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Item 5 of the provisional agenda

PROPOSALS FOR AMENDMENTS TO ANNEXES A AND B OF ADR

Guidelines for the calculation of risks in the transport of dangerous goods

Transmitted by the Government of Germany */

SUMMARY	
Executive Summary:	Proposal of the wording of a "General Guideline for the Calculation of Risks in the Transport of Dangerous Goods by Road" and the inclusion of a reference
Action to be taken:	Adoption of the Guideline and inclusion of a reference into ADR
Related documents:	INF.8 (81st session), ECE/TRANS/WP.15/190, paras. 34 and 35, ECE/TRANS/WP.15/2007/3 and ECE/TRANS/WP.15/192 paras. 21 to 23

1. With document ECE/TRANS/WP.15/2007/3 Germany had highlighted the subject "calculation of risks" and explained the objective, the contents and the applicability for the transport of dangerous goods by road. These explanations and the initiative to adapt the

*/ The present document is submitted in accordance with paragraph 1(c) of the terms of reference of the Working Party, as contained in document ECE/TRANS/WP.15/190/Add.1, which provides a mandate to "Develop and update the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)".

Guideline developed by international experts for the scope of application of RID to the concerns of road transport and to provide it as a tool for decision-makers was welcomed by many delegations.

2. The wording of the Guideline adjusted to the scope of application of ADR is submitted in Annex.

Proposal:

3. The guideline reproduced in Annex is to be adopted and published by the Secretariat of the UNECE on the UNECE website.

4. It is proposed to add the following footnote at the end of paragraph 1.9.4: "The General Guideline for the Calculation of Risks in the Transport of Dangerous Goods by Road adopted by WP.15 on [insert date] may be consulted on the web site of the Secretariat of the United Nations Economic Commission for Europe [http://www.unece.org/trans/danger/danger.htm]".

Justification, Safety implications, Feasibility

5. The provision of a decision-making tool facilitates the work of the competent authorities. At the same time flexibility is maintained since there is no obligation to apply the Guideline.

Enforceability

6. Not applicable.

Annex

General Guideline for the Calculation of Risks in the Transport of Dangerous Goods by Road
An introduction to the basic principles of risk assessment for chapter 1.9 ADR

Contents

1. Introduction

1.1 Background

The transport of dangerous goods will continuously increase through the growing together of the European Economic Areas. For all modes of transport, but especially on the road, also those transport operations of dangerous goods will continue to increase which can present an additional risk for the road users themselves, but also for the immediate environment (nature and population). For this reason appropriate risk analyses have to be developed for the transport of dangerous goods by road which make an assessment of these risks possible.

All types of transport of dangerous goods by road are subject to the ADR regulations. The objective of these regulations is to ensure safe transport and to minimise the risk of accidents connected with harm to people or the environment by applying general technical and organisational rules for packaging, carrying and handling dangerous goods.

Over and above these safety regulations the competent authorities of Member States are allowed to apply certain additional provisions in their territory in case of special risks at certain locations. The relevant regulation is found in Chapter 1.9, "Restrictions on carriage imposed by the competent authorities". Due to, among other things, the major accidents in the Alpine tunnels in 1999 (Montblanc, Tauern) and 2001 (Gotthard) - which incidentally were not caused by the transport of dangerous goods – the concerns in some Members States of the European Union regarding the transport of dangerous goods in the trans-European networks increased, especially regarding the transport of dangerous goods through road tunnels [1].

First more detailed information on the scopes of application outside tunnels and the relevant requirements were laid down in Chapter 1.9.3 ADR:

(a) Additional provisions or restrictions in the interest of safety for special structures like bridges, combined transport or transhipment installations,

(b) provisions for areas with special local risks (e.g. residential areas),

(c) special provisions for routes which have to be travelled or for stopping and parking in special situations (extreme natural phenomena, unrest, etc.) and

(d) restrictions for the transport of dangerous goods on certain weekdays.

In all of the above cases it is, as opposed to rail transport, not necessary for the competent authority to provide special evidence for the need of the measure. Chapter 1.9.4, however, stipulates that the measures according to 1.9.3 (a) and (d) have to be notified to all the ADR Contracting Parties.

Special attention is given to road tunnels, particularly in view of the fact that in case of accidents involving dangerous goods in tunnel structures serious consequences have to be expected (loss of human lives, traffic congestion, diversion via higher-risk deviations etc.). This is why in Chapter

1.9.5 ADR the so-called „tunnel restrictions" are mentioned on the basis of the assumption that three main risks emanate from dangerous goods, and they are

- Explosions;
- Release of toxic gas or volatile toxic liquids;
- Fires.

Furthermore 5 tunnel categories A – E are defined with increasing restrictions.

If possible, the required classification should be effected on the basis of risk analyses. This guideline, however, does not refer to the risk estimation in road tunnels; Directive 2004/54/EC of 29 April 2004 [1] already contains separate definitions in this respect. The subject of this guideline is rather the scope of application for transport restrictions according to 1.9.3 (a), (b) and (d) for which it has not been compulsory to carry out risk analyses up to now and for which there are no recommendations for a voluntary procedure in road transport as opposed to the relevant paragraphs 1.9.2 (a) and (b) in rail transport.

1.2 Guideline Objectives and Application

The objective of this guideline is to obtain a more uniform approach for the risk assessment of the transport of dangerous goods by road in the ADR Contracting Parties and consequently to make individual risk assessments comparable. The guideline should be a reference for risk assessment in situations where the risk connected with the transport of dangerous goods is relevant.

