

# NEW AUSTRIAN GUIDELINE FOR THE TRANSPORT OF DANGEROUS GOODS THROUGH ROAD TUNNELS

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## ABSTRACT

In the Austrian guideline RVS 09.03.11 the Austrian Tunnel Risk Analysis Model TuRisMo defines how to assess the risk for tunnel users. The same guideline stipulates that the specific risk involved in the transport of Dangerous Goods (DG) through road tunnels should be assessed in a separate procedure. Consequently, based upon European Directive 2004/54/EC and the Austrian Road Tunnel Safety Law, a uniform risk assessment procedure for the transport of DG through road tunnels has been developed. For a methodical risk analysis approach, the OECD/PIARC-Model DG-QRAM was chosen. The results shall be published in new Austrian guideline RVS 09.03.12 in 2010.

The main objectives of the research project are the verification of existing DG transport data, the development of a complete risk assessment procedure in line with the new ADR tunnel regulations and the definition of decision criteria for each level of risk evaluation.

*Keywords: dangerous goods, road tunnel safety, quantitative risk assessment, expected value, FN-curve*

## 1. LEGAL ASPECTS OF TUNNEL SAFETY

### 1.1. Directive 2004/54/EC

This Directive defines minimum safety requirements on an international level to be met by road tunnels forming part of the Trans European Road Network (TERN). The remarkable aspect about this Directive is the fact that it combines both a “regulation-based” and a “risk-based” approach. According to Article 13, a risk analysis shall be performed for all tunnels featuring a special characteristic, taking into account all design factors and traffic conditions.

### 1.2. Austrian Road Tunnel Safety Law

The Road Tunnel Safety Law translates the requirements contained in the EC-Directive into Austrian law. It defines the following measures for the transport of dangerous goods (DG):





- Prior to the definition or modification of regulations and requirements regarding the transport of DG through a tunnel, a risk analysis is to be performed.
- To enforce the regulations, appropriate signs indicating alternative routes, are to be posted ahead of the last possible exit before the tunnel and at tunnel entrances.
- In individual cases, specific operating measures designed to reduce the risks related to some or all of the vehicles transporting DG in tunnels are to be checked (e.g. escorted passage in convoys).

### 1.3. ADR 2007 / 2009

When the European Agreement concerning the International Carriage of Dangerous Goods by Road, commonly known as ADR was revised in 2007, so called tunnel restriction codes were assigned to all dangerous substances according to their potential of damage, amount (mass) and carriage type. These codes serve as a basis for a uniform European regulation governing the transport of dangerous goods through road tunnels.

To enforce restrictions of DG transporting vehicles through a tunnel the relevant authorities shall assign the tunnel to a category defined in the ADR (**Table 1**). The new tunnel regulations of the ADR have been valid since the 1<sup>st</sup> of January 2010.

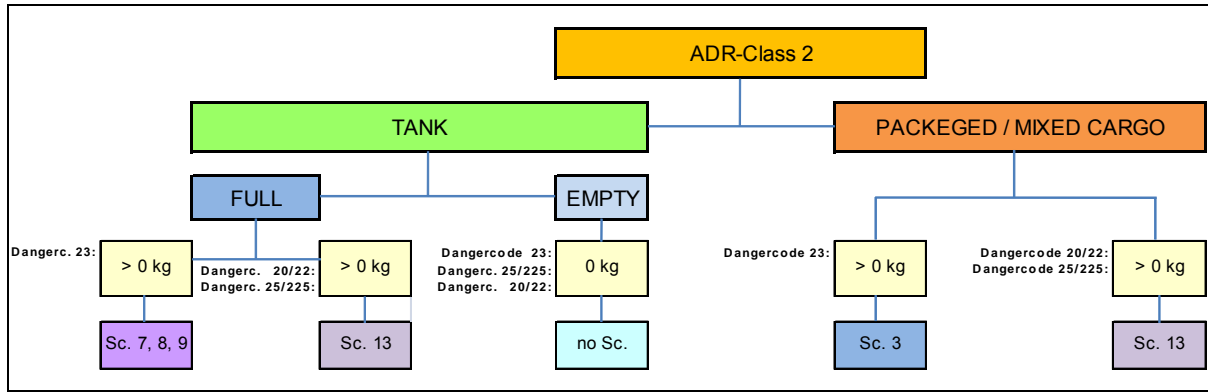
**Table 1:** ADR tunnel categories and signature

