Report

# Capability assessment

# Risk mitigation strategies for the risk of rail transport of dangerous substances in South-Holland South

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# Contents



**Colophon**

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This risk assessment report has no formal status. It was written as part of a demonstration test for the PRISMA project. It is meant to show how the MiSRaR approach plays out in an actual case. No rights can be derived from this report or the information therein.

# 1. Introduction

## 1.1 MiSRaR and PRISMA

In the period 2010-2012, the Safety Region South Holland South worked together with six partners in five other EU Member States in the so-called MiSRaR project (Mitigation Spatial Relevant Risks in European Regions and Towns). This project focused on knowledge exchange between local authorities on ways to reduce spatial planning risks. The exchanged lessons are defined in a joint handbook. Following on the MiSRaR project, the VRZHZ together with four European partners, launched a follow-up project to test the lessons learned in practice. This is the PRISMA project (Promoting and Implementing Strategies for Risk Management and Assessment). In this project, each of the international partners had to develop a strategy for risk management for a specific risk in its own territory. The first objective of the project was to test the cross-sectoral implementation of the risk assessment and risk management (prevention) strategies as described in the brochures and handbook of the InterregIVC project MiSRaR (Mitigation Spatial Relevant Risks in European Regions and Towns). The partners tested these strategies on the following priority risks:

- rail transport of dangerous substances (VRZHZ)
- risks of dangerous substances in SEVESO industries and its road and rail transport (Aveiro)
- urban fires in the historic city centre (Mirandela)
- fires in the urban area with protected wooden houses (Tallinn)
- forest fires (SZREDA).

The second objective was to promote risk management and organize knowledge exchange between other local, regional and provincial governments and cross-sectoral risk management partners within the European Union (and associated states) on:

- the concepts, strategies, best practices and lessons learnt on risk assessment, risk management and the relation with disaster preparedness as described in the aforementioned handbook;
- the practical experiences with the implementation of the handbook as described under objective 1;
- the consequences of the 'EU staff working paper on Risk Assessment and Mapping Guidelines for Disaster Management' for local, regional and provincial governments and the possibilities for connecting national and decentralized risk assessment and risk management policies.

During the project each partners have:

- built a risk management network
- performed a risk assessment
- performed a capability assessment
- developed an implementation strategy

and together the partners organized 3 international conferences, developed and maintained a website and published newsletters and press releases.

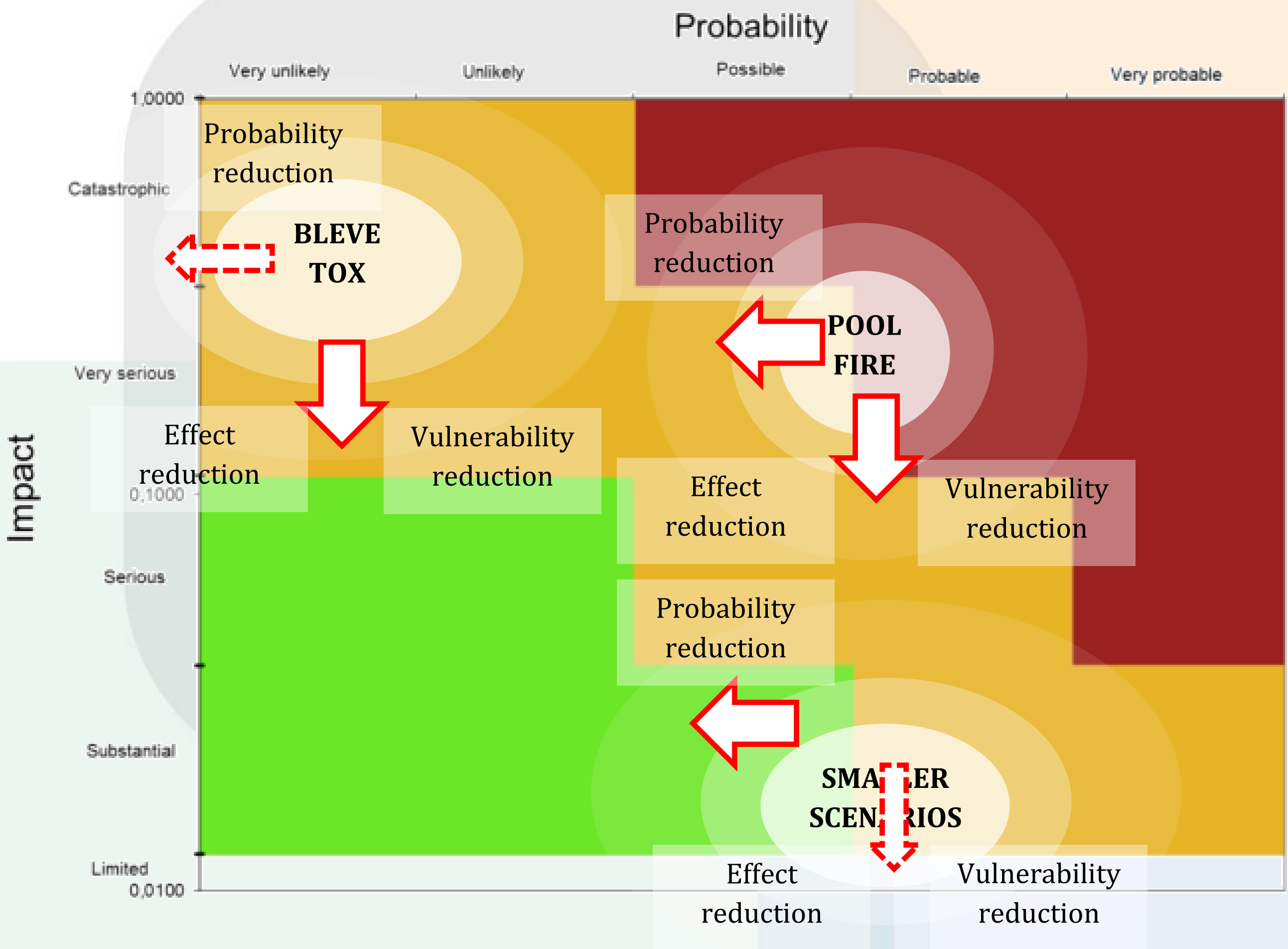
During the implementation of the project, the partners have supported each other and exchanged their experiences in four ‘partner advice and counselling meetings”. A “virtual office” was available to work together on the project like colleagues in ‘real life” The partners assisted each other and presented their findings at the end of three international conferences. For the Safety Region South-Holland South the PRISMA project has been an opportunity to develop a risk management plan for the “Spoorzone Dordrecht-Zwijndrecht”. This allowed smart use of international lessons for a risk that was a priority for the region anyway. Moreover, the PRISMA project provided an environment to experiment with the approach, without direct far-reaching consequences. The project is in fact a test of the possible risk management strategies. The actual implementation of measures is not planned within the project. The results of PRISMA can set the agenda for our work towards the future, but are non-contractual.

## 1.2 Status of this report

This capability assessment report has no formal status. It was written as part of a demonstration test for the PRISMA project. No rights can be derived from this report or the information therein. The goal of PRISMA has been to test, learn and disseminate methods for risk assessment and risk management. The assessment is meant to show how the MiSRaR approach plays out in an actual case, but not to influence the actual risk or have actual consequences for the risk management in this case. Because of the limited time of the project, the assessment was performed on the basis of existing information and expert judgement of the local working group. The assessment includes several assumptions which could not be validated or researched in detail. This means that the assessments and outcomes do not have to be taken literally, but as examples and show cases for the general approach to risk management.

## 1.3 Starting point for the capability assessment: outcome of the risk assessment

In the risk mitigation process the capability assessment follows the setting of objectives based upon the risk assessment. The risk diagram resulting from the risk assessment provided the first insight for the setting of objectives. It clearly indicates the relative importance of probability reduction as opposed to effect and vulnerability reduction for the different categories of scenarios (see figure).




With the insight derived from the different perspectives of the risk evaluation (see separate risk assessment report), the following objectives have been selected as the starting point for the capability assessment. *During the PRISMA project these priorities and objectives have not been politically consulted, because it is a testing project.*

### *Short term*

1. Improvement of disaster relief: already part of project "Spoorzone"
2. Risk communication: already part of project "Spoorzone"
3. Vulnerability reduction of new buildings: the formal "societal risk" policy
4. National rail safety measures to decrease probability:
   - Safety breaking system: implementation of ATB-vv and ERTMS
   - Hot BLEVE prevention policy (no flammable liquids next to flammable gas)

*Middle term*

5. Vulnerability reduction in spatial planning (in combination with their consequences for preparation like early warning, protocols etc.)
6. Probability reduction through re-routing (rail junction Meteren)

*Long term*

7. Proaction through alternative routes around the Spoorzone Dordrecht-Zwijndrecht: the national government and the municipalities of Dordrecht and Zwijndrecht have already agreed a research will be performed in 2018 to investigate options for a structural solution of the Spoorzone bottleneck (alternative routes).

The capability assessment therefore is focused on **vulnerability reduction in spatial planning**, because [1] probability reduction is a national responsibility for which already several policies exist, [2] preparation already is being improved in the project 'Spoorzone' and [3] fundamental proaction on the long term still has to be investigated nationally. The focus on vulnerability reduction means the capability assessment should mainly be focused on measures to reduce exposure and susceptibility of humans, the man-made environment and the natural environment.

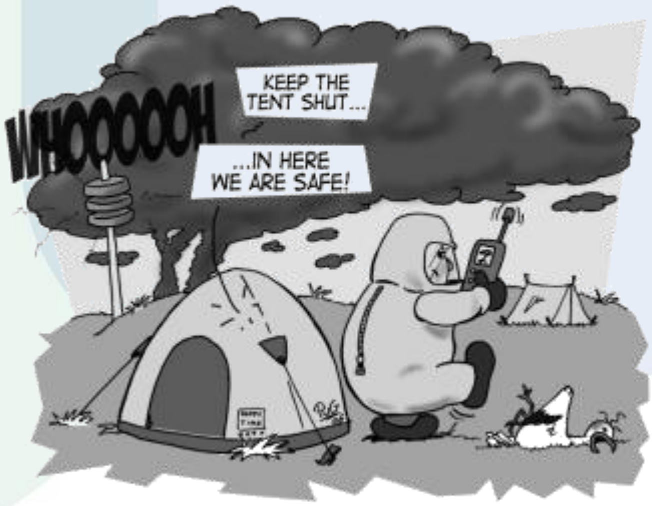
## 2. Process of capability assessment

### 2.1 Capability assessment as part of the MiSRaR/PRISMA approach

The approach of the European PRISMA partners consists of four main steps. First, an analysis of the network for that risk will be made. Achieving a strategy for risk management by definition requires cooperation between a large number of public and private partners. On the basis of this analysis a strong network will be created in which all relevant partners can play their role. After the creation of the network the risk will be analysed. For Spoorzone this means that existing risk assessments of recent years are brought together. This risk assessment provides targets for the search of possible measures for the future. Question is whether these should be found in attributable risk reduction, impact reduction or vulnerability reduction? And what about the preparation, response and follow-up? A good risk analysis is essential in order to understand what the most important risk factors are and where the main bottlenecks are located. This is the basis for the third step: the capacity analysis, in which all possible concrete measures are explored and compared with each other. Finally, in the last stage concerns working on a possible strategy to ensure the most relevant implementation. All these stages are being implemented as part of an overall experiment.

### 2.2 What is capability assessment?

In the risk assessment insight is gained in the nature and severity of risks and the political objectives. The next step should be to perform a capability assessment, which by MiSRaR and PRISMA is defined as "the process of identifying, analysing and evaluating the risk management capabilities available to reduce the priority risks and also the crisis and recovery management capabilities to improve the disaster relief and recovery." Capabilities in this case are defined as "all possible factors, measures and policies with which the risk s can be reduced and the final outcome of disasters and crises can be influenced positively". Important is that capabilities do not only refer to operational capacities like fire engines or ambulances, but also to mitigation measures, or in other words to all possible measures in multi-layer safety.




The purpose of capability assessment is to enable the political decision-makers to make strategic choices on concrete policies and measures that contribute to the chosen objectives. This is actually the phase that is all about the strategy: where are the weaknesses in our ability to reduce risks, and what can we do about it? The MiSRaR partners have found it most transparent to make a distinction in three parts of the capability assessment, similar to the risk assessment.

## 2.3 The concept of ‘risk’

The understanding of options for mitigation and therefore of the approach to capability assessment starts with the understanding of risk. In practice the participating partners of MiSRaR use different definitions of risk, derived from international literature. Comparison has shown that the various definitions ultimately amount to the same thing. The definitions only put different elements of the risk concept on the foreground. The two main definitions are:

**Risk = probability x impact**

**Risk = hazard x vulnerability**

An important distinction is that between the English terms *risk* and *hazard*, which in several languages both translate into the same word. Given the second definition the difference between a risk and a hazard lies in the vulnerability of the risk recipients: a potential hazard involves only the (likely) negative effect of an incident (disaster or crisis). The degree of vulnerability of people and the environment for such an effect determines whether this also amounts to a significant risk. To illustrate: a flooding itself can be seen as a *hazard*. However, if this occurs in an uninhabited area, without economic or ecological value, there is no or little *risk*.

*Vulnerability* is a composite concept, which consists of *exposure* and *susceptibility*. To illustrate: the extent to which buildings are vulnerable to a flood, depends both on the extent of the exposure (what is the height of the water?) and the degree to which it is actually truly affected by water (of what material and how solid is it built?).

The difference between the two definitions lies in the grouping of concepts. Combining these concepts creates the following aggregate definition:

$$\textbf{Risk} = \underbrace{\textbf{probability} \times \rlap{$\overbrace{\phantom{\textbf{effect} \times \textbf{exposure} \times \textbf{susceptibility}}}^{\textbf{impact}}$}\textbf{effect}}_{\textbf{hazard}} \times \underbrace{\textbf{exposure} \times \textbf{susceptibility}}_{\textbf{vulnerability}}$$

The elements of this definition are the focus points of the capability assessment: each element provides potential opportunities for mitigation and prevention.

## 2.4 Checklist for capability assessment

For the execution of the capability assessment the following checklist from the MiSRaR handbook was followed:

- ☑ Develop validated 'causal webs' for the priority risk scenarios.
- ☑ Identify measures in all levels of multi layer safety, using the causal web.
- ☑ *Analyze the costs and benefits of the identified measures.*
- ☑ Make a report (draft mitigation plan) with a proposal for measures.
- ☑ *Take into account potential political perspectives for the evaluation of the measures.*

In accordance with the PRISMA project plan only a 'rough draft' cost benefit analysis was performed and recommendations were made for further research in future. The political perspectives for capability evaluation have been discussed between te experts, but not with the actual political representatives, because PRISMA is only a testing project.

## 2.5 The actual working process

The capability assessment has been performed by different means:

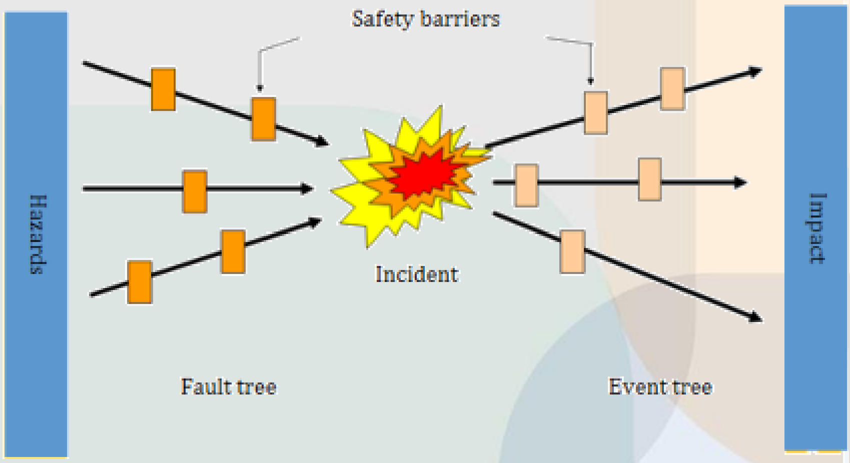
- *Desk study*. Different existing reports are available on mitigation policies.
- *Expert judgement*. The local working group has had several meetings (plenary and in sub committees) to perform the assessment together.
- *Mapping*. The different effect zones of the scenarios were compared with the capabilities.

This report includes lessons learned by the local working group during the process. The sub steps and concept ideas leading to the capability assessment are reported to give insight in these lessons.

# 3. Capability identification

## 3.1 Approach to capability identification

The first step of capability assessment is that of capability identification. This is a follow-up on the scenario analysis performed for the risk assessment: by researching the scenario specific measures can be identified that contribute to the chosen objectives. This means contemplating on the 'causal web' of an incident scenario in order to find possibilities for mitigation. This kind of analysis is called 'fault tree analysis' (FTA) and 'event tree analysis' (ETA), together also referred to as 'bow tie'.




In the 'fault tree' resulting in an incident different possibilities can be identified to reduce the probability. This means analyzing the potential trigger events and safety barriers that might prevent a trigger event from leading to an actual incident. In the projected 'event tree' the potential measures for effect and vulnerability reduction can be identified, as well as possible measures for improved response and recovery. An example is the risk of forest fires. Highly flammable vegetation and a hot and dry season (causes), in combination with human carelessness or arson (trigger event) can create a fire (incident). The lack of preventive stopping lines (open spaces) and large amount of combustible materials due to lack of forest management can lead to the fast development into a big forest fire. The lack of fire brigades and accessibility routes may result in an uncontrollable fire. The direct presence of human habitation and industries (vulnerabilities) might in the end result in a disaster with casualties and a lot of damage. All these factors in the fault tree and event tree provide very concrete options for preventive measures. Another example is the flooding risk. A river bed clogged with sediments and low lands in the direct vicinity (causes), in combination with extreme rainfall (trigger event) might result in a flash flood (incident). The lack of water barriers and dikes means that the high water can flood the surrounding area. If there are people (vulnerabilities) living in this area and no passable evacuation routes, the impact will be severe. If the rescue services are ill equipped and people are not prepared, the impact could be catastrophic. Again this kind of 'causal web' provides plenty of opportunities for mitigation.

This analysis results in a list of all different potential measures, varying from concrete safety measures on site till general measures like public education to improve self-reliance. The politically set objectives are used to narrow the capability identification down to only those measures that might contribute to the objectives. *In this case this means the analysis is limited to vulnerability reduction and therefore to event tree analysis*.

