



**Cefic Guidance on
Safety Risk Assessment
for Chemical Transport Operations
J Verlinden**



Transport Risk Assessment



Background

- As part of its commitment to Responsible Care, the chemical industry strives to continuously improve its safety performance through learning from shared experience and implementing best practices.
- Increasing urbanization and higher risk aversion of society result in more and more restrictions on the transport of dangerous goods (e.g. 'Basisnet' in the Netherlands).
- Risk assessment is an important tool in risk management

In 2012 the Cefic SIG Logistics decided to create a new Issue Team to review current transport risk assessment practices and to develop Cefic guidance on transport risks assessment

Transport Risk Assessment



Objectives of the Cefic Issue Team

- Development of general Cefic guidance on risk assessment for chemical transport operations, assisting companies in identifying transport activities with the highest potential risk and in prioritizing their safety management initiatives
- Identification of high risk scenarios to assist the SIG Logistics in setting priorities for future activities

Scope

- Off-site inland transport operations of dangerous goods by road, rail and inland waterways.
- Focus on events with high potential impact

Issue Team Composition



Hermand Jean-Christoph (Total) *Chairman*

Ostermayer Bertram (BASF)

Knoth Gernot (BASF)

Beddegenoodts Steven (SABIC)

Cabuy Marc (ExxonMobil)

De Block Patrick (Ineos)

Schmidkunz Robert (Evonik)

De Wilde Ingrid (Evonik)

Debelle Jean-Pol (Euro Chlor)

Delzenne Alain (Solvay)

Rupert Leo (Shell)

Denis Ropers (Dow)