As a result of the ADR regulations a high level of intrinsic safety has been accomplished in general. However, the ADR cannot guarantee absolute safety. Some level of risk will always remain and therefore several European States have already adopted their own assessment models for risk calculation together with their own criteria for risk acceptance. These methods and criteria are commonly derived from national implementations of Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances (Seveso II Directive, [2]) which excludes some areas, such as the transport of dangerous goods and the intermediate storage outside establishments.

Examples of supplementary national regulations and standard methods for the assessment and control of risks connected with the transport of dangerous goods by road are either very general compared to rail transport or they deal with very specific questions, e.g. with the collision of road vehicles with constructive parts of structures [3], with the transport of dangerous goods through tunnel structures [4] or with specific road sections [5].

At present there is no harmonised guidance for risk assessment of the transport of dangerous goods by road. There is only a basic structure for road tunnels in form of Directive 2004/54/EC [1], which however does not stipulate an explicit methodology for risk assessment until a planned harmonisation in 2009. So the determination of a relevant methodology is the task of the EU Member States which are to report on this.

Therefore, the objective of this guideline is not to prescribe or define new risk calculation models or new criteria for tolerable risks (see definition in section 2.1). The guideline intends to provide an independent framework for the analysis and evaluation of risks and for the assessment of corresponding safety measures in terms of Chapter 1.9 ADR. It is only intended to define the basic requirements and to recommend basic approaches. Since the acceptance of a risk assessment is largely dependent on the input data and the necessary assumptions and restrictions it should be attempted to achieve absolute transparency of all procedural steps. The guideline concentrates on aspects which should be taken into account for a risk analysis, i.e. on basic contents and quality objectives with reference to Chapter 1.9.3 ADR. A detailed instruction concerning the methods for risk assessment is outside the framework of this document. A new version of the guideline by the competent body will be possible in case of major changes in international regulations and in case of substantial progress in scientific and technical knowledge.

2. Basic Definitions and Requirements

2.1 Definition of Technical Terms

Dealing with risk requires first the definition of some technical terms to ensure a common understanding of this guideline. The use of terms in this guideline is based on the ISO/IEC Guide 73 “Vocabulary – Guidelines for Use in Standards” [6] and ISO/IEC Guide 51 “Safety Aspects – Guidelines for their inclusion in standards” [7], which is to be applied to safety-related standards. In general, risks can be of a different nature, e.g. political, financial, technical or medical, either positive or negative. In the context of this guideline risk is only a transport safety issue. Hence, the more safety specific definitions of risk related terms in ISO/IEC Guide 51 are preferred. ISO/IEC Guide 73 is used to complement the list with definitions for risk management. Comments on the original definitions of Guides 51 and 73 are shown in brackets.

Risk: Combination of the probability (between 0 and 1) of occurrence of harm and the severity of harm ("combination" typically means "product", whereas additional factors, such as **risk aversion** are part of the risk **evaluation** process).

Harm: Physical injury or damage to the health of human beings, or damage to property or the environment.

Risk assessment: Overall process of risk analysis and risk evaluation.

Risk analysis: Systematic evaluation of available information to identify hazards (potential sources of harm) and to estimate the risk.

Risk estimation: Process used to assign values to the probability and the consequence of a risk.

Risk evaluation: Procedure based on the risk analysis to determine whether the tolerable risk has been achieved.

Risk criteria: Reference parameters by which the significance of risk is assessed.

Risk treatment: Application of adopted measures dealing with risk reduction.

Risk management: The overall process of risk assessment, decision, risk treatment and its control (see figure 1).

Decision criteria comprise especially risk treatment and include risks and social, economic and/or political considerations (supplementary definition is not part of ISO/IEC Guides 51 or 73).

Decision: Selection process for risk treatment measures on the basis of the decision criteria (supplementary definition is not part of ISO/IEC Guides 51 or 73).

Tolerable risk: Risk which is accepted in the decision phase on the basis of the decision criteria and which, in a given context, in particular embraces justifiable ideals of society.

Figure 1 gives an overview of the relationship between the processes of risk management which are defined above. As this guideline concentrates on risk assessment, the processes of risk treatment and all subsequent processes of risk management, such as risk acceptance and risk communication, are not included in figure 1.

