Use case example – harmonized description of a risk situation and estimation of the effectivity of risk control measures

Chlorine transport through densely populated areas

The following document describes the procedure and the steps needed to set up a risk estimation study according to the specifications of the harmonised risk management framework RMF. The colours indicate the corresponding chapters/paragraphs in the Guides:

Blue and red: Guide for Risk Estimation, part A and B
Green: Guide for Decision Making
Yellow: Other reference documents

This example is based on a study in behalf of the Swiss Federal Railways[1]. The scope was to examine the effect of speed reduction of chlorine cargo trains on the risk situation along the northern shore of Lake Geneva, Switzerland. Several population scenarios were examined, according to the forecast for population densification due to land use planning in this area. This is a quantitative risk analysis (QRA).

Mandate for risk estimation

Chap. 3.2: decision-maker mandates for the user of the Guide

Decision making is based on risk estimation. The purpose, objectives and risk management options have thus to be defined at the beginning of a decision making project, to allow for a precise and comprehensive calculation of the risks. So the first chapters of a risk study case include a clear definition of the scope of work, the system boundaries and the description of the initial situation (reference system).

New findings can arise during the risk estimation process, leading to the identification of new options for managing the risk. Thus, several risk estimation loops may be necessary to complete a full decision-making process, depending on the complexity of the decision to be taken.

For example, the aim of the study described here was to investigate in detail the risks on two railway sections ("bottlenecks"). The focus was to identify and to quantify the effects of several risk reduction measures (reduction of train speed and quantities of dangerous goods transported) when visualizing the effects of future trends in land use planning on the risk situation (increase and densification of population).

The following system boundaries were set:

- Societal risk, concerned substance category: toxic gases
- Rail line sections A107 and A133 (previous risk survey revealed elevated risk there)
- Year of project scenario "future situation": 2025

How to consider the effect of a risk control measure

Chap. 3.4: modelling of a risk control (safety) measure

The modelling of any user-defined risk control measures (safety measures) requires the clear description and analysis of the expected safety improvement. The effect of those risk control measures can then be modelled by changing the relevant parameters and/or setting

[1] *Schweizerische Bundesbahnen SBB; Transport von Chlor mit der Bahn: Aktuelle und künftige Störfallrisiken der Segmente A107 (Genf) und A133 (Renens), Ernst Basler + Partner AG; 22.12.2015*

correction factors. The pre-existing safety measures are probably considered already in the reference situation.

Common approaches are the comparison of two different routes by comparing their infrastructure, the comparison of two different traffic situations by using traffic parameter descriptions or the comparison of the distribution of vulnerabilities along a transport route. More complex risk control measures may be described by setting correction factors to relevant parameters:

➔ *supporting material available: Draft list of parameters of the Inland TDG framework*

At the beginning of the study case described here, it was not yet clear which of the suggested safety measures would be most effective to reduce the risk: the impact of the variation of each parameter (train speed, transported quantity) had to be investigated first.

Harmonised description of the case

Chap. 4.1: harmonised description of the infrastructure and operations

Chap. 4.2: harmonised description of DG traffic

There are three factory sites in Switzerland using chlorine as a basic reactant for their chemical products. Two of them are located in the Valais, and chlorine is transported there via rail as pressurised gas UN1017 in tank cars.

Reference situation:

The main route leads from the production site in France to Geneva, along the shore of Lake Geneva through Lausanne and then into the Valais valley. The transported quantity on this line is about 25'000 t per year (470 tank cars in total, 9 tank cars per week). There are several densely populated areas along the transport route, leading to elevated risks on some rail sections in Geneva and in Renens (figure 1).