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Transport Risk Assessment

➤ **Qualitative**

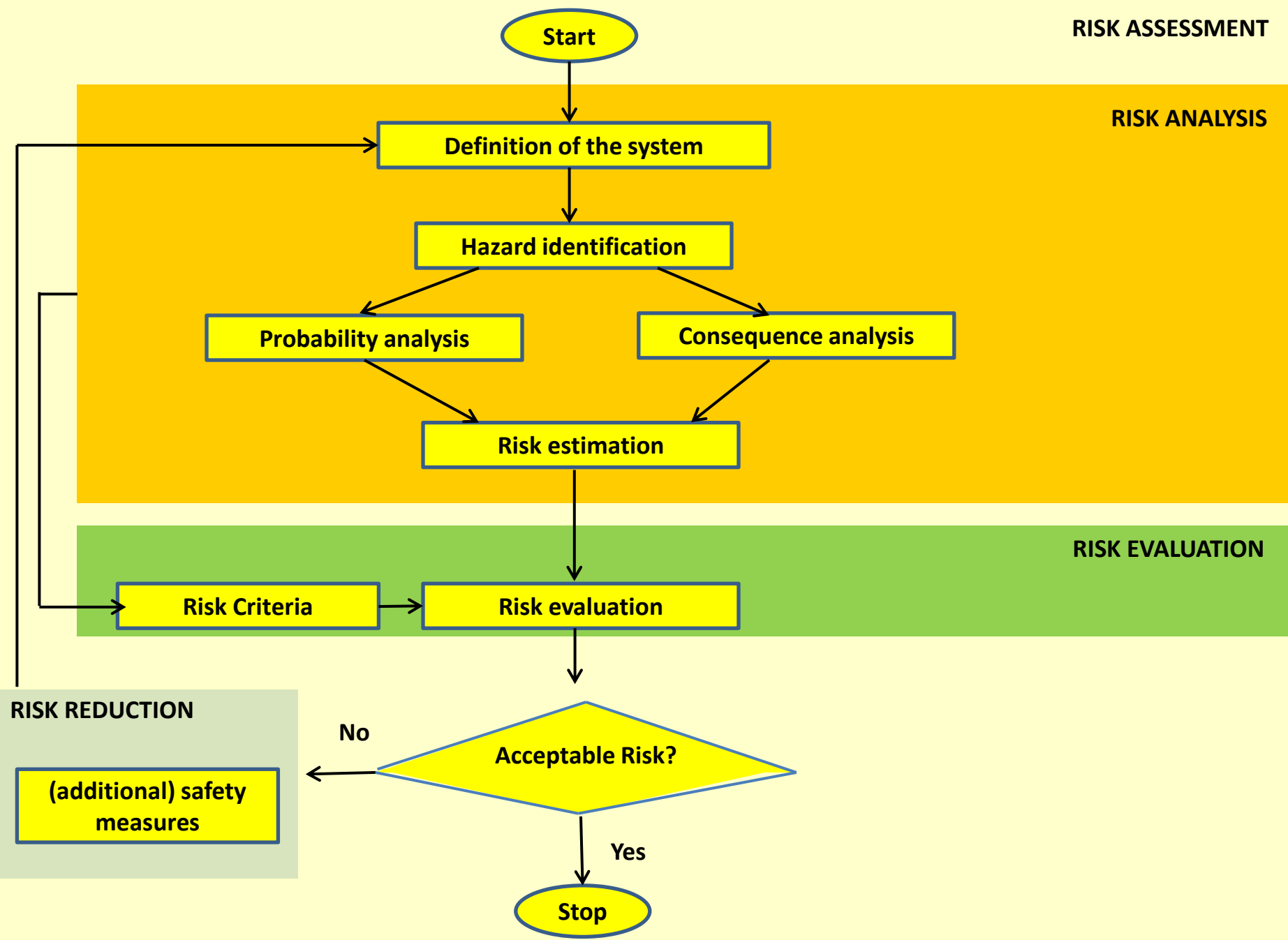
➤ **Quantitative**

Qualitative transport risk assessment



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- **First step in overall risk assessment process**
 - **Results in relative ranking**
 - **Identification of higher risk operations/scenarios**
 - **No use of precise numeric values (probability)**
 - **No detailed calculations of risks**

Same assumptions to be used throughout whole process in order to maintain consistency in the approach



Start

Definition of the system

Hazard identification

Probability analysis

Consequence analysis

Risk estimation

Risk Criteria

Risk evaluation

Acceptable Risk?

No

Yes

Stop

RISK REDUCTION

(additional) safety measures



Qualitative transport risk analysis

Different steps

- **Definition of transport operation to be analysed**
- **Identification of all relevant hazards**
- **Consequence analysis**
- **Probability analysis**
- **Risk estimation (matrix)**

Qualitative transport risk assessment



Consequence analysis = investigation of potential consequences of a transport accident taking into account the intrinsic hazards of the product (**hazard severity analysis**) and the potential exposure to these hazards (**hazard exposure analysis**)



Hazard severity ranking

<i>Hazard severity (potential impact)</i>	<i>Criteria</i>	<i>Score (A)</i>
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



Hazard exposure ranking

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

Total consequence ranking



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



Probability analysis

Probability of occurrence of a transport hazard determined by

- **accident frequencies for the transport mode being assessed**
- **transport volumes and distances**

Data on transport accident frequencies are not readily available, 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).



Probability analysis

Overview of accident frequencies based on accident data of 1994-1996 *

(see Guidelines for quantitative risk assessment. "Purple Book". Report CPR 18E.)

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

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



Example of a risk matrix

Total consequence Ranking Hazard x Exposure	Probability			
	Very unlikely	Not likely	Likely	Frequent
Very high consequences (IV)	Yellow	Red	Red	Red
High consequences (III)	Blue	Yellow	Red	Red
Moderate consequences (II)	Green	Blue	Yellow	Yellow
Low consequences (I)	Green	Green	Blue	Yellow