The MiSRaR partners have discussed on the different *spatial mitigation* capabilities for the main four types of risks for their areas: floods, forest fires, incidents with dangerous substances and landslides. These capabilities can be categorized according to the multi-layer safety concept, leading to the following overview, relevant for PRISMA.

| | **General spatial principles** | **Examples for floods** | **Examples for forest fires** | **Examples for dangerous substances** | **Examples for landslides** |
|---|---|---|---|---|---|
| **Proaction** | Risk zoning: no vulnerabilities in risky areas (near the risk source) | Building restrictions in flood risk areas | Building restrictions in forests;<br>Entrance restrictions in dry season | Safety zones around industries;<br>Restrictions for transport through populated areas | Building restrictions on and beneath slopes |
| **Probability reduction** | Preventing trigger events | Dikes and levies<br>Water buffer/ storage capacity | Clean forest concept;<br>Prescribed burning | Routing of transport, separate high way lanes, safer junctions | Water drainage<br>Nets and concrete structures |
| **Effect reduction** | Containing effects: building walls, separations etc. | Dike compartments<br>Pumping stations | Fire protection lanes<br>Watch towers (early warning) | Safety barriers & compartments | Retaining wall |
| **Vulnerability reduction** | Building safe, enabling evacuation | Building on higher ground<br>Flood safe housing<br>Higher evacuation routs | Building restrictions<br>Evacuation routes<br>Planting less flammable trees | Shock and fire proof building materials<br>Appointing shelters<br>Evacuation routes | Strengthened housing foundations |
| **Response improvement** | Enabling accessibility and operational conditions | Pumping stations<br>Higher access routes | Water tanks/ reservoirs<br>Water pipes<br>Accessibility routes | Water screen system | Redundant accessibility routes |
| **Recovery improvement** | Combination of effect and vulnerability reduction in order to enable self recovery | Flood safe building concept | Planting fire resistant trees | - | - |

## 3.2 Existing capabilities

Before the identification of new mitigation measures and policies, the capability identification is also meant to resume the existing policies. After all, the existing capabilities are the base line for the identification of new policy options and improvement in existing policies.

*Probability reduction*

The national government (Ministry for Infrastructure and Environment), rail infrastructure maintenance company (ProRaiL) and rail transport companies are primarily responsible for the 'internal safety' of the rail transport. To minimize the probability of incidents several national policies are in place, of which the most important are:

- improvement of the existing automated train influencing system (ATB) at high risk locations to an 'improved version' (ATB-vv), so trains are automatically stopped in case they pass a red sign, also if they travel at speeds below 40 km/h;
- replacement on the middle long term of ATB(-vv) by the European Rail Traffic Management System (ERTMS);
- the so-called 'BLEVE free' train concept: adapted train combinations to separate wagons with flammable gas from wagons with flammable liquids to prevent a 'hot BLEVE' (a BLEVE triggered by heat radiation from a pool fire).

*Image: ATB-vv*

Furthermore, the Ministry for Infrastructure and Environment has implemented the so-called 'basic network' (Basisnet) for the transport routes of hazardous materials. The basic network categorises transport routes and assigns a maximum volume of transport of hazardous materials by rail to these categories, measured in number of tank wagons. The document states that the government intends to create a basic network consisting of three types of routes that differ in importance to either spatial development or transport. A distinction is made between three main categories for transport of hazardous materials, with a different value of importance to either transport of hazardous materials or spatial development. These categories are:

- Primary routes with unlimited transport of hazardous materials. Urban development has major limitations due to safety zoning.
- Secondary routes where transport of hazardous materials as well as urban development have their limitations.

Tertiary routes on which transport of hazardous materials is limited and next to which urban development should not be hindered at all.[1]

*Impact and vulnerability reduction: localised risk and societal risk*

In The Netherlands the (single hazard) risk analysis for external safety of industries and transport of dangerous substances is regulated by Law and Decree. Municipalities and provinces are required to calculate the so-called "localised risk" and "societal risk" and ask for advice by the fire services on mitigation and prevention policies. The localised risk is defined as the probability that a person, which is present continuously and unprotected, will die as a direct consequence of an occurrence involving a hazardous substance. By Law the localised risk may not exceed once every million years ($10^{-6}$) for vulnerable objects (buildings with people inside which are limited self-reliant). For other buildings the localised risk is an orientational value, not a hard norm. By calculation the localised risk a "hard distance" can be projected at which vulnerable objects may not be built, indicating a safety zone from the industry or transport axis. The societal risk is defined as the cumulative annual probability that at least 10, 100 or 1000 persons will die as a direct consequence of their presence within the area of influence of an installation or transport axis due to an unusual occurrence involving a hazardous substance. The societal risk is expressed as a curve, the so-called fN curve (frequency-numbers) with the number of persons on the x-axis (10, 100, 1,000 and 10,000) and the probability of simultaneous death due to an incident on the y-axis.

For the societal risk the legislator has consciously adopted a non-normative approach, only providing a holdfast in the form of the so-called "orientational value". This orientational value is expressed in the fN curve as a straight line: $10^{-5}$ for 10 persons, $10^{-7}$ for 100 and $10^{-9}$ for 1,000.

For the "base net transport of dangerous substances" the societal risk has been calculated nationally. The Dordrecht-Zwijndrecht area has the highest societal risk in this part of the country (in fact in the whole country): 11 times above the orientational value in the year 2008. The localised risk for the railway zone Dordrecht-Zwijndrecht has been calculated on several occasions, leading to for example specific measures for the rebuilding of the Thureborgh elderly home. In example: for the development of the so-called Leerpark area next to the Dordrecht curve (the largest bottleneck in the country), the absolute safety distance of the localised risk ($10^{-6}$) has been calculated at 25 metres for 2008 and 99 metres for the forecasted transport in 2020. Also the societal risk has been calculated for the separate "kilometre sections" of the railway zone. The societal risk for the Leerpark area has been calculated at 43 times higher than the orientational value in the year 2008, growing to an expected 61 times higher in the year

[1] Van Vliet, V, *Rail Transport Risks and Urban Planning*, 2011.

2020.[2] Any exceeding of the orientational value and even any substantial growth of the fN curve below the orientational value should be "justified" by the responsible government (municipalities and provinces), meaning they are publicly accountable for their decision to accept the societal risk under the condition of specific measures. The fire services provide advices on how to lower the societal risk, by means of prevention and preparation.

### *Pool fire attention area*

By Law a safety zone is set for vulnerable objects (buildings for people with limited self-reliance). In general this is based upon the norm of the localised risk (once every million years or $10^{-6}$). For the Dutch 'base net of rail transport' a fixed safety zone is set of 30 metres from the edge of the transport axis, the so-called 'pool fire attention area'.[3] In this area the realization of vulnerable objects (buildings for people with limited self-reliance) is limited. Before building this kind of objects the potential consequences of an incident with flammable liquids has to be taken into account. If the building of such an object in the 30 metres zone is considered nonetheless, the following rules should be observed:

- at the side of the transport axis it should contain building materials with an increased fire resistance, resulting in a fire resistance of at least one hour according to NEN 6068.[4] This means the outside construction has to comply to so-called fire class A1 according to NEN-EN 13501-1 and the windows and doors have to comply to the so-called fire class D;
- it should be possible to shut down manually the mechanical ventilation systems (if present);
- the escape routes from the building should be located outside the 30 metres zone, or at least at the side away from the infrastructure.


### *Disaster relief (preparation and repression): project Spoorzone*

With financing of the Ministry of Infrastructure and Environment the safety region and municipalities of Dordrecht and Zwijndrecht started the Spoorzone project. This project aims to improve the assistance and disaster relief given the current risk level of hazardous materials transportation. The project

[2] In 2013 the municipality of Dordrecht has presented a new spatial plan for the Leerpark area. Using the new Law on the Basenet rail transport (enacted in 2012) a new societal risk calculation was made, taking into account the changes made in the spatial plan after the previous calculations. The new situation generated 'only' an exceeding of the orientational value of 5.3 times, showing the added value of risk analysis.

[3] In some cases this distance might be larger, because of the localised risk calculations.

[4] Constructions built *above* the railway should not collapse in case of a fire within the first 90 minutes.

encompassed 23 sub projects to improve specific aspects of the disaster relief:

1. Improvement accessibility and controllability of Spoorzone[5]
2. Improvement of response time fire services
3. Enlargement of fire brigade garage
4. Fall back option for the emergency room
5. Enlargement of fire brigade capacity (fire truck with foam)
6. Development and implementation of virtual scenarios for train incidents
7. Execution of yearly fire brigade exercises for Spoorzone
8. Enlargement of medical response capacity medical emergency mana gement (GHOR) and quality improve ment of preparation by medical services
9. Fire proof protection for the water supply along the rail way tracks
10. Fire extinguishing tests along the existing Betuweline[6]
11. Expansion of the warning and alarm system (sirens for the population)
12. Implementation of 'NL-Alert': the mobile phone warning and alert system (for the population)
13. Specific risk communication to the inhabitants by means of the website [www.spoorzonezhz.nl](http://www.spoorzonezhz.nl)
14. Automated closing of mechanical ventilation systems (AC) directly from the emergency room
15. Drafting of a special coordination plan
16. Implementation of a Central Registration Point for dangerous substances (CRP) which enables direct insight in the substances in each train
17. Purchase of Mobile Data Terminals (MDT) for the emergency services





[5] Accessibility of the railway for the emergency services is irrelevant in case of an instantaneous ('cold') BLEVE, but important for the other scenarios (toxic, pool fire, warm BLEVE).
[6] These tests have shown that the noise barriers along the railway obstruct an effective response. For this reason the fire truck with foam was fitted with an extension arm.

18. Purchase of heat proof cameras on emergency vehikels
19. Installa tion of a camera system along the Spoorzone railway, which can be accessed from the emergency room and the crisis centre
20. Installation of weather stations along the Spoorzone railway
21. Installation of ATB-vv along the Spoorzone railway
22. Support of the MiSRaR project about risk mitigation
23. Multidisciplinary exercises for Spoorzone

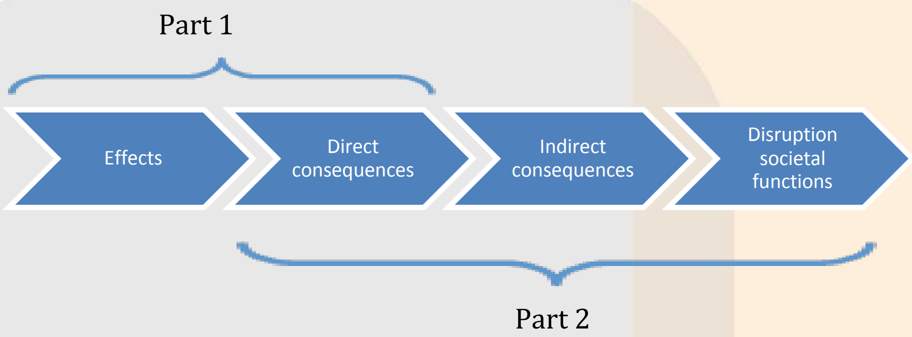
## 3.3 Event tree analysis

The capability identification focusses on the following scenarios:

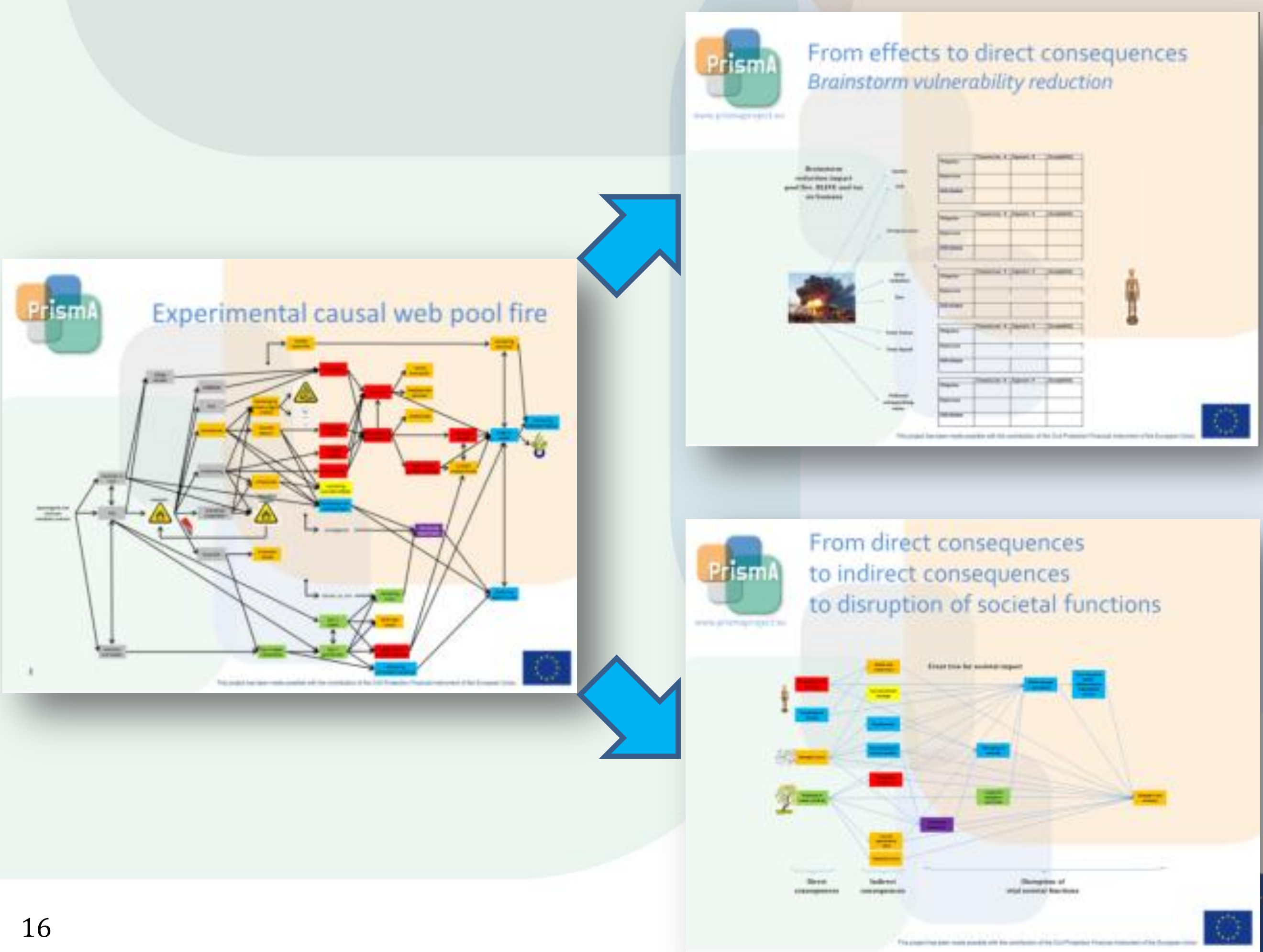
- Pool fire
- Boiling liquid expanding vapour explosion (BLEVE)
- Toxic gas release
- Toxic liquid release
- Ecological (aqua-)toxic release
- Incidents with of small emission
- Incidents with a threat of emission

As a first step a detailed experimental event tree was designed for the pool fire.[7] This experiment made very tangible that it is very difficult to design all correlations between the different primary effects (like fire, smoke, heat, overpressure) and the different kinds of consequences and societal impacts (on people, economy, social stability etc.), including all reverse correlations and 'feedbacks' from one effect or impact to another. Several effects can cause the same consequences (but in a different way), leading to too complex relation schemes. This is difficult even for just one scenario, let alone seven different scenarios (in different gradations). This would require for example 'systems dynamic modelling', detailed scientific research and advanced software tools, which were not available for this process and cannot be assumed to be available for any of these kinds of mitigation processes by local and regional governments. After all, it cannot be expected that actual local mitigation processes are performed according to scientific standards and with extensive use of detailed knowledge about systems dynamic modelling or other methods to research correlations. The locally available resources for a mitigation process are mainly local, empirical experts, with in addition desk top research into existing knowledge. The methodology for ETA simply has to be straightforward and relatively easy to use for local networks of experts. For this reason the local working group deemed it impossible to develop one complete ETA with all correlations. Therefore the decision was made to divide the first experimental event tree in two parts.

[7] This experimental ETA was only made in draft and in Dutch. It was not finalized or translated into English, because after the first discussion it was decided to divide the event tree into two separate parts.




One part concerns the primary effects from the incident (like smoke, heat radiation, toxic fume) and the direct consequences of these effects on humans, the man-made environment and the natural environment (wounding, damage etc.). The second part contains the correlation between the direct consequences, indirect consequences (societal costs of people being disabled, loss of cultural heritage) and the overall impact on societal functions (public outrage, overall economy).

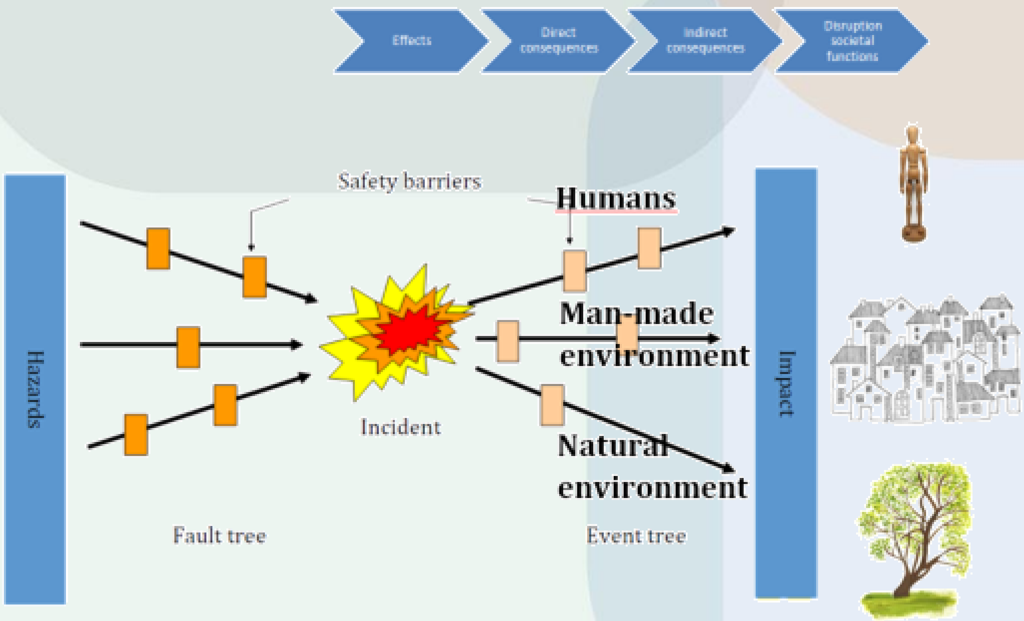


In this way the causal web becomes less complicated, because there is no need to try to correlate the different kinds of effects with all the indirect and societal impacts. After all, these correlations are very indirect: for example, you cannot connect public outrage and anxiety directly to the type of injuries (like burns or toxic contamination). There might be some sort of relation, but it would be to detailed to try to incorporate this in the causal web. Moreover, there are no direct means for the mitigation of these connections. Most options for mitigation are primarily to be found in the prevention of direct consequences from the effects, although in paragraph 3.5 also mitigation options are presented for the overall societal impact.