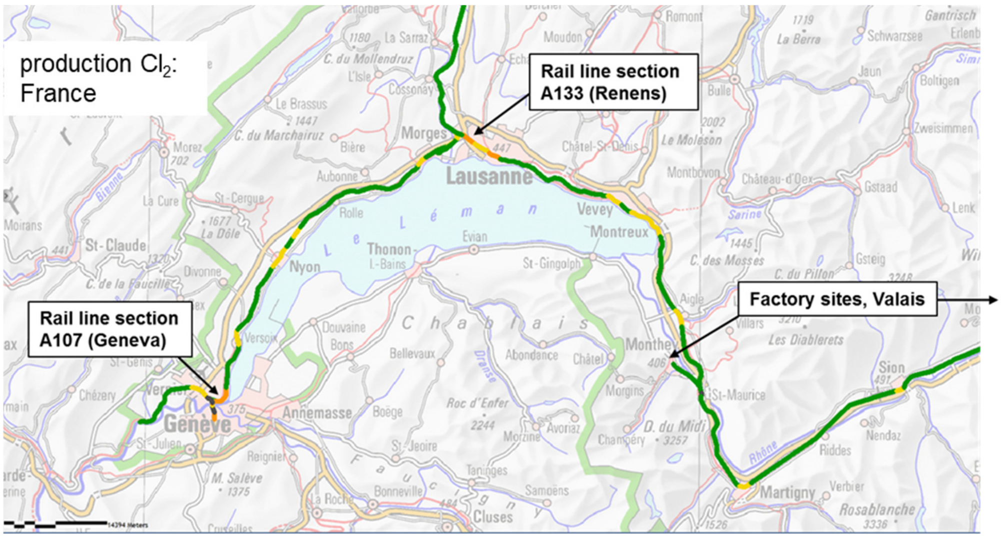

Figure 1: Reference risk situation along the main rail transport route of chlorine (societal risks). Risk determined for the substance category "toxic gases", with the representative substance UN1017 chlorine. Source: Risk survey on rail, 2014[2].

[2] *Federal Office of Transport; Risks to the population when transporting dangerous goods by rail; Methodological Report for the Survey of Risks to Persons 2014; February 2015*

The activity concerned is rail transport on the sections A107 (Geneva) and A133 (Renens) in single wagon freight transport (mixed trains with DG and non-DG wagons). No filling, discharging or marshalling operations are considered for UN1017 chlorine in this example. Both passenger traffic, non-DG freight and DG freight is transported on the line, as there is no separate line for freight transport.

According to the structure in the Guides, this situation can be described as follows:

Chap. 4.1: description infrastructure and operations

- *Infrastructure mode: RL (railway)*
- *Infrastructure category: OLN (open lines) and STSD (stations and sidings)*
- *Transport operation categories: OLN: urban – sub-urban – country side 1+2; STSD: entry – within – exit*
- *Transport operation parameters: traffic operation*

➔ *Template available*

Chap. 4.2: description of DG traffic

- *Concerned substance: RID class 2.3 (toxic gases)*
- *Transport volume: 25'000 t/y*
- *Category of DG load : big tanks (tank wagons only, no tank containers)*[3]

➔ *Default values and template available*

No templates are needed in this use case example, because the corresponding data is already formatted in a specific input file according to the needs of the risk calculation tool used.

Instead of the default values in the Guide which describe a typical traffic structure in the EU, the real transport volumes of RID category 2.3 (toxic gases) on these railway segments are considered. At this time, the net quantity of UN1017 chlorine was not yet known, but because it is the most relevant substance in the category of toxic gases on these segments, this simplification is acceptable.

Project scenario:

Based on the ongoing regional projects to invest in centrally located business and residential areas, the population density will increase at some local points along this transport route, and the risk will most likely increase there. We investigate the effect of two risk control measures: the reduction of train speed and the reduction of transported quantities of dangerous goods per year.

The following parameters are adapted:

- For project scenario: more population along transport route
- For risk control measure 1: reduce quantity of dangerous goods
- For risk control measure 2: reduce train speed.

[3] *Empty, uncleaned tank wagons are taken into consideration indirectly, by a lower average net tonnage per full tank wagon* (53 t/wagon).

Harmonised description of hazards and dangerous goods scenarios

Chap. 4.3: harmonised description of hazards and reference DG scenarios

Hazards are defined as a potential source of harm or damage. The risks from transport of dangerous goods arise from the potential exposure of vulnerabilities (see next paragraph) to harmful effects arising from dangerous goods events.

Dangerous goods scenarios are the events that most likely occur when a substance is released following tank rupture or failure of a valve, and they depend on the chemical and physical characteristics of the substance (RID-classification).

A major part of the risk analysis step is the one where the user of the Guides has to select the corresponding relevant categories of hazards, vulnerabilities and dangerous goods scenarios depending on the specific risk situation he wants to examine. The Guides provide support by listing the most common categories and scenarios.