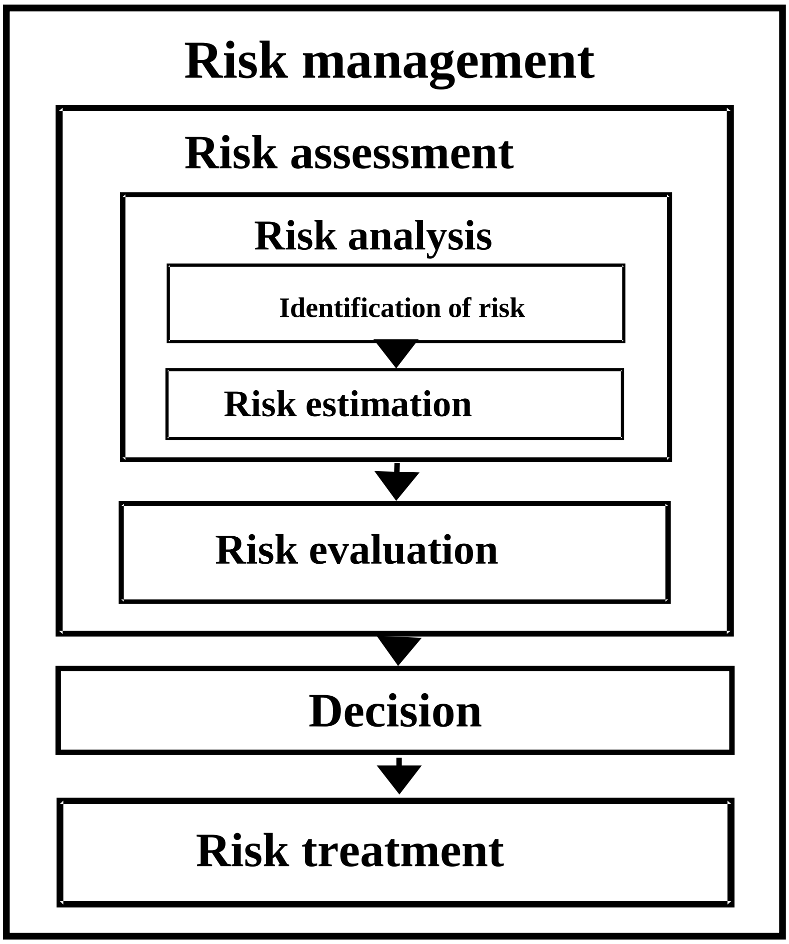

Figure 1: Relationship between risk management processes

The risk evaluation process is based on risk criteria which have not yet been standardised internationally. Existing criteria for risk evaluation which have been developed in a national consensus are expressly not to be referred to in this guideline, but it deals with the process of risk evaluation in order to make the entire process of risk assessment comprehensible. For the risk evaluation at least the following definitions are needed:

Individual risk: Risk of an individual person to come to harm (also called "place-bound risk", depends on the location, definition is not part of ISO/IEC Guides 51 or 73).

Societal risk: Risk of all potentially involved persons to come to harm (probability density function (PDF) of individual risks or the integral of this PDF, definition is not part of ISO/IEC Guides 51 or 73).

External risk: Risk of harm caused to persons who are not involved in the transport or risk of harm to property which is not part of the transport system or infrastructure (also called "third party risk", as opposed to **internal risk**, definition is not part of ISO/IEC Guides 51 or 73).

Risk perception: Way in which a stakeholder views a risk, taking into account his concerns.

Stakeholder: Any individual, group or organisation that can produce a risk or that can be affected by, or perceive itself to be affected by, a risk. Note: The decision-maker is also a stakeholder.

Risk aversion: Additional factor for risk evaluation to account for a more negative perception of events with high harm potential or of events which happen beyond the influence of human beings or of events with unknown risk etc. (see comment below, definition is not part of ISO/IEC Guides 51 or 73).

Note that in case of using the definition of risk simply as the product of probability and harm one may obtain the same risk value from a high probability – low harm event as from a low probability - high harm event, although the risk perception may be different. To account for different kinds of risk perception, an additional factor called risk aversion is used for evaluating the risk (see section 4). Depending on risk perception the risk assessment may also be limited to external risk.

2.2 Basic parameters

This section includes some cornerstones for risk assessment for the carriage of dangerous goods by road which are independent from specific details of the whole process.

Quantification of risk: The application of additional provisions in compliance with chapter 1.9.3 ADR is not linked with an obligation imposed on the competent authority to provide evidence of the need for measures (as opposed to RID). In individual cases, however, it may be useful to provide information on the risk level connected with a certain transport route.

This concerns for example the selection of alternative routes in case of route or situation restrictions according to Chapter 1.9.3.

1. Where no alternative comparable route is available, any restriction or required measure should be justified according to the principle set out in the guidelines for quantitative risk assessment in reference to a tolerable risk level used in the Member State (which may be the nationally used principles ALARA and ALARP, the stand-still principle (GAME) or risk or decision criteria)

2. Where alternative routes are used the risk analysis should substantiate why this routing is considered as more favourable under aspects of risk, i.e.

a) usually on the basis of a qualitative comparison between the routes if it is obvious that the proposed restrictions lead to a significant improvement of safety;

b) in other cases on the basis of a quantitative comparison of the risks inherent in the alternative routes.

Breakdown of risk assessment processes: The risk assessment process is divided into two different parts (see figure 1). The first part is the risk analysis which is required for the quantification of a certain risk related to the fields of application given in chapter 1.9.3 (a), (b) and (d) which has to be as objective and precise as reasonably achievable (see comments on uncertainty below). This "scientific" part (risk analysis) is followed by an evaluation of the calculated risk level. If the risk level is below the tolerable risk level the risk management process requires no further action. Otherwise the decision making process and the risk treatment must be implemented.

Uncertainty analysis: Risk analysis is always connected with uncertainties of different origin (see section 4). In order to be able to use the risk analysis as a basis for a risk evaluation, the derivation (or at least estimation) of uncertainty levels requires special attention. Uncertainty levels are of minor importance in cases of an analysed (estimated) risk being far below the level of tolerable risk, provided they remain low in comparison with the margin of tolerability. In cases with an uncertainty interval substantially covering more than one zone of the risk classification (e.g. tolerable/unacceptable, see also section 4) the recommendation is either to reduce further the level of uncertainty of the analysis as far as reasonably achievable or to justify the adequacy of measures under special consideration of uncertainty levels that have been established.

Risk comparison: in comparing the risks posed by two alternative routes on the basis of an estimation tool, the degree of uncertainty of the tool assumes less significance. What is more important in this case is to be able to estimate whether there is significant advantage in using one or other of the routes, rather than to determine an absolute value of the level of risk. In this case, the risk estimation tool may contain only those elements of estimation which have a low level of uncertainty and which are relevant for estimating the risks of the routes concerned. The other risk estimation parameters, notably those with too much uncertainty, should then be taken into account in the risk criteria that are not estimated by the tool which participates in the risk management decision that has to be taken.