Risk Category

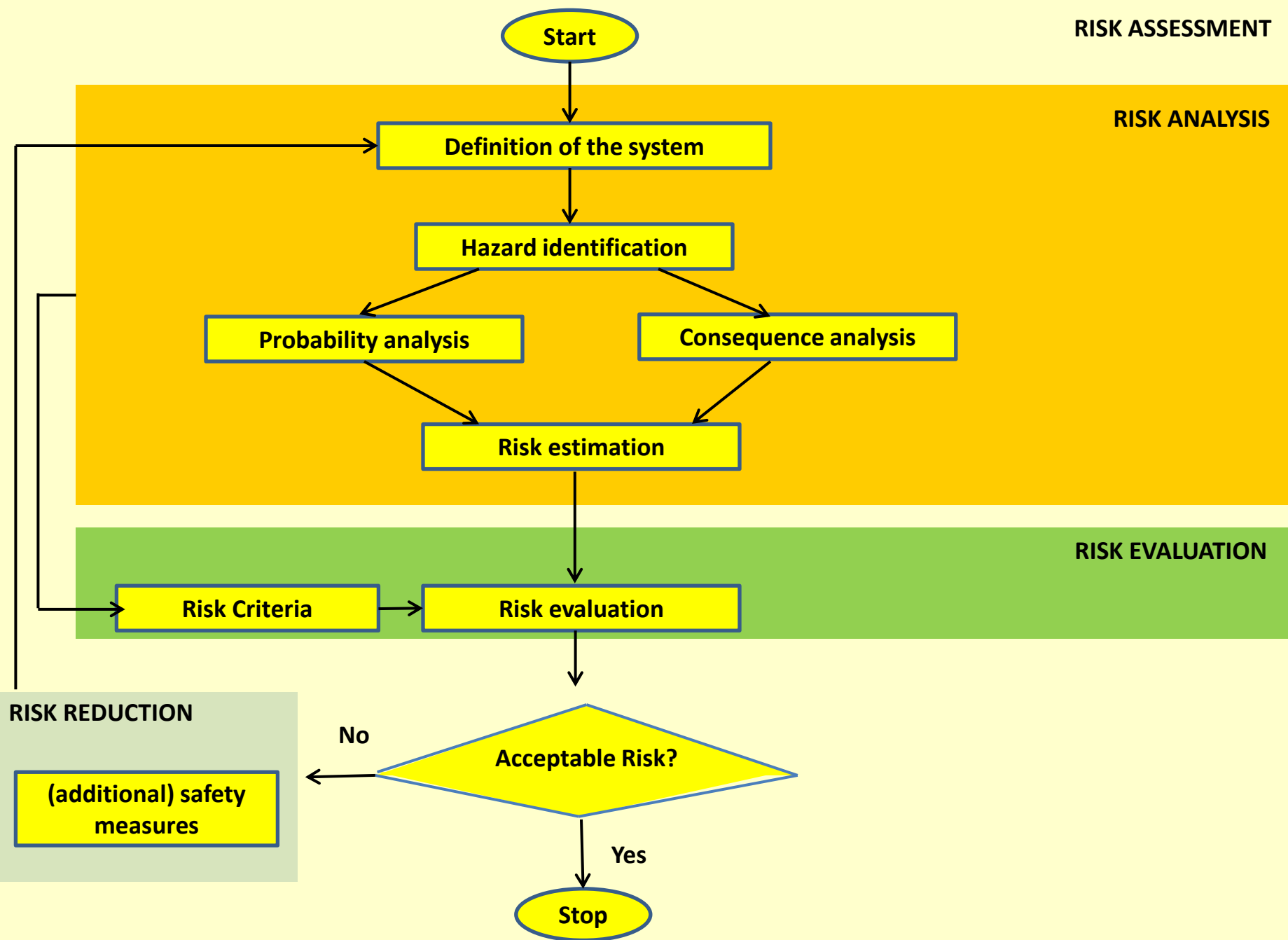
4	Very high risk
3	High risk
2	Moderate risk
1	Low risk



Quantitative transport risk assessment

Based on many assumptions: uncertainty of available accident frequency data

- **To be used primarily for transport operations with very high consequence ranking**
- **Only to be used for relative ranking of different transport options**
- **Calculation of absolute risk levels often not meaningful**





Risk mitigation

Total consequence Ranking	Probability			
	Very unlikely	Not likely	Likely	Frequent
<i>Hazard x Exposure</i>				
Very high consequences (IV)	←	↓		
High consequences (III)		←	↓	
Moderate consequences (II)				
Low consequences (I)				

- Reduction of probability of accidents
- Reduction of probability of leakage in case of an accident
- Reduction of potential consequences



Risk mitigation measures

Reduce the probability of an accident by

- reducing the total volume of transported product
- reducing the distance
- 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, managers, planners,...)
- maintenance and inspection of the transport equipment
- systems increasing the stability of the vehicle
- taking into account weather conditions
- taking measures to improve security



Risk mitigation measures

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, double shell, ...)
- Installing crash-buffers (on rail tank cars)



Risk mitigation measures

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 (change concentration / phase)

Reduction of the size of the containment (packed instead of bulk, compartmentization of tank)

Hazard exposure

Reduce potential exposure along the transport route by changing the

- transport mode
- transport route (e.g. rail route, motorways vs secondary roads; roads avoiding densely populated urban areas)
- time of transport (day vs night).