Tunnel categories	Restrictions	Sign	Traffic Sign
A	No restrictions for the transport of dangerous goods	No sign	-
B	Restriction for dangerous goods which may lead to a <b>very large explosion</b>	Sign with additional panel bearing the letter B	
C	Restriction for dangerous goods which may lead to a <b>very large explosion, a large explosion or a large toxic release</b>	Sign with additional panel bearing the letter C	
D	Restriction for dangerous goods which may lead to a <b>very large explosion, to a large explosion, to a large toxic release or to a large fire</b>	Sign with additional panel bearing the letter D	
E	Restriction for all dangerous goods other than UN Nos. 2919, 3291, 3331, 3359 and 3373	Sign with additional panel bearing the letter E	

## 2. DATA BASE

At the beginning of the research project great emphasis was put on the data base. From 2006 to 2007 investigations of DG transports were carried out at 12 different cross sections on Austria's main traffic routes. In March 2009, the results of these earlier investigations were evaluated and expanded by a detailed review of DG transports in cooperation with the police. For one month (March 2009) the police stopped DG vehicles and controlled their transport documents. The investigation was accomplished in all Austrian federal states and assigned detailed information about the UN number, amount, carriage type and destination of the dangerous substances.

The applied risk model includes for the most part very "severe" scenarios with huge amounts of dangerous substances involved. For example scenario 4 stands for a pool fire of a 28 ton tank of diesel/petrol. Using the model scenarios without an adjustment would lead to an overestimation of risks. For that matter the data collected in the detailed investigation were used to define more realistic allocation rules (see example in **Figure 1**).



**Figure 1:** Allocation key for flammable gases (ADR class 2)

In addition, the results of the investigations revealed that in Austria the composition of the DG carriage varies only slightly on different traffic routes and that these variations have only little influence on the risk faced by tunnel users. Eventually, a standardized, averaged scenario allocation for Austria based upon a detailed DG investigation was found (**Table 2**).

**Table 2:** Standardized scenario allocation for Austria (DG-QRAM)

Accident scenarios - DG-QRAM		Proportion
Scenario 3:	BLEVE of flammable gases in 50kg-cylinder (e.g. Propane)	0,0226
Scenario 4:	pool fire of flammable liquids in bulk (e.g. Petrol, Diesel)	0,4270
Szenario 5:	VCE of flammable liquids in bulk which may lead to explosive air fuel mixture (e.g. Petrol), assigned as fraction of <i>scenario 4</i>	0,3610
Scenario 6:	release of very toxic gases in bulk (e.g. Chloride)	0,0010
Scenario 7 / 8 / 9:	BLEVE / VCE of flammable gases in bulk (e.g. Propane)	0,0113
Scenario 10:	release of toxic gases in bulk (e.g. Ammonia)	0,0010
Scenario 11:	release of toxic fluids in bulk (e.g. Acrolein)	0,0133
Scenario 12:	release of toxic fluids in 100kg-cylinder (e.g. Acrolein)	0,0113
Scenario 13:	burst of a tank of non flammable gases (e.g. liquefied refrigerated CO2)	0,0452

### 3. OECD/PIARC MODEL (DG-QRAM)

To calculate the risks involved in transporting DG an international accepted risk analysis model called DG-QRAM is applied. The risk model was developed on behalf of OECD/PIARC and is widely used on an international basis, but is obviously not the only method available for assessing the risk resulting from the transport of DG.