Required information: The documentation of a risk assessment should contain information on all processes mentioned in section 3.5, either explicitly or as references to documents which are public or available upon request. Transparent and detailed documentation of the risk assessment process is a basic prerequisite for the comprehensible documentation of risk.

3. Risk Analysis

3.1 Introduction

The outcome of the risk analysis part of the risk assessment process (see figure 2) is information on the individual or societal risk of the transport situation under consideration. The risk analysis has to derive probabilities of accident scenarios and potential consequences connected with these accident scenarios. Therefore the following sections cover the major aspects of scenario definition, statistical analysis and consequence analysis.

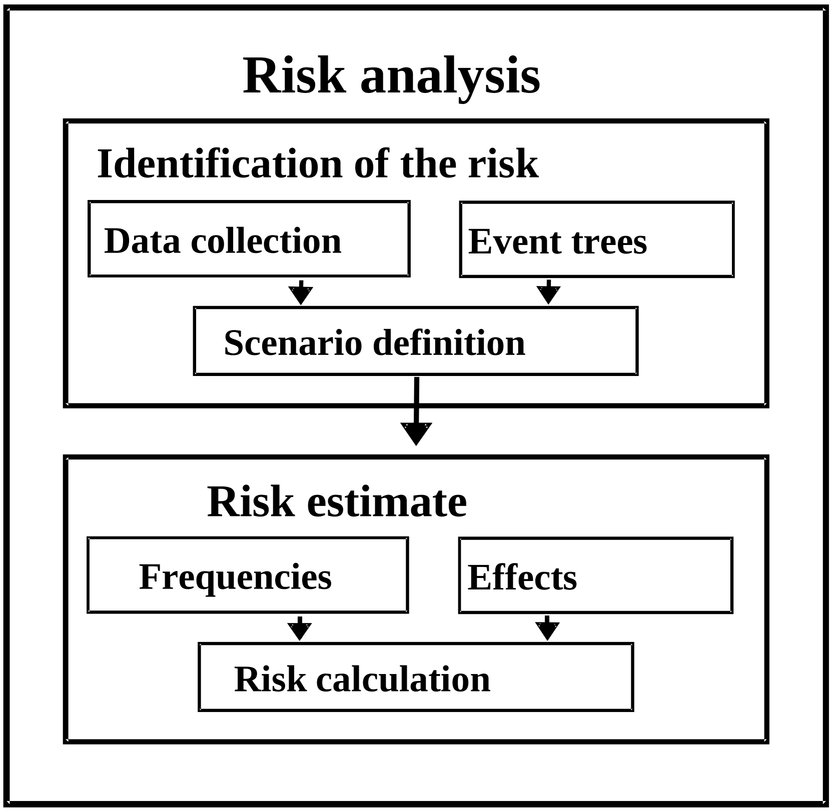

Figure 2: Diagram of risk analysis elements

This guideline aims at meeting the requirements of national characteristics in the transport of dangerous goods by road. All ADR Member States are recommended to use it, although major differences exist between Member States. This concerns for example the topography (flat or mountainous), the climate (temperature and wind), the national policy on transport and traffic, the combination of goods and passenger traffic or the population density. The individual countries can also differ greatly with regard to the technical details of the dangerous goods vehicles used and the infrastructure, for example the state of the road systems.

These differences restrict the possibility of a detailed definition of calculation methods for a risk analysis. Therefore general recommendations prevail.

3.2 Scenario Definition

In order to get a grip on the large number of potential accident scenarios the first step of the risk analysis is the reduction of scenarios to a reasonable number of basic scenarios including a clustering of hazardous substances.

All compounds or substances have their own pattern of chemical and physical properties (flammable, explosive, reactivity with other substances, toxic, radioactive, state of aggregation …). Although the effect of a dangerous good is first of all the property of the material itself, the circumstances also influence the effect that is experienced (e.g. temperature). To avoid the problem of having to describe thousands of compounds, rigorous clustering is recommended. Both the Class (ADR) and the Hazard Identification Number (HIN) are suitable for classifying and clustering.

A grouping of master substances that is too approximate should be avoided in order to reduce the uncertainty of the risk analysis and to ensure a reliable basis for risk evaluation purposes. In addition, grouping of substances should take into account the potential sequence of events of an accident scenario including consequences which may depend on further parameters and circumstances. Hence, a coupled classification of scenarios and substances is recommended.

The structure which is best suited for the classification of accident scenarios and also for the risk calculation itself is the event tree concept which is developed on the basis of a causal tree which specifies the frequency of primary events in a systematic dimension which comprises the elements basic event, place of discharge, quantity discharged etc. Such a structure simplifies the calculation because of the clear overview and indicates the gradual process in the quantitative composition of the calculation. Figure 3 shows an example of an event tree. In order to optimise an accident scenario classification by event tree analysis, absolute frequencies of all scenarios should also be taken into account. This section concentrates on the aspects connected with the structure of the event tree; the derivation of quantitative values for conditional probabilities within the tree is addressed in section 3.3.

The risk analysis should also include the influence of emergency services. In certain cases the actual consequences of an accident, i. e. the number of fatalities, are less severe because of fast and efficient intervention by the emergency services. Two examples are the prevention of a warm BLEVE (in a threatening domino scenario) and the well organised evacuation of an area where a toxic gas has been released. Therefore, an assessment of the preparedness of the emergency services is a parameter in the analysis of accident scenarios.

