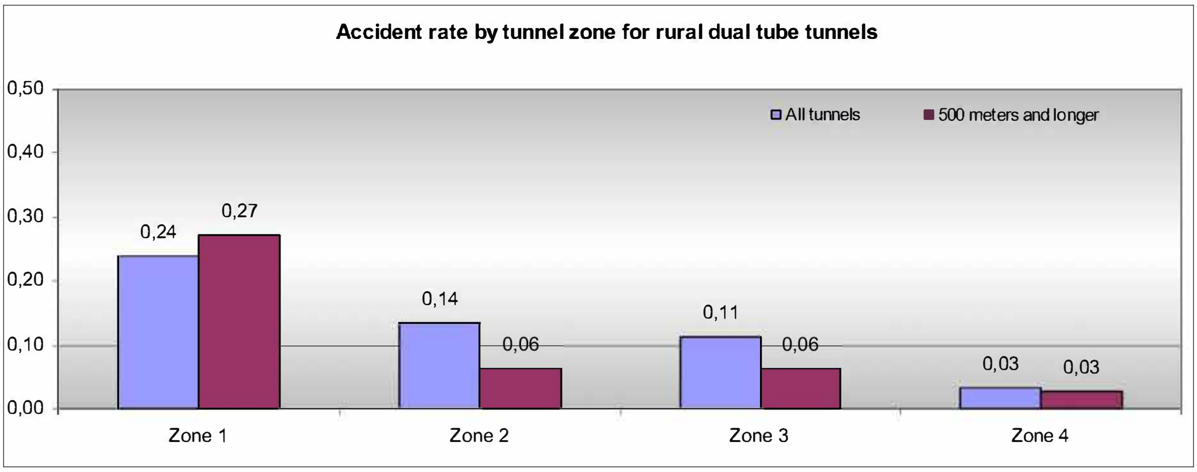


Figure 4.8 Accident rate by zone with rural dual tube tunnels.

With rural dual tube tunnels the accident rate is highest just outside the tunnels. The rate declines with distance from the opening and is rather low in the mid-zone. The accident rate just outside the tunnels is on a par with other type tunnels.

4.5. Accidents and tunnel length

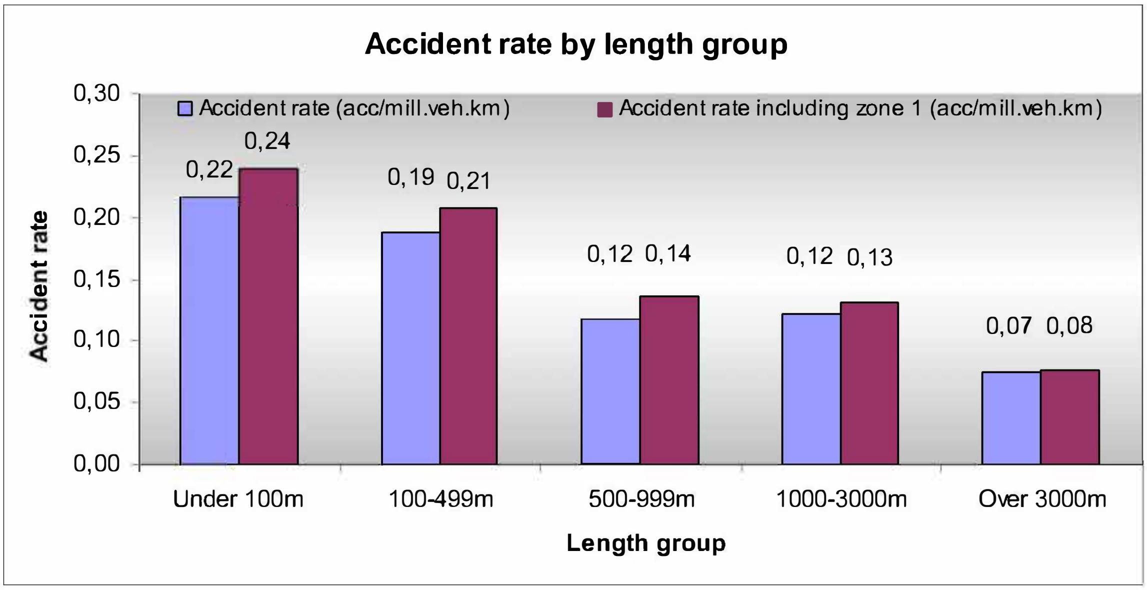


Figure 4.9 Accident rate by length group.

Results from this study support findings from all previous studies with regard to accident rates and tunnel length. Tunnel accident rates vary between 0.22 for tunnels shorter than 100 meters and down to 0.08 for tunnels longer than 3000 meters. When entrance zones are included, the accident rate increases slightly for all length groups. The figure below similarly depicts rates by tunnel type for the four groups selected for study.