The results of the risk analysis model are depicted as Expected Values (EV) or F-N curves, illustrating the relation between accident frequency (F) and accident consequences (N number of fatalities). Whereas the EV represents the average expected number of fatalities as a result of all DG accidents, the F-N curve gives more comprehensive information on the extent of damage in relation to the probability of individual accidents (**Figure 3**).

#### 4. DEVELOPMENT OF A COMPLETE RISK ASSESSMENT PROCEDURE

In the year 2009, the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) launched a research project with the objective of establishing a complete investigation and assessment procedure concerning risk analyses for DG (using DG-QRAM). The research project was exclusively focused on assessing the risk of DG accidents, whereas mechanical accidents and conventional fires are addressed by the risk model TuRisMo. The final results have been presented in a new Austrian guideline (draft). The finalized version should be published in 2010.

The research project served the purpose of defining a clearly structured risk assessment procedure in line with the new ADR tunnel regulations, based upon reliable DG data. In the course of this project, risk reference criteria for every step of the assessment procedure had to be laid down. The project was supported by a work group comprising technical and legal experts of the BMVIT and the Austrian Ministry of Internal Affairs, the Austrian federal provinces, the Austrian Chamber of Commerce, the ASFINAG, the fire brigade, the transport industry as well as ILF Consulting Engineers.

In principle, the risk involved in the transport of DG is determined in a multi-stage assessment procedure.

##### 4.1. Stage 1 – Classification Matrix

Stage 1 involves using a simple classification matrix (**Figure 2**) to define DG risks of road tunnels. The application of the matrix shall permit a simple identification of tunnels with a low DG transport risk.

The classification matrix takes into account the following main risk factors:

- the tunnel length
- the type of tunnel (bi-directional or uni-directional traffic)
- the ventilation system (natural, longitudinal or transverse)
- the traffic volume
- the percentage of heavy goods vehicles (HGV)

The respective parameters of the matrix were defined in a former study performed in 2008. Then, a systematically risk calculation were performed for a set of selected reference tunnels using DG-QRAM. As decision criteria an expected risk value of  $EV = 1 \times 10^{-3}$  fatalities/year was applied for the elaboration of the matrix.

If a tunnel is assigned to a dark field of the matrix, a risk analysis has to be performed.

A first examination of the Austrian road tunnels revealed, that approximately half of the tunnels require no further risk investigation. These tunnels could, in line with the ADR, directly be allocated to tunnel category A.

The application of the matrix is only admissible, if a set of requirements is fulfilled (e.g. proportion of heavy goods vehicles  $\leq 25\%$ , longitudinal gradient  $\leq 3\%$ , no extraordinary proportion of DG, etc.).

type of traffic	ventilation system	tunnel length [m]	daily average traffic volume [veh/day]																														
			≤ 10000				≤ 15000				≤ 20000				≤ 30000				≤ 40000														
HGV [%]			≤ 10	≤ 15	≤ 20	≤ 25	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 5	≤ 10	> 10				
uni directional	natural	≤ 250	[Color-coded cells]																														
	natural	≤ 500	[Color-coded cells]																														
	longitudinal	≤ 700	[Color-coded cells]																														
	longitudinal	≤ 1000	[Color-coded cells]																														
	longitudinal	≤ 1500	[Color-coded cells]																														
	longitudinal	≤ 2000	[Color-coded cells]																														
	longitudinal	≤ 2500	[Color-coded cells]																														
	longitudinal	≤ 3000	[Color-coded cells]																														
	transverse	≤ 4000	[Color-coded cells]																														
	transverse	≤ 7000	[Color-coded cells]																														
bi directional	natural	≤ 250	[Color-coded cells]																														
	natural	≤ 500	[Color-coded cells]																														
	natural	≤ 700	[Color-coded cells]																														
	natural	≤ 1000	[Color-coded cells]																														
	longitudinal	≤ 1500	[Color-coded cells]																														
	longitudinal	≤ 2000	[Color-coded cells]																														
	longitudinal	≤ 2500	[Color-coded cells]																														
	longitudinal	≤ 3000	[Color-coded cells]																														
	transverse	≤ 3000	[Color-coded cells]																														
	transverse	≤ 7000	[Color-coded cells]																														

Figure 2: Classification matrix (stage 1)

#### 4.2. Stage 2 – Detailed Approach

All those tunnels which indicate a relevant DG risk in stage 1 are subsequently reviewed in a detailed, tunnel-specific risk analysis using DG-QRAM (Stage 2a).