A set of hazards is described in table 6 of the Guide for Risk Estimation. The most relevant categories considering risks to persons are exposure to heat from fire, overpressure from explosions, or exposure to toxic or corrosive gases.

The next step is to choose the corresponding relevant scenarios (one or more) for all dangerous goods considered (RID-classification). Supporting material is available on the RMF website: Selection of applicable reference scenario with help of table “table of allocation of DG scenarios”.

➔ *reference material available: Table of allocation of TDG scenarios*

This table also includes the conditional probabilities of occurrence of the possible scenarios.

UN1017 chlorine is classified according to RID as follows: classes 2.3, 5.1, 8; code 2TOC.

The following hazards are attributed to UN1017:

1. Toxic per inhalation
2. Toxic per contact
3. Corrosive
4. Oxidative
5. Harmful to the environment

Only the inhalation toxicity is being considered in this use case, as it is the most relevant one and data on toxicity (e.g. LD values are available). The corresponding scenario is the toxic cloud (figure 2).

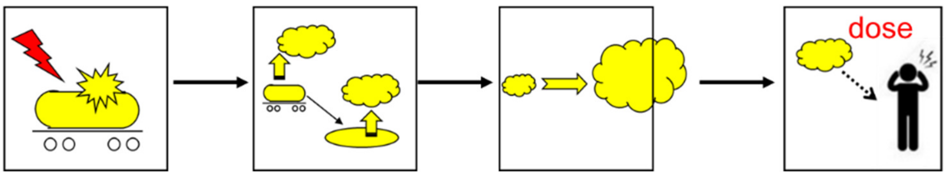

Figure 2: Illustration ot the toxic cloud scenario.

Harmonised description of vulnerabilites

Chap. 4.4: harmonised description of vulnerabilities

The following categories of vulnerabilities are specified in the Guide:

- Human (dead or injured people)
- Assets (built environment, infrastructure, vehicles)
- Operation (disruption of traffic/public services, intervention by emergency services...)
- Environment (polluted drinking water, surface waters or soil)

In this study case, only human vulnerabilies are taken into account (lethalities).

The following table describes the considered population that is exposed to chlorine gas in case of containment failure and potential sheltering effects.

Categories of vulnerability	Affected population	Units	Possible sheltering effects
Passengers (P) in trains	P in the affected or oncoming trains.	P in chlorine cargo train: 0 P in oncoming trains: 120 / train (average)	Evacuation of endangered persons
Passengers on platforms	P in railway stations where the chlorine cargo train passes through.	Number of P on platforms: specific assumption for each railway station	Evacuation of endangered persons
Operators of transport facilities	Train drivers and staff of railway infrastructure.	The driver of the cargo train is not considered. No other staff present.	
Residents	Citizens living in the surroundings of transport facilities.	Density of resident population potentially present in hazardous area.	Protection effect of buildings (general assumption)
Working population	Citizens working in the surroundings of transport facilities.	Density of working population potentially present in hazardous area.	Protection effect of buildings (general assumption)
Sensitive objects	People in schools, hospitals, shopping centres, sports grounds, public events etc.	Number of people per object.	Protection effect of buildings (specific case)

It is important to have an idea of the distance over which the effects of dangerous goods scenarios may affect vulnerabilities. This indicative distance of effects may be obtained from the reference material for the pre-calculated reference scenarios:

➔ *reference material available: reference TDG scenarios, pre-calculated tables*

Frequency of rail events and DG release

Chap. 7.1: Frequency of transport events

Risk is the multiplication of Frequency and Severity of the event: R = F x S

In this step the user has to estimate the frequency of transport events F1. The framework guides propose a harmonised approach. It is based on several types of transport statistics that are continuously developed by EUDG members.

➔ *reference material for frequency of transport events available*

Deviation in the Swiss method: The user may also use specific transport statistics data, where available. The incident frequency of transport incidents in the Swiss study is based on the transport statistics of incidents (derailment and collision) from the two major railway companies, dating back more than 40 years. The data shows that the rate of incidents is decreasing with time due to better security systems. In 2010, the frequency of incidents (derailments + collisions) was $3.12 \cdot 10^{-8}$ per train-km (average over the whole railway network).