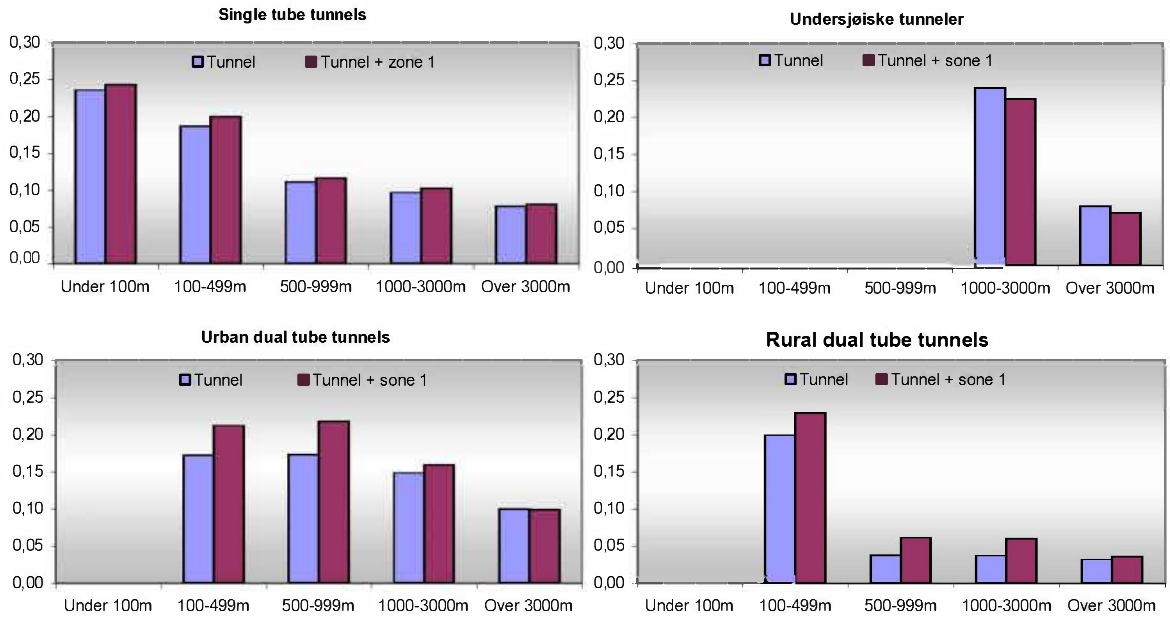


Figure 4.10 Accident rate by length group with the various tunnel types.

With single tube and urban dual tube tunnels there is a significant correlation between tunnel length and accident rate. The longer tunnels are safer than the shorter ones. With sub-sea tunnels and rural dual tube tunnels the accident rate is particularly high with the shorter tunnels.

4.6. Accidents and AADT

To investigate any correlation between tunnel traffic volume and number of accidents, all accidents were arranged by AADT. The basis for estimating vehicle mileage, accident rates and opening year were the same. The results are shown in Table 4.4.

All tunnels (Tunnels 500 meters and longer)				
AADT Class	**Number of tunnels**	**Tunnel accidents**	**Accidents with entrance zone**	**Accident rate (acc/mill.veh.km)**
Under 500	177 (65)	19 (10)	29 (13)	0,18 (0,11)
500-999	148 (70)	36 (31)	42 (35)	0,16 (0,15)
1000-5000	297 (145)	175 (138)	200 (152)	0,11 (0,1)
Over 5000	175 (80)	509 (382)	656 (449)	0,12 (0,1)

Table 4.4 Accidents by AADT group.

The figure below shows the accident rate by AADT group.

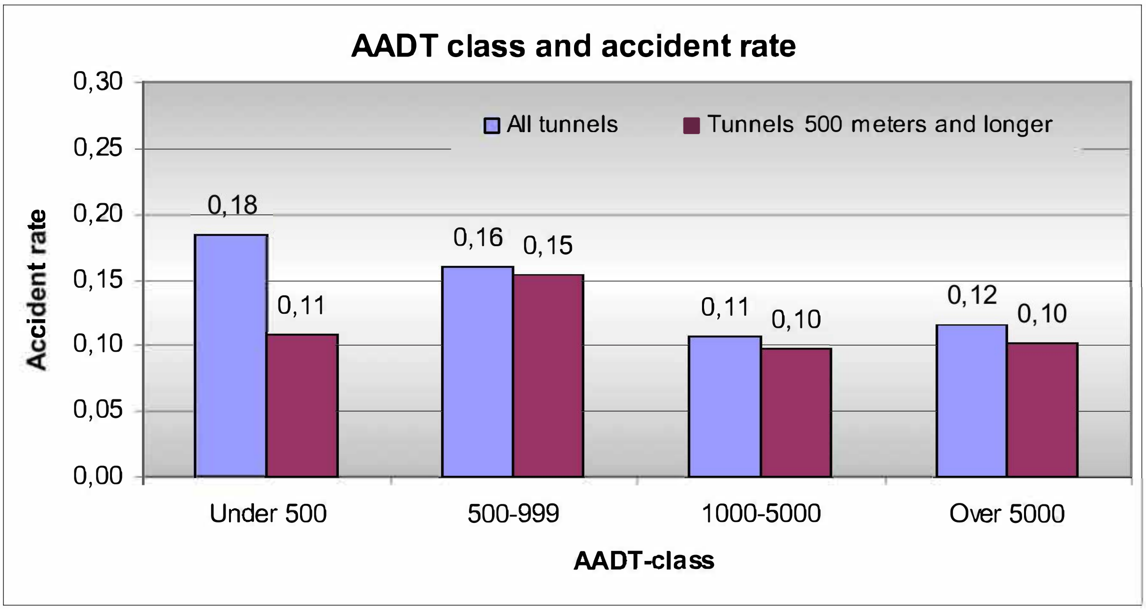


Figure 4.11 Accident rate by AADT group

The results from the study as a whole indicate a certain correlation between traffic volume and accident rate. It appears that the accident rate declines with increasing traffic volume. This might be attributed to the fact that tunnels with less traffic generally also have a lower standard than those carrying more traffic.

When considering tunnels longer than 500 meters it was found that the tunnels with an AADT of less than 500 had the same accident rate as tunnels with an AADT over 1000.

4.7. Accidents and weather and driving conditions

The table below shows the correlation between accidents and visibility.

