Guidance on Safety Risk Assessment for Chemical Transport Operations

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cefic

Responsible Care

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1. Introduction

It is of key importance for the chemical industry to ensure the safe transport and handling of its products, in full compliance with regulations and industry best practices. As part of its Responsible Care programme, Cefic is developing and promoting best industry practices (such as SQAS, BBS and ICE Emergency Response) aiming at continuously improving the safety performance of chemical transport activities. Despite all these preventive actions, transport accidents can however still happen. Since these accidents take place in the public domain, they often attract a lot of attention.

Increasing urbanization in combination with higher aversion to risk of the society, may result in more restrictions on the transport of dangerous goods (e.g. restrictions on the transport mode or transport route that can be used or compulsory transportation time windows).

Risk assessment is an important tool that should be used by companies to manage the risks of their transport operations. In order to assist companies in carrying out transport risk assessments, Cefic has developed this guidance note. It provides general advice on how the safety and environmental risks of transport operations can be assessed, taking into account already existing best practices.

2. Purpose and objectives

The purpose of this document is to provide general guidance on safety risk assessment for chemical transport operations. This should allow the identification of transport activities with the highest potential risk towards people, infrastructure and the environment.

This guidance should assist chemical and transport companies in carrying out risk assessments of their transport operations. This should help companies in identifying transport activities with high potential risks, to choose the safest transport mode or route and to implement other risk mitigation measures.

This document does not aim to provide detailed guidance on risk assessment methods.

3. Scope

The scope of this guidance covers off-site inland transport operations of dangerous goods by road, rail and inland waterways. Transport by pipeline is not included in the scope of this guidance.

The focus is on events with high potential impact on people, infrastructure and the environment.

4. General introduction to risk assessment

The following activities are normally undertaken when carrying out a risk assessment (see also Figure 1):

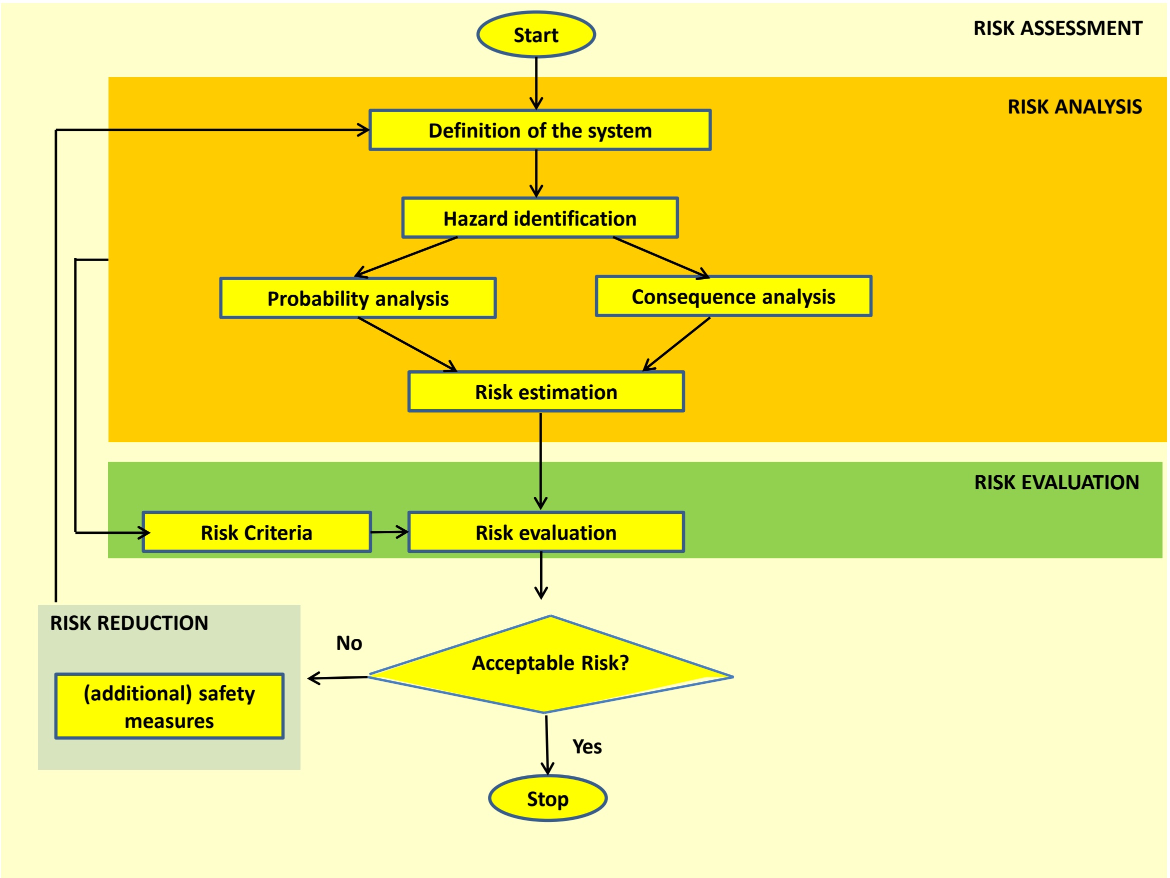
Risk analysis is the systematic analysis of all available information to identify hazards and their consequences, the potential exposure to these hazards and the probability of their occurrence, in order to estimate the risk. The outcome of a risk analysis provides information on the risk of the transport operation under consideration. The purpose of the risk analysis is to derive potential consequences connected with specific accident scenarios and the probabilities of their occurrence.