## 3.4 Vulnerability reduction for the direct consequences of primary effects

For part 1 of the ETA a distinction was made between the three main 'risk recipients':

- impact on humans
- impact on the man-made environment
- impact on the natural environment.

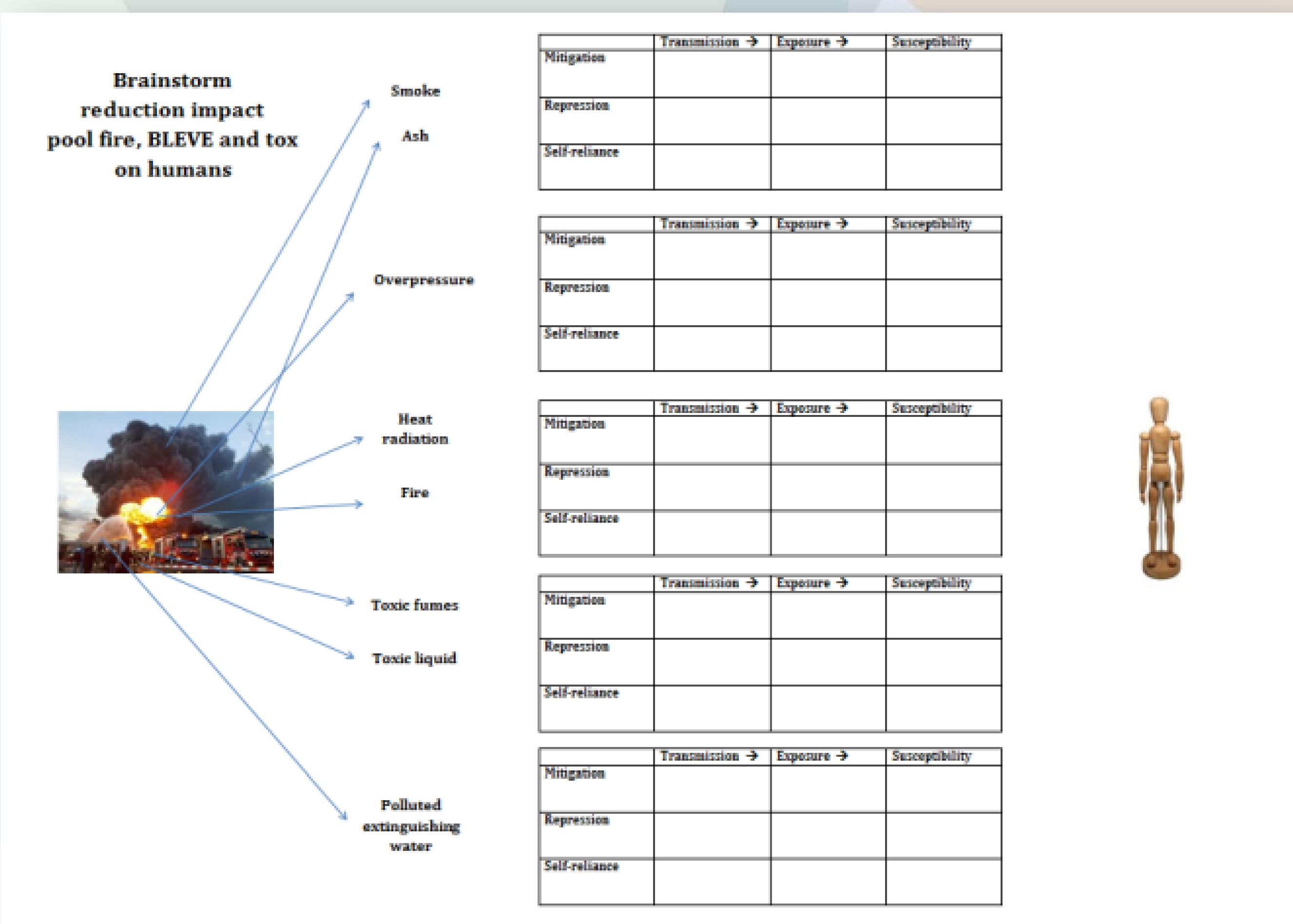



For the analysis the working group used working sheets to brainstorm. These working sheets contained the primary effects of all three main scenarios (poolfire, BLEVE and toxic release):

- smoke
- ash
- overpressure
- heat radiation

- fire
- toxic fumes
- toxic liquid
- polluted extinguishing water.

A special matrix was developed for the identification of measures for each of these effects. One axis of the matrix concerns the subdivision of vulnerability: transmission (the transfer from effect on the surroundings), exposure (are the vulnerabilities exposed to the effects?) and susceptibility (do the vulnerabilities have negative consequences from the effects?). The other axis of the matrix contains the main ways to lower the impact: by means of mitigation, by means of repression or by means of self-reliance. The brainstorm was limited to effect and vulnerability reduction, because probability reduction as a national responsibility is not part of the capability assessment. According to the risk assessment the focus of the capability assessment in fact is only vulnerability reduction. However, a clear distinction between effect reduction and vulnerability reduction cannot always be made. Depending in the perspective a mitigation measure might be considered as effect and vulnerability reduction at the same time. The working group has also concluded that prevention of impact on humans and on the man-made



environment cannot easily be divided. After all, most prevention measures for impact on humans are in spatial policy and the physical surroundings (like buildings).

*One measure, more levels in the matrix*

In the matrices for humans and for man-made environment exactly the same measures might arise. However, the place of measures in the matrices is different: a building measure to prevent *transmission* of effects to humans is from the point of perspective of damage to the man-made environment an example of decreased *susceptibility*. For example: non-splintering glass prevents *transmission* of overpressure to people and at the same time makes a building less *susceptible* for damage due to overpressure. In this report only tables are presented from the perspective of humans (so building measures are presented under 'transmission').

The same 'problem' of duplication arises between mitigation, repression and self-reliance. The best example is evacuation (as a way to reduce exposure): to ensure evacuation one could improve the routes. This is a mitigation measure. During an incident the emergency services might decide to evacuate and therefore warn people and maybe escort them. This is repression. The actual evacuation is also an example of self-reliance. It is the same subject, but on different levels: this example contains components of spatial mitigation, preparation and risk and crisis communication. Therefore the distinction is kept intact.

For the natural environment it is concluded by the local working group that there are only serious mitigation options for polluted extinguishing water and spillage of toxic liquids. Mitigation of the release of toxic fumes, smoke and ash into the environment is no serious option. For this reason, the other matrices are not used for the natural environment. The other way around, the matrix for polluted extinguishing water and spillage of toxic liquids is only used for natural environment and not for humans of man-made environment, because these effects are less indicative for these vulnerabilities.

The effects smoke and ash are left out entirely, because there are no serious mitigation options to prevent transmission, exposure and susceptibility, other than measure that are already listed for toxic fumes. The main options regarding smoke and ash are measurement of toxics and information and advice to inhabitants (and farmers).

In the following matrices the general ideas for mitigation are presented.

*Heat radiation and fire (impact on humans)*

| | Transmission → | Exposure → | Susceptibility |
|---|---|---|---|
| **Mitigation** | ▪ Screen or wall (only for giving a more intervention time due to slowing of effects of a pool fire; not relevant for heat radiation of BLEVE)[8]<br>▪ Smaller surface of glass.<br>▪ Building façade of stone, brick (no flammable materials or metals).<br>▪ Accessibility for emergency services | ▪ Zoning of vulnerable objects[9] | |
| **Repression** | ▪ Fire fighting | ▪ Evacuation | |
| **Self-reliance** | | ▪ Evacuation | |

*Overpressure (impact on humans)*

| | Transmission → | Exposure → | Susceptibility |
|---|---|---|---|
| **Mitigation** | ▪ Screen, wall or buildings to direct the blast upwards<br>▪ Rounded shape of buildings<br>▪ Placement of buildings: with short side directed towards the risk source<br>▪ Non-splintering glass.<br>▪ Windows and doors directed away from railway<br>▪ Robustness of building | ▪ Evacuation routes<br>▪ Early warning<br>▪ Zoning of vulnerable objects<br>▪ Emergency exits away from railway | |

[8] Take in mind that heat reflective walls against pool fires might increase the temperature of the fire itself, which increases the probability of domino effects (pool fire leading to 'warm' LPG BLEVE or toxic scenario, or a petrol BLEVE).

[9] The local working group has discussed on the additional idea of assigning the areas close to the railway tracks as office zones, because they are abandoned during the night. Already 60% of the transport is during the night and maybe this could be increased. It was concluded this is not a real option, because this would make these parts of the city 'dead' and unattractive, which conflicts with the vision of the city government. Also this could lead to more noise problems during the night for other inhabitants.

| | | | |
|---|---|---|---|
| **Repression** | | ▪ Evacuation: only in case of a warm BLEVE (delayed), not for instant BLEVE<br>▪ Barricade entrance routes for other people | |
| **Self-reliance** | | ▪ Evacuation/fleeing: only in case of a warm BLEVE (delayed), not for instant BLEVE<br>▪ Risk communication and education | |

*Toxic fumes (impact on humans)*

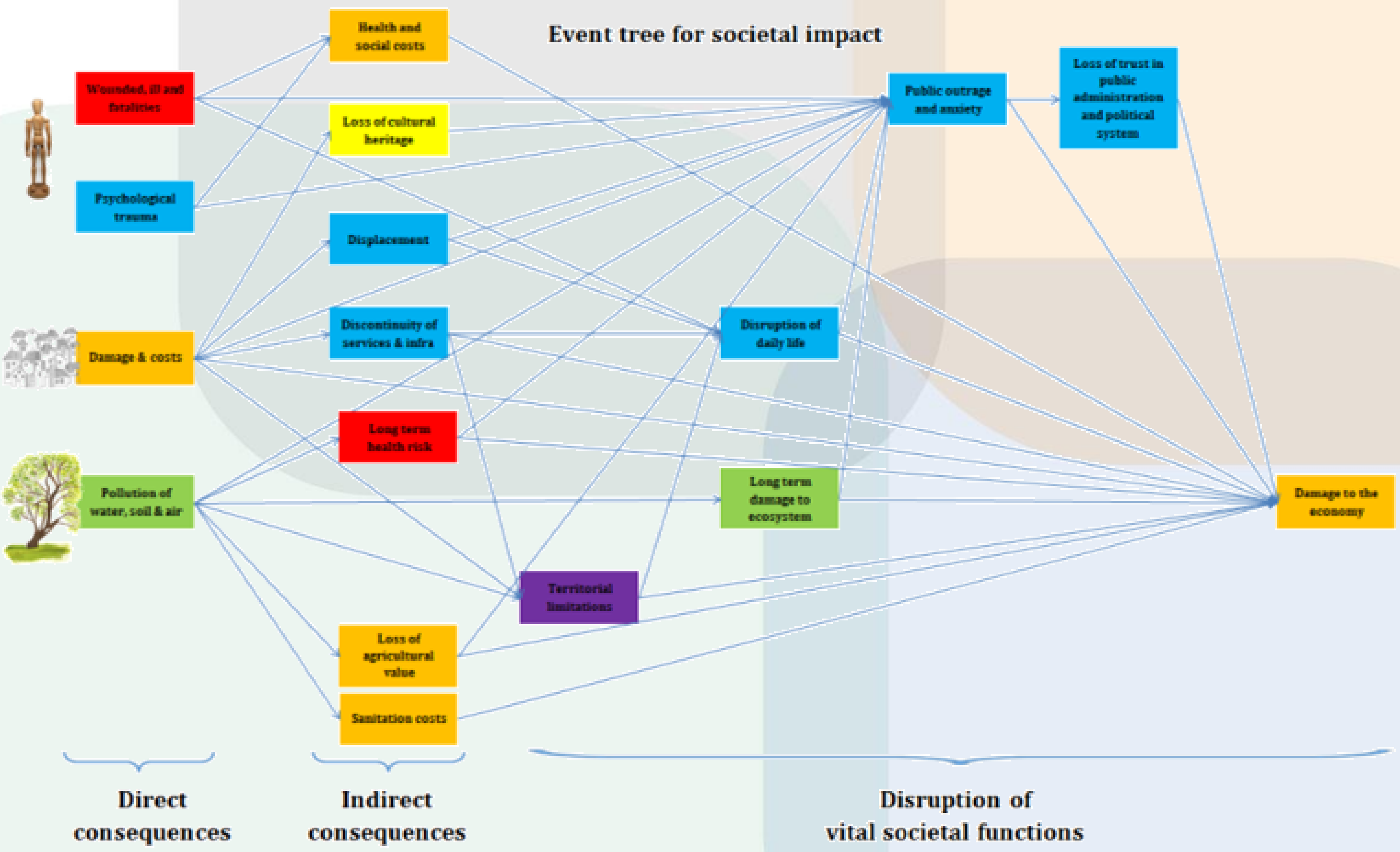
| | **Transmission →** | **Exposure →** | **Susceptibility** |
|---|---|---|---|
| **Mitigation** | ▪ Permanent sprinkler / water screen (only on risk spots) | ▪ Early warning system<br>▪ Closable air-conditioning.<br>▪ Inlet of airco on side away from railway.<br>▪ Turn certain public buildings into designated shelters / 'safe haven'<br>▪ Subsidies for improved isolation of old houses (win-win safety and energy conservation)<br>▪ Renewal of old districts<br>▪ Zoning of vulnerable objects<br>▪ Emergency exits away from railway | ▪ Zoning of vulnerable people (children, elderly, chronically ill) |
| **Repression** | ▪ Water pipes for quick 'water screen' by fire brigade<br>▪ Enough quantities of extinguishing foam<br>▪ Protective covers over liquid surface (in case of non-flammable liquid)<br>▪ Pumping | ▪ Evacuation: only in areas not yet affected, with enough time<br>▪ Barricade entrance routes for other people | ▪ Gasmasks with emergency services to help evacuate people.<br>▪ Action on the bottleneck of respiratory equipment in hospitals |
| **Self-reliance** | | ▪ Risk communication & crisis communication: go inside, close etc.<br>▪ Let people on the street come inside your own house | ▪ Gasmasks in your own house |

*Polluted extinguishing water and toxic liquid (impact on natural environment)*

| | Transmission → | Exposure → | Susceptibility |
|---|---|---|---|
| **Mitigation** | ▪ Seals to close ditches alongside the railway<br>▪ Seals to close parts of the sewage system<br>▪ Drainage pipes (tracks without ballast) | | |
| **Repression** | ▪ Floating oil screens (Rijkswaterstaat)<br>▪ Pumps | | |
| **Self-reliance** | | | |

## 3.5 Vulnerability reduction for the societal impact

As said before, in the second part of the ETA the direct consequences are related to indirect consequences and the overall impact on societal functions. An overview of correlations for this part of the Event Tree has been designed. The colours correspond to the vital interests of the risk assessment methodology.

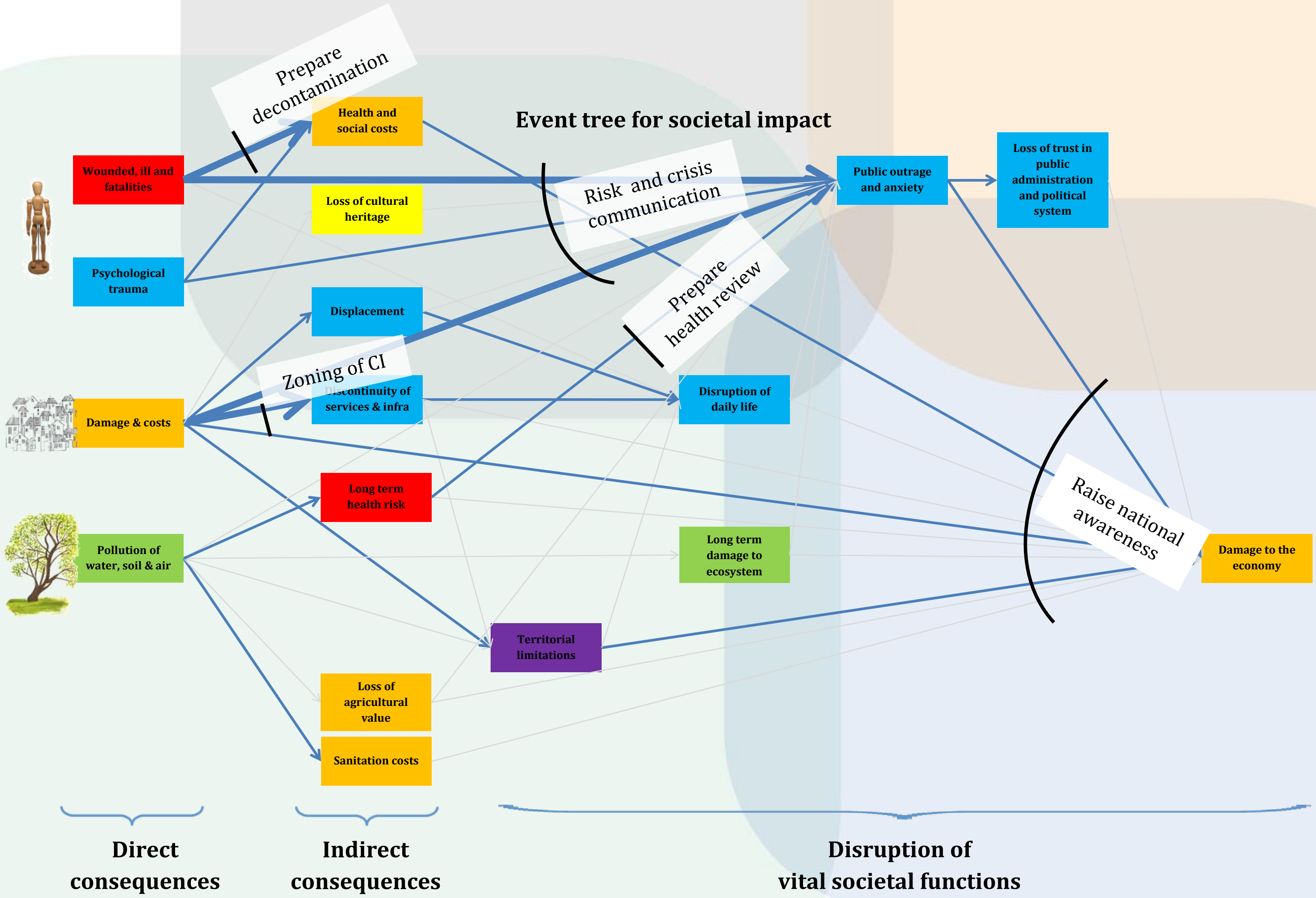



Colour legend

| Vital interest | Criteria |
|---|---|
| 1. Territorial security | 1.1 Infringement of the territorial integrity |
| 2. Physical safety (public health) | 2.1 Number of fatalities<br>2.2 Number of seriously injured and chronically ill<br>2.3 Physical suffering (lack of basic necessities of life) |
| 3. Economic safety | 3.1 Financial costs |
| 4. Ecological safety | 4.1 Long-term damage to the ecosystem |
| 5. Social and political stability | 5.1 Disruption of everyday life<br>5.2 Violation of the democratic system and rule of law<br>5.3 Social psychological impact: public outrage and anxiety |
| 6. Safety of cultural heritage | 6.1 Damage to cultural heritage |

This overview is more generic and is applicable in the same way to the main scenarios for dangerous substances and even to most of the different risks in the regional risk profile (all hazard). The correlations between different kinds of direct consequences cannot be expected to be much different for different crisis types. The strength or magnitude of the correlation will of course differ depending on the scenario, but the correlation itself mostly not.

