QRA in the Netherlands

RID working group
Standardized Risk Analysis
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► General approach
► Available models and software
► Substance categories
► Scenarios, event trees, failure frequencies, consequences
► Overview of the software

Questions: Ask them during the presentation
Risk criteria: individual risk

Individual risk (location specific risk)

- Probability per year that a person who stays permanently and unprotected on a place along the route dies due to a transport accident with dangerous substances

- Connect points with the same probability: risk contour

- $10^{-6}$ location specific risk contour
  - Limit value for vulnerable objects for new situations
  - Guide value for limited/not vulnerable objects

Legend
- Contour 10-6 per j
- Contour 10-7 per j
- Contour 10-8 per j
Risk criteria: societal risk

- Probability per year per km-transport route that a group of 10 persons or more dies due to a transport accident with dangerous substances on the transport route
Societal risk: guide value

- When risk has increased or has exceeded the guide value the competent authorities have to give a motivation on the acceptability of the risk
- Investigate if risk reducing measures can be taken (ALARA)
- Elaborate possibilities for self-rescue and emergency response
Standardized approach

- Guidelines for QRA described in Purple Book (1999): Publication series on dangerous substances (PGS 3), Guideline for quantitative risk analysis
  - Establishments and transport

- Updated version in progress,
  - Calculation protocol Railway (2005)
  - Protocol Sea- and inland waterways (2005)

- Free software made available by ministry of Transport:
  - First version IPORBM 1997
  - New, extended version RBMII (2005), recently updated
General and standardized approach (PGS3, Purple Book)

Start

Number transports > threshold values?

Yes

Global analysis with IPORBM

No

Ready

Are risk criteria met?

Yes

Ready

No

Detailed QRA

Threshold value was determined with old model (IPORBM); will be updated applying RBMII

IPORBM is replaced by RBM II

RBM II provides more details
Threshold values rail transport

Individual risk contour $10^{-6}$ contour can occur with quantities larger than:

<table>
<thead>
<tr>
<th></th>
<th>High speed</th>
<th>Low speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flammable liquids</td>
<td>3000</td>
<td>No $10^{-6}$ contour</td>
</tr>
<tr>
<td>(C3, tank cars/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of dangerous</td>
<td>7000</td>
<td>No $10^{-6}$ contour</td>
</tr>
<tr>
<td>subst. (tank cars/year)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exceeding of guide value societal risk:
- Dominated by transport of LPG
- Depends on intensity of population along route
- Example:
  - Population density of 100 persons per hectare on one side of the route, and 1600 tank cars at high speed leads to exceeding of guide value
Standardized software: RBM II

- Used for calculation of IR and SR: to check if there is a conflict between transport activities and urban development
  - Module road traffic
  - Module railway traffic
  - Module inland waterways

- Only a limited set of input data is necessary

- Most transport QRA in the Netherlands are performed with RBMII (> 80%?)

- 624 registered users
Applicability of RBMII

- Suitable for standard situations, on-going traffic, open air situations, flat land

- Representative for most special situations such as lower or higher situated tracks, tracks with windscreens, crossings.

- Not to be used for private sidings and shunting yards

- Not suitable for waterways with more than 10% sea ships

- More detailed analysis necessary for tunnels and complex railway situations
The standard risk analysis

- Calculation of individual risk and societal risk

- Determine probabilities and consequences of accidents with dangerous substances
  - Flammable liquids
  - Toxic liquids
  - Flammable (liquefied) gasses
  - Toxic (liquefied) gasses
## Substances categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Rail</th>
<th>Road/waterway</th>
<th>Repr. subs. RBMII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flam. Liquid</td>
<td>C3</td>
<td>LF1</td>
<td>Heptane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LF2</td>
<td>Pentane</td>
</tr>
<tr>
<td>Tox. liquid</td>
<td>D3</td>
<td>LT1</td>
<td>Acrylonitril</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LT2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D4</td>
<td>LT3</td>
<td>Acroleine</td>
</tr>
<tr>
<td>Flam. gas</td>
<td>GF1</td>
<td></td>
<td>Etheenoxide</td>
</tr>
<tr>
<td></td>
<td>GF2</td>
<td></td>
<td>n-Butane</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>GF3</td>
<td>Propane</td>
</tr>
<tr>
<td>Tox. gas</td>
<td>GT2</td>
<td></td>
<td>Methylmercaptane</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>GT3</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GT4</td>
<td>Chlorine</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>GT5</td>
<td>Chlorine</td>
</tr>
</tbody>
</table>
Scenarios: liquids

<table>
<thead>
<tr>
<th>Initial freq.</th>
<th>Speed</th>
<th>Release</th>
<th>Substance</th>
<th>Ignition</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>&lt; 40 km/h</td>
<td>continuous</td>
<td>D3/D4</td>
<td>immediate</td>
<td>Pool fire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300 m3</td>
<td>D3/D4</td>
<td>delayed</td>
<td>Flash Fire</td>
</tr>
<tr>
<td></td>
<td>&gt; 40 km/h</td>
<td>instantaneous</td>
<td>D3/D4</td>
<td>immediate</td>
<td>Pool fire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>600 m2</td>
<td>D3/D4</td>
<td>delayed</td>
<td>Flash Fire</td>
</tr>
</tbody>
</table>
Scenarios: flammable gases