Viarregio – LPG rail accident



	VIARREGIO LPG
Hazard Classification HIN	UN 1075 Class 2/ flammable gas HIN 23
Containment	Bulk
Hazard severity ranking Fig 2	Very high potential risk A = 4
Hazard exposure ranking Fig 3	Population density : high/very high B = 3/4
Total consequence ranking Fig 4	A x B = 12-16 (IV) Very high consequence
Probability	4.5 x very unlikely
Risk category	Yellow (3) High risk



Risk matrix Viarregio

Total consequence Ranking	Probability			
	Very unlikely	Not likely	Likely	Frequent
Hazard x Exposure				
Very high consequences (IV)	Viarregio			
High consequences (III)				
Moderate consequences (II)				
Low consequences (I)				

Waldhof - barge sulphuric acid



	WALDHOF Sulphuric Acid
Hazard Class HIN	UN 1830 Class 8 /Corrosive liquid – PG II HIN 80
Containment	Bulk
Hazard severity ranking Fig 2	Intermediate potential risk A = 2
Hazard exposure ranking Fig 3	Proximity of water course: very close B = 4
Total consequence ranking Fig 4	A x B = 8 (III) High consequence
Probability	1.4×10^{-6} (not likely)
Risk category	Yellow (3) High risk



Risk matrix Waldhof

Total consequence Ranking	Probability			
	Very unlikely	Not likely	Likely	Frequent
Hazard x Exposure				
Very high consequences (IV)				
High consequences (III)		Waldhof		
Moderate consequences (II)				
Low consequences (I)				

Risk Category

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

Antwerp – road bromine accident



	ANTWERP bromine
Hazard Class HIN	UN1744 Class 8/Corrosive liquid, toxic – PG I HIN 886
Containment	Bulk
Hazard severity ranking Fig 2	Very high potential risk A = 4
Hazard exposure ranking Fig 3	Population density: high B = 3
Total consequence ranking Fig 4	A x B = 12 (IV) Very high consequence
Probability	1.8×10^{-7} (not likely)
Risk category	Red (4) Very high risk



Risk matrix bromine

Total consequence Ranking	Probability			
	Very unlikely	Not likely	Likely	Frequent
Hazard x Exposure				
Very high consequences (IV)	Yellow	Antwerp Bromine	Red	Red
High consequences (III)	Blue	Yellow	Red	Red
Moderate consequences (II)	Green	Blue	Yellow	Yellow
Low consequences (I)	Green	Green	Blue	Yellow

Potential risk reduction measures

Risk Reduction Measures	Rail VIARREGIO LPG	Barge WALDHOF Sulphuric acid	Road ANTWERP Bromine
Reduce hazard exposure level	<ul style="list-style-type: none"> - Change rail route to avoid populated areas - Change transport mode to avoid populated areas (to barge/road/ pipeline) ??? 	<ul style="list-style-type: none"> - Change transport mode (to road or rail)??? 	<ul style="list-style-type: none"> - Change route in port of Antwerp ? - Change transport mode ???
Reduce probability of occurrence	<ul style="list-style-type: none"> - Better inspection & maintenance of equipment - Lower speed of train - Remove sharp objects along the rail track - Install crash buffers - Use tank cars with higher shell thickness - DDD 	<ul style="list-style-type: none"> - Increase stability of ship - Better management of ballast water - Improve training of ship crew - Improve ship vetting system 	<ul style="list-style-type: none"> - Increase stability of truck by lowering chassis and gravity point - Improve selection of transport company (dedicated haulier) - Improve experience and training of drivers (awareness of high density of product)

Accident scenarios with potential high consequences



- **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**