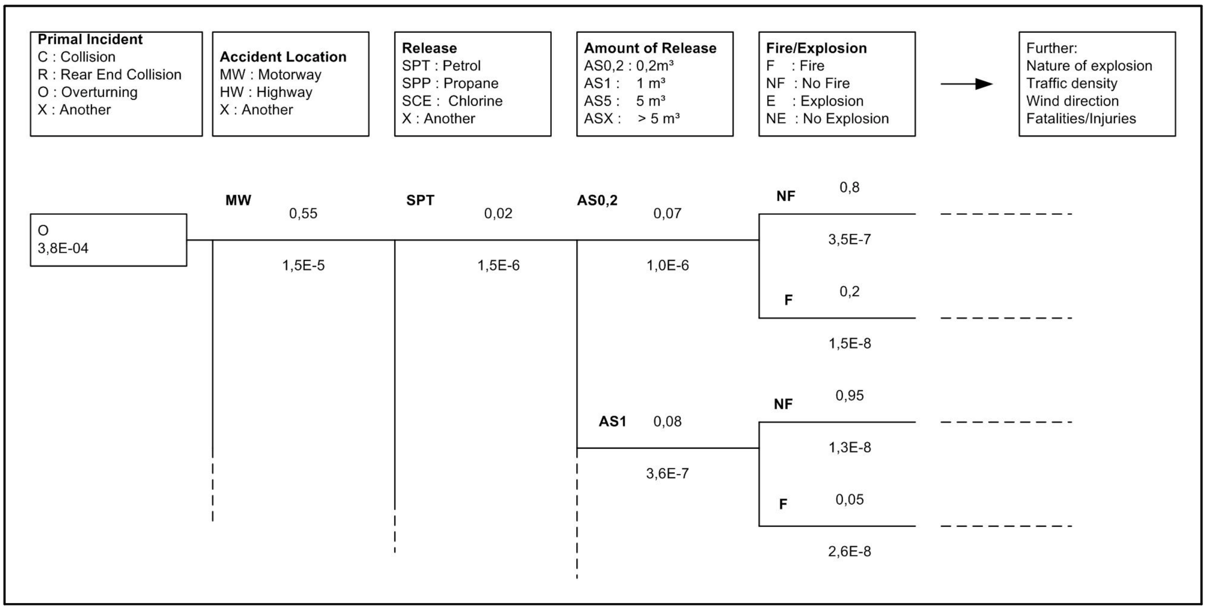

Figure 3: Example of a section of an event tree for a road tank-vehicle for inflammable liquids. The quantitative values are arbitrary.

The following aspects have to be taken into account in event tree analyses for the carriage of dangerous goods (either for the definition of scenarios or for the risk analysis itself):

Vehicles and traffic: Data about the goods and the vehicles have to be collected in order to obtain information about potential branching in the event tree and about the likelihood of events and scenarios.

- Types of goods transported
- Vehicle and tank types
- Specific safety measures and transport time (day/night)

Road network: It is obvious that the infrastructure has to be taken into account in a risk analysis, notwithstanding the fact that the analysis is primarily focused on vehicle and transport. The infrastructure comprises the entire „system road network“ including junctions with other modes of transport (railway crossings, tunnels, bridges, safety installations, pipelines etc). It is therefore recommended to incorporate an examination of the infrastructure and to indicate the contributions to the risk. In this context reference should be made to the special treatment of passages through tunnels in Chapter 1.9.5. ADR. The required information also includes:

- Type of road (open-area, level section, road gradient, population density of residential areas, bridge, one-way traffic, oncoming traffic etc.),
- Speed limits,
- Safety installations (e.g. crash barriers, traffic lights, overpasses),

- Tunnel passages,

- Railway crossings.

Primary event: For a risk assessment in the context of ADR Chapter 1.9.3 only major accidents (and incidents with the potential to become major accidents) are considered. Relevant scenarios are:

- Collision,

- Rear-end collision,

- Overturning,

- Collision with other objects (deer pass, railway crossings),

- Fire (similarly to an explosion or toxic release, a fire is also to be considered as a subsequent potential effect of other primary events)

- Sudden tank failure.

In a specific connection influences like vandalism, terrorism, storms, earthquakes and floods can also be of significance, see ADR 1.9.3 c). Most of these scenarios do not require an additional explanation. The scenario 'sudden tank failure' incorporates a variety of incidents with sudden release of tank contents due to overpressure after violating filling regulations or because of corrosion, brittleness or fatigue of the tank material etc.

Scenario for discharge of substances: In case of an accident, the final extent of damage is highly dependent on the question of whether the packing of the dangerous good resists the impact or not. Minor details of the specific local situation can make the difference here. A suitable combination of both casuistry and laboratory and/or outdoor tests must be found for a certain scenario (see also section 3.4). Since it is not conceivable to foresee all the cases of discharge of substances for every specific accident situation, it is possible in practice to lay down representative and agreed scenarios (general and statistical determination of leakage conditions). In this case, the scenarios thus determined are taken into consideration as test scenarios which make a simplified assessment of consequences which may be standardised between the ADR Contracting Parties possible. When substances are discharged a differentiation has to be made between continuous and spontaneous discharge.

- Instantaneous/continuous release

- Complete/partial release

3.3 Statistical Data

For every type or scenario a general accident frequency depending on the initial event frequency and on conditional probabilities of the branches of the fault tree has to be determined from – in the first instance – appropriate national casuistry. This task requires a large amount of accident data to cover all branches of the scenarios even when the number of scenarios is already reduced by appropriate clustering. In order to obtain statistically significant information on frequencies and conditional probabilities the demands increase further with regard to the number of accidents.