Whereas the decision criterion in stage 1 is based upon the expected value, in stage 2 the assessment is assigned to the log scaled F-N diagram. The results (scenario-based FN-curves) are evaluated by comparing them to a defined reference line in the F-N diagram (see example in Figure 3). If the reference line is exceeded, additional risk reducing measures are to be investigated (Stage 2b).

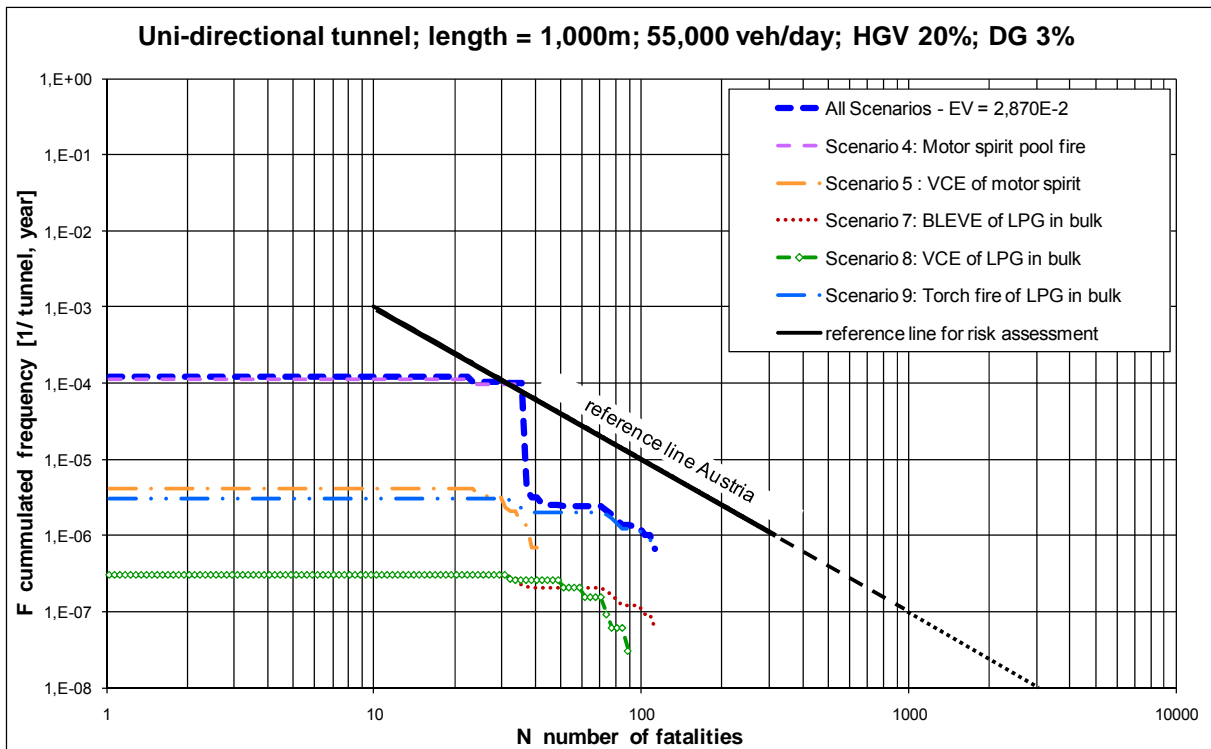


Figure 3: Reference line as assessment criterion in the F-N diagram (stage 2a)

### 4.3. Stage 3 – Alternative Route

Generally, the transport of DG on the road is not restricted as long as the requirements of the ADR are met. If the assessment procedure determines that the investigated tunnel possesses an intolerably high risk, restrictions to the DG transport for a tunnel are to be examined. In this case the existence of an adequate alternative route is investigated. A road only qualifies as an alternative route if the entire road segment is suitable and approved for heavy goods traffic. This requires such aspects as: the number of lanes, the longitudinal gradient, the road width, curve radii, etc. (be reviewed on a case-to-case basis).

