APPENDIX 3 – referring to chapter 3 "*Collisions within road tunnels*"

3.1. TUNNEL ZONING SYSTEMS USED IN DIFFERENT COUNTRIES

In Spain the following zones are considered:

- Before the entrance of the tunnel (the distance covered in 10 seconds by a vehicle traveling at the speed limit)
- Interior of the tunnel
- After the exit of the tunnel (the distance covered in 10 seconds by a vehicle traveling at the speed limit)
- Other (Control Centre, etc.)

In the proposal made by Austria, France and Italy and submitted to the Road Tunnel Safety Committee of the European Commission, they propose the discretization in the following zones:

- Before the entrance portal (starting -250 m to -10 m relative to the entrance portal)
- Around the entrance portal (starting -10 m to +10 m relative to the entrance portal)
- In the entrance zone (starting +10 m to 150 m relative to the entrance portal)
- In the internal zone (starting +150 m after the entrance portal up to 250 m before the exit)
- In the exit zone (starting 250 m before the exit up to the exit portal)
- Other/unknown

In Norway Amundsen and Ranes (1997) proposed a reasonable discretization of the tunnel in four different zones:

- Zone 1: Last 50 m before the tunnel portal.
- Zone 2: First 50 meters within the tunnel.
- Zone 3: Next 100 meters into the tunnel.
- Zone 4: 150 meters from the tunnel portal, mid-zone of the tunnel.

The discretization is extended to the exit zones of the tunnel and three more zones are considered:

- Zone 5: 150 meters to 50 meters before the exit portal.
- Zone 6: 50 meters to 0 meters before the exit portal.
- Zone 7: next 50 meters after the tunnel portal.

3.2. DATA BASIS FOR THE CALCULATION OF COLLISION RATES

Introduction

In the following paragraphs the data concerning collision rates and the implied background are presented. The figures used have been obtained directly from official reports of the countries or if such reports were not available, figures have been obtained from information provided by representatives of the Administrations of these countries. The reliability of the results depends mainly on the amount of data used to obtain the collision rates. The robustness of these data depends mainly on the number of tunnels and years considered. For instance, a collision rate obtained from one tunnel during a period of three years is clearly not as statistically representative as one obtained from one hundred tunnels over a period of a decade. Therefore, countries with a higher number of tunnels and years considered have more reliable results than others.

AADT by convention used in this report referred to both directions i.e. the AADT is the traffic per tunnel.

As explained in the main text of *chapter 3* the following formula should be used in order to calculate collision rates of a set of n tunnels:

$$C_{Rn} = \frac{CWC_n}{365 \text{ x} \sum_{i}^{n} (L_i \text{ x } AADT_i)} \text{x}10^8$$

<u>Where:</u>
C_{Rn}: The collision rate for the set of *n* tunnels.
CWC_n: Annual number of collisions with casualties (injured people and/or fatalities) in the set of *n* tunnels (collisions/year).
L_i: Length of tunnel i (km).
$AADT_i$: Annual average daily traffic in tunnel i (vehicles/day).

The term related to traffic performance as indicated in this formula:

$$\sum_{i}^{n} (Li * AADTi)$$

takes into account the length of every tunnel contained in the considered set of tunnels. It must include all tunnels which are part of the sample taken as a basis for the calculation of the collision rates (also those where no collisions with casualties were observed).

In order to apply the above formulas it is necessary to have data on traffic and length of all tunnels. This is not always the case. The problem is that each country uses its own methodology. There are differences not just in the way to calculate these figures but also in the consideration of what is a CWC.

The annual number of vehicle kilometres is calculated as: AADT*Tunnel length*365d/yr (where AADT by convention is the traffic in both directions).

In case the tubes of a tunnel differ in length, then the annual number of vehicle kilometres in the tunnel must be calculated as follows:

365d/yr* [AADT_direction1*Tube length_direction1+ AADT_direction2*Tube length_direction2].

If the AADT is not known for each specific direction, it will in most cases be a reasonable approximation to calculate:

365d/yr* [AADT*½*Tube length_direction1+ AADT*½*Tube length_direction2] = 365d/yr* AADT*½*[Tube length_direction1+ Tube length_direction2].

Using that approximation, the collision rate can be estimated based on a tunnel length, which is the average length of the two tubes.

In the following tables, background information on the collision rates of individual countries as presented in *chapter 3.5* is provided.