Both qualitative and quantitative risk analysis methods can be used. Qualitative risk analysis is used as a first step in the overall risk assessment process, so that attention can be focused on higher risk scenarios using quantitative methods of risk analysis if needed.

Risk evaluation is the evaluation of the acceptability of the identified risk. To allow a systematic risk evaluation, risk criteria need to be defined to determine whether a given risk level is acceptable or not.

Risk reduction: If the estimated risk of the transport activity under consideration is considered as not acceptable, measures need to be taken to reduce the risk.

Figure1. Schematic overview of the main steps of the risk assessment process



Ref. PIARC Technical Committee C 4 Road Tunnel Operation: Technical Report “Risk Evaluation” Draft Version 5.0 (April 2010)

5. Qualitative risk analysis

Qualitative risk analysis should be used as a first step in the overall risk assessment process. This allows filtering out the lower risk activities so that attention can be focused on higher risk scenarios. Qualitative risk analysis methods do not use precise numeric values. A commonly applied method to support the classification of risks in a qualitative approach is the use of a risk matrix.
When carrying out a qualitative risk analysis it is important to maintain consistency in the approach throughout the whole process in order to ensure that the results are based on the same assumptions.

The procedure for qualitative risk analysis consists of the following steps:

- **Definition** of the transport operation to be analyzed and **identification** of all relevant hazards involved in the transport operation;
- **Consequence analysis**: investigation of the potential consequences taking into account product hazards and potential exposure to these hazards;
- **Probability analysis**: determination of the probabilities of exposure to certain hazards.

5.1. Consequence analysis

A consequence analysis aims to assess the potential consequences of a transport accident by analyzing the hazards of the transported product (hazard severity analysis) and the potential exposure to these hazards in case of an accident (hazard exposure analysis).

5.1.1. Hazard severity analysis: Identification of the potential product hazards and their severity, for example by using the existing UN hazard classification system for dangerous goods transport which is based on the hazard class, the packing group (PG) (see annex 2) and the hazard identification number (HIN) (see annex 3), in combination with the volume of the transport container (i.e. packed or bulk*).