The examination of the alternative route follows the principle that a generally allowed, existing transport volume of DG should be carried on that route which shows the slightest transport risk. Therefore, it must be shown that the risk of transporting DG on the alternative route is significantly lower for the resident population than the risk of unrestricted transport through the tunnel for the tunnel users.

The risk calculations for the alternative routes (open road sections) are also performed by application of the risk analysis model DG QRAM.

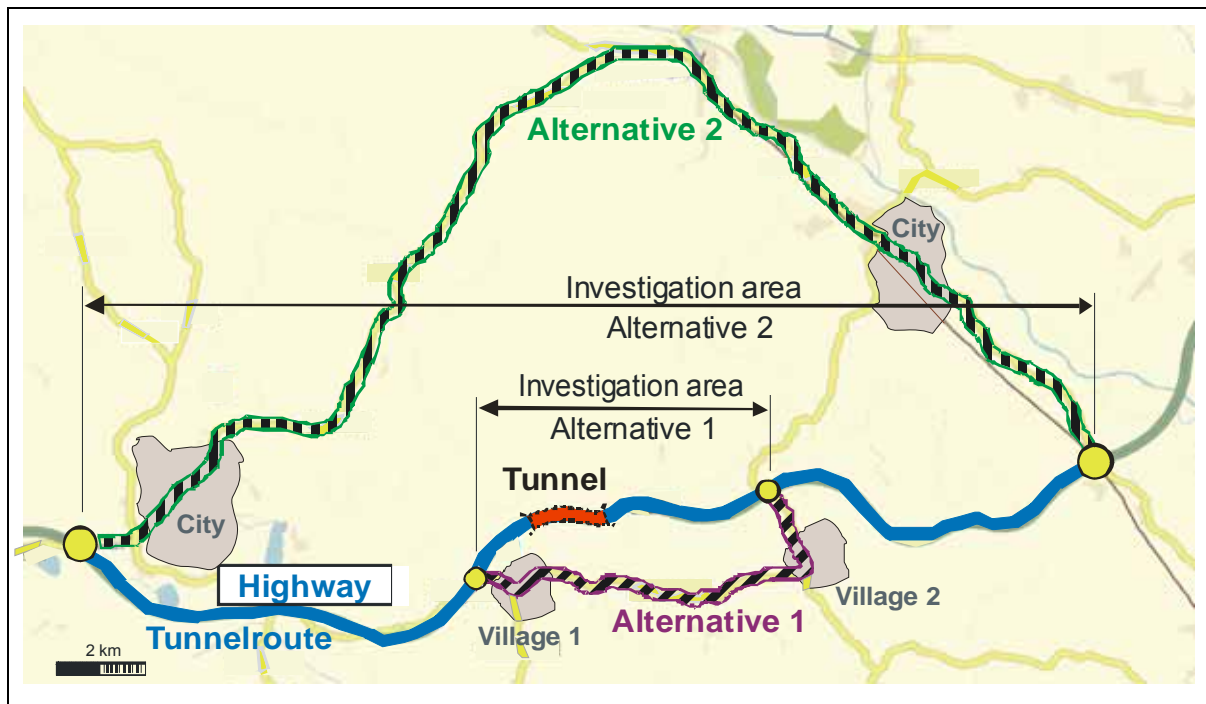


Figure 4: Alternative route (stage 3)

## 5. MEASURES

If in stage 2a the reference criterion in the F-N diagram is exceeded, the DG risk is rated as unacceptable and special additional risk reduction measures need to be investigated (Stage 2b).