<table>
<thead>
<tr>
<th>Initial freq.</th>
<th>Speed</th>
<th>Release</th>
<th>Ignition</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40 km/h</td>
<td></td>
<td></td>
<td>Delayed</td>
<td>Flash fire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Immediate</td>
<td>Cold BLEVE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Instantaneous</td>
<td>entire tank contents</td>
</tr>
<tr>
<td>&gt; 40 km/h</td>
<td></td>
<td></td>
<td>Immediate</td>
<td>Jet fire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flash fire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Delayed</td>
<td>Explosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Domino-effect of poolfire: Hot BLEVE
Toxic gas

<table>
<thead>
<tr>
<th>Initial freq.</th>
<th>Speed</th>
<th>Release</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 40 km/h</td>
<td>instantaneous</td>
<td>toxic gas cloud</td>
</tr>
<tr>
<td>F0</td>
<td></td>
<td>entire tank contents</td>
<td>toxic gas cloud</td>
</tr>
<tr>
<td></td>
<td>&gt; 40 km/h</td>
<td>continuous 0.075 m hole</td>
<td>toxic gas cloud</td>
</tr>
<tr>
<td></td>
<td></td>
<td>same branches as above</td>
<td></td>
</tr>
</tbody>
</table>
Failure frequencies (rail)

- **Initial failure frequency**
  - High speed track: $2.77 \cdot 10^{-8}$ per wagon per kilometre
  - Low speed track: $1.36 \cdot 10^{-8}$ per wagon per kilometre

- $0.8 \cdot 10^{-8}$ per wagon per kilometre for each level crossing
- $3.3 \cdot 10^{-8}$ per wagon per kilometre for a kilometre track with set of points

- **Failure frequencies based on Dutch accident data period 1981-1992**
- Update with new data will be performed this year
Failure frequencies (2) (rail)

- Based on accident data (13 damaged railway tankers)
- Probability of outflow:

<table>
<thead>
<tr>
<th>Category</th>
<th>Speed &lt; 40 km/h</th>
<th>Speed &gt; 40 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flam. Liquid</td>
<td>0.079</td>
<td>0.56</td>
</tr>
<tr>
<td>Toxic. Liquid</td>
<td>0.0079</td>
<td>0.056</td>
</tr>
<tr>
<td>Flam. Gas</td>
<td>0.00079</td>
<td>0.0028</td>
</tr>
<tr>
<td>Toxic. gas</td>
<td>0.00079</td>
<td>0.0028</td>
</tr>
</tbody>
</table>

- Ratio instantaneous and continuous release: 0.4 : 0.6
- Probability ignition flammable liquid: 0.25
- Ignition flammable gas, inst. release: immediate: 0.8
- Ignition flammable gas, cont. release: immediate: 0.5
- Flam. Gas, flash fire vs. explosion: 0.6 vs. 0.4
Basic assumptions consequence modelling

- Flammable and toxic liquids: pool size is fixed
- Inventory pressurized tanks
  - Flammable gasses: 48 tonnes
  - Toxic gasses; 50 tonnes
- Prescribed models for dispersion, exposure damage same as used for installations, prescribed in
  - Purple Book (PGS3),
  - Yellow Book (PGs2),
  - Green Book (PGS1)
- Use of meteorological data:
  - 6 weather classes,
  - 12 wind directions,
  - data available from 18 weather stations
Consequences, some results

- **Flammable liquids:**
  - Pool fire: consequence. *distances 10-30 metres*

- **Flammable gasses:**
  - Continuous release, immediate ignition: jet fire: *ca. 80x 30 m*
  - Instantaneous release, immediate ignition: BLEVE: *100% let in radius van ca. 150 meter*
  - Instantaneous or continuous release, delayed ignition: Flash fire or explosion *size gas cloud ca.145 bij 45 m.*

- **Toxic liquids:**
  - Pool evaporation, exposure to toxic gasses: *1% lethality at several hundreds metres depending on substance, weather conditions*

- **Toxic gasses (ammonia, chlorine):**
  - exposure to toxic gasses: *1% lethality at several kilometres depending on substance, weather conditions*
Calculation of risks

- Risks are calculated by placing accident points along the route:
  - Individual risk every 10 metre (railway, road)
  - Societal risk every 25 metre (railway, road)

- Check for each location and each scenario which areas are affected and cumulate results:
  - Lethality rate per location: individual risk contours
  - Number of casualties per scenario: FN-curves, for transport calculates per km transport route
An overview of the standardized software RBMII

- Input of data:
  - Type of transport
  - Project data
  - Weather data
  - Data on the route
    - Transported substances:
      - Category, amount
      - Length, type, etc.
      - Build environment
  - Calculation
  - Analyse results
    - FN-curve
    - Individual risk
    - Reports