Accidents and visibility				
	All tunnels		Tunnels 500 meters and longer	
	Tunnelzones 2-4	Tunnelzones 1-4	Tunnelzones 2-4	Tunnelzones 1-4
1 Good visibility, no precipitation	76,2 %	76,2 %	77,5 %	77,3 %
2 Good visibility, precipitation	8,5 %	9,4 %	6,8 %	7,3 %
3 Poor visibility, precipitation	1,8 %	2,2 %	1,1 %	1,4 %
4 Poor visibility, fog/haze	0,3 %	0,2 %	0,4 %	0,3 %
5 Poor visibility otherwise	3,1 %	2,9 %	3,4 %	3,4 %
9 Unknown	10,1 %	9,1 %	10,9 %	10,3 %
Total	739	926	561	648

Table 4.5 Accidents and visibility

The table shows that most accidents take place during periods with good visibility. This is not unexpected as this is the driving condition that predominates. Unfortunately no data is available to study the distribution of accidents by type of weather.

The table shows that there are more accidents during poor visibility when including the entrance zone than when only the tunnel itself is included. Poor visibility inside the tunnel can be caused by adverse weather conditions extending into the entrance zone. It may also result from inadequate illumination and also that ventilation, where it exists, cannot adequately eliminate particles produced by traffic.

The next table shows the correlation between roadway conditions and accidents.

Accidents and driving conditions				
	All tunnels		Tunnels 500 meters and longer	
	Tunnelzones 2-4	Tunnelzones 1-4	Tunnelzones 2-4	Tunnelzones 1-4
1. Dry, bare road	63,7 %	61,3 %	66,1 %	64,4 %
2. Wet, bare road	23,8 %	25,1 %	23,0 %	23,3 %
3. Snow or ice covered	2,4 %	2,9 %	1,4 %	1,9 %
4. Partly snow or ice covered	3,4 %	4,1 %	2,1 %	2,9 %
5. Otherwise slippery	2,2 %	2,3 %	2,3 %	2,5 %
6. Unknown	4,5 %	4,3 %	5,0 %	5,1 %
Total	739	926	561	648

Table 4.6 Accidents and roadway conditions

Understandably, most tunnel accidents take place on dry road surfaces. As expected, the relative extent of dry surface conditions diminishes slightly when accidents in zone 1 are included. The recording of snow and slippery road in tunnels can be due to recording mistakes. But it is also known that vehicles to some extent drag with them snow/ice and other matter from the outside that they shed inside tunnels. It appears that the problem with poor road conditions inside tunnels is greater with shorter tunnels than those longer than 500 meters.

4.8. Accidents and speed limits

All tunnel accidents are in this section assigned speed limits according to the NVDB data. There are most likely some errors in this data bank, but it might still shed some light on the situation.

The initial table shows all tunnel accidents by speed limit.

All tunnels by speed limit (Tunnels 500 meters and longer by speed limit)							
	50 and lower	60	70	80	90	100	Total
Killed	5 (5)	3 (3)	7 (7)	25 (24)	0 (0)	0 (0)	40 (39)
Severely injured	10 (6)	6 (5)	11 (5)	56 (43)	2 (2)	0 (0)	85 (61)
Lightly injured	91 (42)	124 (99)	232 (195)	515 (401)	32 (21)	11 (11)	1005 (769)
Number of accidents	72 (40)	95 (74)	163 (135)	384 (297)	19 (9)	6 (6)	739 (561)
Length in km	20,4	40,5	74,3	627,9	9,9	5,4	778,5

Table 4.7 Person injury accidents by speed limit.

That most accidents take place in tunnels with 80 km/h speed limit is to be expected because this is the predominant speed limit in tunnels. What is surprising are the many fatalities in tunnels with speed limits of 50 km/h or less. This might be a result of recording mistakes, or due to lack of respect for temporary speed limits for example in connection with road work. The tunnels in question are: Bergjeland in Rogaland county, Moa in Møre and Romsdal county, Breivika and Sentrumstangenten in Troms county (the latter being a special tunnel containing roundabouts and having sections with both 50 km/h and 70 km/h speed limits) and Skarveberget in Finnmark county. Tunnels with 90 km/h or 100 km/h speed limits experience few accidents with low injury severity. This might be because these are relatively modern tunnels with one-way traffic.

4.9. Accidents and curvature

All tunnel accidents (zone 2-4) are in this section of the report linked to gradient and radius. Unfortunately, curvature data is lacking for 141 of the accidents or about 19%. Of these accidents 77 take place in single tube tunnels, 9 in sub-sea, 50 in urban dual tube and 5 in rural dual tube tunnels. Data on gradient and radius is lacking for just over 2% of the overall tunnel length.

A result of this is that the accident rate will be underestimated.

The table below shows the number of tunnel accidents and accident rates by gradient group for various tunnel lengths.

Number of accidents (Length in km)				Accident rate		
	Under 500 meter	500 meters and over	All tunnels	Under 500 meter	500 meters and over	All tunnels
Gradient under 1%	64 (26)	112 (189)	176 (216)	0,18	0,07	0,09
Gradient 1-3%	58 (24)	159 (242)	217 (267)	0,22	0,09	0,11
Gradient 3-5%	18 (15)	84 (114)	102 (129)	0,10	0,09	0,09
Gradient 5-8%	8 (11)	78 (78)	86 (89)	0,12	0,10	0,10
Gradient over 8%	1 (7)	16 (54)	17 (61)	0,03	0,07	0,06
Unknown	29 (4)	112 (14)	141 (18)	-	-	-

Table 4.8 Accidents and accident rate by gradient group

It is not easy to ascertain any clear correlation between accidents and gradient from the table above. It appears that gradient has no appreciable influence on accident rate. It would have been easier to draw a firm conclusion with data available on all accidents. Moreover, it is also worth mentioning that there might be a difference between gradient along a section and that of a given point along such section. This is a possible source of error when correlating these data.