The number of dangerous goods transport accidents is fairly low which is fortunate for human beings and the environment, but limits the statistical significance of accident frequencies and of conditional probabilities within event tree branches. It is therefore highly recommended when deriving statistical data for risk analysis purposes to consider the following data:

- information from international accident databases and

- accident data of general goods transport.

The applicability of these statistics to the individual dangerous goods transport scenario has to be checked and the assumptions made for using them must be substantiated.

The harmonisation of accident investigation and reporting through section 1.8.5 ADR will improve the basis for international accident statistics and for detailed analyses of accident sequences in future. Systematic differences between national accident statistics due to differences regarding roads, vehicles, freight quantity, minimum thresholds for the definition of accidents and other parameters should be taken into account. Special attention should be paid to long term trends in accident statistics due to improved safety levels.

Physical, numerical or statistical analyses of package performance under impact conditions may also serve as suitable sources of information on conditional probabilities of the event tree. Expert estimations have to be avoided as far as possible in order to achieve an objective and reliable database for risk analysis and to ensure transparency for quality control.

Further data needed for the statistical analysis of accident data are transport kilometres differentiated by year, goods, route type etc. in order to be able to derive frequencies for every accident scenario. Information about the number of persons injured or killed with similar differentiation is needed to estimate the risk level of the entire carriage of dangerous goods and to check the plausibility of risk estimation for a certain location.

3.4 Modelling Accident Consequences

The event tree contained in figure 3 ends with the discharge and, if applicable, the burning of the main substance petrol. For the derivation of harm (e.g. fatalities and injuries) further tracking of potential branching of event tree is necessary. Factors which affect the conditional probability of a certain sequence of events following a discharge of hazardous substances depend on the accident location and its surroundings.

Relevant information includes

- Population density in the area around the transport route (depending on time of day)

- Traffic density and probability of congestion (depending on seasons and times of the day),

- Nature and the use of the surrounding buildings and other infrastructures,

- Accessibility of the infrastructure for emergency services

- Atmospheric conditions (wind and temperature statistics) and

- Topography

Some parameters are only relevant for certain scenarios (e.g. wind statistics for discharge of gaseous toxic substances) whereas others are needed in all cases. Two geographical (topological) elements are crucial: Firstly the distance to the built-up areas, secondly the population densities in all parts of the near surroundings in a grid appropriate for the area with significant impact (e.g. resolution 25 x 25 m to 100 x 100 m).

The nature of the buildings is examined with the purpose of estimating the protection against fire or explosion. Inventories of the types of buildings, including information about their usage, are helpful for calculating the presence of human beings (residential/industrial/ commercial areas, schools, hospitals, etc.).

Relevant scenarios of impact on people and the environment are

- Explosion
- Fire (flash or pool)
- Atmospheric dispersion of toxic substances and
- Contamination of water and soil

In order to derive accident consequences for every scenario, at first numerical or analytical models have to be used to estimate the physical effects of each scenario (radiation, pressure, concentration of toxic substances, debris impact). Suitable models and equations are given in e.g. [8], [9]. Models used for risk estimation should be previously verified and compared with real scenarios or model benchmarks.

The degree of simplification inherent in physical models affects the validity and the level of detail of the risk estimation process. Hence, the choice of models and the number and quality of parameters to be included in the physical analysis should be kept compatible with the level of accuracy required for risk evaluation (see section 4).

In general, four types of harm or damage should be examined:

1. People killed during or shortly after the accident
2. People injured
3. Damage to important buildings and structures
4. Environmental pollution linked to the cargo discharged.

Concerning fatalities and injuries the damage to persons has to be estimated with the help of statistical and physiological models based on the estimated physical effects. These models assign figures for the probability of injury or death to physical effects as e.g. the exposure to radiation or toxic gases (e.g. [9], [10]). There is still an unsatisfactory level of uncertainty in some of these models depending on the type of the consequences (e.g. probit functions for toxicity). Hence, a considerable part of the level of uncertainty in risk analysis has its origin in estimation of harm.

The use of objective and transparent methods and the realistic inclusion of mitigating parameters like escape or shelter effects of buildings are indispensable for an adequate risk analysis. The systematic use of pessimistic assumptions, for example, is counterproductive for a risk analysis, especially if it is carried out in order to establish an absolute level of risk to be compared with a fixed threshold. In the case of the comparative approach (using a particular tool) this is less important, as more emphasis is given to the difference (gain) between one transport route and another. In all cases, consideration and discussion of uncertainty levels is part of the risk evaluation process.

3.5 Risk Estimation

The risk estimation process includes the application of the event tree and of the physical and physiological models for the location under consideration. Calculated/estimated values of individual or societal risks are assigned to all potential accident scenarios on the basis of specific local data for dangerous goods transport capacity and route use. Following the simplified definition in section 2.1 risk is the product of harm and probability. But still, presenting risk as a single probability of harm (e.g. probability of one fatality per year) is not common practice in risk analysis. Risk is normally considered as the probable frequency of harm (e.g. frequency of fatalities) either in a spatial context or as a frequency distribution of the level of harm (see below).

For systematic risk estimation the transport route under consideration has to be divided into different sections with a standard length in order to make risk values comparable to risk criteria. A typical reference length for the derivation of risk (per year) is 100 m to 1 km. When alternative routes are under consideration the total societal risk of every route is assessed for comparison. In this case, the risk of a route in relation to a reference length provides no additional information that can be used.

Individual risk is typically depicted by means of ISO-risk contours (e.g. fatalities per year and route length) on a map of the area under consideration in order to give information about the spatial distribution of risk irrespective of the real actual population density distribution. Societal risk is shown in form of a graph showing the relationship of harm (e.g. N people killed) to frequency F (often called F-N curve). In this case the population density distribution has to be taken into account. Examples for both risk types are given in figures 4 and 5.