Consideration made to improve traffic safety predominantly focuses on organisational and operational measures. In this context, it should be noted that not every measure is equally suited or efficient. The envisioned measures will thus have to be checked individually for the respective tunnel system in an in-depth risk analysis.

The current regulation for highways BGBl. 395/2001 issued by the Federal Ministry for Transport, Innovation and Technology (BMVIT) already stipulates operational measures depending on tunnel length:

- Tunnels with a length between 1,000 m and < 5,000 m require a flashing warning light on the vehicle.
- Tunnels with a length of > 5,000 m require a flashing warning light, an escort vehicle following the transport unit and the distribution of transport documents to the personnel of the escort vehicle.

Additional operational measures aimed at reducing the transport risk of DG may include:

- Introduction of an overtaking ban
- Introduction of a speed limit
- Installation of an information system
- Installation of a speed control system

## 6. DEFINITION OF RISK CRITERIA

As mentioned earlier, the societal risk is usually expressed in a graph (F-N diagram). To determine whether the safety level is acceptable or not, an assessment of the societal risk can be made. This is based upon a risk reference criterion which is often determined specifically for the project in question.

For example, an officially established risk limit line concerning DG is used in Switzerland (in the Swiss Accidents Ordinance).

### 6.1. Reference line for risk assessment

In the detailed analysis (stage 2), the assessment is based upon a defined assessment criterion in the F-N diagram. This reference line was calculated by the following formula:

$$\text{For } N \geq 10 \text{ fatalities:} \quad F = \frac{10^{-1}}{N^2} \quad \dots \text{ for 1 km of tunnel} \quad (1)$$

The slope of the equation reflects the risk aversion level. If the number of fatalities increases by a factor of 10, the acceptable occurrence frequency decreases by a factor of 100.

The reference line was defined taking into account several aspects:

- risk level in comparable reference systems (e.g. aviation)
- reference criteria used in other countries (e.g. Switzerland, Netherlands)
- special model characteristics of DG-QRAM (e.g. adjustment for length)

## 6.2. Adjustment of the reference line for tunnel length

A risk assessment based upon the defined reference line requires a standardized tunnel length, as the reference criterion (1) is usually based on 1 km. For the assessment criterion to be used in the F-N diagram, an adjustment for the length of the tunnel had to be made.

Concerning the tunnel safety topic, the length of the tunnel is an especially critical factor. Therefore, the adjustment should not be linear to the length of the tunnel. Hence, the relationship between tunnel length and risk was modelled as an exponential function:

$$\text{For } N \geq 10 \text{ fatalities:} \quad F = \frac{10^{-1}}{N^2} \times L^{0.5} \quad \dots L = \text{tunnel length [km]} \quad (2)$$

To evaluate the reference criterion (2) transport risks of several common road tunnels in Austria were calculated and assessed in the F-N diagram.

## 7. INTERNATIONAL OUTLOOK

The ADR's tunnel regulations have been valid since the 1<sup>st</sup> of January 2010. Although the European countries have already assigned many tunnels with restrictions to ADR's tunnel categories, this implementation process isn't completely accomplished. The network-wide risk assessment and the assignment to risk categories will take some time to be finalized; especially for states with a great number of road tunnels.

Thus current development trends in the transport industry ought to be observed and taken into account. The transport industry is likely to face certain additional costs for the transport of DG as alternative routes tend to result in longer transport times and longer carriage distances.

## 8. REFERENCE LIST

Directive 2004/54/EC of the European Parliament and of the Council of 29 April on minimum safety requirements for tunnels in the Trans-European Road Network

Bundesgesetz über die Sicherheit von Straßentunneln (Straßentunnelsicherheitsgesetz STSG), BGBl 54/2006, Österreichischer Nationalrat, 2006

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Transport of Dangerous Goods through road tunnels – Quantitative Risk Assessment Model, OECD/PIARC/EU, 2003

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