Example of an hazard severity ranking system (see also Figure 2)

- Hazardous goods with a **low potential impact**: hazardous goods of Packing Group III transported in bulk* and not fulfilling the criteria of very high potential impact goods (see below);
- Hazardous goods with an **intermediate potential impact:** hazardous goods of Packing Group II transported in bulk* and not fulfilling the criteria of very high potential impact goods (see below);
- Hazardous goods with **high potential impact:** hazardous goods of Packing Group I transported in bulk* and not fulfilling the criteria of very high potential impact goods (see below);
- Hazardous goods with **very high potential impact**:

  - Goods that are toxic by inhalation (TIH), transported in any quantity.
  - Goods transported in bulk* with one of the following ADR/RID hazard identification numbers:

    - flammable gases with HIN 23, 263, 238 or 239;
    - toxic gases with HIN 26, 265 or 268;
    - highly flammable liquids with HIN 33, 333, 336, 338, 339, X323, X333 or X338;
    - highly toxic liquids with HIN 66, 663, 664, 665, 668, 669, 886, X88 or 668.

Figure 2 Example of hazard severity ranking system

Hazard severity (potential impact)	***Criteria***	***Score (A)***
Low potential impact	PG III in bulk*	1
Intermediate potential impact	PG II in bulk*	2
High potential impact	PG I in bulk*	3
Very high potential impact	-Toxic by inhalation in any quantity - Flammable gases in bulk* - Toxic gases in bulk* - Highly flammable liquids in bulk* - Highly toxic liquids in bulk*	4

** Bulk means goods transported in tank vehicles, tank containers, rail tank cars or tank barges*

5.1.2. Hazard exposure ranking: Identification of the potential exposure to the transport hazard based on **population densities** along the transport route and **environmental considerations** (proximity of drinking water reservoirs, water courses or protected nature areas). The score (B) is based on the most severe ranking based on either population density or proximity of environmental sensitive areas. The scoring should always be used consistently, for example when comparing the hazard exposure ranking of different routes.

Figure 3 Example of hazard exposure ranking system

Population density along the transport route	***Proximity of environmentally sensitive areas *****	***Score (B)***
Low	Very distant	1
Intermediate	Distant	2
High	Close	3
Very high	Very close	4

** Drinking water reservoirs, water courses or protected nature areas

5.1.3. Total consequence ranking: By combining the hazard severity ranking (A) and the hazard exposure ranking (B), the total consequence ranking is obtained. The result should be used to set priorities and to decide whether further steps in transport risk analysis for a transport operation should be undertaken. Total consequence ranking can be done by using a simple scoring approach (see example in Figure 4 below). Based on the total consequence ranking, a selection of transport operations can be made that require further risk analysis.

Figure 4 Example of a total consequence ranking system

Hazard Severity Ranking Score (A)	***Hazard Exposure Ranking Score (B)***			
	4	***3***	***2***	***1***
4	16 (IV)	12 (IV)	8 (III)	4 (III)
3	12 (IV)	9 (III)	6 (III)	3 (II)
2	8 (III)	6 (III)	4 (III)	2 (II)
1	4 (III)	3 (II)	2 (II)	1(I)

Total Consequence Ranking	***Total score***
Very high consequence (IV)	16/12
High consequence (III)	9/8/6/4
Moderate consequence (II)	3/2
Low consequence (I)	1

5.2. <u>Probability analysis</u>

The probability analysis aims at identifying the **probability** of occurrence of a transport hazard, taking into account the average accident frequencies for the transport mode being assessed.

Data on transport accident frequencies can be difficult to find, in particular data on frequencies of accidents with loss of containment. Transport accident frequencies are normally expressed as number of accidents per distance driven by the transport vehicle (truck, train, barge).

Annexes 4 and 5 provide examples of accident frequencies mentioned in the Purple Book. More country/product/mode specific accident frequencies can be found in literature.