Another possibility of not finding an expected clear correlation could be that the accident itself can be triggered by a steep gradient followed by a less steep section where the incident is recorded to have happened.

Table 4.9 below shows the number of accidents and accident rate by radius groups for various tunnel lengths.

Number of accidents (Length in km)				Accident rate		
	Under 500 meter	500 meters and over	All tunnels	Under 500 meter	500 meters and over	All tunnels
Radius under 150	11 (7)	20 (8)	31 (14)	0,26	0,36	0,31
Radius 150-299	25 (12)	46 (26)	71 (38)	0,23	0,17	0,19
Radius 300- 599	20 (14)	91 (73)	111 (87)	0,14	0,12	0,12
Radius over 600	93 (52)	292 (570)	385 (622)	0,15	0,07	0,08
Unknown	29 (3)	112 (14)	141 (17)	-	-	-

Table 4.9 Accidents and accident rate by radius group.

Even though the accident rates in the above table are underestimated, the variation is so large that it can with confidence be claimed that the accident rate declines with increasing gradient.

4.10. Tunnels and special characteristics

The table below shows the number of accidents by length group for single tube, dual tube and sub-sea tunnels. Dual tube tunnels are again attempted split into urban and rural tunnels because their accident propensity is anticipated to be rather different. The first table gives tunnel accidents both with and without zone 1 being included.

Number of accidents by length group and tunnel type								
	Single tube		Sub-sea		Urban dual tube		Rural dual tube	
Length group	Tunnel	Tunnel + zone 1	Tunnel	Tunnel + sone 1	Tunnel	Tunnel + sone 1	Tunnel	Tunnel + sone 1
Under 100m	9	24	0	0	0	0	0	1
100-499m	113	171	0	0	31	48	25	34
500-999m	85	102	0	0	60	81	8	14
1000-3000m	119	134	11	13	154	170	9	15
Over 3000m	57	60	35	35	16	16	7	8
Sum	383	491	46	48	261	315	49	72

Table 4.10 Accidents by length group and tunnel type

When strictly considering the number of accidents, most take place in single tube and urban dual tube tunnels. With single tube tunnels this is clearly linked with the fact that this is the most common type tunnel. With urban dual tube tunnels this might be caused by a number of factors such as traffic volume, daily traffic volume variation, ramp design, standards, age etc.

The accident rate for the various tunnel types is shown in the tables below, where the first table concerns the tunnel itself.

Accident rate by tunnel type								
	Single tube		Sub-sea		Urban dual tube		Rural dual tube	
Length group	Tunnel	Tunnel + zone 1	Tunnel	Tunnel + sone 1	Tunnel	Tunnel + sone 1	Tunnel	Tunnel + sone 1
Under 100m	0,24	0,24						
100-499m	0,19	0,20			0,17	0,21	0,20	0,23
500-999m	0,11	0,12			0,17	0,22	0,04	0,06
1000-3000m	0,10	0,10	0,24	0,22	0,15	0,16	0,04	0,06
Over 3000m	0,08	0,08	0,08	0,07	0,10	0,10	0,03	0,04
All tunnels	0,11	0,13	0,09	0,10	0,15	0,18	0,06	0,09
Tunnels 500 and longer	0,10	0,10	0,09	0,10	0,15	0,17	0,04	0,06

Table 4.11 Tunnel accident rate by length group and tunnel type.

The table shows that the accident rate declines with tunnel length for all tunnel types. Single tube tunnels over 3000 meters have about the same accident rate as sub-sea tunnels. With consideration to generally steeper gradient in sub-sea tunnels, a larger difference should possibly be expected.

It is also interesting to notice the large difference in accident rate between urban and rural dual tube tunnels. This applies to all tunnels exceeding 500 meters. The explanation might be traffic volume, standards, ramp design etc.

When including zone 1, it appears that the overall risk increases in most cases. This means that zone 1 contributes with a disproportionately large share of the person injury accidents.

The severity of accidents (expressed as number of fatally and fatally/severely injured per accident) for the various tunnel length groups is found in the table below.

Numbers killed and numbers killed plus severely injured for tunnel (zone 2-4)								
	Killed per accident				Killed and severely injured per accident			
	Single tube	Sub-sea	Urban dual tube	Rural dual tube	Single tube	Sub-sea	Urban dual tube	Rural dual tube
Under 100m	0,00				0,22			
100-499m	0,01		0,00	0,00	0,19		0,00	0,06
500-999m	0,06		0,00	0,02	0,12		0,00	0,05
1000-3000m	0,08	0,27	0,00	0,01	0,25	0,45	0,11	0,04
Over 3000m	0,19	0,09	0,00	0,06	0,51	0,23	0,00	0,19
All length groups	0,07	0,13	0,00	0,02	0,23	0,28	0,02	0,05
Tunnels 500m and longer	0,10	0,13	0,00	0,02	0,24	0,28	0,03	0,05

Table 4.12 Accident severity by tunnel length group

This table shows that single tube tunnels and sub-sea tunnels (with two-way traffic) experience significantly more severe accidents than dual tube tunnels (with one-way traffic). That sub-sea tunnels have the highest severity can be a result of the fact that these are single tube tunnels often with a steep gradient resulting in high speeds down towards the low point of the tunnel. From the power model it is known that there is a strong correlation between driving speed and the resulting injuries from an accident.