The main question for this figure is: for which of these correlations might preventive measure be possible? The expert judgment of the local working group is represented in the image below.



In this image the correlations between the direct consequences, indirect consequences and disruption of vital societal functions is depicted for the rail transport scenarios. The thicker arrows indicate a stronger relationship. The local working group identified five options to build 'lines of defense' to stop or decrease the cascade effects in the event tree. Beneath these identified potential mitigation measures are discussed.

*Discontinuity of health services: planning for decontamination*

Discontinuity of health services is difficult to prevent. Preparation by means of a hospital emergency plan (ZiROP) is the only way: prepare for the coordination in case of unexpected walking-wounded and for dispersion of casualties amongst hospitals and also to the posts of general practitioners (HAP). Specific for the toxic scenarios is the question of decontamination. It is impossible for the most nearby hospitals (mainly the Albert Schweitzer hospital) to prepare in time for decontamination of large numbers of casualties. Not only because there might be little warning time and large numbers of people might just start walking in, but also because it might take a while before there is information about the substance and the required treatment. It might be an option to investigate the possibilities for enabling self-reliance (public showers in the hospital in which people can start decontaminating themselves even when there is not enough hospital personnel to assist). Furthermore a quick diagnosis of substances is important: by means of permanent measuring poles, fast measuring equipment for the fire brigade, fast national lab diagnostics by the RIVM and (beforehand) complete registration of the content of all rail containers.

*Discontinuity of public services and infrastructures: zoning of CI*

A very concrete issue is the discontinuity of public services and infrastructures as a result of direct damage. The most important measure here is zoning: have enough space between the railway and vulnerable objects of the public services, like electricity transformer stations and drinking water pumping stations. The conclusion is that the disruption of communication systems (telephone, mobile phone, internet) is the most important risk. Disruption of water or gas might be annoying, but poses less direct danger. People can survive without this and there is enough time to re-establish it in the recovery phase. However, communications are of vital importance during the incident. In the initials phase communications are used to inform people about their perspectives for action (going inside, take shelter, evacuate). If communications break down, the options for improving self-reliance are seriously endangered. Moreover, communications are of vital importance for the rescue services to coordinate their efforts and work as safe as possible under the difficult circumstances. The working group therefore suggests to investigate which mobile phone and C2000 transmitters might be too close to the risk and what the potential cascade effects are of power disruption and failure of nearby communication transmitters for the rest of the city. Power failure in itself is no direct problem for the rescue services, because they have their own emergency backup power systems. However, if it results in failure of communication systems, it is a big problem. The WTC attack has proven this.

*Public outrage and anxiety: risk and crisis communication*

Prevention of public outrage and anxiety is difficult. Good risk communication and crisis communication might help to decrease this, but cannot prevent it completely. It might be advisable to invest in better screening of and intervention on social media. Important is to realize that the municipalities never communicate that they accept the risk: they see it as more or less unavoidable (because of the national interest), but from the point of view of their own responsibilities, they do not accept it.

*Long term health impact: preparation of health review*

For long term health risks the execution of a 'health review after disasters' (GOR) is important. A future problem might be that the municipalities are intended to stop registering all people who are affected by disasters, in which case it becomes very difficult to find the people you want to invited for participation in the health review.

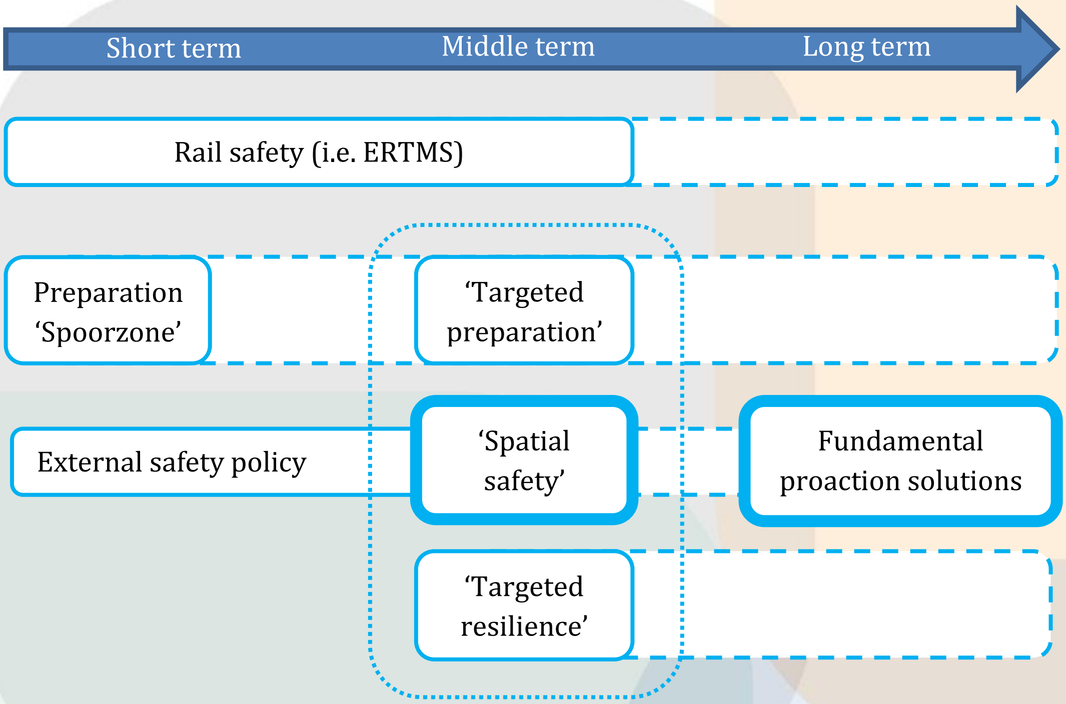
*Damage to the economy as a whole: national awareness*

Discontinuity of rail infrastructure might result in big damage to the national economy, but this is considered beyond the responsibilities of the municipalities and safety region. The only thing the safety regions and municipalities can do is try to raise awareness with the national government and the industry and transport sector about the potential economic impact of local incidents. For example, in the past a small jam on the railway in Barendrecht resulted in a queue of freight trains all the way to Switzerland.

For the other indirect consequences it is concluded that mitigation is very difficult or even not possible. Reduction of these consequences can only be realized by means of mitigation measures for the primary effects and vulnerability for direct consequences (see paragraph 3.4).

## 3.6 Conclusions of capability identification: overview mitigation options

The capability identification has resulted in many different kinds of existing capabilities and potential capabilities for the future. To be able to perform a capability analysis and preliminary CBA, these measures have to be categorized. This categorization is presented in the following figure, taking into account the different aspects of multilayer safety and the objectives as identified in the risk assessment and resumed in paragraph 1.3.




*Capability analysis PRISMA*

The capability analysis in the following chapter, focuses on the circled part. This part contains three main strategies in which the identified capabilities have been divided:

- **Spatial safety**: this is the core of the proposed mitigation strategy for the middle term. It contains a combination of maximum safety zoning and specific architectural and technical capabilities. Its focus is mainly that of vulnerability reduction: transmission, exposure and susceptibility.
- **Targeted resilience**. The second strategy resulting from the capability identification is that of enhanced resilience and self-reliance of the inhabitants and organizations.
- **Targeted preparation**. The current Spoorzone project implements no less than 23 subprojects, most of them meant for improving the preparation of emergency services. The capability identification of PRISMA has brought to light several additional potential preparation measures (some of them building on the current Spoorzone project), on the one hand from the new perspective of 'societal impact mitigation' and on the other hand from the perspective of creating the preconditions for resilience.

Within these three strategies the following capabilities have been identified.[10] They are explained below. Because this is only the capability identification, these descriptions should not be regarded as the end proposals for mitigation. They are merely the listed *options*, which will be analysed and evaluated in the following chapters.

| | |
|---|---|
| **1.** | **Spatial safety** |
| 1.1 | Assessment tool spatial safety |
| 1.2 | Increased safety distance |
| 1.3 | Zoning and protection of critical infrastructures |
| 1.4 | Zoning of objects with vulnerable people |
| 1.5 | Expansion of closable mechanical ventilation |
| 1.6 | Integration of defence against toxic fumes in housing isolation subsidies |
| 1.7 | Compartmentalisation of sewage system |
| 1.8 | Drainage pipes and compartmentalisation of canals |
| 1.9 | Spatial support for evacuation |
| **2.** | **Targeted resilience** |
| 2.1 | Targeted risk communication |
| 2.2 | Community resilience |
| 2.3 | Self-reliance of entities |
| **3.** | **Targeted preparation** |
| 3.1 | Improved early warning |
| 3.2 | Improved crisis communication |
| 3.3 | Improved preparation of decontamination |
| 3.4 | Buildings with shelter capability |
| 3.5 | Improved preparation of public health review |
| 3.6 | Improved preparation of containment of ecological spills |

[10] The identified 'capability' for decreasing economic damage is lobbying for national awareness about the potential economic impact of (local) incidents. This lobbying is of a completely different nature than the other capabilities. Therefore it is taken into account in the recommendations for political evaluation (chapter 5), but not considered in the capability analysis or CBA.

## 1. Spatial safety


### *1.1 Assessment tool spatial safety (‘afwegingskader ruimtelijke veiligheid’)*

The overall vision of the local working group is that safety and spatial planning should “meet” as early as possible and should find a “shared rhythm to dance” in order to synchronize their processes. The early inclusion of risks in the spatial development and planning often yields the most fundamental opportunities for mitigation. For example, in the earliest stages of planning for new industries, housing projects or spatial restructuring a lot of options are still open. The most fundamental option is to really consider the safety aspects of projected locations of risk sources and vulnerabilities, in order te create adequate safety distances. In the early phases of spatial design this kind of fundamental mitigation options is still possible. Also spatial measures in other levels of multi-layer safety, like evacuation routes, structural protection measures for vital infrastructures and stricter safety norms for buildings, can often be realized with far less costs than in later stages when the designs are already made.

The local working group has concluded there is the wish and need for a framework or assessment tool to incorporate safety issues more easily into spatial planning. This kind of ‘capability’ is of a higher level than just the individual spatial, architectural and technical prevention measures, like fire proof glass or blast proof buildings. It should be the encompassing framework that helps spatial planners and safety experts to find each other in the earliest stages of spatial development and to ‘talk the same language’. On the one hand the framework or assessment tool should focus on the process: how does early involvement take place, how do formal processes of decision making and advice relate to the desired more informal ‘bargaining’ process, what expertise can be made available by the safety experts? On the other hand the framework should provide guidelines for the assessment of what measures might be required or advisable at what place.[11] Ideally it should include concrete suggestions for different safety zones with the different kinds of measures. The PRISMA capability analysis has provided the first insights for this zoning (see chapter 4). It is considered important that the concepts and guidelines that are developed for this assessment tool also aim at visualizing the risk in spatial perspective, because that is the ‘language’ of spatial planners. The mapping of effects helps to break free from the formal $10^{-6}$ zone (and the legal ‘pool fire attention area’) and to think in

[11] The assessment framework for external safety in the Spoorzone (“toetsingskader externe veiligheid Spoorzone Dordrecht/Zwijndrecht”, TNO, 2004) could be a starting point for this.

broader perspective. It is important to prevent that $10^{-6}$ becomes an absolute line: on the one side you have to take a lot of measures, on the other side none.

The assessment tool is suggested to include at least the following aspects:

- **Process and 'culture'**. How does the cooperation process between spatial planning and safety work? What are the formal responsibilities and how can professionals meet and help each other, transcending the formal judicial cadre? What are the differences in culture and language between the sectors and how can these be bridged?
- **Expanding the "non-building" safety zone**. See the explanation in the following paragraph.
- **Zoning of specific functions**. General ideas about which kind of measures are relevant for which zone, including zoning of critical infrastructure and vulnerable objects (see the next two paragraphs). Ideally this should be based upon a further CBA research: starting to consider measures in whole the 'maximum credible' effect zone, the ratio might be negative, because of the big areas and low probability. But afterwards you can 'size down' until you find a smaller scale where the ratio is neutral (smaller scenarios, smaller area, higher probability). However, this is less valid for BLEVE scenarios because they are all big. It is important that zones to follow 'natural' borders and are not represented as a straight line at a certain distance.
- **Tools for scenario analysis**. Use scenario analysis / risk assessment not only for mitigation measures but also for spatial planning. Develop tools for spatial planners they understand.
- **Room to manoeuvre.** Spatial planning requires 'room to manoeuvre': with knowledge about the different risk zones you can design an optimal lay-out of new/renovated districts, but only if the area is big enough to shift buildings and functions from one place in the design to another.
- **Safe building.** "Safer building" should be made more concrete: resilience against pressure, "backside to the railway", buildings as buffers etc. with technical standards. The IPO'10 catalogue for measures in buildings can be the basis for this.
- **Vulnerable people**. Specific policies for people with limited self-reliance (disabled, chronically ill, elderly, children) is not that easy. Not placing cure and care functions within the first safety zones is the clearest option. Another option is to have office functions instead of housing functions, because offices have less people in them and are only used during part of the day. However, a policy to have less elderly and disabled is very difficult, because you cannot excluded specific target groups: you can only direct 'building functions'. It is signaled that a foreseeable development in the near future is more distinction between housing and care: elderly people will stay longer at home and there will be less elderly care homes. This will increase the significance of the issue of limited self-reliance.
- **Correlation between spatial planning, preparation and risk communication**. The zoning of safety measures directly relates to preparation and risk communication (as a basis for resilience). Depending on the implemented physical measures, specific planning or

training of emergency services can be required. Also preparatory measures like shelters and evacuation routes are directly related to the overall spatial policy. Moreover, the risk communication to inhabitants should include the actual spatial profile of their surroundings, including the implemented measures for shelter, evacuation and fleeing.

The local working group thinks the development of such an assessment tool for spatial safety is the most fundamental mitigation option *for the middle term*. If designed, it should be based upon a political and societal vision about the desirability of risk reduction (including risk acceptance!), the need for a direct interconnection between safety and spatial planning and the added value of 'room to manoeuvre' and searching for win-win. As a whole the costs and benefits of this mitigation option cannot be analysed (in chapter 4), because the added value and the required investments directly depend upon the concrete elaboration of safety distances, architectural measures etc. These specific parts of the overall assessment tool and vision are described in the following paragraphs as separate mitigation options (1.2 to 1.7, but also in relation to mitigation options under 2 and 3.4 and 3.5). In the capability evaluation (chapter 5) the correlation between these separate mitigation options is made and presented as a potential vision on different kinds of safety zones.

The assessment tool cannot be considered as *the* fundamental mitigation option that provides a full and complete reduction of the current high risk levels. It only decreases the vulnerability and should certainly be accompanied by policies to decrease probability and primary effects at the risk source and improve the preparation. For the long term a research into the fundamental proaction and prevention options is still needed.

### *1.2 Increased safety distance*

As described before, by Law a safety zone is set of 30 metres from the edge of the transport axis, the so-called 'pool fire attention area'. This is a minimum, because the specific localised risk calculations[12] might lead to increased distances at some points.[13] However, in this zone buildings are not prohibited completely. For vulnerable objects the zone is a norm, but they can still be built if applying to the set fire resistance norms (see paragraph 3.2). For other buildings the zone is not even a norm, but just an orientational value.

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[12] Also the group risk calculations might result in specific measures and in larger zones (up to a maximum of 200 metres), but this is not the same as the formal distance requirements as set for the base net rail transport and for the localised risk. The main difference between the two is the judicial basis to demand that specific requirements are met by the construction companies.

[13] In case of transport the calculations are made for "kilometer sections", so the exceeding of the norm for the localised risk is not for small points, but for a whole kilometer along the railway.


Even if the whole 30 metres of the pool fire attention area would be kept clear of all buildings, that would not be a full protection against pool fires. As described in the risk assessment report (page 58), the zone of irreparable damages reaches up to 40 metres, heavy damage and secondary fires occur up to 50 metres and secondary fires might occasionally reach up to 60 metres. The outer effect zone (light damage) has been calculated at 75 metres. These distances are based upon both the Scenario book external safety (2011) and the scenario calculations with the EFFECTS software. However, the pool fire attention area is not based upon absolute effect distances but upon the $10^{-6}$ contour of the localised risk, taking into account both effect and probability. This means that the pool fire attention area can never be regarded as a full protection, but as e legally set 'acceptable' distance. Moreover, for the BLEVE and toxic scenarios this zone has very limited (if any) value to protect against actual effects (although these ofcourse have a significantly lower probability than pool fires).