5.3. Risk matrix

By a combination (multiplication) of the total consequence ranking (see Figure 4) with the probability of accidents (accident frequency), a risk matrix is obtained which allows the classification of individual accident scenarios on a numerical scale (see example in Figure 5 below). Such a risk categorization may be used for the comparison of risks and the identification of scenarios that warrant further investigation and consideration of risk mitigation measures (see Section 8).

Figure 5 Example of a risk matrix

Total consequence Ranking	**Probability of incidents**			
	Very unlikely	**Not likely**	**Likely**	**Frequent**
Very high consequences (IV)				
High consequences (III)				
Moderate consequences (II)				
Low consequences (I)				

Risk Category

4	**Very high risk**
3	**High risk**
2	**Moderate risk**
1	**Low risk**

Practical examples illustrating the qualitative risk analysis are given in Annex 6. These examples are based on serious accidents that have happened in the past.

Note

By using the definition of risk as the combination (multiplication) of consequence and probability, one may obtain the same risk value for accidents with high probability and low consequences as for accidents with low probability and high consequences. The risk perception by the general public of these two types of accidents may be completely different. The general public is in general more concerned about accidents with a high impact (e.g. many fatalities in one accident) than about 'smaller' accidents happening frequently. To take these different kinds of risk perception into account, an additional factor called 'risk aversion' can be used for evaluating the total risk.

6. Accident scenarios with potential high consequences

The following accident scenarios with potential high consequences can be identified for the most commonly transported chemical products. The transport of explosives (class 1) and radioactive materials (class 7) have not been taken into consideration in the selection of these scenarios.

These scenarios can be caused by different accident types (collision, overturned vehicle, derailment etc) that can create an impact with sufficiently high energy required to damage the containment of the product.

6.1 Accident scenarios

- UVCE (Unconfined Vapor Cloud Explosion)
- Hot BLEVE (Boiling Liquid Expanding Vapour Explosion)
- Toxic vapor cloud release
- Pool fire
- Jet fire
- Spillage of substances harmful for the environment

6.2 Accident types that can cause scenarios with potential high consequences

- Energy is required to initiate these scenarios: either kinetic energy (high speed) or potential energy (fall).
    - For gaseous substances small leaks are most of the time enough to generate scenarios with a potential high consequence. Gas containers have however a higher shell thickness than liquid containers and can therefore withstand higher energy impacts.
    - For liquids large leaks are required to create scenarios with a potential high consequence. To create such large leaks, an accident with sufficient energy to damage the containment is required.

- The direct vicinity of the accident has also an impact:
    - Presence of other dangerous goods (e.g. in freight trains)
    - Traffic density surrounding the transport vehicle (e.g. on a congested road)
    - Population density alongside the transport route
    - The proximity of environmentally sensitive areas: river, protected nature area…

- Leaking transport equipment (valves, man-lids etc) is not included in the scenarios as this is under control of the loaders.

*6.3 **Analysis of scenarios with potential high consequences***

- UVCE (Unconfined Vapor Cloud Explosion)
  - Flammable cargo (gas or liquid)
  - Delayed ignition
  - Instantaneous impact
  - High impact range
  - Nearby populated areas will be impacted

- Hot BLEVE (Boiling Liquid Expanding Vapor Explosion)
  - Flammable liquid, flammable gas or peroxide
  - Heating source or exothermic reaction necessary
  - Takes time to develop
  - High impact range
  - Nearby populated areas will be impacted

- Toxic vapor cloud release
  - Toxic gas or toxic volatile liquid (toxic by inhalation hazard – TIH)
  - Instantaneous impact
  - High impact range
  - Nearby populated areas will be impacted

- Pool Fire
  - Flammable liquid
  - No instantaneous impact – time needed to have sufficient leaked product
  - Ignition source needed
  - Impact by thermal radiation or fire propagation
  - Impact limited to direct surroundings
  - Presence of other Dangerous Goods (e.g. other Rail Tank Cars in same train) could create domino effect (such as a hot BLEVE). A pool fire under the leaking tank could also generate a hot BLEVE.