The table below shows the same type data, but with zone 1 included.

Numbers killed and numbers killed plus severely injured for tunnel (zone 1-4)								
	Killed per accident				Killed and severely injured per accident			
	Single tube	Sub-sea	Urban dual tube	Rural dual tube	Single tube	Sub-sea	Urban dual tube	Rural dual tube
Under 100m	0,00		0,00		0,29		0,00	
100-499m	0,03		0,00	0,00	0,17		0,03	0,04
500-999m	0,07		0,00	0,02	0,15		0,29	0,05
1000-3000m	0,07	0,23	0,07	0,02	0,22	0,38	0,20	0,04
Over 3000m	0,18	0,09	0,00	0,06	0,48	0,23	0,25	0,19
All length groups	0,07	0,13	0,01	0,02	0,22	0,27	0,14	0,05
Tunnels 500m and longer	0,09	0,13	0,03	0,02	0,24	0,27	0,24	0,05

Table 4.13 Accident severity by tunnel length group with entrance zone included

This table shows that injury severities are rather similar except for the rural dual tube tunnel type. With this type tunnel nearly all accidents during the study period occurred in zone 1 which encompasses the last 50 meters before the tunnel opening.

Of dual tube tunnels, those located in urban areas have the highest accident rate, but the accident severity is higher in the rural ones. This becomes evident when grouping together fatally and severely injured. It is difficult to draw any conclusions with regard to fatal injuries alone because their numbers are very low.

4.11. Injury costs in tunnels

Injury costs are estimated as total economic accident costs to society per vehicle kilometer within tunnels.

	Injury costs zone 1-4			
	Single tube	**Sub-sea**	**Urban dual tube**	**Rural dual tube**
Under 100m	1,61	-	0,21	-
100-499m	0,75	-	0,29	0,41
500-999m	0,54	-	0,34	0,31
1000-3000m	0,46	-*	0,22	0,31
Over 3000m	0,62	0,34	0,11	0,32
Total	0,58	-*	0,23	0,32
500m and longer	0,52	-*	0,22	0,31

Table 4.14 Tunnel injury costs by type and length group.

* Excluded as there is only one tunnel in this length group.

It is worth noting that the relatively large difference in injury costs for dual tube tunnels reflects whether it is located in an urban or rural area. Earlier it has not normally been distinguished between these two tunnel types, but from this study it seems appropriate to introduce such differentiation.

The injury cost table also shows that cost declines with tunnel length, which is in complete agreement with earlier data on accident rates and injury severity.

4.12. Correlation between tunnel length and accident rate

The figure below shows the correlation between accident rate and tunnel length. Caution should be used when interpreting the results as length is also included in the accident rate.
Another aspect is the fact that most tunnels had no accidents during the study period, a fact that makes interpretation of results more difficult.
The graph below is also limited to tunnels with lengths between 100 meters and 10 000 meters.

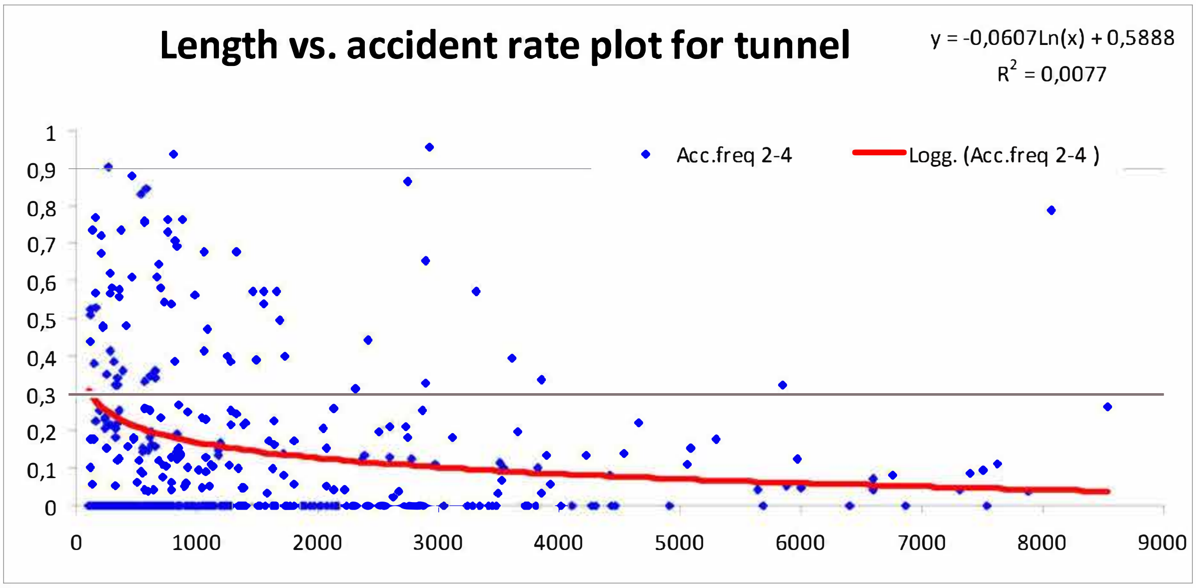


Figure 4.12 Trend line for tunnel length and accident rate.

It might appear that there is a tendency for the accident rate to decline with increasing tunnel length. That there is no strong correlation is not a weakness in this case. It would have been strange if tunnel length should have been the only explanation for tunnel accident levels.

When eliminating tunnels with no accidents during the study period the following graph emerges.