All said and done, one of the mitigation options is to increase the 'safety zoning'. What is meant here, is a voluntary decision of the municipalities to gradually increase the safety distances for new buildings and restructuring of urban areas, exceeding the legal pool fire attention area. This would mean a "supra-legal" policy which has no judicial basis and therefore may involve public costs to pay for safety measures and none-usage of land outside the area where there is a legal basis to issue demands and constraints. Question is to what extent this safety zone should be increased. A safety distance related to BLEVE and/or toxic scenarios can hardly be considered as realistic, because it would influence the whole built areas of the municipalities of Dordrecht and Zwijndrecht and potentially even beyond. Discussing this mitigation option, the local working group therefore has proposed to set the increased distance for this mitigation option at a level which reduces the probability of an inhabitant or worker *inside of a building* being killed by a *pool fire* to zero, because the pool fire risk has highest probability, making it more difficult to explain why it has not been mitigated.[14] The distance for zero percent lethality inside as calculated with EFFECTS and in the Scenario book External Safety would mean a safety zone of 60 metres. This would mean an effort to gradually ban all buildings within 60 metres of the railway (and not just vulnerable objects).[15]

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[14] Of course, the setting of such an objective should be done politically. Because this potential objective was only identified during the capability assessment, it has not been part of the risk evaluation (see risk assessment report).

[15] This distance is measured from the outside perimeter of the railway. However, specific terrain characteristics might require a larger distance to obtain the same level of protection. This is especially the

The overall value or benefit of this safety zone could be substantiated not only by the mitigated risk of people being killed by a pool fire, but also by decreased vulnerability to the effects of BLEVE and/or toxic scenarios. The local working group has suggested to express this in terms of "total percentage of the potential incidents for which the occurrence of fatalities is mitigated". An additional way to express this is in terms of reduced probability of fatalities (from once every X years to once every Y years). This safety zone of 60 metres would at least "protect" against *inside* fatalities for 94,7% of the total incidents with more than 100kg emission, namely all scenarios with emission of flammable liquids.[16] In addition to this percentage, the zone would also protect against fatalities for a fraction of the BLEVE and toxic scenarios. The actual calculation of this additional percentage (or reduced probability of fatalities) is not immediately possible. The HART guideline for probability calculation does not provide calculation rules which relate specific probabilities to effect distances of BLEVE and toxic scenarios (nor for pool fire scenarios to proof the difference between the current level of protection by the 30 metres pool fire attention area and the 94,7% protection by a 60 metres zone). For BLEVE it can be assumed that an increased safety zone does not protect against the occurrence of fatalities at all (although it will decrease the actual number of fatalities), because these in almost all cases will have a much larger effect distance. However, for toxic scenarios it might mean an additional protection against the smaller emissions. Because these toxic scenarios have a low probability anyway, it is unlikely that the total percentage of all scenarios for which the 60 metres distance would protect against fatalities will exceed 95%. In future research could be done (in case it would be considered to really advice the implementation of this mitigation option) to see whether the RBM II software module for the localised and societal risk might be used for a more detailed analysis on the correlation between this distance and fatalities by toxic scenarios, but it remains a question whether this is really needed as a substantiation of the 60 metres zone. Moreover, it must be prevented that the whole discussion of safety distances is reduced only to the question of fatalities, not taking into account wounded, damage and the whole societal impact.

### *1.3 Zoning and protection of critical infrastructures*

As discussed in paragraph 3.5 mitigation should be considered to prevent the discontinuity of public services and infrastructures as a result of direct damage alongside the railway. The main issue here is not so much the actual discontinuity (because this can always be remedied in the

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case if the railway is located on a slope, ramp or viaduct above the surrounding area, because the flow of flammable liquids could result in a much larger or displaced pool fire area. To be able to make this distinction, specific local analyses are required, to gain insight in the specific behavior of large quantities of liquids and the options to contain this at the source with retention basins or drainage pipes in the railway bed.

[16] Calculation based upon the HART guideline, as specified in annex I of the risk assessment report. This "percentage of protection" is not valid for outside fatalities (passers-by), nor for wounded or damage.

recovery phase), but the direct effects this failure might have on alarming, warning, fleeing and shelter capabilities and the overall disaster relief and rescue, which might even result in additional direct and indirect fatalities and wounded because people are overexposed to effects and because the rescue and medical aid is delayed and obstructed. The main focus therefore should be infrastructure for communication and electricity. The working group has suggested to investigate which mobile phone and C2000 transmitters might be too close to the risk and what the potential cascade effects are of power disruption and failure of nearby communication transmitters for the rest of the city. The most important measure here is zoning: have enough space between the railway and vulnerable objects of the public services. This mitigation option is aimed at vulnerability reduction:

- reducing exposure: on the one hand as much zoning of critical infrastructures as possible, i.e. placing important knots and systems at a safe distance;
- reducing susceptibility: on the other hand physical protection of critical infrastructures which cannot be moved or for which the costs of moving are too high, in order that they can withstand the effects of the different scenarios.

This should begin with a research into actual physical vulnerability and domino effects within the infrastructure (damage to one point leading to overall failure) and domino effects between different critical infrastructures (power failure leading to communications failure). The actual measures which should be undertaken cannot be predicted without this further research. This mitigation option therefore is defined in general terms as implementing exposure and susceptibility reduction measures. These kinds of measures might be considered in the following zones:

- at minimum the 60 metres zone in which medium damage and occasional secondary fires might occur in case of a pool fire, because these have the highest probability;
- preferably also the 250 metres zone in which heavy damage and secondary fires will occur in case of a BLEVE;
- optimally also the 360 metres zone of medium damage and occasional secondary fires in case of a BLEVE.

In addition a quick scan could be done of important critical infrastructures between 360 metres and 600 metres zone, because in that area still light damage might occur due to a BLEVE (overpressure and flying projectiles). For toxic scenarios a specific analysis might be needed, to investigate whether corroding effects might cause direct damage.

### *1.4 Zoning of objects with vulnerable people*

As described in paragraph 3.2 and under mitigation option 1.2, by Law a safety zone of 30 metres is set for 'vulnerable objects'. This means buildings for people with limited self-reliance, like children, elderly and disabled. However, in this zone these buildings are not prohibited completely. For vulnerable objects the zone is a norm, but they can still be built if applying to the set fire resistance norms. An additional mitigation option, as identified by the local working group, is for municipalities to implement an active, 'supra-legal' spatial safety policy aimed at no vulnerable objects in the safety zone whatsoever. Here we must emphasise that this can only be aimed at new objects and new spatial plans or the restructuring of objects or spatial plans. A full and fundamental mitigation of the existing situation would be too large and encompassing and would encounter legal and financial issues which are difficult to overcome. What is meant here, is that in case of new applications for or restructuring of vulnerable objects the municipalities do not limit themselves to the pool fire attention area and localised risk and societal risk calculations, but actively try to find solutions to enlarge the distance of such an object to the railway. Important condition for such a policy is early involvement of safety concerns in the spatial development process and the will to find win-win and 'room for manoeuvre'.

For the actual zone for such an approach different distances could be argued:

- the pool fire attention area of 30 metres, meaning the legal norm would be enforced, without permitting exceptions, even if the legal fire resistance norms are met;
- the 60 metres zone as discussed under mitigation option 1.2, reducing to zero[17] the probability of fatalities inside vulnerable objects due to a pool fire;
- the maximum distance at which the costs (i.e. displacements from intended locations, moving or removal and loss of land value) and benefits (prevented impact on all impact criteria, see chapter 4 for a discussion and potential basis for CBA methodology) are in balance. Because the costs increase with the distance (a larger distance means it affects more buildings, thus resulting in higher costs) and the benefits decrease with the distance (the effects are smaller at a larger distance and also the probability of an effect reaching that distance is smaller), it should be possible to calculate or estimate an 'equilibrium distance'. This would require additional research.

In all cases the rule is "the more distance, the better". This means that probably the most benefit would be made if safety professionals and spatial planners would recognize the shared interest to find 'room to manoeuvre' on a voluntary basis and not just cling to legal norms.

[17] This should not be interpreted as a full and 100% proof protection. Under certain circumstances a pool fire can always have a larger effect zone than the estimated one, for example due to specific terrain characteristics or a larger spill of flammable liquids from several containers at once.

No specific choice for one of these distance options is made by the local working group. Therefore, for the calculation of the cost-benefit ratio of this mitigation option (see chapter 4) general assumptions are used, not relating directly to one of these three options for the actual zoning distance. Because the outcome of the rudimentary CBA suggests a potential balance between costs and benefits (not a clear positive, nor a clear negative CBA outcome), the actual choice of the zoning distance might tip the balance. If this mitigation option is considered for actual implementation, there are two potential paths: either select the 30 or 60 meters zone as a general principle (related to respectively the pool fire attention area or the pool fire maximum effect area), without trying to further rationalize this, or perform the additional research to find the rational distance on basis of a CBA equilibrium. In this last case, the actual selected distance should be rounded to whole tens of meters, to prevent the image of safety as an exact science.

### *1.5 Expansion of closable mechanical ventilation*

Nowadays most of the new buildings have mechanical ventilation. In case of toxic clouds and vapours, but also in case of smoke it is desirable to shut of this ventilation. The regulations on the pool fire attention area require the ability to shut down (at least manually) mechanical ventilation in vulnerable objects within 30 metres of the railway. With the Spoorzone project the Safety Region South-Holland South has developed a devise to shut down mechanical ventilation automatically by the personnel emergency room for all buildings that are connected to this system. More and more buildings are equipped with this devise, mostly on a voluntary basis. For them this connection to the emergency room means an annual cost of around 1,500 euros.

The mitigation option as suggested by the local working group is aimed at a radical expansion of the automatically closable mechanical ventilation. The local working group has suggested the "yellow areas" for toxic scenarios (the LBW or *life threatening value* of 1% lethality outside) as the zone in which the automated or forcible closing of mechanical ventilation directly by the emergency room is indicated. Based upon the risk assessment this zone is set at 2000 metres. However, the national catalogue for architectural measures concerning external safety sets the distances as follows, according to substance category[18]:

| | |
|---|---|
| B2. Toxic gas | 600 m |
| D3. Toxic liquid | 200 m |
| D4. Very toxic liquid | 2,900 m |

The calculations and assumptions for these figures seem to be lacking in the aforementioned catalogue (and also in the annex in which they are supposed to be). The suggested distances for B2 and D3 substances show a remarkable and not directly explainable difference to the

18 *Bouwkundige maatregelen externe veiligheid (architectural measures external safety)*, InterProvincial Counsel, 2010, page 14.

distances calculated for PRISMA. However, the distance for D4 (which is not calculated for PRISMA, because the D4 transport is very limited) is exceeding the suggested 2000 metres zone based upon the PRISMA risk assessment. This supports the overall conclusion of the local working group that the effort should be to get this specific mitigation measure implemented in a zone "as large as possible" within the whole municipalities of Dordrecht and Zwijndrecht[19] (so beyond 2000 metres or even 2,900 metres), because on the one hand effects in an actual case might always travel further and on the other hand the costs of this measure are very small (see also the CBA).

### *1.6 Integration of defence against toxic fumes in housing isolation subsidies*

Most municipalities have an active policy to stimulate housing isolation to save on energy. In Dordrecht there is the Energy Cooperation (www.energiedordrecht.nl). In the so-called Drechtsteden (which includes Dordrecht and Zwijndrecht) there is also the citizen initiative 'Drechtse Stromen' to promote energy conservation. These policies include advice to households and the opportunity to apply for subsidies.[20] As a good example of win-win the local working group has identified as a potential mitigation measure the integration of defence measures against toxic fumes and smoke in the current subsidy policy for housing isolation. [21] This could not only provide extra protection against incident with toxic liquids[22] and toxic gasses, but also against smoke from pool fires, BLEVE or secondary fires. The profitability of the idea to use housing isolation subsidies to make older houses more resistant to toxic fumes lies in the win-win: this measure does not cost anything, but requires lobbying and information about how to do it. This measure is not only win-win with ecological sustainability (energy saving), but also with health (inside climate, noise reduction of train traffic).

This mitigation option would mean that in the municipal advices and norms for isolation, special attention is paid to defence against toxic fumes, gasses and smoke. This concerns for example the time it takes for outside air the penetrate a house. For health purposes, in all houses the air needs to be refreshed in a certain time. For old houses the time in which all air inside is replaced by outside air can be one hour, whilst in modern houses this can be six hours. Too slow might be

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[19] Other municipalities within the region, for example alongside the Betuwe line, are not part of the PRISMA test, but a comparable conclusion for those areas is imaginable.
[20] The municipality of Zwijndrecht itself seems to have no specific housing isolation subsidies.
[21] Also double glazing provides additional protection, in this case against overpressure due to explosions. However, more stringent general norms for the resistance to overpressure is not considered realistic, notwithstanding specific requirements for objects within the pool fire attention area or related to the localised or societal risk. This means that the protection by double glazing is considered as a positive side-effect of existing policy, but not as an opportunity for further win-win.
[22] Many flammable liquids (like petrol) also have a toxic effect in case of evaporation. This means that in the cost-benefit analysis for this mitigation option, also the flammable liquids are included, meaning a much higher probability than just the toxic gasses and toxic liquids alone.

unhealthy, but too quick is energy insufficient and also more dangerous in case of rail transport incidents.

The NEN 2687 cadre includes 2 classes for airtightness: class 1 and class 2. Class 2 is valid in case of balanced ventilation, which requires a higher air humidity. In the publication Airtight building (SBR 2009) a class 3 is introduced, meant for housing with a very low energy consumption. The classes have the following airthightness:

- Class 1: < 1,0 $dm^3/(s.m^2)$
- Class 2: < 0,4 $dm^3/(s.m^2)$
- Class 3: < 0,15 $dm^3/(s.m^2)$

The inclusion of safety in the existing isolation advices and subsidies requires targeted attention for the recognition of "air leaks":

- cracks at the edges of doors and windows
- connection between door and window frames and the façade
- connection of roof and façade
- connection between walls and foundation floor
- roof vent flanges
- roof ridge
- letterboxes

Attention points for class 2:

- good working 2 and 3 point closures
- packing seals for the roof and facade vent flanges
- adjustable hinges and lockes
- if possible prefabricate air seals

Attention points for class 3 (in addition to class 2):

- taping of seams and cracks
- double air seals in the turning parts of door and window frames
- 'wet glazing' for wooden frames and specific quality requirements for plastic and aluminum frames
- prefabricated packing seals at roof and facade vent flanges, taping and glue in tubes
- taping of connections between damp reducing foils
- check on breaking of damp reducing foils
- targeted control of air seals
- control measurements (inflating test, infrared).[23]

[23] *Bouwkundige maatregelen externe veiligheid (architectural measures external safety)*, InterProvincial Counsel, 2010, pages 34-35.

### *1.7 Compartmentalisation of sewage system*

May 4th 2013 a train derailed in the Belgian village of Wetteren (originating from the Kijfhoek shunting yard). The incident resulted in a spillage of acrylonitrile from 3 wagons and a subsequent fire, leading to the decomposition products hydrogen cyanide, nitrogen oxide and acetylene. With the water of the fire extinguishing toxics ended up in the sewage system and through consequent evaporation entered the surrounding houses. The incident resulted in one fatality and 100 intoxicated people who had to be treated in the hospital. A mitigation option for this specific effect is compartmentalisation of the sewage system. This means specific baffles in the sewage system which can be activated during an incident, either manually by the fire brigade, or automatically from a control centre or the emergency room.

### *1.8 Drainage pipes and compartmentalisation of canals*

In order to prevent the spillage of an ecological (aqua)toxic substances and of polluted extinguishing water directly into a larger water system, a mitigation option is to install drainage pipes and prepare compartmentalisation of canals alongside the track.

### *1.9 Spatial support for evacuation*

In spatial planning evacuation might be taken into account on different levels. The normal level is that of evacuation of a single building. All bigger organizations have to have an evacuation plan and an assigned 'disaster meeting point' outside. For bigger incidents it is an option to organize disaster meeting point for a district or quarter of a city (away from the railway), with assigned routes (with directions) towards them. These should have to be constructed in a way facilitation fast evacuation: wide enough, clear signs, no obstacles, no bottlenecks and in the right direction away from the risk zone. An option is also to make reversible lanes, which increase the evacuation potential of a road. It is also important to take into account normal human behaviour: people tend to take the same way out as they came in. This is true for buildings, but also for areas. So make sure that the *main* entrance into a risk zone is not alongside the tracks: even though there might be other, secondary roads in another direction, you want to avoid that people take the 'normal' way they are used to and bring themselves in harm's way.

The external orientation of emergency exits from buildings is deemed irrelevant for an instantaneous ('cold') BLEVE, because the blast is unforeseen and therefore people will only start fleeing after the explosion has already happened. For a delayed ('warm') BLEVE it might be helpful to have the emergency exits oriented away from the railway, or at least have emergency exits on more sides, so people can use the best one. Apartment buildings facing the direction of the railway should therefore preferably also have an (emergency) exit on the backside. However, the design of public spaces is more relevant: roads directing away from the railway (and not parallel to it), a wide enough space, not too many obstacles and no conflicting fleeing routes from different buildings (same direction, the one not obstructing the other).

This mitigation option is aimed at an integral spatial approach to evacuation connecting the level of single buildings, construction of public spaces and the broader road infrastructure. This measure should ideally be accompanied by early warning.

## 2. Targeted resilience

### *2.1 Targeted risk communication*


On the subject of risk communication it is concluded that it is important to really define the options for self-reliance actions. Up to now the Dutch government has for many years propagated that people should "go inside, close windows and doors and listen to the designated radio station". This is not always true. For example, in case of a potential warm BLEVE people might have to be evacuated. The room for actions really depends on the kinds of scenarios, combinations of potential escalations (fire leading to warm BLEVE, fire or BLEVE leading to toxic release) and the accompanying timeframes. The general rule is that inside is safer than outside. However, sometimes there is time to evacuate. In several scenarios evacuating might greatly diminish the potential impact. Moreover, the perspective for action differs for the distance from the incident. In some cases you would like to evacuate people far enough from the incident, while leaving people inside on closer range. It might be advisable for the project to determine the differences in actions for the set of different combination scenarios, with a distinction for different zones (distances), taking into account that the Spoorzone project has already started this kind of 'layered' risk communication.