- Jet fire
  - Flammable pressurized cargo (gas or liquid)
  - Same conditions as UVCE but with instantaneous ignition
  - Instantaneous impact
  - Fire propagation risk
  - Impact limited to direct surroundings
  - Presence of other Dangerous Goods (e.g. other Rail Tank Cars in same train) could create domino effect, like hot a BLEVE

- Liquid or solid spillage of environmentally hazardous substance
  - Low energy accident can be sufficient for creating leak
  - Close proximity of a sensitive zone is required
  - Instantaneous impact
  - Potential high impact range

7. Quantitative risk analysis

After identification of the high risk scenarios using qualitative methods, companies can consider the application of quantitative methods of risk analysis if necessary. Quantitative risk analysis methods should be used primarily for specific transport operations with a very high consequence ranking. **Since quantitative risk analysis assessment is based on many assumptions**, **it is recommended to use quantitative risk analysis only for the relative ranking of different transport options.** Calculation of absolute levels of risks is in most cases not meaningful due to the high degree of uncertainty of the available accident frequency data.

8. Risk mitigation

The risk of a transport operation can be reduced by taking measures that either reduce the probability (frequency) of accidents taking place or reduce the potential consequences of an accident.
Some examples of risk mitigating measures are listed below (without aiming to be comprehensive). See also Annex 6.

8.1 Reduction of probability/frequency of occurrence of accidents

The following examples are focusing on road transport:

- **Reduce the probability of an accident by**
  - reducing the total volume of transported product
  - selection of the mode of transport
  - selection of the route of transport
  - selection of the carrier (using SQAS etc)
  - training of all people involved in the transportation process (drivers, loaders etc)
  - maintenance and inspection of the transport equipment
  - systems increasing the stability of the vehicle
  - taking into account weather conditions (postpone transport in case of bad weather conditions)
  - taking measures to improve security

- **Reduce the probability of leakage in case of an accident by**
  - reducing the speed of the vehicle
  - improving the quality of the containment (e.g. shell thickness of tanks)
  - installing crash-buffers (on rail tank cars)

8.2 Reduction of potential consequences

Hazard severity
Since in most cases the hazards are intrinsic to the product to be transported, there is little opportunity to reduce these. One possible way to achieve this is by changing the concentration or the phase of the product (liquid vs gas).
Another option is a reduction of the size of the containment (packed instead of bulk, use of compartimented tanks).

Hazard exposure

Since exposure is related to the proximity of people and environmentally sensitive areas along the transport route, the hazard exposure of a specific transport operation can be reduced by changing the

- transport mode
- transport route (e.g. motoways vs secundary roads; roads avoiding densely populated urban areas)
- time of transport (day vs night).

ANNEXES

Annex 1. Definition of Technical Terms

Risk: Combination (product) of the consequence (severity of harm) and the probability of occurrence.

Consequence: 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: Process to determine whether the tolerable risk has been achieved.

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

Tolerable risk: Risk which is accepted on the basis of agreed decision criteria.

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

Risk management: The overall process of risk assessment, risk mitigation and risk communication.

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**

Individual or location-based risk: The risk an individual is exposed to, based on his/her distance from the risk source.

Societal risk or group risk: The risk that a group of people is simultaneously exposed to the consequences of an accident, expressed – using an 'FN curve' – as a relationship between the expected frequency of the accident, and the number of people who will die (or be injured) as a result of the accident.

Risk perception: Way in which a stakeholders view a risk, taking into account their concerns.

Stakeholder: Any individual, group or organization that can produce a risk or that can be affected by, or perceive itself to be affected by, a risk.

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.

Quantitative risk analysis: The aim of quantitative risk analysis is to generate numeric values for individual (location based) risk and societal risk that include risk contributions from all possible accidents scenarios.