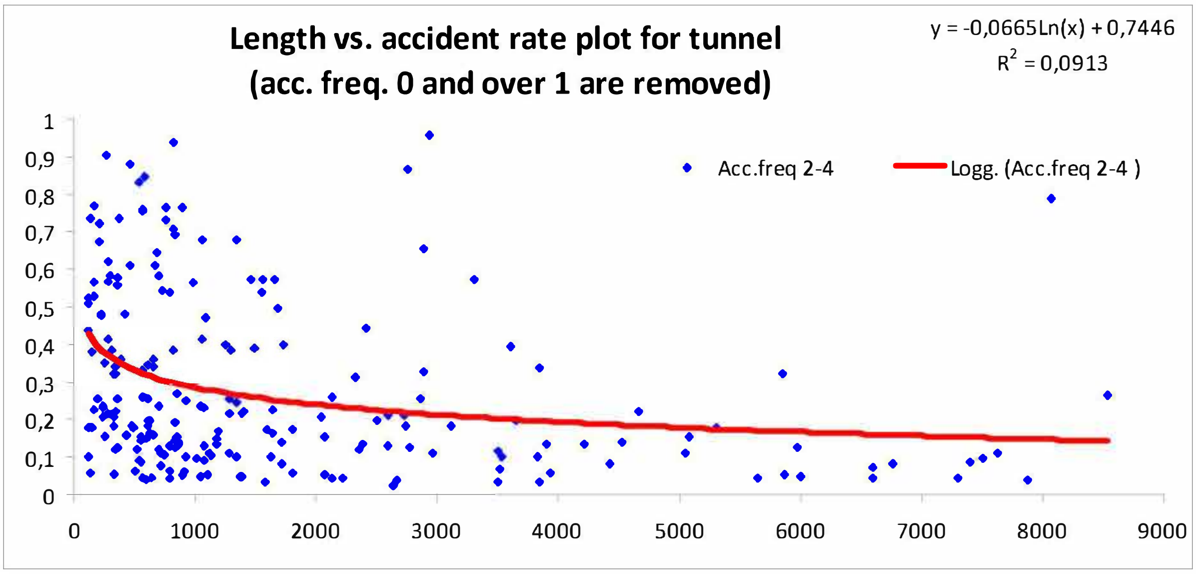


Figure 4.13 Trend line for tunnel length and accident rate, tunnels without accidents excluded.

Trend lines for the two graphs have similar shape and correspond with the shape found from sub-sea tunnel studies.

4.13. Correlation between accident rate and AADT

When studying the correlation between traffic volume and accident rate, caution is again warranted when making interpretations because AADT is also included in the accident rate.

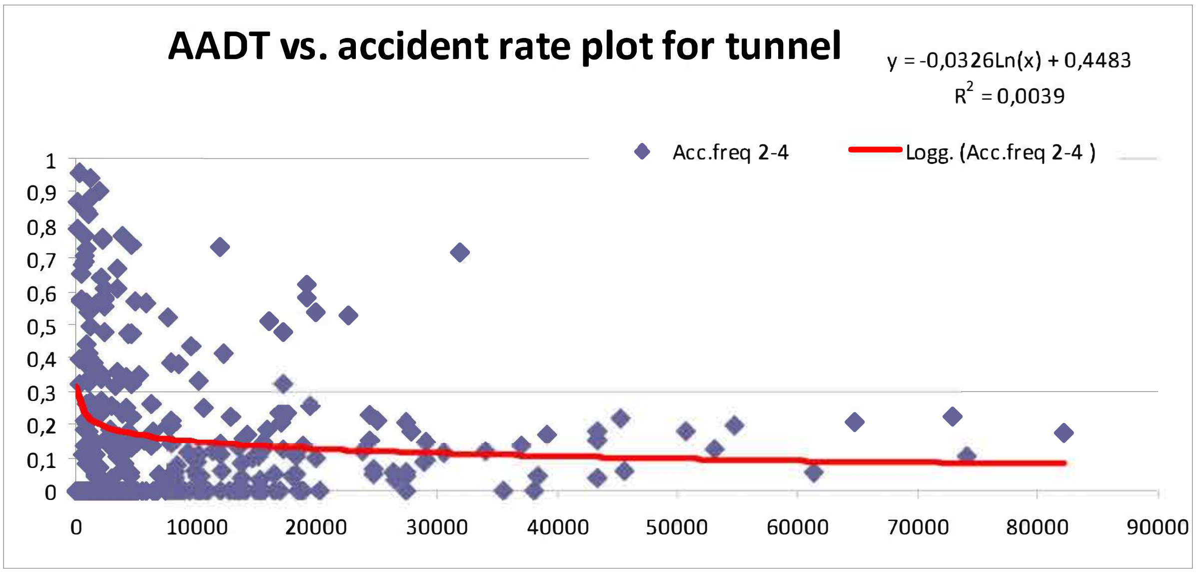


Figure 4.14 Trend line for AADT and accident rate

It appears that the accident rate declines with tunnel length, but the correlation is weak also in this case. It would have been just as strange if AADT could be a factor explaining tunnel accidents as is tunnel length. The shape of the graph also corresponds to those of earlier studies.