For risk communication 'natural borders' have to be respected. It is not logical to connect risk communication to an absolute distance, but follow the natural borders in the city landscape. Up to now the distance for specific risk communication (in addition to the general risk communication to all inhabitants) is between 500 and 600 meters. This does not directly correlate to the effects zones on the map. In general it could be said that for the yellow zones it is sufficient to communicate by means of the existing instrument of the 'risicowijzer'. For the red and orange zones the risk communication should be 'custom made': giving concrete advice about how to act (go inside, leave the area et cetera). It is important to take in mind the distinction between permanent residents, employees (and *BHV*) and 'passers-by'.

### 2.2 Community resilience

Self-reliance is very 'fashionable' these days. The policy of our current Cabinet is to enable self-reliance in all fields of society. The aim is to strengthen local social networks. This might also be an approach to Spoorzone: involve local society in improving self-reliance. For normal fire safety this step towards 'community safety' is already being made. A problem might however be that the risk scenarios are 'too big to handle' for self-reliance. Instead of improvement of resilience, close involvement might lead to social distress.

### 2.3 Resilience and self-reliance of entities

For rescue we should not only look at the emergency services. Equally important is self-reliance of organizations. The legally required "internal office assistance" (bedrijfshulpverlening - BHV) should be able to cope not only with internal incidents, but also external ones. This is primarily directed at the safety of the personnel and "clients" inside (office workers, schoolchildren, elderly, disabled), but could (or should) also include assistance of people outside to seek shelter inside. This is especially the case for buildings that might be assigned as public shelter. To improve this kind of resilience, additional preparation (procedures, training) for organizations might be needed, expanding the internal focus with an external one. This could be achieved by cooperation with commercial BHV training institutes to help them improve their curricula.

## 3. Targeted preparation

### 3.1 Improved early warning

Early warning is very important as a necessary condition for getting people inside their houses (shelter) or away from harm (evacuation, fleeing) in time. Parts of early warning could be:

- *'Sniffing poles'*: automated instruments that detect substances in the air directly. The existing national network of sniffing poles of the RIVM is not suitable for this, because the poles are too far apart, it is directed at general health hazards of air pollution (and not instant risks of toxic releases) and there is no direct alarm to the emergency room. In general there are limitations to the range of substances which can be measured and the speed of measuring. In many cases people will smell a substance before instruments can. However, the option is worth investigating (for example for some of the most dangerous substances).
- *Cameras*: with cameras on the railway track it can be observed instantly when an incident happens. This is not enough to determine the severity, but it helps to start early warning.
- *Drones*: the use of drones might be a very interesting one. It is relatively cheap, gives a better overview (because of a higher point of view) and helps a faster and safer reconnaissance.
- *Registration of trains:* with complete information about the substances in a train (preferably with GPS tracking) the potential effects and domino scenarios can be determined much more easily.

- *Use of social media.* Incidents are very often reported on social media before they are officially acknowledged. A thorough screening of social media might help early warning. Furthermore, social media should also be used for crisis communication.

A successful ‘system’ of early warning is preferably composed of several or all of the parts mentioned above.

### *3.2 Improved crisis communication*

To enable resilience (shelter, evacuation, fleeing) the early warning must directly be followed by transparent crisis communication. This crisis communication can ‘built on’ the targeted risk communication (see before): if the inhabitants know about their options beforehand, it is easier to reach them with the right message during an incident. Crisis communication is organized in general terms by means of procedures and training. The implementation of other measures from this capability assessment will definitely raise the need of further preparation of the crisis communication, which should encompass the different levels of measures in the safety zones and the targeted risk communication for the different safety zones.

### *3.3 Improved preparation of decontamination*

The capacity for large decontamination is by all means insufficient. Past experiences have shown that even a few contaminated casualties cause the emergency services and health system serious problems. It might be an option to investigate the possibilities for enabling self-reliance (public showers in the hospital in which people can start decontaminating themselves even when there is not enough hospital personnel to assist).


### *3.4 Buildings with shelter capability*

The ‘window of opportunity’ for evacuation is for most scenarios very limited. Pool fires and anticipated cold BLEVEs are the most obvious scenarios for which evacuation might be possible. For toxic scenarios it is in most cases best for people to stay inside.[24] A directed and organized evacuation of large populations is very difficult. The best is to enable ‘self-evacuation’ (fleeing) by the design of open spaces (spatial planning).

[24] Examples for which evacuation might be indicated are: a scenario of an evaporating toxic liquid during more days, like recently in Wetteren (Belgium) and scenarios with an anticipated change of wind direction.

Evacuation is closely related to shelter: often you want to evacuate people close by and you will have to provide shelter for them. This shelter will not only have to provides the basic necessities of life, but will also have to be safe from the effects of the incident (safe haven). The normally designated buildings for accommodation of evacuated people (like sport complexes) might not be safe enough in case of a delayed BLEVE or toxic cloud.

### *3.5 Improved preparation of public health review*

For long term health risks the execution of a 'health review after disasters' ('gezondheids-onderzoek na rampen', abbreviated as GOR) is important. Swift and well prepared review can directly contribute to prevent and decrease public anxiety and unrest. The main strategic questions for a health review in case of a rail way incident can be definitely be prepared more concretely. The different strategic questions for different scenarios (like smoke, toxic fumes, aqua toxic spillage, environmental and soil pollution) can be developed and partially answered beforehand, for example by means of simulation exercises. Through more targeted preparation it will be easier to react and (crisis) communicate quickly and to ask for the right guidance and advice by the national institutions like RIVM. The value of this was proven by the two Moerdijk incidents: during the second one in 2014 the emergency services could directly build on their experiences from the first one in 2011. This enabled quicker answers and better insight in the actual strategic questions and demands of the population. Because this was only for a "smoke scenario", the same still has to be developed for toxic gas and liquid scenarios.

### *3.6 Improved preparation of containment of ecological spills*

Finally, an option to reduce the impact of spills of environmental and (aqua)toxic substances is to prepare the administering of floating screens and the operation of compartmentalisation measures in canals and sewage systems. This includes the preparation of protocols, development of agreements between partners (fire brigade, Rijkswaterstaat, water police, engineering companies etc.), instruction of personnel and joint exercises.

# 4. Capability analysis

## 4.1 Approach to capability analysis

The second step of capability assessment is researching the relative added value of the identified capabilities. The research questions for the local working group were:

1. Which measures can contribute most to reduction of the highest impacts?
2. In which zones might they be applicable?
3. What is the "safety profit" (plus other societal benefits) of the mitigation strategies?
4. What are the costs of the mitigation strategies?
5. What is the return of investment (costs and benefits in relation to time)?

The first two question are covered in paragraph 4.2. The final three questions concern a cost-benefit analysis (CBA) and are covered in paragraph 4.3.

## 4.2 Spatial distribution of mitigation policies

The local working group has discussed which of the primary effects of the scenarios might have the largest part in the impact and therefore are most important to take into account in the analysis of potential mitigation measures. In fact, this question is directly related to the risk assessment, but only during the capability assessment the specific wish arose to assess the relative magnitude of the primary effects (instead of just the different scenarios). This illustrates the interconnection between the both assessments and the incremental nature of the mitigation process. After discussion the following was concluded:

- Toxic fumes will have the largest geographical scope and therefore result in the most affected people, or at least the most affected people on a big distance. However, of these affected people mostly the ones outside will suffer injury (a lesser number).
- Heat radiation of a BLEVE might result in the largest number of fatalities and seriously injured and is 360 degrees, whilst toxic scenarios are only in one direction ('cigar').
- Overpressure might result in the largest number of homeless people.
- Smoke and ash might be very dominant for societal impact, like outrage and anxiety, as we have seen after the Moerdijk chemical fire, but the direct and even the long term health impact is in most cases limited (with exception of highly carcinogenic substances).
- Polluted extinguishing water might be responsible for a lot of the direct costs, in case of a pool fire. In case of a BLEVE the costs of destruction and damage is expected to be higher, whilst for the toxic scenarios the health and social costs might be the highest. However, in all cases the direct costs might be surpassed by the indirect economic damage, due to on the one hand temporary obstruction of transport and on the other hand diminished public support for transport of dangerous substances.

For the risk assessment specific effect maps were developed  (see separate report). The effect distances on these maps are not absolute. They are derived from the calculation of small, medium and big scenarios, with different terrain types. For the correlation with spatial policies the 'maximum credible' scenarios are projected on these maps. When considering the cost-effectiveness of measures in relation to probability, the smaller scenarios (with higher probability) also come into view. In the end (after the CBA) the result might be smaller zones in which certain measures are useful (see paragraph 4.4).

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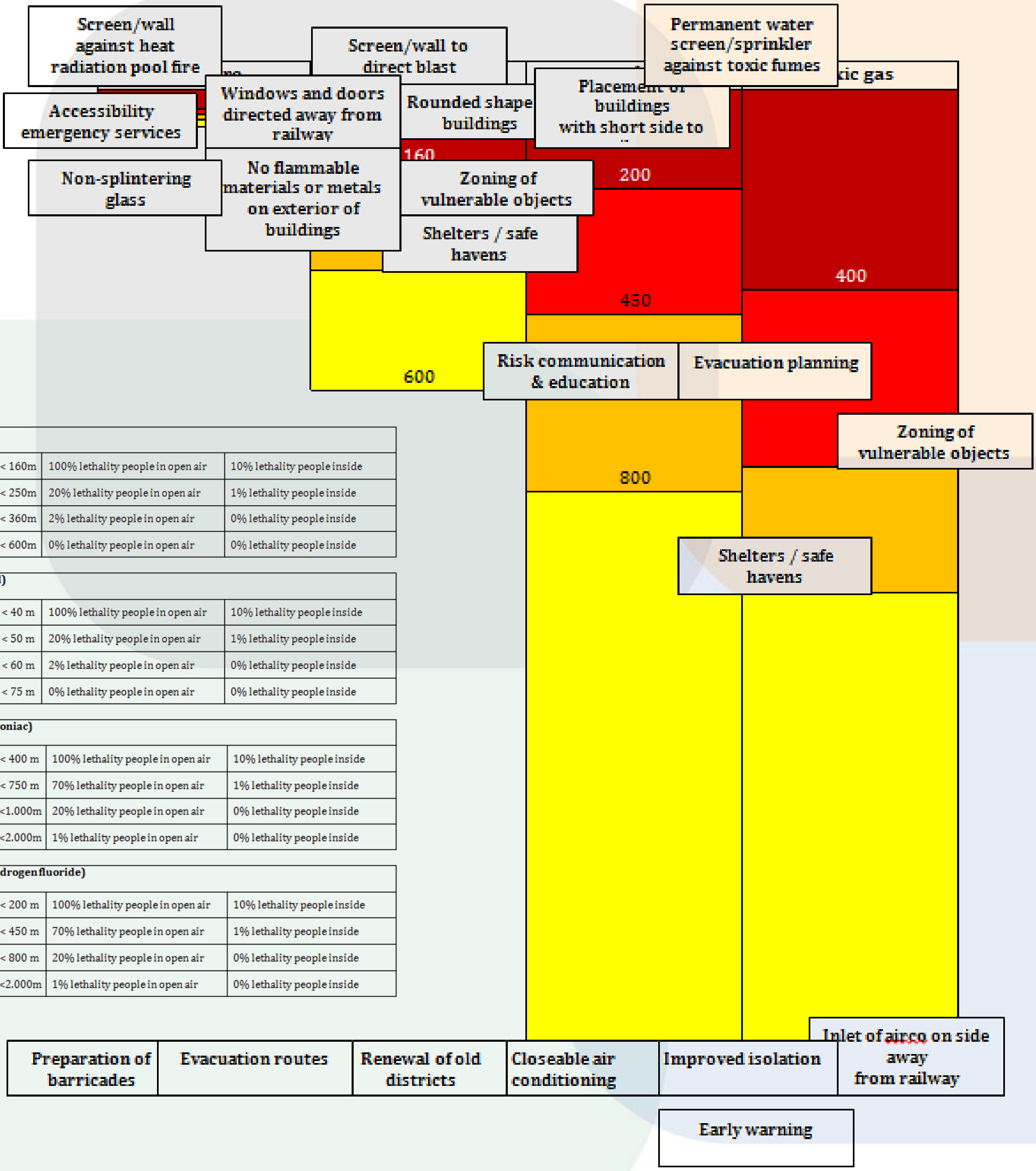
*Warning about the interpretation of effect distances*

*The reader must be aware the process of the PRISMA project was not meant to achieve full-proof scientific evidence of the exact effect distances, but merely as a test of how the assessment process works and what insights you can get from them. For this a deviation of several (tens of) meters more or less is irrelevant. The aim was to obtain effect distances which are 'realistic enough' to be able to perform further research into potential mitigation measures. This means that the presented effect distances have to be interpreted carefully. They should not be regarded as beyond doubt. Depending on assumptions and the used software, other outcomes might be generated.  Moreover it is important to realize that calculated effect distances are no guarantee that effects will certainly reach a certain distance, nor that it is safe beyond a specific point. Calculations are made with mathematical assumptions in software trying to model the real world. Each scenario in real-life can be different. The scenarios presented are 'credible worst case scenarios', meaning in most actual cases the effects should be smaller, but at the same time bigger effects are not completely ruled out. This is especially the case for scenarios with toxic substances, because they are based upon the nationally set 'example substances', whilst other substances in that same category might behave differently. In any case the actual weather conditions (mainly wind direction and force) can greatly influence the magnitude of these scenarios.*

To be able to make a preliminary CBA the different (maximum credible) the local working group has placed the identified mitigation measures (as far as they have a spatial component) in the effect zones of the different scenarios. The local working group has suggested to add the lethality percentages for people <u>inside</u> to the effect zones as defined in the risk assessment report, because for spatial planning the protection inside is the main issue. The mitigation measures could also be divided into these two categories: for outside and for protection inside.

The following figure shows the mitigation measures from spatial perspective, with the added percentages for lethality *inside*.




| BLEVE (LPG) | | | |
|---|---|---|---|
| Dark red zone | < 160m | 100% lethality people in open air | 10% lethality people inside |
| Red zone | < 250m | 20% lethality people in open air | 1% lethality people inside |
| Orange zone | < 360m | 2% lethality people in open air | 0% lethality people inside |
| Yellow zone | < 600m | 0% lethality people in open air | 0% lethality people inside |

| Pool fire (petrol) | | | |
|---|---|---|---|
| Dark red zone | < 40 m | 100% lethality people in open air | 10% lethality people inside |
| Red zone | < 50 m | 20% lethality people in open air | 1% lethality people inside |
| Orange zone | < 60 m | 2% lethality people in open air | 0% lethality people inside |
| Yellow zone | < 75 m | 0% lethality people in open air | 0% lethality people inside |

| Toxic gas (ammoniac) | | | |
|---|---|---|---|
| Dark red zone | < 400 m | 100% lethality people in open air | 10% lethality people inside |
| Red zone | < 750 m | 70% lethality people in open air | 1% lethality people inside |
| Orange zone | <1.000m | 20% lethality people in open air | 0% lethality people inside |
| Yellow zone | <2.000m | 1% lethality people in open air | 0% lethality people inside |

| Toxic liquid (hydrogen fluoride) | | | |
|---|---|---|---|
| Dark red zone | < 200 m | 100% lethality people in open air | 10% lethality people inside |
| Red zone | < 450 m | 70% lethality people in open air | 1% lethality people inside |
| Orange zone | < 800 m | 20% lethality people in open air | 0% lethality people inside |
| Yellow zone | <2.000m | 1% lethality people in open air | 0% lethality people inside |

*Figure: mitigation measures from spatial perspective*

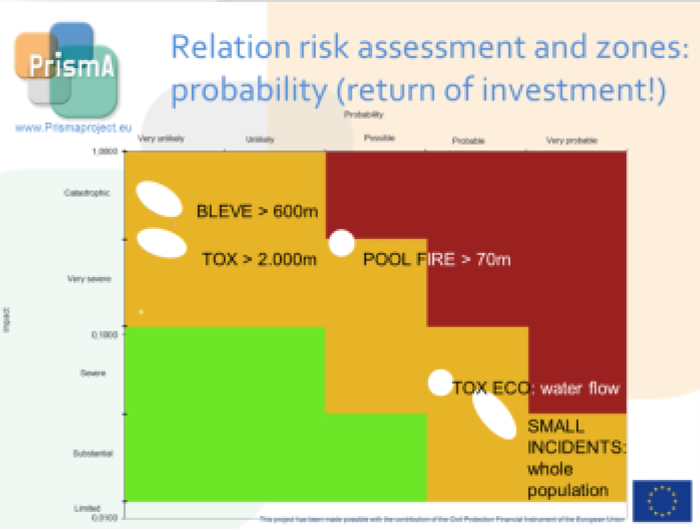
## 4.3 Draft cost-benefit analysis

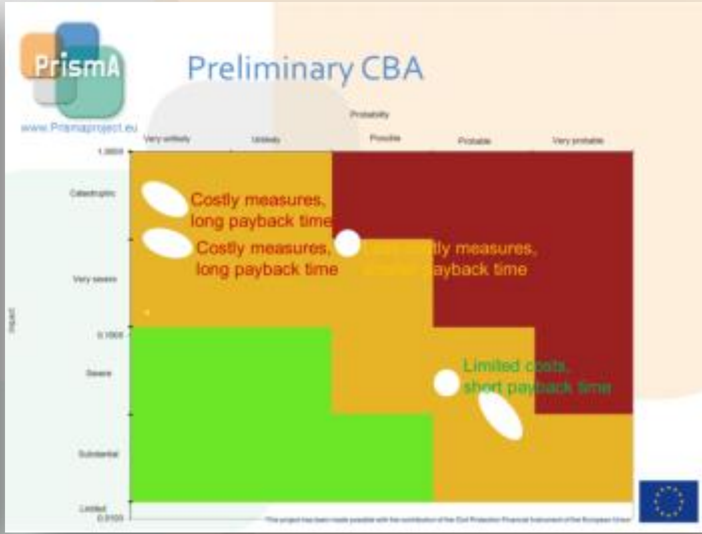
The capability analysis is ideally based upon the quantification of projected positive and negative effects in a cost-benefit analysis (CBA). CBA is defined by the EU as “a procedure for evaluating the desirability of a *project* by weighting benefits against costs. Results may be expressed in different ways, including internal rate of return, net present value and benefit-cost ratio.” The goal of a CBA is to enable informed decisions on the use of society’s scarce resources. CBA is within the EU quite commonly used, specifically nationally in the fields of infrastructure, environmental policy, traffic safety, spatial planning, external safety and also risk management.