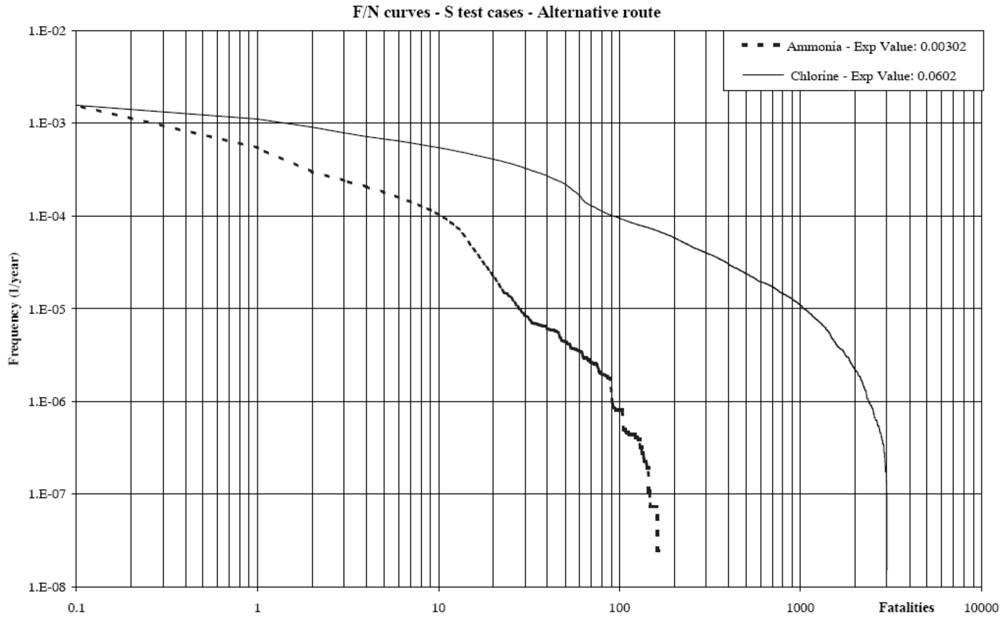

Figure 4: Example of an FN graph for the societal risk of the main substances ammonia and chlorine for a road tunnel (from[11])

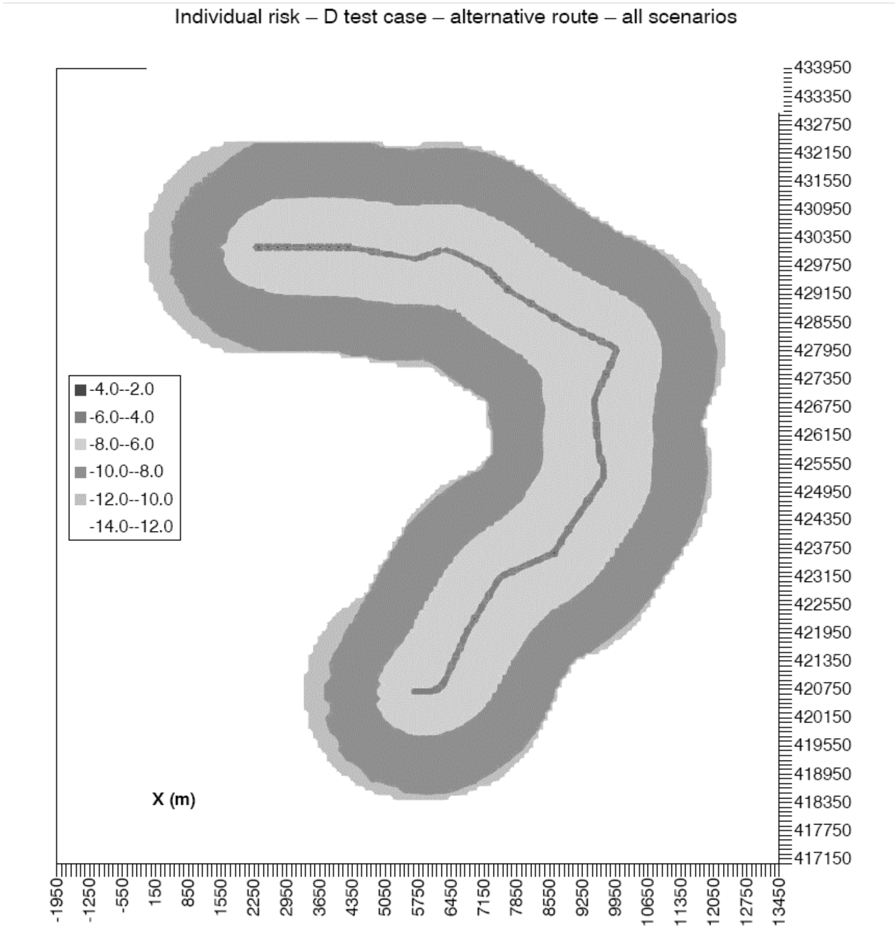

Figure 5: Example of a diagram with ISO risk graphs of the spatial distribution of the individual risk (exponent for 10^n/annum, from [11])

4. Risk Evaluation

At present an ADR Contracting Party is free according to its national safety policy to define target safety levels and to define measures in case of violation, as far as these provisions are not contrary to international regulations. Up to now there is no uniform approach to assess risks initiated by the transport of dangerous goods.