When tunnels without accidents are disregarded the following graph emerges:

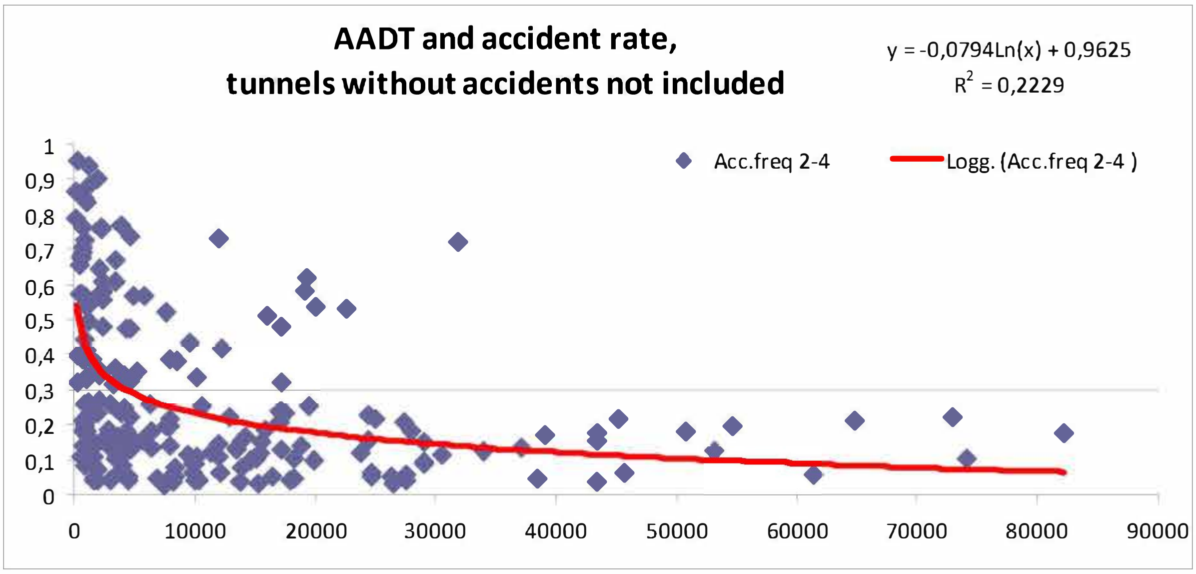


Figure 4.15 Trend line for AADT and accident rate, tunnels without accidents excluded.

The tale ends look relatively similar in both cases, but with AADT up towards 40000 there is a noticeable difference. This is due to the fact that most tunnels (all) without accidents experience a lower AADT.

5. Summary and Results

The objective of this road tunnel accident study is in part to view the accident development relative to that of previous studies and partly to acquire data to develop and calibrate risk analyses. The results can also be used in conjunction with revision of guidelines and handbooks.

The study is based on 797 tunnels opened to traffic before 2006. A total of 926 person injury accidents were registered in 250 tunnels during the six-year period between 2001 and 2006. Thus, no accidents have occurred in 69% of the tunnels. In the study the tunnels are divided into the following four groups: Single tube tunnels (729), sub-sea tunnels (22), urban dual tube tunnels (25) and rural dual tube tunnels (22).

In general, the study shows that in spite of fewer accidents occurring in the tunnels, their severity is higher. The number of accidents per vehicle kilometer, however, is lower than on the open road. This difference can in part be attributed to the fact that several types accident rarely occur in tunnels, while the most common tunnel accidents are often serious. The three most common tunnel accident types are: Same direction (rear end or lane change) with 43%, single vehicle accidents with 35% and head-on accidents with 15%. In single tube tunnels single vehicle accidents are most common, while collisions between vehicles in the same direction are most common in dual tube tunnels.

The accident risk is greatest just outside the tunnel and on the first 50 meters into the tunnel, i.e. in the entrance zone. In the mid-zone the risk is low. The accident risk in single tube tunnels and urban dual tube tunnels are at the same level. Dual tube rural tunnels experience low risk when disregarding the first 50 meters into the tunnel.

The accident risk seems to be highly correlated with tunnel length. The longer tunnels have a significantly lower accident rate than the shorter tunnels. This is partly due to the fact that the entrance zone represents a smaller part of the longer tunnels and that there appears that drivers adapt to tunnel driving.

It also appears that tunnels with a high AADT are safer than low traffic volume tunnels. This is partly due to high volume tunnels are being built to a higher standard and in part that dual tube tunnels have an inherently low risk and high standard.

The study also shows that there is a close correlation between accident risk and horizontal curvature. It has been impossible to find a similar correlation between accident risk and gradient. This might be because the data does not catch the gradient problem well enough.

Litterature

Amundsen, Finn H. Roald, Per Ola Ragnøy, Arild Engebretsen, Arild	Trafikkulykker i undersjøiske vegtunneler Rapport 05/2005. Veg og trafikkavdelingen. TS-seksjonen Oslo 2005
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Appendix 1. Tunnels with the most accidents by region.

The sorting is done on tunnel accidents, i.e. zone 2-4. Numbers in parenthesis include entrance zone accidents, i.e. zones 1-4.

Region east.

County	Road	Name	Length	AADT_2005	Height	Width	Tub	Accidents zone 2-4 (zone 1-4)	Killed zone 2-4 (Zone 1-4)	Seriously injured zone 2-4 (zone 1-4)	Slightly injured zone 2-4 (zone 1-4)
Oslo	EV 18	Festnings	1800	82192	4,5	12	2	55 (59)	1 (2)	1 (1)	86 (90)
Oslo	RV 150	Tåsen	1282	45254	4,5	12	2	27 (27)	0 (0)	1 (1)	44 (44)
Oslo	RV 190	Ekeberg	1600	39100	4,5	7,3	2	23 (30)	0 (0)	0 (0)	29 (40)
Oslo	RV 190	Vålereng	831	54676	4,5	7	2	19 (25)	1 (1)	1 (1)	29 (41)
Oslo	EV 6	Svartdal	1391	24976	4,5	-	2	16 (19)	0 (0)	1 (1)	16 (22)

Region south.