To be able to incorporate a CBA in the mitigation process it is important that it is not limited to money value alone. The nature of (all hazard) mitigation is that different vital interests of society are taken into account: just like economic aspects also the societal costs of casualties or ecological damage should be considered. Therefore a CBA, or *Societal* CBA, also should incorporates information on effects (advantages and disadvantages) which cannot be put into money value. Because this requires a multi-criteria approach the expertise needed for a CBA is divers. For the calculation of vulnerability and actual potential damage in Euros in many cases extensive research is needed.

*Preliminary CBA for types of scenarios*

To present the outcome of the risk assessment a risk diagram is be used. It would be best to be able also to present the outcome of the CBA in this risk diagram. In that case the decision-makers can really visualize for themselves what the projected reduction of impacts are. So as a first step to gain insight in the potential outcome of a full CBA, the risk diagram has been used. The zones in which measures might be indicated or at least useful were used as a first indicator of the costs. In the risk diagram this can be correlated to the probability as an indicator for how often the benefits of mitigation will occur.




This shows that in general measures for the low probability scenarios are expected to have a negative cost benefit ratio, because of the long time for return of investment.  For pool fires the payback time is shorter and the costs might in general be lower, so a break-even cost-benefit ratio might more easily be expected. Moreover, the cost-benefit ratio of measures against pool fires are easier to calculate than measures for the other scenarios. On one hand this has to do with the difference in probability (highest for pool fire, with less margin for error). On the other hand the measures for pool fire are mostly directly and material, while the other measures (especially for toxic scenarios) are more to be found in (spatial) policies, for which the costs and benefits are more difficult to establish. Finally, this first analysis indicates a possible positive ratio for measures against ecological toxic scenarios, because of the higher occurrence and lower costs. However, these scenarios have a very low overall impact score, so the benefit is also low.

*Preliminary CBA for the mitigation strategies*

For the risk assessment an “all impact” approach has been used, meaning risks are assessed in terms of not just casualties, but also economical costs, ecology, social stability etc. In this cases it is necessary to take these same impacts into account in the CBA. In the following table the identified measures are qualitatively analysed on their benefit for the 10 impact criteria.

| Vital interest | Criteria |
|---|---|
| 1. Territorial security | 1.1 Infringement of the territorial integrity |
| 2. Physical safety (public health) | 2.1 Number of fatalities<br>2.2 Number of seriously injured and chronically ill<br>2.3 Physical suffering (lack of basic necessities of life) |
| 3. Economic safety | 3.1 Financial costs |
| 4. Ecological safety | 4.1 Long-term damage to the ecosystem |
| 5. Social and political stability | 5.1 Disruption of everyday life<br>5.2 Violation of the democratic system and rule of law<br>5.3 Social psychological impact: public outrage and anxiety |
| 6. Safety of cultural heritage | 6.1 Damage to cultural heritage |

For these 10 criteria the relative benefit is qualitatively indicated as:

- N/A: not applicable
- 0: no significant benefit
- +: positive benefit
- ++: very positive benefit

For a better indication of the benefit this qualitative analysis is multiplied with the relative importance of the impact criteria, as derived from the risk assessment. The highest average impact criterion gets a score of 10 points, the second 9 points etc. These scores are multiplied with 1 (+) or 2 (++). There is no scientific basis or methodological proof for this approach. It is just one way to gain more insight in the relative benefit of the measures, taking in mind the 10 criteria and their relative importance. The table below shows the resulting scores, which should not mistakenly be interpreted as 'concrete' figures. In a later table they are transformed back into qualitative terms.

| | Impact criteria | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1 | 2.1 | 2.2 | 2.3 | 3.1 | 4.1 | 5.1 | 5.2 | 5.3 | 6.1 | Score |
| **1. Spatial safety** | | | | | | | | | | | |
| 1.1 Assessment tool spatial safety | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 1.2 Increased safety distance | N/A | ++ | ++ | N/A | ++ | + | + | ++ | ++ | + | 87 |
| 1.3 Zoning and protection of critical infrastruct. | N/A | + | + | N/A | + | + | ++ | + | + | ++ | 61 |
| 1.4 Zoning of objects with vulnerable people | N/A | ++ | ++ | N/A | ++ | N/A | + | + | + | N/A | 70 |
| 1.5 Expansion of closable mechanical ventilation | N/A | ++ | ++ | N/A | + | N/A | ++ | + | + | ++ | 78 |
| 1.6 Integration of defence against toxic fumes in housing isolation subsidies | N/A | + | + | N/A | + | N/A | ++ | + | + | 0 | 53 |
| 1.7 Compartmentalisation of sewage system | N/A | + | + | N/A | 0 | ++ | + | + | + | 0 | 43 |
| 1.8 Drainage pipes & compartmentalisat. of canals | N/A | 0 | 0 | | + | ++ | 0 | + | + | N/A | 22 |
| 1.9 Spatial support for evacuation | N/A | + | + | N/A | + | N/A | 0 | + | + | 0 | 37 |
| **2. Targeted resilience** | | | | | | | | | | | |
| 2.1 Targeted risk communication | N/A | + | + | N/A | 0 | N/A | ++ | + | ++ | N/A | 47 |
| 2.2 Community resilience | N/A | + | + | N/A | + | N/A | ++ | + | ++ | N/A | 53 |
| 2.3 Self-reliance of entities | N/A | + | + | N/A | + | N/A | ++ | + | ++ | + | 59 |
| **3. Targeted preparation** | | | | | | | | | | | |
| 3.1 Improved early warning | N/A | + | + | N/A | + | N/A | ++ | + | ++ | + | 59 |
| 3.2 Improved crisis communication | N/A | + | + | N/A | + | N/A | ++ | + | ++ | + | 59 |
| 3.3 Improved preparation of decontamination | N/A | + | + | N/A | + | N/A | 0 | + | + | N/A | 37 |
| 3.4 Buildings with shelter capability | N/A | + | + | N/A | + | N/A | 0 | + | + | 0 | 37 |
| 3.5 Improved preparation of public health review | N/A | 0 | + | N/A | 0 | N/A | + | ++ | ++ | N/A | 41 |
| 3.6 Improved preparation of containment eco | N/A | 0 | 0 | N/A | + | ++ | 0 | + | + | N/A | 22 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Relative importance of the criteria[25] (ranking: 1 most important, 9 least important) | 7 | 2 | 1 | N/A | 5 | 9 | 3 | 6 | 4 | 8 |

One more reason to use this method, is to be able to relate the benefit to the probability. To perform a CBA on the measures, the "frequency" is needed. By frequency we mean the occurrence of the scenarios for which the specific measure will be used, expressed as "once every ... years". Only this enables a qualitative comparison with the costs. The probabilities are calculated according to the numbers of the HART guideline as calculated in annex I of the risk assessment report. The presented frequencies are those for the territory of the municipalities of Dordrecht and Zwijndrecht (column total region South-Holland South without Betuwe line),

[25] Based upon the average scores of the impact criteria, see risk assessment report, page 43. The colours correspond to the colours of these average scores.

unless indicated otherwise. In the following table the benefit scores are represented as "benefit per year", based upon the probability calculations.

| | Useful for scenario | Once every .. years[26] | Benefit score | Benefit per year |
|---|---|---|---|---|
| **1. Spatial safety** | | | | |
| 1.1 Assessment tool spatial safety | All | N/A[27] | N/A | N/A |
| 1.2 Increased safety distance | All | 16 | 87 | 5,44 |
| 1.3 Zoning and protection of critical infrastruct. | All | 16 | 61 | 3,81 |
| 1.4 Zoning of objects with vulnerable people | All | 16 | 70 | 4,38 |
| 1.5 Expansion of closable mechanical ventilation | All incidents emission[28] | 55 | 78 | 1,42 |
| 1.6 Integration of defence against toxic fumes in housing isolation subsidies | All incidents emission[28] | 55 | 53 | 0,96 |
| 1.7 Compartmentalisation of sewage system | Incidents liquids | 171 | 43 | 0,25 |
| 1.8 Drainage pipes & compartmentalisat. of canals | Eco toxics | 110 | 22 | 0,20 |
| 1.9 Spatial support for evacuation | Cold BLEVE Pool fire | 175 | 37 | 0,21 |
| **2. Targeted resilience** | | | | |
| 2.1 Targeted risk communication | All | 16 | 47 | 2,94 |
| 2.2 Community resilience | All | 16 | 53 | 3,31 |
| 2.3 Self-reliance of entities | All | 16 | 59 | 3,69 |
| **3. Targeted preparation** | | | | |
| 3.1 Improved early warning | All | 16 | 59 | 3,69 |
| 3.2 Improved crisis communication | All[29] | 3 | 59 | 19,67 |
| 3.3 Improved preparation of decontamination | Toxic scenarios >100kg emission | 5.265 | 37 | 0,01 |

[26] This probability calculation does not include the probability of other type of transport or other crisis types for which these measures might also be applicable.
[27] The usefulness of spatial planning depends on the specific selected measures in relation to the different scenarios, so no overall frequency of usage can be given.
[28] The toxic incidents include incidents with flammable liquids, which have a simultaneous effect of toxic vapors/fumes and/or smoke and ash (in case of ignition). The probability of toxic incidents with an emission over 100kg is once every 170 years, as opposed to once every 81 years a smaller incident. Also for the smaller incidents the closing of windows in most cases will be advised, either because of an actual health hazard or because of stench problems and the consequent public unrest and anxiety. For this reason the combined probability of once every 55 years is selected as base assumption: any spatial measure related to toxic scenarios is useful both for the bigger and the smaller incidents.

| | | | | |
|---|---|---|---|---|
| 3.4 Buildings with shelter capability | All incidents >100kg emission | 169 | 37 | 0,22 |
| 3.5 Improved preparation of public health review | All[29] | 3 | 41 | 13,67 |
| 3.6 Improved preparation of containment eco | Eco toxics | 110 | 22 | 0,20 |

These relative values for benefit per year are translated into 3 categories: low for a score less than 1, high for a score higher than 10 and medium in between. To compare to these benefits the costs are also estimated qualitatively as low, medium and high. Together this provides a preliminary insight in the cost-benefit ratio, as depicted in the following table.

| | Costs | Benefits | Cost benefit ratio |
|---|---|---|---|
| **1. Spatial safety** | | | |
| 1.1 Assessment tool spatial safety | N/A | N/A | N/A |
| 1.2 Increased safety distance | Medium | Medium | +/- |
| 1.3 Zoning and protection of critical infrastruct. | Medium | Medium | +/- |
| 1.4 Zoning of objects with vulnerable people | Medium | Medium | +/- |
| 1.5 Expansion of closable mechanical ventilation | Low | Medium | + |
| 1.6 Integration of defence against toxic fumes in housing isolation subsidies | Nihil | Low | + |
| 1.7 Compartmentalisation of sewage system | Low | Low | +/- |
| 1.8 Drainage pipes & compartmentalisat. of canals | Medium | Low | - |
| 1.9 Spatial support for evacuation | High | Low | - |
| **2. Targeted resilience** | | | |
| 2.1 Targeted risk communication | Low | Medium | + |
| 2.2 Community resilience | Low | Medium | + |
| 2.3 Self-reliance of entities | Low | Medium | + |
| **3. Targeted preparation** | | | |
| 3.1 Improved early warning | Medium | Medium | +/- |
| 3.2 Improved crisis communication | Low | High | + |
| 3.3 Improved preparation of decontamination | Medium | Low | - |
| 3.4 Buildings with shelter capability | High | Low | - |
| 3.5 Improved preparation of public health review | Low | High | + |
| 3.6 Improved preparation of containment eco | Low | Low | +/- |

[29] This measure is generic for the whole region and not just targeted at Dordrecht and Zwijndrecht. Therefore the total probability for the whole region is used, including the Betuwe line.

## 4.6 Recommendations for further CBA research in future

The performing of a CBA to make informed decisions requires different kinds of expertise. It involves not only technical expertise on the mitigation measures itself, like knowledge on risk, crisis and recovery management and for example engineering, forestry, geology and geostatistics, but also specific economical and statistical expertise. This expertise is mostly not available within local governments and professional safety institutions. The local working group doubts whether a full CBA research is advisable. It will certainly help to reach a more informed decision, but it is not certain it will result in other insights than the ones gained from the preliminary research.

The probability of a risk has a very high influence on the outcome of a CBA. It makes quite a difference whether a structural investment into mitigation measures has to be valued against a scenario with a probability of for example once every 10, 100 or 1000 years. The problem is that the probabilistic estimation of risks is in most cases very uncertain. The macro-factors which govern the probability of a risk are significantly uncertain. When this uncertainty cannot be reduced the outcome of a CBA in many cases could go either way: positive or negative. For this reason a specific point of attention is the validity of any CBA calculations, because of the differences in transport volumes over time and also the differences of area characteristics, like the value of the threatened vulnerabilities. In many cases a CBA is only valid for a specific location and timeframe and has to be repeated over and over to be able to make informed decisions for a larger area.

For transport of dangerous substances the specific problem is the variability of the transported volumes. The last few years have shown that the 'societal risk' calculations for the Spoorzone have varied each year. For example, the societal risk for the Leerpark area has been calculated at 43 times higher than the orientational value in the year 2008, growing to an expected 61 times higher in the year 2020.[30] In the meantime, since the start of the economic crisis the transport has dropped with 63% (see risk assessment report, page 17), resulting in societal risk levels of around 7 times the orientational value. This means that for each year over and over again a different cost-benefit ratio could be calculated, sometimes resulting in a positive outcome and other times in a negative one. This arises serious questions about the representativeness, validity and added value of CBA calculations. After all, the CBA is meant as an instrument to support informed decisions for the middle and long term, but the actual risk will certainly develop over time, in a way which cannot easily be predicted. Especially probability figures of over 100 years (up to thousands of years) present a serious dilemma: we cannot predict what the Dutch economy and ways of transport will look like in the future, taking in mind on the one

[30] *Advice pre-design zoning 2nd review Leerpark*, page 10 and *Analysis external safety Leerpark*, page 11.

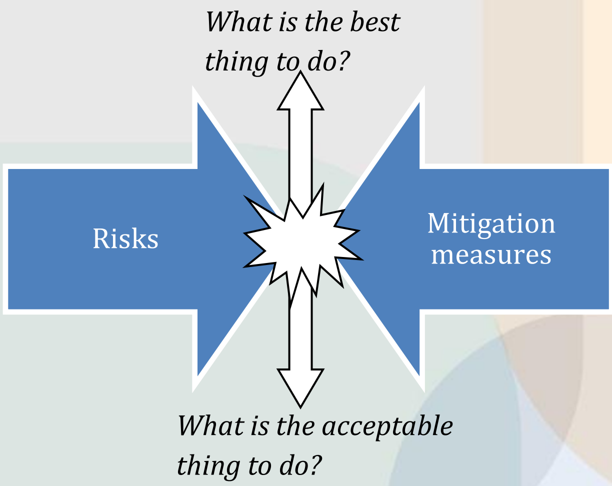
hand all technological developments and on the other hand the strategic question of energy policy for the long term.

For any future CBA research the working group wants to stress the importance of objective information as a basis for informed *but subjective* decisions on the political level. It seems attractive to incorporate ‘risk acceptance’ directly into the CBA, but this has to stay part of the risk evaluation, to keep the clear distinction between technical (objective) analysis and political (subjective) evaluation.

# 5. Capability evaluation

## 5.1 What is capability evaluation?

The relation between the second and third step of capability assessment is best illustrated by the following figure. When confronting risks with possible mitigation (and preparedness) measures the first question that arises is: which are the 'best' measures? Answering this question is the goal of the capability analysis.




The second question is: which measures are most acceptable to the decision-makers? The best thing is not necessarily the most acceptable. This is the step of a capability evaluation: a comparison by the decision-makers of the possible measures on basis of their political criteria. The outcome of a cost-benefit analysis might help to objectify the political evaluation, but other political preferences and interest may always interfere. During MiSRaR it was discussed with the international partners to make a clear distinction between the professional-technical analysis and the final political judgement. The professionals should be aware of the paradigms and preferences of politicians and inhabitants, but should not let this interfere with the 'neutral' analysis beforehand. It is the job of technicians and experts to present the decision-makers with the relevant information, but the final judgment has to be made by the elected officials who are accountable. For them risk acceptance might be equally important as the costs-benefit ratio. Therefore, in the rational process of a CBA (informed decision) one always should consider that politicians might use additional criteria, like:

- Risk acceptance.
- Public and media pressure.
- Incidents in the (recent) past.
- Popularity of the measure(s), even if they are not effective.
- Quick wins in relation to the next election.
- The need to comply to legislation.

- Current value (such as developments) over future value (prevented damage).

The main research question for the capability evaluation therefore is: what political criteria could determine the acceptance of the proposed mitigation strategies?


## 5.2 Potential political evaluation criteria

Safety professionals have to perform objective risk analysis, but must be well aware that the decision-makers will interpret the outcomes on basis of their own subjective political preferences. To evaluate which of the analysed capabilities should be chosen to implement, many different evaluation criteria can be taken into account. Therefore, an option is to ask the decision-makers to explicit their subjective evaluation criteria during the decision process. The actual involvement of politicians was not part of the PRISMA project, because it was only meant for *testing* the process and methodologies. The potential priorities for mitigation strategies concluded from the "technical" analysis have not been presented to or discussed with actual politicians in the region. However, several perspectives are provided below. For the internal consistency these are the same perspectives as provided for the risk assessment (see risk assessment report, paragraph 5.2).

