Report

Hot spot based risk assessment for transportation dangerous goods by railway
a new proposal for transportation risk assessment

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Hot Spot Based Risk Assessment for Transportation Dangerous Goods by Railway

Implementation within a Software Platform

A new Proposal for Transportation Risk Assessment

Laboratory for Safety Analysis (LSA), ETH Zurich
Introduction

Recent risk assessments transportation dangerous goods by rail combine statistic based loss of containment frequencies with scenario definition using event tree analysis to determine a risk figure as complementary cumulative distribution function (CCDF).

The present fact sheet concerns a new proposed approach
- using a detailed master logical diagram (MLD), which includes fault tree / event tree analysis to determine a loss of containment frequency based on a set of basic events,
- the selection of a resulting source term following an accident,
- the calculation of its various impacts on the population around the accident site, and
- the integration of the results into a CCDF format using the new proposed hot spot approach.

In this approach the vast array of possible accident scenario sequences is replaced by a manageable number of scenarios based on information about railway infrastructure (e.g. switches, tunnels) in order to achieve a risk figure / profile for a selected traffic segment.

The new proposed approach is integrated within a software platform based on the framework of a decision support system (DSS) and using intelligent maps and GIS (geographical information systems) data processing.

Goal of the Risk Assessment

The goal of a quantitative risk assessment is the determination of the annual collective risk due to potential accident scenarios from the transportation dangerous goods, through a particular traffic segment.

Structure of the new Approach

The overall structure of the new approach is given in figure 1.

The elements of the approach and the new aspects involved are described in more details in the subsequent chapters.

Release Frequency Calculation

The following mechanisms are taken into account for the determination of a loss of containment (LOC) release frequency calculation:
- By Collision
  - Intrusion of a shunting manoeuvre
  - Passing red signal
  - Collision with foreign object
- By Derailment
  - Track related derailment (may be of importance in some countries)
  - Derailment while maintenance on track
  - Bogie failure
  - Hot wheels, bearings overheating

The general structure of the LOC frequency calculation model is presented in figure 2.
Following the use of a MLD technique, a set of fault trees and event trees analyses represent the LOC mechanism and the associated model structure, and allow the calculation of the LOC frequency (see figure 3 and 4).

**Consequence Calculation**

Calculation of the number of fatalities, based on state of knowledge, due to

- Pool fire
- Flare fire
- BLEVE
- Explosion
  - Lung injury
  - Head injury by shock wave
  - Body injury by shock wave
  - Body injury by fragments / debris
  - Head injury by broken window panes
- Acute intoxication
  - IDLH (Immediate Danger for Live and Health)
  - TLV (Threshold Limit Value)
  - STEL (Short Term Exposure Limit)
  - EPRG-1, EPRG-2, EPRG-3 (AIHA 2001)

Each type of impact mechanism is calculated individually by giving the relevant input data (see figure 5), and consequently the impact radii can be graphically represented for each impact mechanism (see also figures 6 to 8).

Other consequences, like number of injured people, polluted surface water or financial loss are not yet implemented / activated, but the respective modules are available within the same computational platform.

Based on information about the substance, the tool recognises circular type of impacts (fire, BLEVE, explosion, see figure 6) and plume type of impacts (in case of release of a toxic substance, see figure 7).

**Figure 4 Fault Tree / Event Tree Analysis and Graphical Representation of the Contributors of each distinct Mechanism to the LOC Frequency**

**Figure 5 Consequence Calculation**

The DSS allows a wide use of data such as GIS data, digital data provided by orthographical and / or satellite technologies etc.

**Figure 6 Circular Type of Impact**

**Figure 7 Plume Type of Impact using orthographic Pictures**
Cadastral type of information is not considered yet, but the respective module is available within the same computational platform.

Figure 8 Cadastral Type of Information

**Chemical Data Base**

The consequence calculation is based on a chemical data base with more than 700 substances, with its physical properties, threshold values and probit functions coefficients. The data sheet for ammonia is given, as an example, in figure 9.

