Safety Risk Assessment for Chemical Transport Operations

Semi-quantitative Approach

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Safety Risk Assessment for Chemical Transport Operations

General approach


Supply scenario

Product + Mode + Route

Consequence analysis
- Product hazards
- Potential exposure

Probability analysis
- Probability of exposure

Risk reduction

(additional) safety measures

Acceptable risk?

Risk criteria

Risk estimation

Risk analysis

Definition of the system

Hazard identification

Probability analysis

Consequence analysis

Risk evaluation

Start

Stop

Risk evaluation

No

Yes
Definition of the system / Hazard identification

• Focusing on specific transport operations with a very high consequence ranking (Cefic Guidance, Score III/IV)
  ➢ Dangerous goods with very high potential impact (Cefic Guidance, Score 4)

Dangerous goods with very high potential impact (acc. Cefic Guidance):

• Goods that are toxic by inhalation (TIH), transported in any quantity
• Goods transported in bulk with one of the following hazard identification numbers (HIN):
  ➢ Flammable gases          HIN 23, 263, 238, 239
  ➢ Toxic gases              HIN 26, 265, 268
  ➢ Highly flammable liquids HIN 33, 333, 336, 338, 339, X323, X333, X338
  ➢ Highly toxic liquids     HIN 66, 663, 664, 665, 668, 669, 886, X88, X668
Definition of the system / Hazard identification

• Focusing on specific transport operations with a very high consequence ranking (Cefic Guidance, Score III/IV)
  ➢ Dangerous goods with very high potential impact (Cefic Guidance, Score 4)
  ➢ Significant shipping volumes and/or number of shipments per year
  ➢ Modes and/or routes critical with respect to hazard exposure

Consequence analysis

• Consequences of an accident are considered to depend on
  ➢ the properties of the dangerous good and
  ➢ to be of similar extent for different modes (“Iceberg”-Theory; worst case approach)
Probability analysis

Identification of the probability of occurrence of a transport hazard

• Transport accident frequencies, normally expressed as number of accidents per distance driven by the transport vehicle (truck, train, barge)

• Basic information provided by
  - company internal records
  - statistical surveys published by national/regional authorities
  - statistical investigations prepared by engineering consultants

• Detailed data on transport accident frequencies partly difficult to find, i.e. mode specific accident frequencies for transportation of chemicals, drilled down to
  - incidents with loss of containment
  - specific information related to the route

• Alternatively, average accident frequencies for general freight transportation in the country or region, at least specific for the different modes have to be used
## Freight Transportation in China

### Accident statistics

<table>
<thead>
<tr>
<th>KPI, 2010</th>
<th>Road (20 t per truck)</th>
<th>Rail (1,100 t per train)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping Volume [t/a]</td>
<td>$2.45 \times 10^{10}$</td>
<td>$3.64 \times 10^{9}$</td>
</tr>
<tr>
<td>Hauling capacity [t.km]</td>
<td>$4.34 \times 10^{12}$</td>
<td>$2.76 \times 10^{12}$</td>
</tr>
<tr>
<td>Average mileage [km]</td>
<td>177</td>
<td>759</td>
</tr>
<tr>
<td>Shipments</td>
<td>$1.22 \times 10^{9}$</td>
<td>$3.31 \times 10^{6}$</td>
</tr>
<tr>
<td>Accidents</td>
<td>757,791</td>
<td>21,211</td>
</tr>
<tr>
<td>Accident frequency rate per t.km</td>
<td>$1.75 \times 10^{-7}$</td>
<td>$7.67 \times 10^{-9}$</td>
</tr>
<tr>
<td>Accident frequency rate per shipment</td>
<td>$6.19 \times 10^{-4}$</td>
<td>$6.41 \times 10^{-3}$</td>
</tr>
<tr>
<td>Accident frequency rate per transport kilometer</td>
<td>$3.49 \times 10^{-6}$</td>
<td>$8.44 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

**a)** National Bureau of Statistics of China: Database 2010 (Status 07/2012)

**b)** Ministry of Transportation P. R. China: China 2010 Traffic Accident Report

**c)** PLANCO / BAGK: Verkehrswirtschaftlicher und ökologischer Vergleich der Verkehrsträger Straße, Schiene und Wasserstraße (November 2007; WSD Ost, Hrsg.)