Frequency of dangerous goods release

Chap. 7.3: Frequencies of occurrence of DG releases

Fortunately dangerous goods accidents are rare. As a consequence it is difficult to provide robust statistics on the different size categories of release that have occurred in the past and which are considered in risk estimations. Some of the risk estimations consider DG scenarios which have never happened in reality but may happen in the future.

The TDG framework establishes a mechanism of regular review and update of the key statistics and it is foreseen that better assumptions will be available in the future. However, some existing databases can be used to refine the ratio between small, medium and high loss of containment events.

The TDG experts concluded that a conventional ratio should be defined and used for harmonised risk estimations, allowing mutual recognition.

Deviation in the Swiss method: We assume that the number of incidents with dangerous goods is proportional to the sum of all incidents, but significantly lower (cargo trains only, DG cargo only, not all provoke a release of DG).

The local frequency of release of DG (per 100m and year) for a given substance class (e.g. flammable liquids or toxic gases) is calculated by a formula, which takes into account the quantity of substance transported per year and local-specific parameters (e.g. train speed and local safety systems) at a specific point of the railway network. The quantities released vary between 3 and 60 tons, depending on the substance an the type of release (instantaneous, continuous). Small loss of containment is not taken into account.

Frequency of DG-scenarios

The frequency of a DG-specific scenario (e.g. formation of a toxic cloud or a pool fire) is determined by the method of event trees: the local frequency of release is multiplied with the conditional probabilitiy that this specific DG-scenario will occur. In future, Bayesian statistics will be used for this.

The full event tree can be found in the Swiss methodology report, along with the determination of the frequencies for incidents and release [4].

[4] *https://www.bav.admin.ch/bav/de/home/publikationen/berichte/stoerfallvorsorge/screening-der-personenrisiken.html. English version available on request.*

Results of the RE study: effective risk control measures

Chap. 6.3: Frequency/Severity curves

Calculations for societal risks were made with the Swiss IT-tool “Screening Personenrisiken”. The results are depicted as Frequency-Severity (F/S) curves. The illustration below shows the reference situations and the three project scenarios and allows both a qualitative comparison and a quantitative rating according to the Swiss risk acceptance criteria[5].

- Reference Situation: segment A107, risk situation according to risk survey 2014
- Project Scenario a): segment A107, increase of population density
- Project Scenario b): same as a), showing the effect of reduction of DG quantity 25’000 t/a → 5’000 t/a
- Project Scenario c): same as a), showing the effect of train speed reduction 80km/h → 40 km/h

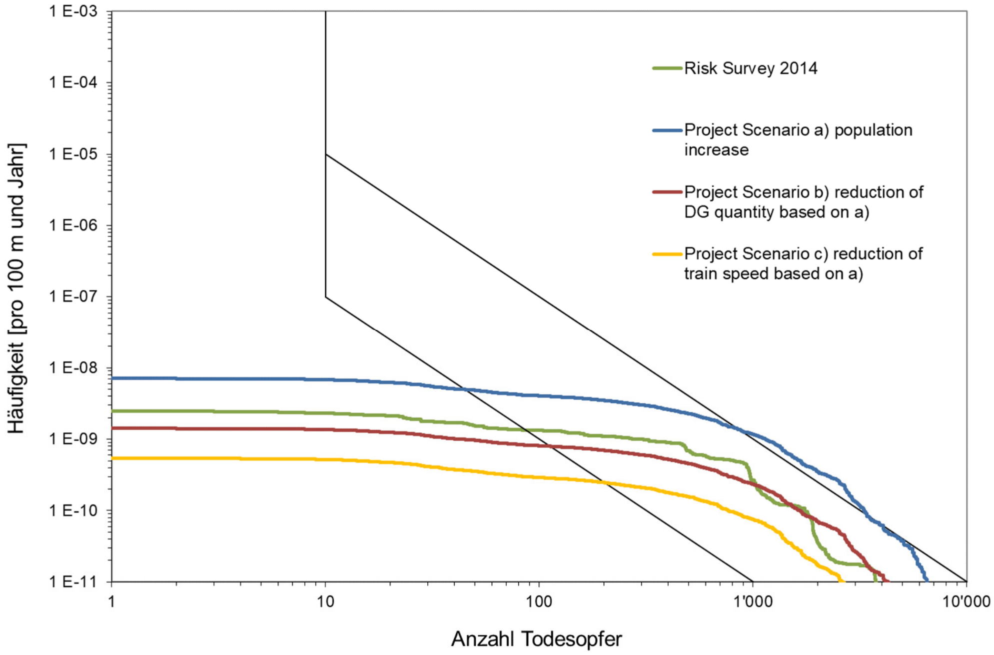

Figure 3: Frequency-Severity (F/S) curves of the reference situation and the project scenarios. x-axis: number of lethalities, y-axis: frequency of the DG-scenarios (formation of toxic cloud after DG release).