County	Road	Name	Length	AADT_2005	Height	Width	Tub	Accidents zone 2-4 (zone 1-4)	Killed zone 2-4 (Zone 1-4)	Seriously injured zone 2-4 (zone 1-4)	Slightly injured zone 2-4 (zone 1-4)
Vest Agder	EV 18	Baneheia	785	20000	4,5	9	1	15 (19)	1 (1)	0 (0)	18 (24)
Vest Agder	RV 457	Flekkerøy	2319	3250	4,5	5,6	1	5 (6)	1 (1)	1 (1)	4 (5)
Telemark	RV 354	Vabakken	566	10200	4,5	-	1	4 (4)	0 (0)	0 (0)	5 (5)
Buskerud	EV 18	Kleivene	553	28983	4,7	7,3	1	3 (3)	1 (1)	0 (0)	9 (9)
Buskerud	EV 16	Nes	1276	10155	4,5	6,7	1	3 (4)	0 (0)	1 (1)	3 (4)

Region West.

County	Road	Name	Length	AADT_2005	Height	Width	Tub	Accidents zone 2-4 (zone 1-4)	Killed zone 2-4 (Zone 1-4)	Seriously injured zone 2-4 (zone 1-4)	Slightly injured zone 2-4 (zone 1-4)
Hordaland	EV 39	Fløyfjell	3825	19884	4,5	6,5	2	16 (16)	1 (1)	2 (2)	19 (19)
Hordaland	RV 540	Løvstakken	2045	17096	3,8	7	1	15 (18)	1 (1)	2 (2)	19 (22)
Hordaland	RV 555	Damsgård	2360	23800	4,6	6,5	2	14 (14)	0 (0)	0 (0)	18 (18)
Hordaland	EV 39	Eidsvåg	854	43400	4,5	6,5	2	12 (17)	0 (0)	1 (1)	17 (26)
Hordaland	RV 555	Nygård	864	37100	4,5	7	2	9 (12)	0 (0)	0 (0)	11 (14)
Hordaland	RV 555	Lyderhorn	1115	30600	4,5	6,5	2	8 (10)	1 (1)	1 (1)	15 (20)
Rogaland	RV 509	Bergjeland	705	17200	4,6	6,5	1	6 (7)	1 (1)	0 (0)	6 (7)
Hordaland	EV 39	Mundalsberget	1085	4660	4,3	6,1	1	5 (5)	0 (0)	2 (2)	8 (8)
Hordaland	RV 555	Kolltveit	1070	13500	4,5	6,5	1	4 (5)	0 (0)	0 (0)	5 (7)
Hordaland	EV 16	Risnes	1718	7971	4,5	7	1	4 (4)	1 (1)	1 (1)	4 (4)

Region Middle.

County	Road	Name	Length	AADT_2005	Height	Width	Tub	Accidents zone 2-4 (zone 1-4)	Killed zone 2-4 (Zone 1-4)	Seriously injured zone 2-4 (zone 1-4)	Slightly injured zone 2-4 (zone 1-4)
Sør-Trøndelag	EV 6	Hell	3928	12120	4,5	7	1	6 (6)	1 (1)	0 (0)	10 (10)
Sør-Trøndelag	EV 6	Være	1625	14630	4,5	7	1	5 (5)	0 (0)	0 (0)	10 (10)
Møre og Romsdal	RV 70	Freifjord	5086	2400	4,5	9	1	4 (4)	0 (0)	2 (2)	5 (5)
Møre og Romsdal	RV 658	Valderøy	4222	3300	4,5	9	1	4 (4)	0 (0)	0 (0)	4 (4)
Sør-Trøndelag	EV 6	Stavsjøfjell	1720	13870	4,5	7	1	4 (4)	0 (0)	1 (1)	12 (12)

Region North.

County	Road	Name	Length	AADT_2005	Height	Width	Tub	Accidents zone 2-4 (zone 1-4)	Killed zone 2-4 (Zone 1-4)	Seriously injured zone 2-4 (zone 1-4)	Slightly injured zone 2-4 (zone 1-4)
Troms	EV 8	Tromsøysund	3500	9360	4,6	6	2	8 (8)	0 (0)	1 (1)	10 (10)
Troms	RV 862	Breivik/Sentrumstangenten	3899	6372	4,5	6,5	1	7 (8)	2 (2)	3 (3)	3 (4)
Nordland	RV 835	Steigen	8079	219	4,2	6,5	1	3 (3)	1 (1)	1 (1)	2 (2)
Nordland	EV 6	Korgfjell	8533	1213	4,6	6,5	1	2 (2)	1 (1)	0 (0)	1 (1)
Nordland	EV 6	Leirvik	549	1092	4,2	5,4	1	2 (2)	1 (1)	0 (0)	1 (1)
Troms	RV 868	Pollfjellet	3306	500	4	3	1	2 (2)	0 (0)	0 (0)	2 (2)
Finnmark	EV 69	Skarvberget	2930	340	4	4,7	1	2 (2)	1 (1)	0 (0)	2 (2)
Finnmark	EV 75	Vardø	2895	1000	4,5	6,5	1	2 (2)	1 (1)	1 (1)	1 (1)
Nordland	EV 6	Aspfjord	1496	799	4,1	5,5	1	1 (1)	0 (0)	0 (0)	1 (1)
Nordland	RV 827	Brattli	3606	326	4,6	5,5	1	1 (1)	0 (0)	0 (0)	1 (1)

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