<table>
<thead>
<tr>
<th>1. CATALYST</th>
<th>AMMONIA HYDRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. FORMULA</td>
<td>NH3</td>
</tr>
<tr>
<td>3. MOLECULAR MASS (kg/mol)</td>
<td>17.03</td>
</tr>
<tr>
<td>4. BOILING POINT (deg C)</td>
<td>-33.0</td>
</tr>
<tr>
<td>5. FLAMMABILITY</td>
<td>NA</td>
</tr>
<tr>
<td>6. LETHAL Dose (mg/kg)</td>
<td>370.0</td>
</tr>
<tr>
<td>7. SPECIFIC HEAT liquid (kJ/kg/K)</td>
<td>4.6</td>
</tr>
<tr>
<td>8. IDENTIFYING EXTRAVASATE (g/100 ml)</td>
<td>1.31</td>
</tr>
<tr>
<td>9. SOLUBILITY (g/100 ml)</td>
<td>89.5</td>
</tr>
<tr>
<td>10. SPECIFIC GRAVITY (relative to water 4 C)</td>
<td>0.62</td>
</tr>
<tr>
<td>11. VAPOR PRESSURE (mm Hg at 20 C)</td>
<td>760</td>
</tr>
<tr>
<td>12. VAPOR PRESSURE (relative to air 2 C)</td>
<td>0</td>
</tr>
<tr>
<td>13. VAN DER WAALS INTERNAL PRESSURE 4 (dyn/cm4)</td>
<td>NA</td>
</tr>
<tr>
<td>14. VAN DER WAALS VOLUME (cm3/mol)</td>
<td>NA</td>
</tr>
<tr>
<td>15. CRITICAL PRESSURE (standard atm)</td>
<td>NA</td>
</tr>
<tr>
<td>16. CRITICAL TEMPERATURE (C)</td>
<td>NA</td>
</tr>
<tr>
<td>17. CRITICAL TEMPERATURE (C)</td>
<td>NA</td>
</tr>
<tr>
<td>18. IMMEDIATELY DANGEROUS FOR LIFE &amp; HEALTH (IDLH mg/m3)</td>
<td>355</td>
</tr>
<tr>
<td>19. THERMAL LIMIT VALUE (75 mg/m3)</td>
<td>18</td>
</tr>
<tr>
<td>20. SHORT TERM EXPOSURE LIMIT (STEL mg/m3)</td>
<td>25</td>
</tr>
<tr>
<td>21. PROBABILITY COEFFICIENT a</td>
<td>0.269</td>
</tr>
<tr>
<td>22. PROBABILITY COEFFICIENT b</td>
<td>0.15</td>
</tr>
<tr>
<td>23. PROBABILITY COEFFICIENT c</td>
<td>0.2</td>
</tr>
<tr>
<td>24. PROBABILITY COEFFICIENT d</td>
<td>0.5</td>
</tr>
<tr>
<td>25. EXPLOSIVE LIMITS (HV exp)</td>
<td>0-128</td>
</tr>
<tr>
<td>26. COMBUSTION LIMIT (HV)</td>
<td>0.846e7</td>
</tr>
<tr>
<td>27. FIRE HAZARDS</td>
<td>Combustible. Vapors may explode if ignited in an enclosed area. Irritating vapors generated. Presence of oil or other combustibles increases fire hazard. Container may explode in fire. Toxic vapors</td>
</tr>
<tr>
<td>28. SYNONYM</td>
<td>amonia anhydrous liquid ammonia</td>
</tr>
<tr>
<td>29. ATOMIC DATABASE INDEXES</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 9 Ammonia Data Sheet

**Hot Spot Definition**

The calculation is based on the **Hot Spot Concept** which takes into account infrastructural objects along the route. An infrastructural object is understood as one of the following objects:
- Station
- Signal
- Switch
- Speed Change
- Bridge
- Passage
- Canalization
- Tunnel
- High-Voltage-Crossing
- Weak-Track

A spot is then defined either by the presence of at least one object at the actual location (see figure 10, where the listed objects are marked with symbols on the map), or by the fact that a location is in an area with high population density, irrespective of the existence of an object (see figure 11).

GIS Data

For consequence calculation and risk representation, the software uses intelligent maps with a wide category of GIS (geographical information systems) data.

Figure 12 gives an example for the GIS data.
for a specific location defined by:
- Coordinates
- Elevation
- Population density
- One of 24 possible land use types
- Type of object (see chapter "Hot Spot Definition")

format, the software calculates for
- each hot spot,
- each transported substance,
- each release category (i.e. small releases, middle size and complete loss of containment),
- and for each type of impact

the consequences and the respective frequency, as illustrated in figure 13.

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**CCDF Calculation**

For the risk representation in a CCDF (complementary cumulative distribution function)

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**Results**

Figure 15 shows a selected route segment on a map, for which a risk assessment has been done.
The assumptions are as follows:
- 97.7 % Gasoline transports
- 2.1 % Propane transports
- 0.1 % Chlorine transports
- Wind speed 2 m/s
- Doury stability class 1
- Ambient temperature 20 °C
- Population density based on GIS data
- Appropriate train frequency, infrastructural objects, tanker size as given inputs

### Final Product

The actual final product can be characterised as follows:
- Interactive software tool, living risk assessment
- Large chemical data base
- Full GIS data integration
- CCDF societal risk representation
- Graphical representation of impact areas
- Can be extended to other damage indicators (e.g. polluted water, financial loss)
- Risk informed policy making (technical improvements, operation and management, strategic decisions)
- Emergency oriented information tool using ERPG indicators
- Sensitivity studies
- Stakeholders oriented tools and computations approaches

### Concluding Remarks

- Road risk assessment transportation dangerous goods is a product which has been recently developed, following a similar approach as for rail.
- Using rail and road transportation dangerous goods DSS allows direct comparability of societal risks using tools, modules and architecture which are similar in design.
- KOVERS-KT (Centre of Excellence Risk and Safety – Knowledge Transfer), part of ETH-LSA, is offering its knowledge and expertise for risk assessment transportation dangerous goods for companies, regulatory bodies and stakeholders interested or involved in such activities.

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Figure 16 Risk Representation in a CCDF Format

Figure 16 is the result of the societal risk representation in a CCDF format, including the acceptance lines given by the authorities in Switzerland.

Figure 17 is a graphical representation of possible impact areas, based on detailed calculations considered in a realistic case study.

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