The smoother lines are due to the fact that the real wind directions have been taken into account in the project scenarios, compared to the risk survey, which is based on a simplified meteorological situation.

The results showed that

- both the population density in the area potentially affected by a toxic cloud (possible areas of urban development) and the train speed have significant influence on the risk situation (project scenarios a), b)). The conditional probability of dangerous goods release is a factor of train speed: slower speed, lower kinetic energy, lower impact on tank. The number of potential vulnerabilities increases with increasing population density.
- the reduction of transported quantities to 5’000 tons/year (e.g. on-site production of chlorine, alternative transport routes) has a comparable risk reduction effect than the

[5] *The figure shows the RAC that were in force in 2015, when this study was made. In the meantime, RAC für UN1017 have been adapted and are more severe now.*

speed limitation of 40 km/h: the incident frequency is directly influenced (less wagons, less incidents, project scenario c))

- however, neither the reduction of train speed nor the reduction of the quantity of chlorine transported per year can reduce the maximum distance of damage in case of an incident: when the tank is damaged or the fittings fail, a toxic cloud is formed. The size of this cloud depends on the quantity of chlorine set free from this wagon, which brings in the idea of smaller tank volumes. The dispersion behaviour of the toxic cloud largely depends on the meteorological situation and the geographical conditions (data not shown).

Conclusion:

Appropriate measures identified with considerable potential to reduce risk for the described situation are a limitation of train speed and a limitation of the DG quantities transported per year.

Decision-Making Indicators (DMI)

Chap. 4: Using risk indicators to assess DMPs (decision making principles)

Risk indicators can help to evaluate the potential influence of risk control measures and to provide support for decision-making.

Risk indicators for five different situations are defined in the Guide for Decision Making. They are described in the left column of the table. How the criteria are met in this specific use case is described in the right column.

Indicators for assessment of risk control measures	How they are met in this use case
Detect increase or reduction of system safety	Can be detected by F/S-curves.
Assess continuous safety improvement	The survey of DG risks on the whole rail network is regularly updated, including chlorine transport.
Assess utility for society	Due to risk control measures, delivery of chlorine as industrial base product is guaranteed.
Assess fair treatment of individuals or groups	Due to risk control measures, the risk on the population along lake Geneva is reduced. A transfer of some of the DG to alternative transport routes may occur (import of chlorine from Italy). If the total quantity of chlorine does not increase, the increase of risk on the population along alternative transport routes is limited (see “avoid uncontrolled risk transfer” below).
Avoid uncontrolled risk transfer	No transfer to road transport due to limitation of chlorine quantities per road vehicle. A transfer of some of the DG to alternative transport routes may occur (import of chlorine from Italy). If the total quantity of chlorine does not increase, the increase of risk on the population along alternative transport routes is limited, and the total risk over both the main and alternative transport routes might be reduced anyhow.

Use of Risk Acceptance Criteria (RAC)

Informal document Inf. 6 for autumn meeting 2019 of the Joint Meeting of the RID Committee of experts and the working Party on the Transport of Dangerous Goods: Reporting from the EUDG concerning the use of RAC with the Inland TDG Risk Management Framework.

Risk acceptance criteria have been used in Switzerland for many years. They are depicted in the F/S-curves shown in this use case. This quantitative rating of the risk situation is an important instrument for the authorities to develop and impose risk reduction measures in case of elevated risk.

This is compliant to the Risk Management Framework RMF, as it described in the INF.6 document:

“Currently, the RMF is using a comparative approach to assess the acceptability of risk situations. However, the RMF approach is also fully compatible with the use of risk acceptance criteria (thresholds), when they are defined by the user. Users of the RMF who would like to use it in combination with their own risk acceptance thresholds should be allowed to do so.“

Federal Office of Transport Switzerland, Version 1.0, 12.2.2020