Currently the ADR Contracting Parties also have different approaches to risk evaluation at national level due to specific parameters (see item 3.1). These differences concern

- type of evaluated risk (individual, societal, environmental)
- level and shape of acceptance and tolerability limits
- areas/categories of acceptance and tolerability.

Each type of risk needs a risk criterion to evaluate whether a risk is tolerable. These risk criteria should be measured against risk criteria for comparable types of risk (e.g. risks from industrial installations which are subject to the regulations of the Seveso II Directive, [2]).

The ALARP principle (as low as reasonably practicable) applied in the UK defines an area of unacceptable risk which implicates the need for risk treatment when risk analysis results fall into this area. The adjacent tolerability area with lower risk values leads to measures according to the ALARP principle whereas the acceptable area with even lower insignificant (residual) risk does not require any action by the competent authority.

In derogation from this the approach to risk evaluation in the Netherlands does not contain an ALARP or transition area between tolerable and non-acceptable risks, but for societal risk it takes into account an additional differentiated risk aversion due to the different risk perception in an event with low probability and great damage and an event with high probability and small damage [12]. It is also possible to restrict the risk evaluation to major damage and an additional disregard of accidents with a very low probability (figure 6).

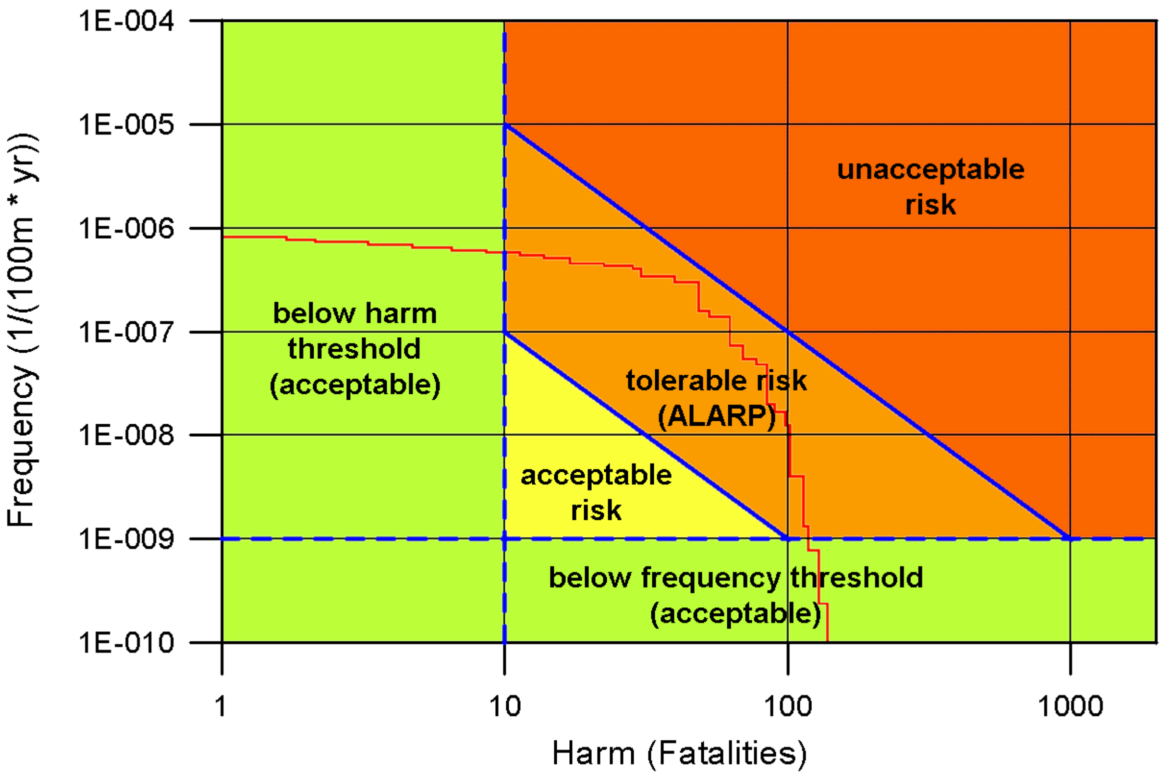

Figure 6: Example of an FN graph for societal risk with possible areas for risk evaluation (presentation of principle with arbitrary scaling)

The French GAMAB principle (globalement au moins aussi bon – in total at least equally good) provides a possible evaluation principle for a qualitative risk analysis which would in a comparison of routes require not more than the same risk for an alternative route compared to the existing route (standstill principle).

Within the previous sections several potential sources of uncertainty have been discussed (accident statistics, physical and physiological models, time-dependent local parameters, etc.) For a useful risk evaluation on the basis of fixed risk criteria it is crucial to aim at minimising uncertainty. Particularly when restrictive measures are envisaged, transparent analysis and discussion of uncertainty within the evaluation process is advisable for the understanding and acceptance of the measures.

5. Risk Management

The risk evaluation provides information on whether an analysed situation corresponds to a tolerable risk or not. This evaluation takes place independently of the risk analysis phase. With appropriate documentation of the risk assessment a description suitable for Chapter 1.9.3 ADR of the appropriate nature of measures can be provided. Nevertheless, the documentation should also contain information about the selection of measures and particularly about the definition of decision criteria outside the risk estimation itself.

It is straightforward to use the same methods and models as for the risk estimation for the comparison of the effectiveness of different potential measures. The effectiveness of measures includes aspects such as the potential for risk reduction and the cost to stakeholders. A proper justification of measures increases the chance of their broad acceptance.

It is advisable to check the risk management process periodically in order to take into account changes in context or process.

6. References

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