Background and data concerning colission rates for bidirectional tunnels

TABLE 1: BIDIRECTIONAL

Country	Total number of collision (In the set of tunnels and for the years considered)	Annual average CWC per tunnel (CWC / tunnel, year)	Average tunnel lenght (km)	AADT per tunnel (veh/day)	Total traffic veh.Km (in the set of tunnels and for the years considered)
Austria*	205	1.162	4.21	17.237	$5.69.10^9$
Argentina**	7	0.466	2.39	4.340	$0.122.10^9$
France***	86	0.478	3.53	14.633	$1.62.10^9$
Norway****	444	0.099	0.98	2.344)	$3.79.10^9$
Spain*****	31	0.155	1.6	2.757 (2013)	$0.33.10^9$
Vietnam******	54 (14)	6.429	6.28	3.904	$0.075.10^9$

TABLE 2: BIDIRECTIONAL

Country	Nº of tunnels considered	Total length of tunnels (km)	Years considered	Nº of years considered
Austria*	16	67.4	1999 - 2009	11
Argentina**	1	2.4	2000 – 2014	15
France***	18	63.5	2002 – 2011	10
Norway****	750	737.9	2001 - 2006	6
Spain*****	20	32.0	2004 - 2013	10
Vietnam******	1	6.3	2005 - 2013	8.4

* Figures obtained from the report [34] Safety of Road Tunnels; Traffic Safety in Highway and Expressway Tunnels (1999 to 2009), *table 6*. AADT figure refers to the year 2009 only.
** The collision rate reported for Argentina covers only one tunnel (Túnel Subfluvial Uranga-Sylvestre Begnis [50]
*** Figures obtained from the report [47], average length found based on total length 63.5 km for 18 tunnels.
**** Figure derived from the report [29] "*Studies on Norwegian Road Tunnels II, - An analysis of traffic accidents in road tunnels 2001-2006*"
***** Figures derived from the report [53], NOTE: All tunnels considered in this report are longer than 500m.
****** The collision rate reported for Vietnam covers only one tunnel (Hai Van tunnel), the collision rate includes all collisions – also those without casualties; the number in brackets gives an estimation of the rate for collision with casualties (reduction by a factor 4 – based on expert judgement).

Background and data concerning colission rates for unidirectional tunnels

TABLE 3: UNIDIRECTIONAL TUNNELS

Country	Total number of collision (In the set of tunnels and for the years considered)	Annual average CWC per tunnel (CWC / tunnel, year)	Average tunnel lenght (km)	AADT per tunnel (veh/day)	Total traffic veh.Km (in the set of tunnels and for the years considered)
Austria*	814	0.79	1.25*	29,620	$8.3.10^9$
Denmark	22	0.93	1.45	44,138	$0.6.10^9$
France**	877	1.19	1.92	37,662	$10.0.10^9$
Italy	762	0.98	1.11	40,000	$6.4.10^9$
Netherlands***	46	0.9	1.46	31,600	$0.9.10^9$
Norway****	295	1.05	0.86	28,674	$2.5.10^9$
South Korea	57	0.15	0.78	24,274	$2.7.10^9$
Spain*****	418	0.25	1.08	10,486 (2013)	$6.61.10^9$
Switzerland	2661	-	~1.1	26,660 (1992) – 36,203 (2009)	$35.1.10^9$

TABLE 4: UNIDIRECTIONAL TUNNELS

Country	Nº of tunnels considered	Total length of tunnels (km)	Years considered	Nº of years considered
Austria*	94	117.5	1999 - 2009	11
Denmark	6	8.7	2009 - 2012	4
France**	74	142,3	2002 - 2011	10
Italy	98	108.8	2009 – 2012	4
Netherlands***	17	24.9	2010 - 2012	3
Norway****	47	40.5	2001 - 2006	6
South Korea	79	61.3	2005 - 2009	5
Spain*****	164	176.6	2004 - 2013	10
Switzerland	-	118 (1992) – 225 (2009)	1992 - 2009	18

* Figures obtained from the report [34] Safety of Road Tunnels Traffic Safety in Highway and Expressway Tunnels (1999 to 2009), table 6 and appendix. AADT figure refers to the year 2009 only and is found as the average traffic per tube (14810 veh/day) multiplied with 2.
** Figures obtained from the report [47] NOTE: The total length of tunnel tubes is 140.9 km . The number of tunnel tubes is 69. Length and number of tunnels is not known as in some unidirectional tunnels there is only one unidirectional tube. The average daily traffic per tube is 20196 veh/day. The figures in the table are based on the assumption of 2 tubes per tunnel.
*** The total length of 24.9 km refers to the total length of tubes not tunnels.
****Figures derived from the report "*Studies on Norwegian road tunnels II, - An analysis of traffic accidents in road tunnels 2001-2006*" table 4.10 and table 3.3
***** Figures derived from the report [53], NOTE: All tunnels considered in this report are longer than 500m.