Qualitative risk analysis: The qualitative risk analysis covers a range of different methods that do not use numeric values (i.e. precise figures) for individual (location-based) risk or societal risk**.**

Annex 2. ADR/RID PACKING GROUPS

2.1.1.3 For packing purposes, substances other than those of Classes 1, 2, 5.2, 6.2 and 7, and other than self-reactive substances of Class 4.1 are assigned to packing groups in accordance with the degree of danger they present:

Packing group I: Substances presenting high danger;
Packing group II: Substances presenting medium danger;
Packing group III: Substances presenting low danger.

The packing group(s) to which a substance is assigned is (are) indicated in Table A of Chapter 3.2.

Annex 3 ADR/RID Hazard Identification Numbers (HIN)

20	asphyxiant gas or gas with no subsidiary risk
22	refrigerated liquefied gas, asphyxiant
223	refrigerated liquefied gas, flammable
225	refrigerated liquefied gas, oxidizing (fire-intensifying)
23	flammable gas
238	gas, flammable, corrosive
239	flammable gas, which can spontaneously lead to violent reaction
25	oxidizing (fire-intensifying) gas
26	toxic gas
263	toxic gas, flammable
265	toxic gas, oxidizing (fire-intensifying)
268	toxic gas, corrosive
28	gas, corrosive
30	flammable liquid (flash-point between 23 °C and 60 °C, inclusive) or flammable liquid or solid in the molten state with a flash-point above 60 °C, heated to a temperature equal to or above its flash-point, or self-heating liquid
323	flammable liquid which reacts with water, emitting flammable gases
X323	flammable liquid which reacts dangerously with water, emitting flammable gases
33	highly flammable liquid (flash-point below 23 °C)
333	pyrophoric liquid
X333	pyrophoric liquid which reacts dangerously with water [1]
336	highly flammable liquid, toxic
338	highly flammable liquid, corrosive
X338	highly flammable liquid, corrosive, which reacts dangerously with water 339 highly flammable liquid which can spontaneously lead to violent reaction
36	flammable liquid (flash-point between 23 °C and 60 °C, inclusive), slightly toxic, or self-heating liquid, toxic

362	flammable liquid, toxic, which reacts with water, emitting flammable gases
X362	flammable liquid toxic, which reacts dangerously with water, emitting flammable gases
368	flammable liquid, toxic, corrosive
38	flammable liquid (flash-point between 23 °C and 60 °C, inclusive), slightly corrosive or self-heating liquid, corrosive
382	flammable liquid, corrosive, which reacts with water, emitting flammable gases
X382	flammable liquid, corrosive, which reacts dangerously with water, emitting flammable gases
39	flammable liquid, which can spontaneously lead to violent reaction
40	flammable solid, or self-reactive substance, or self-heating substance
423	solid which reacts with water, emitting flammable gases, or flammable solid which reacts with water, emitting flammable gases or self-heating solid which reacts with water, emitting flammable gases
X423	solid which reacts dangerously with water, emitting flammable gases, or flammable solid which reacts dangerously with water, emitting flammable gases, or self-heating solid which reacts dangerously with water, emitting flammable gases
43	spontaneously flammable (pyrophoric) solid
X432	spontaneously flammable (pyrophoric) solid which reacts dangerously with water, emitting flammable gases
44	flammable solid, in the molten state at an elevated temperature
446	flammable solid, toxic, in the molten state, at an elevated temperature
46	flammable or self-heating solid, toxic
462	toxic solid which reacts with water, emitting flammable gases
X462	solid which reacts dangerously with water, emitting toxic gases
48	flammable or self-heating solid, corrosive
482	corrosive solid which reacts with water, emitting flammable gases
X482	solid which reacts dangerously with water, emitting corrosive gases
50	oxidizing (fire-intensifying) substance
539	flammable organic peroxide
55	strongly oxidizing (fire-intensifying) substance
556	strongly oxidizing (fire-intensifying) substance, toxic
558	strongly oxidizing (fire-intensifying) substance, corrosive
559	strongly oxidizing (fire-intensifying) substance, which can spontaneously lead to violent reaction
56	oxidizing substance (fire-intensifying), toxic
568	oxidizing substance (fire-intensifying), toxic, corrosive
58	oxidizing substance (fire-intensifying), corrosive
59	oxidizing substance (fire-intensifying) which can spontaneously lead to violent reaction
60	toxic or slightly toxic substance
606	infectious substance
623	toxic liquid, which reacts with water, emitting flammable gases
63	toxic substance, flammable (flash-point between 23 °C and 60 °C, inclusive)
638	toxic substance, flammable (flash-point between 23 °C and 60 °C, inclusive), corrosive