*The relative importance of the vital interests*

The main perspective is that of the (conflicting) vital interests of society. For example, for one decision-maker capabilities to prevent a lot of casualties might be most important, whilst another might want to give priority to measure to reduce severe economic or ecological consequences. Because the methodology used for the risk assessment includes all "vital interests of society" as defined by the national government, these vital interests (10 criteria) have also been taken into account in the qualitative CBA. In this way there is a transparent basis for the separate perspectives to prioritize mitigation policies:

- **Physical safety perspective**. The physical safety (fatalities and injured) is the traditional perspective of the rescue services and the Mayors which are legally responsible for crisis management. Only taking into account the physical safety does not exclude any of the identified mitigation options, because all of them have positive effects on criteria 2.1 and 2.2 in one way or another. However, this perspective suggests a main focus on spatial safety measures, like an increased safety zone, the zoning of vulnerable objects, expansion of automatically closable mechanical ventilation and spatial support for evacuation and a secondary priority for resilience and targeted preparation.

- **Economic perspective**. For the country as a whole the economic benefit of the rail transport is very important, because it connects the Rotterdam harbour and the (petro-chemical) industrial area of Rotterdam, Moerdijk, Terneuzen etc. with the European hinterland. This perspective might lead to risk acceptance, but might also place emphasis on the prevention of incidents (probability reduction) or the prevention of social impact (effect and vulnerability reduction). After all, an incident might lead to a disruption of the rail transport network with direct economic damage. Moreover, a serious incident might result in a lower risk acceptance and even a public debate about banning or seriously limiting transport of dangerous substances. As suggested in the risk evaluation (see risk assessment report chapter 5) the capability assessment has not included probability reduction. Therefore, this part of the economic perspective does not suggest any specific prioritization between the measures as identified and analysed for vulnerability reduction. However, this perspective does suggest serious attention for potential long-term solutions. Concerning prevention of secondary societal impact (which might decrease risk acceptance), some specific measures were identified. This suggests a priority for risk and crisis communication and good preparation of a public health review in order to minimise anxiety and rage.
- **Psychological perspective**. As analysed in the risk assessment, the social-political impact of the different scenarios is potentially very serious and has a much higher probability than other kinds of impacts. Important distinction from the physical safety perspective is the probability: whilst fatalities and injured only occur in the case of actual larger emissions, psychological impact (anxiety, public outrage, social unrest and potentially civil disorder and riots) might also occur in case of smaller incidents, with small emissions (leakage), small amounts of casualties or even only the threat of an emission after a derailment or collision. The chemical fire in Moerdijk (2011) and the explosion at Shell Moerdijk (2014) have shown the societal impact in case of uncertainty about potential health impacts and the corresponding negative (social) media attention. Therefore, this perspective suggest a larger emphasis on risk and crisis communication, resilience, public shelters, decontamination, public health review and also zoning and protection of critical infrastructures.
- **Ecological perspective.** As analysed in the risk assessment, at average the impact of the different scenarios on ecology and the environment is limited. However, specific scenarios might have serious consequences, especially for the aquatic environment but also the agricultural grounds. This perspective suggests priority for compartmentalisation of the sewage system, drainage pipes and compartmentalisation of canals and improved preparation of containment of ecological spills.

The perspectives of “territorial security” and “cultural heritage” are left aside, because the impact analysis has shown those criteria are negligible compared to the others.

## 5.3 Recommendations for evaluation of the mitigation strategy

Actual political decisions about the prioritization of the mitigation strategy are not part of the PRISMA project. In this paragraph the outcome of the capability analysis of chapter 4 is confronted with the potential political evaluation perspectives as described in the previous paragraph. This results in concrete recommendations for the mitigation strategy.

*Measures with a positive CBA ratio*

The capability analysis has indicated that 7 of the 18 mitigation options have a clear positive CBA ratio. None of the political evaluation perspectives opposes or contradicts these measures. <u>Recommendation: implement the following measures</u>:

- **1.5 Expansion of closable mechanical ventilation**
- **1.6 Integration of defence against toxic fumes in housing isolation subsidies**
- **2.1 Targeted risk communication**
- **2.2 Community resilience**
- **2.3 Self-reliance of entities**
- **3.2 Improved crisis communication**
- **3.3 Improved preparation of public health review**

*Measures for which the CBA ratio could go either way*

7 of the 18 mitigation options do not give a clear CBA ratio in a negative or a positive direction. In itself a neutral CBA ratio might be an indication to consider implementation. However, it cannot be ruled out that in the end after more detailed research the ratio would become more clearly positive or negative. This means that each of these measures has to be evaluated on contextual basis (relation with the other measures in the overall mitigation strategy) and political preferences.

- **1.1 Assessment tool spatial safety ('afwegingskader ruimtelijke veiligheid')**. This mitigation option is one of the most fundamental. It aims at a closer interconnection between safety and spatial planning. Important conditions are early involvement of safety concerns in the spatial development process and the will to find win-win and 'room for manoeuvre'. This assessment tool and its underlying vision form the backbone of the proposed mitigation strategy. <u>Recommendation: develop an assessment tool, test and implement it. Invest from the start in a shared development process of the safety and spatial planning sectors in order to find the interconnections, the mutual interests, mutual understanding and a shared language. On the basis of this tool, invest in the quality of the 'supra-legal' advice tasks of the safety regions and secure these tasks in an updated policy plan of the safety region.</u>
- **1.2 Increased safety distance**. Increasing distance to the railway as much as possible is a fundamental form of mitigation and has shown the third highest 'benefit per year'

estimation. The actual distances cannot be set beforehand and will have to be studied more closely, taking into account costs and probabilities to find optimal distances. However, searching for more distance and 'room to manoeuvre' should be adopted as a general principle, but without fixing it as a dogma. Recommendation: perform further research into reasonable and acceptable distances and implement these in the assessment tool (1.1).

- **1.3 Zoning and protection of critical infrastructures**. This mitigation option has benefits for the whole spectrum of impact criteria. It fits as a priority into all evaluation options. However, a lot is depending on the actual costs. The actual options and their benefits are complex to foresee, because of complex interdependencies (domino). Recommendation: perform further research into the options and costs of zoning and protection measures for critical infrastructures, as a basis for further political choices.
- **1.4 Zoning of objects with vulnerable people**. In general zoning of vulnerable people is a sound principle. Vulnerable groups justify specific attention. However, the current legislation already has elaborate requirements for this. This mitigation options aims at voluntarily increasing the safety level above the legislation (supra-legal). A full and fundamental mitigation of the existing situation would be too large and encompassing and would encounter legal and financial issues which are difficult to overcome. What is meant here to try to find solutions to enlarge the distance within the 'room to manoeuvre'. Recommendation: implement increased zoning of vulnerable objects as part of the assessment tool for spatial safety (1.1).
- **1.7 Compartmentalisation of sewage system**. This is a very targeted mitigation option, that only works for specific scenarios. However, the costs are estimated to be low, if practical and easy to use (during an incident) solutions are developed in cooperation with the water board. The fact that in past instances actual fatalities and wounded have been caused by transmission through the sewage, is an extra reason to consider the implementation. Recommendation: perform further research with the water boards to see if implementation is possible.
- **3.1 Improved early warning**. Early warning is very important as a necessary condition for getting people inside their houses (shelter) or away from harm (evacuation, fleeing) in time. A successful 'system' of early warning is preferably composed of at least ways to speed up the recognition and first assessment of an incident, the warning of people and communication about their perspectives for action. The fact that effects of rail transport incidents can reach so far into both municipalities and have a potential (although not very high probable) catastrophic effect of unrivalled dimensions, makes it difficult to be accountable for a decision not to invest in this measure. Recommendation: research and implement further options for improved early warning.
- **3.6 Improved preparation of containment of ecological spills**. This is aimed at the preparation of the use of floating screens and other containment devises by means of protocols, development of agreements between partners, instruction of personnel and joint

exercises. From the ecological evaluation perspective this might be a priority. The CBA ratio is around zero, but the costs are low (as are the 'benefits per year', because of its limited use). Although this issue does not belong to the primary responsibilities of the safety region, a small investment in this preparation might improve the relation with network partners like the water board, Rijkswaterstaat and water police, which is an added value in itself. Recommendation: discuss with the primarily responsible partners whether a joint preparation with the safety region fits with their own priorities.

*Measures with a negative CBA ratio*

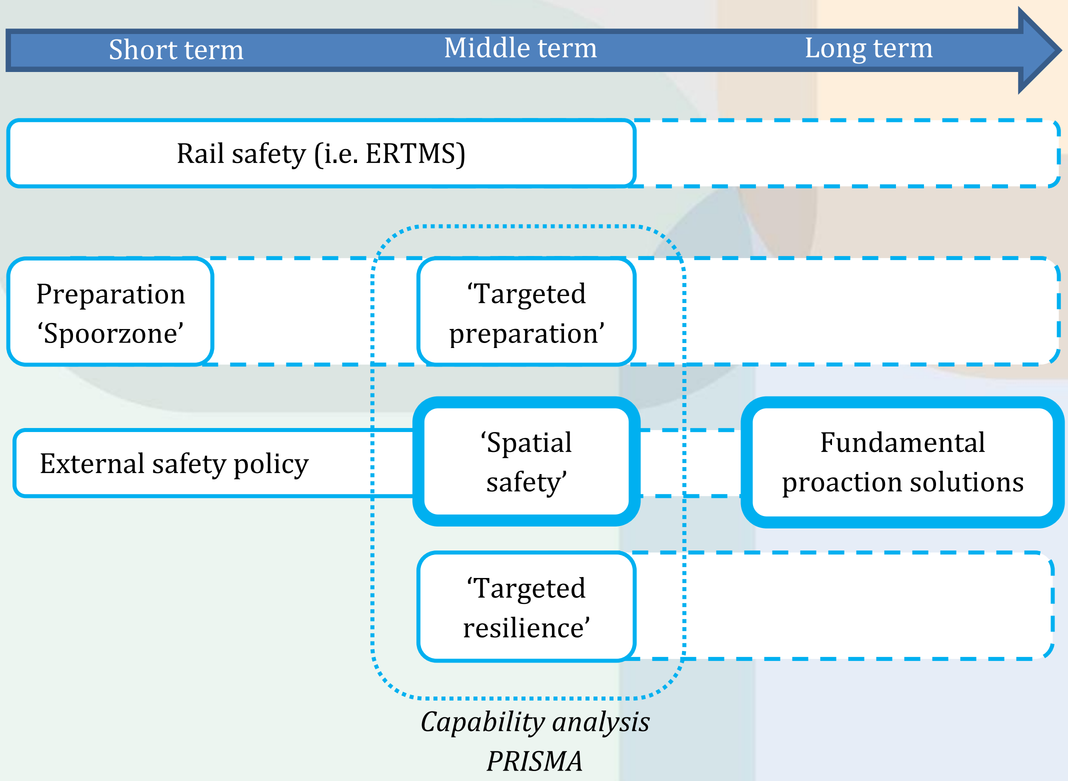
Of all the identified measures in the capability analysis of PRISMA four have a negative CBA ratio. However, this does not automatically mean they should not be considered. From different political evaluation perspectives, they might still be favoured. Taking this into account, the following is recommended:

- **1.8 Drainage pipes and compartmentalisation of canals**. The ecological evaluation perspective suggests that 1.8 could be considered nonetheless, but this does not erase the higher costs than benefits. Moreover, the ecological impact is very limited in the total overview of all potential impacts. Besides, the assessment of environmental impact has its own instrument (environmental impact assessment, MER in Dutch). This is more detailed than the overall assessment for the risk analysis, which is merely meant to include environmental impact in the considerations of all impacts. Recommendation: do not implement, unless (future) environmental impact assessments indicate otherwise.
- **1.9 Spatial support for evacuation**. The added value of this measure is mainly less injuries. The CBA ratio is negative, but from the evaluation perspective of physical safety it could still be considered important. However, it might cause serious costs. Moreover, an effective implementation is only possible on the long term, because it requires restructuring. Recommendation: do not implement, but stick to the normal, legal advices on evacuation in the context of external safety policy.
- **3.3 Improved preparation of decontamination**. This does not only help for the rail transport, but also for incidents with road transport, water transport and SEVESO industries. The accumulated probability of these different risks might enhance the CBA ratio. Both the physical safety evaluation perspective and the psychological perspective suggest that this measure is considered. Moreover, this measure concerns the core business of the safety region (both the fire brigade and GHOR – medical emergency management), making it difficult to explain why it is not improved in case of an actual incident. Recommendation: implement.
- **3.4 Buildings with shelter capability**. Notwithstanding the negative CBA ratio this measure might be considered mainly from the evaluation perspective of psychological impact: it provides the comfort for passers-by that they can shelter in case of an incident. However, there are numerous complications thinkable for this option, like the required level

of safety to provide a good shelter, the legal basis to issue demands, the financial coverage of the costs and also a potential negative impact on inhabitants (visible preparation of shelters might incite anxiety). Recommendation: do not implement a specific policy or requirements to make public buildings suitable as a shelter, but involve the "internal office assistance" (bedrijfshulpverlening - BHV) of these buildings in preparation to help passers-by outside to get in (as part of measure 2.3).

## 5.4 Summary of the proposed mitigation strategy

In the figure below the full extent of mitigation strategies is recapitulated.




For the middle term, in addition to national policies mainly focused on the risk source itself, the proposed regional/local mitigation strategy consists of 3 paths.[31]

[31] The numbers are the same as for the measures as proposed before. The measures that "did not make it" are left out, so some numbers are missing in this list.

*1. Spatial safety*

1.1 Develop an assessment tool spatial safety ('afwegingskader ruimtelijke veiligheid'), test and implement it. Invest from the start in a shared development process of the safety and spatial planning sectors in order to find the interconnections, the mutual interests, mutual understanding and a shared language. On the basis of this tool, invest in the quality of the 'supra-legal' advice tasks of the safety regions and secure these tasks in an updated policy plan of the safety region.

1.2 Perform further research into reasonable and acceptable safety distances and implement these in the assessment tool.

1.3 Perform further research into the options and costs of zoning and protection measures for critical infrastructures, as a basis for further political choices.

1.4 Implement increased zoning of vulnerable objects as part of the assessment tool for spatial safety.

1.5 Expand closable mechanical ventilation.

1.6 Integrate defence against toxic fumes in housing isolation subsidies.

1.7 Perform further research with the water boards to see if compartmentalisation of the sewage system is possible.

*Targeted resilience*

2.1 Implement targeted risk communication in correlation with the safety zones of the assessment tool.

2.2 Strengthen local networks to increase community resilience.

2.3 Advocate for additional preparation (procedures, training) of the "internal office assistance" (bedrijfshulpverlening - BHV), to increase the self-reliance of organizations and to expand the internal focus with an external one.

*Targeted preparation*

3.1 Research and implement further options for improved early warning.

3.2 Improve the crisis communication.

3.3 Improve the preparation of decontamination.

3.5 Improve the preparation of public health reviews.

3.6 Discuss with the primarily responsible partners whether a joint preparation with the safety region for the containment of ecological spills fits with their own priorities.

*Long term proaction*

The middle term strategy cannot be considered as *the* fundamental mitigation option that provides a full and complete reduction of the current high risk levels. It only decreases the vulnerability and should certainly be accompanied by policies to decrease probability and primary effects at the risk source and improve the preparation. For the long term a research into the fundamental proaction and prevention options is still needed. This research has earlier been announced by the Ministry of Infrastructure and Environment for the year 2018. The municipalities and safety region have the opinion that this research should include an alternative railway line around the urban city centres of Dordrecht and Zwijndrecht. Another option would be a so-called 'on the ground tunnel', like the ones constructed in Barendrecht (railway) and in Amsterdam, Utrecht and Maastricht (highway). This is an example of win-win between safety, spatial development and also noise prevention and public health (particulate matter reduction). For a better integration in spatial planning, a possibility would be to make buildings part of this on the ground tunnel, or to use buildings in a way that they together act like a tunnel. However, this kind of development is currently not allowed by the new Law for rail transport, because in that case the buildings are in the pool fire attention area and would certainly exceed the localised and societal risk calculations. This means the integration of buildings into the sides of the tunnel is not possible. A car park building might be an exception, because therein are no permanent inhabitants or workers. However, this is just one of the options for fundamental proaction, alongside the option of an alternative route. Taking in account the amount of time needed for this research, the decision making and implementation, it is recommended to start this research at an earlier moment than 2018. An important argument for this is the potential economic damage of incidents. Discontinuity of rail infrastructure might result in big damage to the national economy. It is important to raise awareness with the national government and the industry and transport sector about this potential economic impact of local incidents and the need to prevent this.

## 5.5 Epilogue: warning about risk substitution

Within the Dutch legal framework there is a very important inherent risk which might nullify the positive benefits of the proposed *spatial* mitigation measures, namely the assessment tool spatial safety (1.1), increased safety zoning (1.2) and zoning of vulnerable objects (1.4). These measures aim to decrease the vulnerability through clever use of the available space. Whenever this results in 'less people' or 'people at a greater distance' this will lower the localised risk and the societal risk, as calculated according to the legislation (BTEV – Decree transport routes external safety). In itself this is very positive. However, a decreased localised and societal risk automatically creates a legal 'room to increase' the transport. The reason for this, is that in the localised and societal risk the probability (transport volume) and the impact (only calculated in number of fatalities) are combined into one single number. This method creates "communicating vessels", potentially resulting in risk *substitution* instead of risk mitigation: if the impact is diminished (less casualties due to spatial measures), the probability can be increased (more transport), still resulting in the same level of localised and societal risk.

In itself the use of spatial planning to enable extra room for transport could be a valid strategy (if it is decided transparently and democratically accountable). However, this is a completely different responsibility. If the aim is to increase transport, this is a national economic interest, for which the national government is responsible and therefore should pay the costs. The legal responsibility of the municipalities (Law on Safety Regions and Decree transport routes external safety) is *safety* and any of their investments to decrease the vulnerability to incidents should therefore benefit the safety of their inhabitants and not the transport on the railway.

Because the Law on transport safety allows and the prognosis for the year 2020 predicts a substantial increase of transport, this whole discussion is certainly not unimaginable (although for the moment the economic crisis slows down this increase). To prevent such a perverse effect, a national agreement is needed between the municipalities on the one hand and the Ministry of Infrastructure and Environment and the (rail) transport sector on the other hand. This should comprise an agreement not to "use up" any of the increased safety levels created through clever municipal spatial planning by means of an increase of the transport itself. If such an agreement cannot be reached, the whole municipal effort to increase spatial safety could be nullified (or in other words "misused") by the national government.

# Partners of PRISMA

**Safety Region South-Holland South**
The Netherlands

**Municipality of Tallinn**
Estonia

**Stara Zagora Regional Development Agency**
Bulgaria

**Municipality of Mirandela**
Portugal

**Municipality of Aveiro**
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