- Number of truck accidents **b)** derived from the total number of traffic accidents of 3,906,137 applying the share of overall fatal accidents affected by vehicles carrying fright of ~ 19.4 %

- Accident statistics for rail operations in China **c)** publicly not available; data used for the present report adopted from statistics of “Deutsche Bahn Cargo” (Germany, 2005), which proved to reflect the performance of rail operations in Germany, Europe, USA and Mexico quite reliable; number of rail accidents projected accordingly
Risk estimation

- Definition of supply scenarios by mode, route, distance and number of shipments per year
- Calculation of the number of expected accidents related to each supply scenario
- Risk Points are determined by the ratio of the expected number of accidents with respect to the level defined by the BASF benchmark (BM)
  - One risk point is representative for a rail supply scenario of EO, daily operated by a unit train, over a distance of 500 km (BASF benchmark, BM)
  - Relative ranking of different / alternative supply scenarios (mode, distance, number of shipments)
## Benzene Supply, China

### Risk estimation

<table>
<thead>
<tr>
<th>Supply route</th>
<th>Railway lines</th>
<th>Mileage [km]</th>
<th>Shipping volume [t/a]</th>
<th>Shipments per year</th>
<th>Expected number of accidents</th>
<th>Expected number of accidents (Risk points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>Line A – B – C</td>
<td>1,456</td>
<td>250,000</td>
<td>227</td>
<td>1.2</td>
<td>(1.8)</td>
</tr>
<tr>
<td></td>
<td>Line D – E</td>
<td>1,226</td>
<td>250,000</td>
<td>227</td>
<td>1.0</td>
<td>(1.5)</td>
</tr>
<tr>
<td>S2 – BASF Site</td>
<td>Line F – G</td>
<td>550</td>
<td>250,000</td>
<td>227</td>
<td>0.4</td>
<td>(0.7)</td>
</tr>
<tr>
<td></td>
<td>Line F – H – I</td>
<td>363</td>
<td>250,000</td>
<td>227</td>
<td>0.3</td>
<td>(0.5)</td>
</tr>
<tr>
<td>BASF-Benchmark</td>
<td>DB Germany 1)</td>
<td>500</td>
<td>400,000</td>
<td>365</td>
<td>0.7</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Road</td>
<td>S2 – BASF Site</td>
<td>390</td>
<td>250,000</td>
<td>12,500</td>
<td>17.0</td>
<td>(26.5)</td>
</tr>
<tr>
<td></td>
<td>CN5</td>
<td>390</td>
<td>250,000</td>
<td>12,500</td>
<td>17.0</td>
<td>(26.5)</td>
</tr>
<tr>
<td></td>
<td>CN6</td>
<td>390</td>
<td>125,000</td>
<td>6,250</td>
<td>8.5</td>
<td>(13.2)</td>
</tr>
<tr>
<td></td>
<td>CN7</td>
<td>390</td>
<td>100,000</td>
<td>5,000</td>
<td>6.8</td>
<td>(10.6)</td>
</tr>
<tr>
<td></td>
<td>CN8</td>
<td>390</td>
<td>50,000</td>
<td>2,500</td>
<td>3.4</td>
<td>(5.3)</td>
</tr>
<tr>
<td></td>
<td>CN9</td>
<td>390</td>
<td>25,000</td>
<td>1,250</td>
<td>1.7</td>
<td>(2.6)</td>
</tr>
</tbody>
</table>

1) BM: Unit train with direct connection, daily operated by DB Schenker; Database “Deutsche Bahn Cargo”, Germany 2005 (for reference)

- Rail supply operated by unit trains (~ 1,100 t) presuming sufficient storage capacity on site; unit trains are not subject to shunting operations, thus facing only ~ 42 % of possible train accidents (derived from statistical data of the DOT, USA)
- Risk points are determined by the ratio of the expected number of accidents with respect to the level defined by the BASF benchmark BM (severity of accidents assumed to be of comparable extent for all routes)
Risk evaluation

- Results of the risk estimation in terms of risk points are displayed in a standardized *Risk Plot* to compare the different supply scenarios
  - The corridor of accepted risks in transportation is defined by 10 risk points (one order of magnitude)
  - Scenarios rated beyond 10 risk points are only temporarily accepted or subject to phase-out
Example

Benzene Supply, China

Risk Plot

- CN5
- CN6
- CN7
- CN8
- CN9
- CN1
- CN2
- CN3
- CN4
- BM

Risk Points

- Exit
- Only temporarily acceptable
- Acceptable

Scenarios

GUS/D_Nov_2014
Risk mitigation

• The risk of a transport operation can be reduced by taking measures that either
  ➢ reduce the frequency (probability) of accidents or
  ➢ reduce the potential consequences of an accident
  ➢ Redesign of the supply scenario, e.g. mode, route, limitation of shipping volumes, selection of equipment and service providers, etc.

• Local specifics of the routes deviating from the standards and average conditions covered by the accident statistics require a Field Survey
  ➢ Identification of topographic situation, climatic conditions, crossings, bridges, tunnels, vicinity of sensitive installations, etc.
  ➢ Basis for conclusions and recommendations on individual measures of risk mitigation (e.g. convoying, pilot vehicles, time schedules, etc.)
Risk based analysis of the Field Survey

- Yearly demand ~ 250,000 tons of Benzene
- Transportation by rail preferred option for both supply sources, S1 and S2
- Transportation by road from S1
  - Due to the rural road conditions in a mountainous area and the overall distance of more than 1000 km, use of this route not recommended
- Transportation by road from S2
  - Route is acceptable based on the technical standard and short distance of about 390 km
  - Quantity transported by road is recommended to be limited to 40,000 – 35,000 t/a in order to stay within the acceptance corridor
Thank you for your attention!

Questions?