639	toxic substance, flammable (flash-point not above 60 °C) which can spontaneously lead to violent reaction
64	toxic solid, flammable or self-heating
642	toxic solid, which reacts with water, emitting flammable gases
65	toxic substance, oxidizing (fire-intensifying)
66	highly toxic substance
663	highly toxic substance, flammable (flash-point not above 60 °C)
664	highly toxic solid, flammable or self-heating
665	highly toxic substance, oxidizing (fire-intensifying)
668	highly toxic substance, corrosive
X668	highly toxic substance, corrosive, which reacts dangerously water
669	highly toxic substance which can spontaneously lead to violent reaction
68	toxic substance, corrosive
69	toxic or slightly toxic substance, which can spontaneously lead to violent reaction
70	radioactive material
78	radioactive material, corrosive
80	corrosive or slightly corrosive substance
X80	corrosive or slightly corrosive substance, which reacts dangerously with water
823	corrosive liquid which reacts with water, emitting flammable gases
83	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C, inclusive)
X83	corrosive or slightly corrosive substance, flammable, (flash-point between 23 °C and 60 °C, inclusive), which reacts dangerously with water
839	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive) which can spontaneously lead to violent reaction
X839	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive), which can spontaneously lead to violent reaction and which reacts dangerously with water
84	corrosive solid, flammable or self-heating
842	corrosive solid which reacts with water, emitting flammable gases
85	corrosive or slightly corrosive substance, oxidizing (fire-intensifying)
856	corrosive or slightly corrosive substance, oxidizing (fire-intensifying) and toxic
86	corrosive or slightly corrosive substance, toxic
88	highly corrosive substance
X88	highly corrosive substance, which reacts dangerously with water
883	highly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive)
884	highly corrosive solid, flammable or self-heating
885	highly corrosive substance, oxidizing (fire-intensifying)
886	highly corrosive substance, toxic
X886	highly corrosive substance, toxic, which reacts dangerously with water
89	corrosive or slightly corrosive substance, which can spontaneously lead to violent reaction
90	environmentally hazardous substance; miscellaneous dangerous substances
99	miscellaneous dangerous substance carried at an elevated temperature.

Annex 4

Overview of accident frequencies based on accident data of 1994-1996 *
(see Guidelines for quantitative risk assessment. “Purple Book”. Report CPR 18E. Committee for the Prevention of Disasters. First edition. Sdu Uitgevers Den Haag, 1999. ISBN 90 12 08796 1)

ROAD Average	1.8×10^{-7}/truck.km
RAIL Average Speed >40 km/h Speed <40 km/h	3.6×10^{-8}/car.km 4.5×10^{-8}/car.km 2.2×10^{-8}/car.km
BARGE Navigability Class (CEMT) 4 Navigability Class (CEMT) 5 Navigability Class (CEMT) 6	6.7×10^{-7}/vessel.km 7.5×10^{-7}/vessel.km 1.4×10^{-6}/vessel.km

* More country/product/mode specific accident frequencies can be found in literature.

Annex 5

Overview of outflow frequencies (> 100 kg) based on accident data of 1994-1996 *
(see Guidelines for quantitative risk assessment. “Purple Book”. Report CPR 18E. Committee for the Prevention of Disasters. First edition. Sdu Uitgevers Den Haag, 1999. ISBN 90 12 08796 1)

	Pressurized tanks	**Atmospheric tanks**
ROAD Average Motorway Outside built-up area Inside built-up area	2.0×10^{-9}/veh.km 1.3×10^{-9}/veh.km 3.7×10^{-9}/veh.km 1.1×10^{-9}/veh.km	1.6×10^{-8} /veh.km 8.4×10^{-9} / veh.km 2.8×10^{-8} /veh.km 1.2×10^{-8} /veh.km
RAIL Speed >40 km/h Speed < 40 km/h	1.3×10^{-10}/car.km 1.7×10^{-11}/car.km	2.5×10^{-8}/car.km 1.7×10^{-9}/car.km

* More country/product/mode specific accident frequencies can be found in literature.

Annex 6.

Examples of qualitative risk analysis and risk mitigation measures applied on accidents that have happened in the past

1. Viarregio – Train derailment

Risk analysis

Rail accident resulting in 23 fatalities as a result of an explosion following the derailment (caused by an axle break) of rail tank cars loaded with LPG close to a populated area.

Liquefied petroleum gas:

- UN Hazard Class 2 / HIN: 23
- Hazard severity ranking: very high potential impact (A= 4)

Population density: high/very high (B= 3/4)

Total consequence ranking: A x B = 12-16 (IV - very high)

Probability: very unlikely

Risk category: 3 (yellow) = high risk

Type of worst case scenario: UVCE (Unconfined Vapor Cloud Explosion)

Possible mitigation measures to be considered

Reduction of hazard exposure level

- Change rail route to avoid populated areas
- Change transport mode (to pipeline/barge/road/intermodal)?

Reduction of probability of occurrence

- Better inspection/maintenance of equipment (chassis/axles)
- Remove sharp objects along the rail track
- Lower speed of train
- Install crash buffers
- Use tank cars with higher shell thickness
- Install derailment detection devices

2. Waldhof – Sunken barge on river Rhine

Risk analysis

Accident involving the sinking (caused by wrong balancing of ballast water) of a double hull barge loaded with sulphuric acid, resulting in1 fatality and closure of the river Rhine for freight transport during several weeks.

Sulphuric acid:

- UN Hazard Class 8 / Packing Group II / HIN: 80
- Hazard severity ranking: intermediate potential impact (A=2)

Proximity of environmentally sensitive areas: very close (B = 4)

Total consequence ranking: A x B = 8 (III – high)

Probability: not likely

Risk category: 3 (yellow) = high risk

Type of worst case scenario: Spillage of substances harmful for the environment

Possible risk mitigation measures

Reduction of hazard exposure level

- Change transport mode (to road or rail)?

Reduction of probability of occurrence

- Increase stability of ship
- Better management of ballast water
- Improve ship vetting system
- Improve training of ship crew

3. Overturned bromine road tanker – port of Antwerp

Risk analysis

Overturned bromine road tank container in port of Antwerp (caused by changing direction at road crossing at a too high speed), resulting in leakage of bromine in sewer system and evacuation of several hundreds of people.

Bromine:

- UN Hazard Class 8 / Packaging group I / HIN: 886
- Hazard severity ranking: very high potential impact (A= 4)

Population density: / high (B= 3)

Total consequence ranking: A x B = 12 (IV - very high)

Probability: not likely

Risk category: 4 (red) = very high risk

Type of worst case scenario: Toxic vapor cloud release

Possible risk mitigation measures

Reduction of hazard exposure level

- Change route in port of Antwerp ?
- Change transport mode ?

Reduction of probability of occurrence

- Increase stability of truck by lowering chassis and gravity point
- Improve selection of transport company (SQAS/dedicated haulier)
- Improve experience and training of drivers (awareness of high density of product)